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RÄUMLICHE UND ZEITLICHE KONSOLIDIERUNG IN DER ABWASSER-QUALITÄTSÜBERWACHUNG:

EINE FALLSTUDIE AUS DEM EL-SALAM KANAL-PROJEKT IN ÄGYPTEN

Dissertation

zur Erlangung des akademischen Grades eines
Doktors der Naturwissenschaften
(Dr. rer. nat.)

vorgelegt von

Mohamed Shaban Mohamed Abu-Salama
aus Kairo, Ägypten
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1. Gutachter : Prof. Dr. Wolfgang Ruck
2. Gutachter : Prof. Dr. Brigitte Urban
3. Gutachter : Prof. Dr. Holger Wildhagen

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SPATIAL AND TEMPORAL CONSOLIDATION OF DRAINAGE WATER QUALITY MONITORING NETWORKS:

A CASE STUDY FROM THE EL-SALAM CANAL PROJECT IN EGYPT

Dissertation

A Thesis Submitted for the Fulfillment of the Requirements for
The Degree of Doctorate in Natural Sciences
(Dr. rer. nat.)

Submitted by

Mohamed Shaban Mohamed Abu-Salama
From Cairo, Egypt
2007

1. Refree	: Prof. Dr. Wolfgang Ruck
2. Refree	: Prof. Dr. Brigitte Urban
3. Refree	: Prof. Dr. Holger Wildhagen

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SPATIAL AND TEMPORAL CONSOLIDATION OF DRAINAGE WATER QUALITY MONITORING NETWORKS:

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ABSTRACT

The El-Salam Canal Project aims at increasing the Egyptian agricultural productivity through agricultural and stock development by irrigating about 263,500 ha gross of new lands.

In order to stretch the limited water supply to cover these new reclaimed areas, fresh River Nile water is augmented with agriculture drainage water from Hadus and Lower Serw drains, which receive almost all kinds of wastes. The overall objective of this research is to introduce a rationalization technique for the drainage water quality-monitoring network for Hadus drain as a main feeder of El-Salam Canal Project. Later on, this technique may be applied for other parts in the National Water Quality Monitoring Program in Egypt.

The rationalization process started firstly with assessing and reformulating the current objectives of the network. Then, the monitoring locations were identified using integrated logical and statistical approaches. Finally, a sampling frequency regime was recommended to facilitate proper and integrated information management.

As a result, the monitoring network was divided into three priority levels (Layers I, II and III) as following:

- **Layer I:** highest priority level and includes eight monitoring locations
- **Layer II:** second priority level and includes three locations
- **Layer III:** lowest priority level and includes five locations

These results were validated using three integrated statistical methods. The validation results ensure that excluding the monitoring locations in layer III does not significantly affect the information produced by the monitoring network.

Based on the evaluation of sampling frequencies, it is recommended to have 6 (instead of 12) samples per year for 18 (out of 36 examined) parameters (COD, TSS, TVS, N-NO_3, Pb, Ca, Na, Cl, Visib, BOD, Cu, Fe, Mn, pH, TDS, K, SO_{4_m} and DO). The measured parameter SO_{4_m} will automatically replace the SO_4 (calculated). SAR and Adj. SAR also can be calculated from the other parameters. For the other fifteen parameters (Mg, EC, Br, Ni, Sal, Cd, TN, TP, Temp, Fecal, Coli and N-NH_4, Zn, P and Turb), it is recommended to continue with 12 samples/year.

These recommendations may ensure significant reduction in the total cost of the monitoring network. This facilitates a fiscal resource, which is a key prerequisite in developing a successful program. The rescued budget can be redirected to achieve better performance in terms of improving the current resources. In addition, a frame of stakeholders-participation mechanism was proposed to ensure better water quality management in the project area.

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ABBREVIATIONS

AAS	Agricultural Advisory Service	
ACF	Autocorrelation Function	
ADB	Asian Development Bank	
Adj. SAR	Adjusted Sodium Adsorption Ratio	
ANOVA	Analysis of Variance	
APRP	Agricultural Policy Reform Program	
ARC	Agriculture Research Center	
asl	Above sea level	
BMI	Benthic Macro-Invertebrate	
BOD	Biological Oxygen Demand after 5 days in 20 oC	(mg/l)
Br	Boron	(mg/l)
Ca	Calcium	(meq/l)
CA.	Cluster Analysis	
CCA	Canonical correspondence analysis	
Cd	Cadmium	(mg/l)
CIDA	Canadian International Development Agency	
Cl	Chloride	(meq/l)
COD	Chemical Oxygen Demand	(mg/l)
Coli	Total Coliform	(MPN/100ml)
Cu	Copper	(mg/l)
DA	Discriminant Analysis	
DAS	Drainage Advisory Service	
DCA	De-trended Correspondence Analysis	
DFA	Discriminant Function Analysis	
DO	Dissolved Oxygen	(mg/l)
DRI	Drainage Research Institute, Egypt	
ds/m	Decisimens per meter	
DWIP	The Drainage Water Irrigation Project	
EALIP	Executive Agency for Land Improvement Projects	
EC	Electrical Conductivity	(dS/m)
EEAA	Egyptian Environmental Affairs Agency	
EPA	United States Environmental Protection Agency	
EPADP	Egyptian Public Authority for Drainage Projects	
FA	Factor Analysis	
FAO	Food and Agriculture Organization of the United Nations	
Fe	Iron	(mg/l)
Fecal	Fecal Coliform	(MPN/100ml)

Fed	Feddan = 0.42 Hectare (ha) = 4200 square meter (m^2) = 1.038 acres (ac)	
GAFRD	General Authority for Fish Resources Development	
GARPAD	General Authority for Rehabilitation Projects and Agricultural Developments	
GDEH	General Department of Environmental Health	
GOFI	General Organization for Industry	
IAS	Irrigation Advisory Service	
IBI	Index of Biotic Integrity	
ID	Irrigation Department	
IIP	Irrigation Improvement Project	
K	Potassium	(meq/l)
Km	Kilometer = 1000 meter	
m/d	Meter per day	
m^3/y	Cubic meter per year	
MALR	Ministry of Agriculture and Land Reclamation	
MANOVA	Multivariate Analysis of Variance	
MDEQ	Montana Department of Environmental Quality	
Means	Total Means For Water Quality Measurements	
MED	Mechanical and Electrical Department	
Mg	Magnesium	(meq/l)
MHUNC	Ministry of Housing, Utilities and New Communities	
Mn	Manganese	(mg/l)
MOE	Ministry of Environment	
MOHP	Ministry of Health and Population	
Monthly	Monthly Water Quality Measurements	
MPN	Most probable number	
MWRI	Ministry of Water resources and Irrigation	
Na	Sodium	(meq/l)
Ni	Nickel	(mg/l)
NLB	New Land Beneficiaries	
$N\text{-}NH_4$	Ammonia	(mg/l)
$N\text{-}NO_3$	Nitrate	(mg/l)
NTU	Turbidity units from a calibrated nephelometer	
NAWQAM	National Water Quality and Availability Management	
NWRC	National Water Research Center	
OLB	Old Land Beneficiaries	
P	Phosphorus	(mg/l)
P.S.	Pump Station	

PALR	Public Authority for Land Reclamation	
Pb	Lead	(mg/l)
PCA	Principal Components Analysis	
PFRA	Prairie Farm Rehabilitation Administration	
pH	Acidity / alkalinity scale	
PS	Planning Sector	
R	Correlation coefficient	
Sal	Salinity	
SAR	Sodium Adsorption Ratio	
Sig	Significant statistic	
SO_4	Sulphate calculated from the ion balance	(meq/l)
SO_{4m}	Sulphate measured	(meq/l)
SOM	Stakeholders/Objectives Matrix	
SPSS	Statistical Package for the Social Sciences	
SS	Sum of Squares	
SWRI	Soil and Water Research Institute	
T/ha	Ton per hectare	
TDS	Total Dissolved Solids measured at lab	(mg/l)
Temp	Temperature	(^oC)
TN	Total Nitrogen	(mg/l)
TP	Total Phosphorus	(mg/l)
TSS	Total Suspended Solids	(mg/l)
Turb	Turbidity	(NTU)
TVS	Total Volatile Solids	(mg/l)
USA	United States of America	
USDA	United States Department of Agriculture	
USGS	United State Geological Survey	
Varimax	Variance-maximizing rotation	
Visib	Visibility – Secchi Disk Depth	(Cm)
WHO	World Health Organization	
WQ	Water Quality	
WQM	Water Quality Monitoring	
WQP	Water Quality Parameter	
WUAs	Water User Associations	
Yearly Avg.	Yearly Averages For Water Quality Measurements	
Zn	Zinc	(mg/l)

CHAPTER 1

1. ENVIRONMENTAL ASPECTS OF IRRIGATED AGRICULTURE IN EGYPT

1.1 INTRODUCTION

Egypt's agriculture is an important economic sector providing 33% of all employment that has contributed about 17% to the national gross domestic product in the fiscal year 1998/9 (World Bank, 2001). It relies almost entirely on the artificial watering of crops, though since the mean annual precipitation in the country amounts to only 18 mm - ranging from virtually nil in the desert to a mere 200 mm along the Mediterranean coast. In many districts, rain may fall in significant quantity only once within two or three years. Moreover, most of the precipitation will usually occur during the winter months when plant water demands are low. At the onset of the summer air temperatures rise sharply, often reaching 38°C to 43°C with extremes of up to 49°C in the southern and western desert regions; only the Mediterranean coast has somewhat cooler conditions with 32°C as a maximum (FAO, 1993). Such high temperatures in combination with low air humidity and unhampered solar radiation are the driving force for the considerable evapotranspiration of any crop grown in these areas.

Consequently, throughout Egypt agriculture necessitates irrigation. Even at the temperate Mediterranean coast, farming requires substantial supplemental watering to produce reasonable yields. The traditional agricultural lands along the Nile River and in the Delta are called the "Old Lands", whereas farmland which in recent decades had been reclaimed from the bordering deserts along the Mediterranean coast, in Sinai and in southern (upper) Egypt usually is referred to as the "New Lands". Flowing straight through the country from South to North, the Nile River has served since prehistoric times as the main water source for the Old Lands, assuring a regular water supply to approximately 3.2 million ha of farmland today (Bader, 2004). The latter - traditionally cultivated with crops such as sorghum, cotton, maize, sugarcane, wheat, clover, and a great variety of vegetables and fruit trees - is very fertile and therefore ideally suited for vertical intensification.

Owing to this circumstance, the last century finally witnessed a radical change in Egypt's irrigated agriculture. The ancient system of pre-season water harvesting of the Nile flood in diked fields followed immediately by cultivation of one crop per year, which had prevailed since several millennia, became rapidly replaced with *perennial* irrigation and multi-cropping as soon as Lake Nasser started to form behind the newly constructed Aswan High Dam in the 1960s, providing bright opportunities for any kind of agricultural production. Even though the water volume to be legally diverted from the Nile River is limited to 55,5 billion m^3 per annum according to the treaty reached with Sudan in 1959, the huge storage capacity of Lake Nasser upstream of the Aswan High Dam can ensure this quota even over several dry periods. Given the favorable climate and a continuous water supply, irrigation farming nowadays can be performed all year round under excellent physical framework conditions enabling very high yields. In fact, productivity levels in Egypt often supersede world standard averages with wheat, maize and rice being regularly harvested at around 5.9 t/ha, 6.2 t/ha and 8.3 t/ha, respectively (Gomma, 1996). Under perennial irrigation conditions, the total cropped area now is estimated at about 5.1 million ha, which resembles a cropping intensity of around 160% for the country as a whole. This unique story of success would not have been possible without a reliable water supply network, though.

1.2 WATER DELIVERY SYSTEM

Egypt's vast irrigation system stretches over a length of 1,200 km from Aswan northwards clear up to the Mediterranean Sea. Controlled by seven main barrages along the Nile River at Aswan, Esna, Nagga Hammadi, Asyut, Delta, Zifta and Edfina, irrigation water is brought to the Old Lands by diverting at these locations part of the river flow to public principal canals. These in turn feed a complex distribution network consisting of approximately 1,000 km of main canals, 30,000 km of secondary (branch/distributary) canals, and 80,000 km of tertiary feeders, the so-called "Mesqas" (Abu Zeid, 1995).

The water delivery system, which includes large canals discharging up to 1000 m^3/sec, is classified according to size and function as follows (El Gamal, 1997):

- **Principal canals** continuously receive water directly from the Nile River to convey it to public main canals. Direct irrigation from these canals is not permitted.
- **Main canals** continuously receive water from principal canals for conveyance to public branch canals. Some main canals may take water immediately from the Nile River. Direct irrigation from main canals is not permitted.
- **Branch canals** continuously receive water from main canals to convey it to public distributary canals. Direct irrigation is permitted only along the lower reaches of these canals, where their size compares to a distributary canal.
- **Distributary canals** usually continuously receive water from branch canals for further distribution. Direct irrigation along all distributary canal banks is permitted through legal farm outlets. From this canal level further downwards water distribution follows different rotational schedules.
- **Tertiary feeders** ("Mesqas") and private ditches receive water from distributary canals for rotational delivery directly or via on-farm ditches ("marwas") to basins, border strips and/or furrows on the farm.

The distribution system in the Old Lands almost exclusively operates on gravity flow. However, water is generally supplied throughout the network *below* field surface levels, which forces farmers to finally lift the water from the watercourse next to their land by 0.5 - 1.5 m. The latter is usually achieved by means of animal-powered or hand-operated devices, increasingly though with fuel-powered pumps. Exceptions to this include the Fayoum region and some canal command areas in Upper Egypt, where water deliveries to and beyond the farm turnouts continue by uninterrupted gravity flow (FAO, 1997). In contrast, the distribution system in the reclaimed areas of the New Lands had to be based from the very beginning on a cascade of pumping stations between the main canals and the farm turnouts with a total lift of up to 50 m.

So far most of the irrigation canals in the Old Lands are lacking any form of lining. The main problem arising from this feature generally manifests itself in water losses by seepage and flow rate reduction due to weed growth or eroded canal cross-sections - leading to an apparent inequity in water delivery between the inlet and the tail end of a distributary canal or Mesqa. In due course, affected irrigation farmers become increasingly apathetic towards public water delivery and seek to exploit localized solutions such as shallow or even deep wells to gain a more reliable water supply directly on the farm. The removal of weeds from and a general maintenance of private Mesqas traditionally is the responsibility of the riparian farmer. But in the presence of excessive weed growth and blocking of canals caused by sediment, garbage and debris especially in or next to villages, many farmers are unable to successfully cope with this situation (Wolff, 1999). So *trust* in the (water delivery) system as such has become one of the most pressing issues of irrigated agriculture in the country today. Therefore, a reliable and equitable supply of irrigation water - in both quantity and quality - is an absolute prerequisite for maintaining Egypt's success in agricultural development for future generations!

1.3 IRRIGATION PRACTICES

Egyptian farmers of the Old Lands traditionally distribute irrigation water over the entire area of their fields by the gravity method - commonly known as "surface irrigation". For best results each field is devided into *small* plots of not more than 10m by 10m in size arranged as basins, border strips or furrows, which receive their irrigation water via on-farm ditches called marwas. Small plots generally provide the operator with good water and crop control, allow reasonably uniform application of water even if fields are somewhat unleveled, and also enable a fast disposal of excess water, which remains on the surface after soils have sealed, into open field drains or - as in some cases - back into the Mesqa. Such practice is very common whenever farmers are not required to pay for water (El Gamal, 1997).

Irrigation water is delivered to summer crops like rice between 1 May and 15 October on an *official* rotational schedule, consisting of 4 days of water supply and 6 days pause (4/6 rotation); in some cases a 5/5 rotation has to be followed. Winter crops between 15 October and 30 April usually require 5 days of water supply and 10 days pause (5/10 rotation) (Oad, R. and Azim, R., 2002**)**. The number of days the water delivery is turned off during one irrigation cycle usually depends on averaged crop consumptive use in accordance with seasonal climatic conditions. But often farmers have a prolonged irrigation pause between the final water application to a previous crop and the first irrigation of the next, the duration of which varies with *individually* preferred agronomic practices. If large standardized volumes of water are conveyed during such a period, a considerable amount will flow unused through the delivery system directly into the drains. Therefore, irrigation water supply strategies must also take into account the spatial and temporal variability of agronomic practices within an entire canal command area.

In the reclaimed areas of the New Lands, farmers are obliged to apply sprinkle or micro irrigation technologies since gravity irrigation is prohibited by law. The main reason for this ban is that these regions - usually located at the tail end of the delivery system - are more prone to water shortages. In addition, most of the reclaimed land lies in areas with sandy soils, where sprinkle and micro irrigation technologies can be operated with much higher efficiency requiring overall substantially less water than gravity irrigation. Apart from their labour easing and saving effects both mechanised irrigation methods have the advantage of continuous operation, whereas applying water at night is not very popular with gravity irrigation (El Gamal, 1997). However, sprinkle and micro irrigation necessitate a completely different timing of the water supply and ideally lend themselves to the so-called *continuous flow* regime. As of today, sprinkle irrigation is practiced on 117,000 ha while micro irrigation covers 83,000 ha (3.6% and 2.6% of the agricultural land, respectively).

Already in 1979, the Minister of Irrigation noted that Egyptian agriculture is considered to be one of the most consumptive in irrigation water worldwide. The high consumption is not due to reasons related to soil; instead it reflects the wasteful use of irrigation water (Samaha, 1979). Merely half if not even much less of the water volume made available to the irrigation system is required to satisfy crop evapotranspiration needs. Most of the remainder gets lost in the conveyance and application process by seepage and evaporation, but also as non-utilized efflux some of which might be reallocated elsewhere for domestic, industrial and navigation uses. Since the seepage nourishes the groundwater reservoir of the Old Lands, it is sometimes not looked upon as being a real loss.

Recent measurements revealed that farmers generally apply 50-250% more water than has been calculated to meet both crop evapotranspiration and leaching requirements (IIP, 1993). One reason for this vast over-irrigation lies in the lack of water control incentives, and farmers generally have the tendency to apply too much water too soon (Clemmens, 1987). Egyptian agriculture consumes about 85% of all surface waters presently made available in the country (Abu Zeid/Rady, 1992) and it is the sector that bears - in terms of total volume - the greatest potential for conserving water. Even relatively small reductions in the on-farm water input will result in considerable water savings on the national scale; conservative estimates are in the range of 15% (World Bank, 1993).

Unfortunately, poor irrigation management not only wastes water but also precious plant nutrients, which are washed away with the seepage. In addition, it contributes to the problem of critical groundwater table height and tends to overload the drains. Furthermore, costly labor and energy resources are spent in vain when applying excess water to crops. Best agricultural water management practices require precisely leveled field surfaces and appropriately designed on-farm application systems, but foremost *knowledge* of when to irrigate and how much water to apply.

1.4 SPECIFIC SOIL WATER ISSUES

Until the 1960s, farmers in the Nile Valley and Delta had access to water only during the flood season and hence stored all they could get at this time by diking their fields. In those days the question of whether *too much* water had entered the soil matrix was obsolete in the face of an inevitable flood and with the dry season ahead. Unfortunately, this mental approach towards irrigation still governs most farmers' behaviour and lets them apply water excessively, even though the latter is now available in regular intervals during the whole year from the irrigation canal right next to their farm. The problem gains in severity by the fact that no effective/direct service fee for irrigation water deliveries has been charged so far, and that only minimum control is exerted when farmers are pumping water from the canals. If water application practices in gravity irrigation continue this way, even larger tracts of Egypt's limited agricultural land will become affected from waterlogging.

In an arid environment, not only waterlogging but also soil salinity and soil sodicity on previously unaffected fields are basically due to irrigation in the absence of adequate drainage. Especially soil salinity and soil sodicity must be looked upon as the most hazardous natural threats to irrigated agriculture in the tropics and subtropics, confining land use to a few tolerable crops if at all. Once the damage is apparent, substantial additional capital investments and management input will be required on this land just to keep the negative effects at acceptable levels (Abu Zeid, 1995).

The predominantly fine textured soils in the Nile Valley and Delta resemble alluvial and alluvio-marine deposits. The common textural class is clay of the montmorillonite or illite type, sometimes mixed with silt. Overall permeabilities are low ranging from 0.02-0.80 m/d, with little chance to improve naturally - partly due to the low salt concentration in the irrigation water (i.e. electrical conductivity values of Nile water less than 1 dS/m). Already more than 200,000 ha of heavy clay soils in the northern Delta are highly saline often combined with poor internal drainage properties. In a large number of cases the sodicity hazard is considerable and contributes to the very low permeability. Reclaiming these soils requires improvement of their physical and chemical properties by means of a well-designed drainage system in combination with various intelligent rehabilitation practices.

"*Soils in the Nile Valley and Delta range among the most fertile in the world*" (Abu Zeid, 1983). Because of the tense demographic situation in the country, Egypt cannot afford to loose even a small portion of this precious natural resource. When irrigation systems are planned and implemented, soil degradation problems usually are not expected for the first 10-15 years. Therefore, often no urgency is felt to install a drainage system from the very beginning. But the more the soils become affected over time, the less profits can be skimmed off the land to pay for the rehabilitation expenses necessary. This leaves decision-makers with the difficult task of finding the best point of intervention, when the cost of improvement still can be recuperated easily.

1.5 AGRICULTURAL DRAINAGE

In Egypt, artificial drainage commonly takes the form of either open ditch drains dug along the field edges (surface drainage) or slotted corrugated plastic drain pipes or drain tiles laid across the plots underground at average depths of 1-2 m (subsurface drainage). A lot of experience has been gained in the country with both on-farm drainage systems, which divert their effluent via the collector drains to a densely woven network of public open drains finally discharging into the Mediterranean Sea. Today, more than 17,000 km of public drains mingle with the nation's vast irrigation infrastructure. Surface drainage has been under construction since the turn of the 20th Century, whereas the implementation of large-scale subsurface drainage projects began around 1970. By now, approximately 1.7 million ha (53%) of irrigated land are equipped with one or the other type of drainage system.

Similar to the water delivery system, the drainage discharge system comprising also large canals conveying up to 1000 m^3/sec can be classified according to size and function as follows:

- **Sub-collector drains** and tailwater ditches intermittently receive their effluent on-farm directly from open/subsurface field drains, or basins, border strips, furrows and marwas right after an irrigation event, to further divert it to collector drains.
- **Collector drains** more or less continuously receive effluent on the farm from the sub-collector drains to convey it to public branch drains. Like sub-collector drains, in subsurface drainage systems collector drains may be pipes installed underground.
- **Branch drains** continuously receive effluent from on-farm collector drains to divert it to public main drains. Usually, branch drains are open ditches densely woven into the rural infrastructure running often through or next to the villages.
- **Main drains** continuously receive effluent from branch drains for further conveyance either to a public multi-purpose conduit or to finally discharge into the Mediterranean Sea like the lower reach of the Hadus Drain.
- **Multi-purpose conduits** receive effluent *on demand* from the main drains to be blended with river water, serving in large public projects the goal of long-distance water transfer - as is the case with the El-Salam Canal supplying the Sinai region.

In order to manage intermittently or constantly high watertables for maximum crop yields, drainage systems are designed to *continuously* remove excess water from the root zone to keep watertables at or close to the desired depth. However, when controlling soil salinity and sodicity drainage systems discharge - in more or less regular *intervals* - only a certain, relatively small amount of water, which is called the leaching fraction, containing all salts as dissolved solids. In the case of soil sodicity, additional measures such as subsoiling, amendment of conditioners like gypsum, or/and deep ploughing are required before leaching. Concerning irrigated agriculture in Egypt both drainage approaches have to be dealt with today, because waterlogging due to heavy over-irrigation as well as soil salinity and sodicity resulting from perennial irrigation in the absence of a prolonged Nile flood seriously threaten crop production and the well-being on farms in general.

Specific constraints come about with conventional subsurface drainage in areas, where paddy rice is integrated into the crop rotation, leading to great differences in drainage requirements between rice and non-rice crops. While all other crops necessitate a well-aerated root zone, rice needs ponded conditions throughout its growing season. Under the current conventional (large scale) layout of subsurface drainage systems and the prevailing traditional crop mix in Egypt, rice plots usually share the same field drain with non-rice plots in a random pattern that changes with the crop rotation. The hydraulic head of an open water surface far above the subsurface drain causes tremendous drainage outflows from rice fields. Farmers faced with this unfortunate situation either have to find a way to block the drains temporarily during the rice season or keep replenishing the ponded fields. In addition to the costs and efforts involved with the latter solution, irrigation water is usually scarce at the required time, especially for users at the tail ends of irrigation canals.

Although being illegal, blocking the drains then often seems to be the only solution to maintain an open water surface in rice fields. However, it has some serious consequences under a *conventional* drainage layout: Putting a plug in a collector pipe outlet at a manhole usually stops drainage outflows not only from the rice field, but also from all other fields upstream of the blocked section. Excess hydraulic head will then develop in the system due to continued seepage from the rice field, causing water tables in fields upstream to rise substantially, possibly as high as the soil surface. This situation may seriously damage summer and perennial non-rice crops like cotton, maize, fruit trees etc. Another problem is operational as farmers usually employ plugs made of straw, leaves and mud, which often slip into the pipe causing permanent clogging of the drain. Then, additional maintenance will be required to clean up the system (DRI, 1996).

In order to avoid the problems associated with conventional drainage systems in paddy rice, it became necessary to implement drainage *sub-units* just as small as one coherent area of seasonal rice plots, which could be plugged individually. Such a controlled drainage system basically consists of a collector pipe and a number of sub-collectors, each serving a unit area that must be planted *entirely* with either rice or non-rice crops during the summer growing season. Two sub-collectors feed into the main collector at manholes, where a simple closing device (flap gate) has been added to the sub-collector outlet. When the area served by a sub-collector is cultivated with rice, the outlet can be easily closed according to the required water management in that specific rice field. The other sub-collectors serving non-rice crops will continue to have their outlets open during the whole growing season to enable maximum drainage.

Several studies concerning the application of controlled drainage in rice fields have been carried out by the Drainage Research Institute (DRI) of the Ministry of Water Resources and Irrigation (MWRI). The results are very promising: Water savings of up to 40% have been achieved with no reduction in crop yield or increase in soil salinity (DRI, 1998). However, the question remains whether rice fields are negatively affecting neighbouring crop stands by substantial seepage through the soil matrix, since the crop rotation in Egypt does not allow an impermeable layer to develop at the bottom of the root zone, which would otherwise inhibit salt leaching.

The flap gate enables farmers also to throttle drainage outflows from non-rice crops in an attempt to store more water below the root zone and make it eventually available to plants. The system is manipulated in a way that drainage occurs only after the groundwater table has risen to a level which would damage the crop, or to provide salt leaching. Irrigation applications can thus be reduced, and the good quality water from Lake Nasser that is saved will become available to other downstream irrigators.

1.6 DRAINAGE WATER REUSE

In view of the ever-increasing gap between the supply and demand for water in the country, the Government of Egypt is under pressure to develop other *innovative* means of stretching the nation's limited water resources. Among the various proposed solutions one will also find the *reuse* of any kind of drainage water (agricultural/industrial/municipal or - most often - a mixture thereof) in agricultural production processes: Especially during the peak season in the summer Nile water may be augmented with a certain quantity of drainage *effluent* (a better term for this kind of composed liquid) to meet crop water requirements. From an agronomic point of view, the limit for this blending of irrigation water is solely defined by the maximum concentration of salts or specific ions tolerated by *all* crops grown simultaneously during one season.

Although it is prohibited to apply undiluted drainage effluent to crops, irrigators short in fresh water supplies are often desperate enough to offend the law. Even though an Egyptian farmer - as reflected by heavy over-irrigation - is not encouraged to change his water use strategies because of the mere *possibility* of regular water delivery communicated by the physical presence of an irrigation canal network, his behavior does indeed take *full* account of the equity and reliability achieved in the daily management of water distribution.

Many farmers, especially at irrigation canal tail ends, immediately will start pumping more or less (or even not at all) diluted effluent from the nearest open drain to irrigate their fields as soon as they feel being inadequately treated in terms of volume or timing of irrigation water delivery. If the water supply has been cut off completely for a prolonged time, this emergency reaction might save the irrigator from a total crop loss. However, under less dramatic circumstances it is most likely that such a practice will affect crop yields negatively, since effluents in open drains are often highly saline and/or polluted with domestic and industrial wastes. The latter raises serious concern about the safety of foods grown in such areas, and a lot of research is carried out to find feasible solutions for these pressing problems.

In terms of volume, *drainage water outflow* from subsurface field drains, *surface runoff* from irrigated fields, and irrigation canal *seepage* usually form the major constituents of the drainage effluent conveyed in open public drains. As a result of the intended leaching process in the soil profile, the concentration of (dissolved) salts in the water discharged from field drains is high, especially in the northern part of the Nile Delta where seawater intrusion and upward seepage contribute extra loads of salts. Egypt's irrigation water supply network was originally designed to operate 24 hours per day, but over the years most farmers have abandoned night irrigation wherever it had been adopted. This explains in great part why today considerable volumes of irrigation water regularly run out of the irrigation canal tail ends and escape unused through emergency outlets right into the drainage network. As a result, the volumes of drainage effluent to be conveyed have increased considerably, which in certain locations might question already the upper limit of the drainage network capacity on the one hand - whereas in principle the diluting effect has the potential to decrease the concentration of salts and other substances in the drainage effluent drastically. Since the direct utilization of *diluted* drainage effluent for irrigation purposes generally does constitute a hard-to-resist subliminal temptation for *all* involved stakeholders, a modified approach towards this new but still delicate way of "water management" has become the subject of highly specialized research in the country now.

In fact, the reuse of drainage effluent appears to be one of the most promising, practical and economical means of increasing the Egyptian water budget. For example, field experience supported by experimental work indicates that utilizing *saline* drainage effluent can improve the permeability of sodic soils. It penetrates easier into the soil profile than pure water and speeds up the leaching process by enhancing the soil structure with its dissolved solids to a certain extent. Yet, such soil amelioration has only a meaning if the salinity of the effluent itself is not a hindrance to plant growth, and if chemical or biological contamination does not pose any threat. Therefore, drainage effluent reuse has obvious advantages but involves also serious risks - both of which are rather of a *managerial* than engineering nature.

Nevertheless, the Government of Egypt looks upon drainage effluent as an ideal new water resource for horizontal agricultural expansion (DRI-DWIP, 1997). The phrasing in the various programs depicts this form of recycling a composed drainage effluent as "drainage *water* reuse" - a term also used in this study further on to ease communication. Since the late 1980s, three major drainage water reuse projects have been initiated on previously barren ground:

- **El-Salam Canal Project**, diverting 2 billion m³/y of drainage water from the *Hadus* and Lower Serw drain basin to reclaim and irrigate 78,000 ha west of Suez Canal and 170,000 ha in Sinai
- **El-Omoum Drainage Project**, reusing 1 billion m³/y of drainage water from the Omoum drain basin to irrigate 210,000 ha in Nuberia
- **Kalapsho Project**, capturing 1 billion m³/y of drainage water from Drain No. 1 and Drain No. 2 to irrigate 23,000 ha of new land in Kalapsho

This resembles in total a 4 billion m³/y drainage water reuse expansion plan - equivalent to 7% of Egypt's annual water budget! Whether it will be achievable depends on the success of control measures such as eliminating municipal and industrial wastewater pollution from agricultural drains, or preventing unofficial and unauthorized reuse.

The drainage system in the Nile Delta is composed of 22 catchment areas. Depending on their quality, effluents are either discharged into the Northern Shore Lakes or are being pumped into irrigation canals at 21 locations along the main drains to augment freshwater supplies (DRI-MADWQ, 1998). An area of about 400,000 ha already *relies* more or less on these drainage water deliveries for the irrigation of crops. Examples are lands served by effluents from the Hadus, El-Gharbia, El-Raisi, Edku and El-Omoum main drains. In Lower Egypt, the total drainage water volume utilized in irrigation applications amounts to roughly 3.5 billion m³/y. As for Upper Egypt, the drainage water volume returned to the Nile is estimated at about 2.3 billion m³/y (Abu Zeid, 1987).

1.7 DRAINAGE WATER QUALITY MONITORING

Today, intensified industrial and agricultural activities cause water pollution to spread rapidly throughout Egypt, especially in the Nile Delta. Huge amounts of municipal and industrial effluents as well as farm and rural domestic wastes are discharged into agricultural drains without being treated *at all*. Due to the scarcity of land and ideal topographic conditions in the Delta Plain, agricultural drains have become comfortable dumping sites for all kinds of waste. After the construction of the Aswan High Dam, the seasonal Nile floods which had flushed the Delta's lowlands periodically clean since ages no longer reach there, so the pollutants precipitating from municipal and industrial wastewater are now accumulating in the system over the years as does the solid waste thrown into the open drains. In combination with an amazing lack of awareness this poses an increasingly serious threat to Egypt's intended drainage water reuse programs, especially in the Nile Delta region.

Approximately half of the Egyptian population lives in cities and towns, whereas the other 50% settles in villages. In larger cities like Cairo and Alexandria but also in many capital cities of the governorates, public sewers and treatment plants are under construction or operating already (Welsh/Khalil, 1991). Yet, more than 23% and 74% of the residents living in small towns and villages respectively do not have sewer systems and treatment facilities (MOHP, 2000). Hence, it is difficult to precisely estimate the amount of wastewater emitted from those sources. Most industries - except for a few large ones - did not install effective wastewater treatment equipment so far. At present, *untreated* industrial effluents are often mixed with municipal wastewater in combined sewers, although this is illegal and prohibited by Egyptian law (Ramadan/Ahmed, 1995).

Therefore, *water quality monitoring* (WQM) as well as strict law enforcement have become indispensable prerequisites for an effective water resources management in Egypt. In general, the term "water quality (WQ)" refers to specific properties of a water body that will affect its suitability for a particular use. Water quality is defined by a great variety of physical, chemical and biological characteristics. An assessment of water quality conditions over a wide area requires monitoring activities to be carried out on large network scale. Consequently, WQM networks are comprised of a statistically meaningful number of sampling sites, at which data on particular water quality parameters (WQPs) will be collected in specific time intervals. However, a systematic coordination within the network will only come about after situation-specific selection of the key design factors from **each** of the three basic factor categories "sampling *locations*", "sampling *frequencies*", and "*parameters* to be sampled"! In contrast, monitoring a number of parameters at random points in random time intervals cannot be considered systematic and thus does not substantiate a network.

The *very first* step in WQM network design always is to define the *objectives* of monitoring, which usually lead automatically to the identification of the necessary design factors within each of the three basic categories (locations, frequencies, parameters). Up to this point, the design process must be regarded as extremely sensitive to errors. Unfortunately, consequences of the latter may produce an unreasonably huge data load with insufficient or redundant information (data rich - information poor) that will only be detected after considerable time of network operation - if at all. Other essential components of monitoring networks - e.g. technologies applied in sampling and measurements, laboratory analyses, data processing and analysis procedures - will be selected in subsequent steps of the network design process after the core has been established.

The importance of WQM cannot be overemphasized, because it is the only tool that *communicates* in-depth information about water quality beyond the pure data acquisition activity. Numerous programs had been developed in the past to monitor the quality of the Nile water and agricultural drainage water in Egypt. Various entities from different ministries were involved in the monitoring process, but effective communication among them and to the outside world was somehow missed. In addition, irrigation canal water and groundwater had been exempted in these programs, which finally made it impossible to delineate the overall water quality status in Egypt. As a remedy, the National Water Quality and Availability Management (NAWQAM) Project was conceived in cooperation with the Canadian International Development Agency (CIDA) to overcome the previous problems and to transform all results from previous monitoring activities into a new sustainable national WQM program.

Already in 1977, the DRI as a member of the National Water Research Center (NWRC) had started under the directive of the MWRI to monitor a few volumetric and qualitative water parameters (predominantly concerning salinity) in some of the main drains in the Nile Delta. Since 1995 the DRI continuously had to expand its monitoring activities (Figure 1-1) to include an ever-increasing number of sampling locations and WQPs as requested by the strategic water resources planning sector. Under the NAWQAM Project it became clear, though that in the meantime the foundation for a sound national WQM network, which manifests itself in the situation-specific selection of the key design factors from each of the three basic categories (locations, frequencies, parameters), had grown *unreasonably* broad - in other words: Today, the network monitors *too* many parameters at *too* many locations at *too* high a frequency!

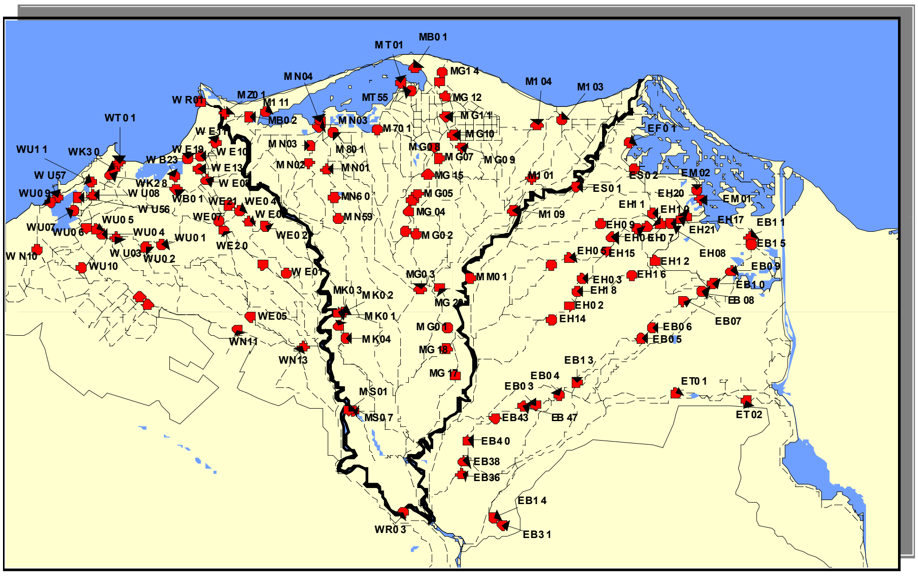

Figure 1-1: Drainage WQM locations in the Nile Delta region

(Source: DRI internal data)

1.8 PROBLEM DEFINITION

Established soon after the completion of the Aswan High Dam, Lake Nasser has improved the water resources management situation in Egypt today in so far as it enables since the 1970s *year-round* water supplies not only to all agricultural users but also to the municipal and industrial sectors. Under such conditions, the standard of living has risen steadily in the country giving way to all kinds of expansion - especially of the population. The most recent census on the specific availability of cultivated land (500 m^2 per capita) and water (850 m^3/y per capita)[1] made it very clear that from now on the consumable Nile volume flow of 55.5 billion m^3/y must be regarded as the true limiting factor for any kind of growth in the country. In fact, without any countermeasure the expected increase in population will cause the internal renewable water resource situation to fall to 350 m^3/y per capita by 2025; simultaneously, the demand for irrigation water will continue to rise over the next decade and beyond, even if the agricultural sector would adjust to a smaller share of the Nile's water (FAO, 2005). Since it is almost impossible to significantly supplement the available Nile flow from other water sources such as groundwater (4.9 billion m^3/y max.) drainage water (7,4 billion m^3/a max.) or sewage water (2.5 billion m^3/y max.) at *reasonable* cost (Abu Zeid, 1995), today's strategies of water resources management also aim at increasing the efficiency of water use in irrigated agriculture, which still receives the largest share of the annually diverted water volume (agriculture 84%, industry 8%, municipalities 5%, navigation 3%).

The Government of Egypt is firmly committed to face the compelling challenges imposed by water scarcity and competition for water. With regard to the continuously increasing water demand of more than 70 million consumers as well as in view of the volumes required to irrigate 480,000 ha in the South Valley and North Sinai Development Projects, it has already agreed upon certain measures to increase water use efficiencies within the whole national irrigation system (El Quosy, 2001):

- Recycling of agricultural drainage water, domestic sewage and industrial effluent [T/M]
- Reduction of evaporation and seepage losses from the irrigation/drainage network [M]
- Conversion to pressurized irrigation systems (sprinkle/micro irrigation technologies) [T]
- Change of cropping patterns as well as of planting and harvesting dates [A]
- Encouragement for land leveling and irrigating at night [T/M]
- Restriction of rice and sugarcane cultivation [E]

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[1] Threshold value: 1000 m^3/a per capita

- Introduction of short season crop varieties [A]

Except for the first two items, this bundle of measures - some already now and some in the process of soon being applied, as per December 2006 - directly aims at water savings to be achieved mainly on-farm. The relevant actions (to be) taken by the Ministry of Agriculture and land Reclamation MALR and/or MWRI under the above initiative can roughly be grouped into agronomic [A], economic [E], technical [T] and resource management [M] approaches. Even though the term "recycling" in the first item rather stresses technical aspects, the phrasing as a whole clearly calls for managerial solutions emphasizing the *reuse* of drainage water, domestic sewage, and industrial effluent as the key aspect to concentrate on.

As the desire (or temptation) to utilize suitable (or unsuitable) drainage effluents keeps on growing fast, the expansion and even the continuation of present drainage water reuse is already threatened by the rapid deterioration of water qualities - mainly owing to municipal and industrial wastewater pollution. In reality, Egypt is facing multidimensional challenges regarding this subject! Parallel to the enormous efforts exerted by all involved governmental bodies international assistance has been rendered continuously over the past decades. Among other activities, the MALR and MWRI recently designed a project concept, which aims at saving irrigation water as well as increasing the income of small-scale irrigation farmers in the Nile Valley and Delta via improved on-farm water management practices. Since July 2002, also Germany supports both ministries through technical assistance for a total period of nine years: Besides advising the MALR and MWRI in formulating and implementing appropriate sector policies, the support primarily aids their extension structures in disseminating improved water management knowledge and skills relevant to irrigation farming - including also the subject of drainage water reuse (Hübener, 2004). In view of the above-described status quo there definitely is an urgent need for reliable information about the quality and quantity of effluents flowing in the national drainage system.

The assessment of a drainage WQM network in the eastern Nile Delta (Shaban, 2001) revealed that the original design of the monitoring program itself - beginning in 1997 - had been based on strategies conceived in the 1970s which focussed mainly on measuring discharge and salinity. In a first attempt to improve the monitoring network, authorities then began to add more WQPs and locations to be sampled. Today, this gives rise to many questions already about the site selections and their appropriateness for current monitoring programs, because the integration between all monitoring locations, which is essential for transferring numerical data into visible and logic information as one of the main monitoring objectives, is somehow missed. In addition, the sampling frequencies had been based on the assumption that the water quality data is normally distributed and that both seasonal variations and serial correlations are not significant. But it is common to detect in water quality data seasonal variation (Schertz et al., 1991) and serial correlation since successive data sets are often not statistically independent. Furthermore, some parameters may exhibit redundant information of little or no use. Such impairments are usually the result of a variety of conditions, including specific agricultural land-use practices, biological activity, or sources of stream flow and sediment.

Yet, the most prominent problem in Egypt's WQM program today simply is its *size* - not so much the physical dimensions of the networks than the huge data load produced in each one of them, which only too often has become more or less unaligned with the specific monitoring objectives over time. Since *too much sampling* takes place in the existing networks, the challenge definitely lies in a refined spatial and temporal *consolidation* of network activities to a logistically and financially managable scale - on the grounds of profound statistical analyses.

1.9 OBJECTIVES

The overall objective of this research is to introduce a rationalization technique for established (drainage) WQM networks that will enable a situation-specific consolidation of monitoring processes as well as a redesign of the network itself, if necessary. This is demonstrated in a case study along the Hadus Drain in the Nile Delta as one of the main feeders within the El-Salam Canal Project - by raising the question: "At how many *locations* should one monitor under the condition of an acceptable benefit/cost ratio which *parameters* at what *frequency*?" Most probably, the answer will lead to reductions in the present network activities, but eventually to some new extensions, too. Through this strategy the thesis attempts to support the great effort of all involved Egyptian authorities to gather *reliable*, yet *affordable* information about the quality and quantity of effluents flowing in the national drainage system, which are meant to augment freshwater supplies and to stretch the country's critical water budget.

More specifically, the following objectives have been chosen under the directive to optimize the information gained from this in-depth doctoral study for direct application in the redesign process of the National Water Quality and Availability Management (NAWQAM) Program:

- To assess and reformulate the currently applied drainage WQM objectives based on realistic expectations

- To determine the location of monitoring sites by using the appropriate statistical methodology in order to avoid redundant, insufficient or even useless water quality data
- To recommend a reasonable sampling frequency regime based on the effects of both seasonal variation and serial correlation in the time series of water quality data sets
- To propose innovative ways and means to facilitate an integrating water quality information management

Formerly in Egypt, selecting the drainage WQM locations had been achieved through a simple, rather crude two-step procedure: The analysis of the *correlation* of water quality and quantity parameters between neighbouring locations - and a location *ranking*, with regard to pollution source type, served area and relative position within the drainage system (DRI-MADWAQ, 2001). Yet, this research will also incorporate an innovative approach towards considering the stochastic and unique characteristics of spatially and/or temporally unpredictable pollution occurring every now and then in the drainage water - e.g. after illegal deposition of wastes from so-called "dump trucks" resembling an intermittent unsteady-state point-source pollution.

Historical data from the drainage WQM network within the El-Salam Canal Project will be used for all analyses. The whole network stretches all over the Eastern Nile Delta region and comprises the Hadus, Farsqur and Serw main drains - and the El-Salam Canal itself.

In order to keep the computational load within reasonable limits, the research confines itself to a fully representative case study on one of the main feeders in the El-Salam Canal Project - the Bahr Hadus drain. Bahr Hadus drain data has been selected especially because of its greatest variety of statistical problems.

CHAPTER 2

2. EL-SALAM CANAL WATER QUALITY MONITORING OBJECTIVES

This chapter introduces the most common objectives for WQM networks that have been recorded in the recent years. In general, eleven main objectives were reported that cover most of the questions related to WQM and can be seen as a good basis for setting the specific objectives for the El-Salam Canal Project. For each objective, a brief description and its possible influence on the other network design items (such as locations, frequency and monitored parameters) were introduced.

Afterward, the detailed activities that were carried out to define the monitoring objectives for El-Salam Canal WQM network were presented.

2.1 WATER QUALITY MONITORING OBJECTIVES

The constant attention accorded the quality and availability of water resources reflects man's dependence on water for personal use, farming needs, and industrial processes. Recently, the water pollution has been recognized as a serious and growing problem. The quality of water and the threat of waterborne diseases (for example, cholera and typhoid) are critical public health issues in many developing countries (ADB, 2002).

From a broad perspective, there are many reasons to monitor WQ. The monitoring process and the data that are generated provide a valuable informative tool for a wide variety of user groups, such as decision makers, watershed councils, researchers, and other interested stakeholders.

Monitoring objectives delineate the eventual information expected from the network, and failure in specification of the expected information leads to failure of the network itself (Harmancioglu et al., 1992).

Monitoring without clearly defined objectives provides little benefit. In this case, the data do not lead to information from which conclusions can be effectively drawn. Cavanagh et al, (1998) mentioned that defining clearly the monitoring objectives is the first, and most crucial step in developing an experimental design. Each objective should be derived from a particular question that needs to be answered. Objectives should be also written simply and should reflect both public questions and scientific and/or managerial needs.

Harmancioglu et al., (1998) indicated that a clear statement of network objectives can ensure the collection of only the necessary data and can avoid needless and wasteful expenditures in time and money. In general, identifying the type of monitoring is not as important as identifying the important resource questions and properly preparing the monitoring plan to answer them (ODEQ, 1998).

2.1.1 Purposes of Monitoring

Definition of monitoring objectives plays a key role in WQM network design. One of the most significant problems associated with current networks is the lack of a precise and proper definition of monitoring objectives. WQM programs often involve a series of repetitive measurements for the purpose of providing information to address historical, current, or desired future conditions, determine ecological trends in the quality of the aquatic environment and how the environment is affected by the release of contaminants, by other human activities, and/or by waste treatment operations, describe impacts from management activities that are taking place, or interpret effectiveness of management actions.

One may refer to Ward (1973), Sherwani and Moreau (1975), Langbein (1979), or to Tirsch and Male (1984), USGS (1995) and Harmancioglu (1998) for different descriptions of monitoring objectives, namely that monitoring is required to:

- Assess compliance with standards;
- Facilitate impact assessment studies;
- Facilitate baseline WQ information (Survey monitoring);
- Determine fate and transport of pollutants;
- Measure effectiveness of conservation practices;
- Make waste-load allocations;
- Validate & calibrate models and establish a database for the planning and development of water resources;
- Conduct research;
- Define WQ problem;
- Detect possible trends in WQ with respect to time and space;
- Assure a publicly credible basis for controversial (hot) decisions.

It should be noted that the information from each of these categories is obtained specifically for the needs of that particular category. However, data from some categories may be useful for others.

- **Assess Compliance with Standards**

Connell and Miller (1984) stated that*"...environmental standards and criteria give an indication of the acceptable levels of occurrence of a pollutant for the maintenance of water quality*". In general, WQM frequently has been used to determine compliance with WQ plans and standards. Compliance monitoring is also a component of permit obligations, for instance, industries or/and municipalities that discharge liquid wastes to a water body should satisfy the standard (allowable) concentrations of particular variables in both the effluent and possibly in the receiving waters.

In proper WQM network design, identifying the monitoring objectives should lead to define the other design items such as site selection, variables to be monitored, sampling frequency. In this concern, the compliance monitoring is generally the least difficult to design. The primary concern is limited to allocating the budget appropriately and ensuring that the personnel undertaking the work are suitably trained. Compliance monitoring should also consider climate conditions.

"*There are general formats that are followed for many compliance monitoring programs. For example, there may be a requirement to sample at a minimum frequency within a given time frame or sampling during the critical periods (typically periods of low or high stream flow). The most intense sampling should occur at locations most likely to exceed the standards*" (Cavanagh et al, 1998).

- **Impact Assessment Monitoring**

Harmancioglu (1992), Whitfield (1988), Chapman (1992) indicated that one of the most common objectives for WQM is to facilitate impact assessment on WQ of a particular project. Projects, in this case, refer to anything associated with industrial activities, resource extractive activities, impoundments (dams), agricultural activities, and urban or recreational developments.

An ideal impact assessment monitoring program is one that has both test and control sites, are initiated prior to project start-up, continues while the project is operational, and extends for a defined post-project time period. In this case, a baseline (pre-operation/treatment) assessment is carried out which can provide data to which post-treatment data can be compared, and allow for better estimates of the limits of normal variation.

When baseline information is not collected, an upstream (or reference) site is the next best option. These types of studies are less powerful because they do not consider the local normal variability as effectively as a study that includes pre-treatment information (Cavanagh et al, 1998).

- **Survey Monitoring**

Harmancioglu et al (1999) stated that "... *a detailed inventory of the basin has to be established, including factors such as the climate population, industry, hydrology, water and land-use, pollutants, and the similar".*

This type of monitoring has often been termed reconnaissance monitoring. Survey monitoring is used to characterize existing WQ conditions over a specified geographic area. As such, it is more of an inventory rather than a true monitoring process because it does not address changes over time. Reconnaissance monitoring however, is generally conducted over a short time frame (unless the resulting data promote cause for concern), and caution should be exercised to assure that decisions regarding targeting are not biased by unusual climate conditions during the period of monitoring. In many cases, this type of inventory occasionally serves as the first step towards establishing more extensive monitoring programs (Cavanagh et al, 1998) and (USDA, 1996).

- **Determine Fate and Transport of Pollutants**

USDA (1996), UNEP/WHO (1996), Whitfield (1988) and Harmancioglu et al. (1992) mentioned determination of "*mass transport in rivers*" as a major objective for WQM. According to this objective, the monitoring network should determine whether a pollutant may move and where it may go. For such networks, normally monitoring over a long period may not be needed.

- **Measure Effectiveness of Conservation Practices**

Alpaslan and Harmancioglu (1991) and Harmancioglu et al. (1992) stated that WQM is required "*to determine the effectiveness of water pollution control measures*". Monitoring to determine the effectiveness of individual conservation practices is typically conducted on a plot or field scale, or as close as possible to the practice. WQ studies of individual practices can be conducted in a relatively short time frame (<5 years). However, for non-point sources[1], extensive monitoring may be needed. An example of a practice suitable for this type of monitoring would be field nutrient management, in which case, sampling of both the field soils and the field runoff would be conducted (USDA, 1996).

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[1] „*Water pollutants are categorized as point source or nonpoint source, the former being identified as all dry weather pollutants that enter watercourses through pipes or channels. Point source pollution comes mainly from industrial facilities and municipal wastewater treatment plants*".

„*Storm drainage, even though the water may enter watercourses by way of pipes or channels, is considered nonpoint source pollution. Other nonpoint source pollution comes from agricultural runoff, construction sites, and other land disturbances*" (Weiner R. E. and R. A. Matthews, 2002).

- **Make Waste-load Allocations**

Monitoring of receiving water bodies would be needed to perform waste-load allocations. Though typically thought of point sources, waste-load allocations are used in some cases for both point and non-point sources. Monitoring could be used to determine how much additional (or less) agriculture or what conservation practice could be allowed in a watershed without exceeding a certain level.

Monitoring to allocate loads from different sources requires a good knowledge of the actual contributions from the sources. For non-point sources, extensive monitoring may be needed to determine the actual source (USDA, 1996 and ADB, 2002).

- **Validate & Calibrate Models and Database Establishment**

Ward (1973), Sherwani and Moreau (1975), Langbein (1979), Tirsch and Male (1984) referred to "*the development, calibration and verification of mathematical models*" as an important objective for WQM.

Schilperoot and Groot (1983) mentioned different WQM objectives, which included monitoring for the purpose of watersheds modeling.

Harmancioglu (1999) stated that "O*ne may consider the significance of potential objectives for the future, such as data needs for implementation of basin management tools like watershed models, GIS and expert systems".*

In general, WQM may be needed to validate or calibrate models to local conditions. Also, it is used to verify a model's adequacy. In such tests, the values predicted by the model are compared to values observed by monitoring. A major difficulty in model validation is that many models are developed to simulate long-term average conditions, whereas, most monitoring data are collected on a relatively short-term basis. In addition, many of the input variables used in a model, such as the hydraulic conductivity or wind speed, typically are not monitored (USDA, 1996).

- **Conduct Research**

Ward (1973), Sherwani and Moreau (1975), Langbein (1979), Tirsch and Male (1984) indicated that monitoring is needed "*to collect data required for research purposes*" as an important objective for WQM.

Harmancioglu (1999) summarized the essential WQM objectives in three major items:

- To assess WQ for water use and impacts;
- To meet ecological demands; and

- To carry out scientific research.

WQM is necessary for addressing specific research questions. A research agency or university would normally conduct such monitoring. The difference between research monitoring and other purposes of monitoring often is not great (USDA, 1996).

- **Define Water Quality Problem**

WQM may be required to give adequate definition to the WQ problem. For example, if a fishery is impaired in a water body or if medical records in a certain area show high infection with waterborne diseases then WQM will be needed to determine the problem cause. Possible causes might include sediment, toxins, reduced dissolved oxygen, temperature problems and bacteria problems (USDA, 1996).

- **Detect Trends**

Ward (1973), Sherwani and Moreau (1975), Langbein (1979), Tirsch and Male (1984), Schilperoot and Groot (1983), Karpuzcu et al. (1987), Sanders et al. (1983) and Whitfield (1988) considered that monitoring objectives include detecting of trends. Ward (1989) considered monitoring as statistical sampling and, thus, requires that objectives should be specified in statistical terms. The basic idea is that collected data are expected to permit reliable statistical analyses in the eventual transfer of data into information. He defined a systematic approach to "*objective definition*" to comprise the following steps:

- Specify objectives of WQ management (general objective) (e.g., preservation of the quality of waters);
- Specify objectives of WQM network within the framework of WQ management (specific objective) (e.g. identification of trends);

Harmancioglu et al. (1992) indicated that WQ data are needed to delineate:

- The general nature and trends in WQ.
- The effects of natural and man-made factors in WQ processes;

Monitoring is made at regular time intervals to determine if long-term trends are occurring for a particular variable. A widely publicized example of trend analysis was that published by Smith and Alexander (1983) on stream chemistry trends at the United State Geological Survey (USGS) benchmark stations.

Trend monitoring is a commitment that extends over a long period (i.e., usually 10 years or more) to ensure that true trends are detected. It is essential that the program minimize variability through time. Therefore, as much as possible, the program should remain consistent in terms of frequency, location, time of day samples are collected, and the collection and analytical techniques that are used (Cavanagh et al, 1998).

- **Assure a Publicly Credible Basis for Controversial Decisions**

A study of monitoring objectives (Harmancioglu et al., 1997) classified networks into three groups:

- Decision-support networks;
- Academic-curiosity networks; and
- Contingency networks.

In this classification, a decision-support network has a clear purpose that results in specific types of data being collected in specific locations, at specific times, with the use of specific data collection technologies to provide the most cost-effective information for decision-making

2.1.2 Complexity Regarding Definition of Monitoring Objectives

In general, it is recognized that the process of setting the monitoring objectives is a difficult task due to:

- The presence of several (or even too many) objectives;
- Complexity of objectives and
- Problems in transferring objectives to other steps of design; i.e., the technical design phase where sampling sites, frequencies, and variables to be sampled are selected.

A monitoring network may be expected to serve more than one objective; however, difficulties arise when such objectives conflict with each other. Furthermore, in this case, selection of the primary objectives and the implementation of a priority list of goals become a difficult problem to be solved. These two problems stem from the fact that monitoring objectives depend essentially on the objectives of water users (Harmancioglu, 1999).

Messer (1989) indicated that the major problem, or rather the most significant error in defining the WQM objectives is to define them in global terms (not in specific, precise, and clear-cut statements). This leads to deficiencies in the selection of appropriate methods to be used in the technical design and further in the assessment and redesign of an existing network.

The above problems lead to discrepancies between the information "expected" and that "produced" by the network (Ward, 1996).

2.2 EL-SALAM CANAL MONITORING OBJECTIVES

This section presents the detailed activities that were carried out to define the monitoring objectives for El-Salam Canal WQM network. The process started with compiling the available project information followed by developing a brief description of its main elements that related to the WQ status. The collected information indicated that several departments in six Egyptian ministries in addition to two principle groups of beneficiaries could be considered as the main project stakeholders. Questionnaires (in a form of ***Stakeholders/Objectives Matrices****)* were developed and then disseminated to investigate the priorities of the WQ objectives proposed by the project's stakeholders. Then, these questionnaires were analyzed and the results and discussions followed by conclusions were presented.

2.2.1 Compiling the Available Information

The first step in setting objectives for WQM network in El-Salam Canal Project was, collecting the available information related to the project water resources (fresh and drainage WQ and quantity). This needed a review of relevant previous monitoring information collected by DRI during the period from August 1977 till Jan 2005. The national drainage WQM program has been set to provide information, which should meet the needs of decision makers in water resources management for the Nile Delta and Fayoum regions. The very initial step in 1977 was to collect drainage water samples from about 47 sites located along the drains and drainage pump stations in Nile Delta region. The data on discharge and salinity were collected on a fortnightly basis. In 1997 many other WQPs were added for monitoring. There are many publications, which have been produced using the data provided by the monitoring program. These publications include technical reports, yearbooks and research articles. Most of them cover the recent phase of the program (started in 1997). Starting from the year 1998, the DRI yearbook included the drainage WQ status in Nile delta and Fayoum.

In general, these yearbooks include normally two major parts. The first contains information about the water quantities and the second describes the water qualities (DRI, 2000 and DRI, 2002). Starting from DRI yearbook 2000, the Fayoum area had separated report describing its WQ status. Most of the scientific articles and other publications concentrated in the assessment of the drainage WQ and the effect of its use on soil properties, crop productivity and public health (DRI-MADWAQ, 2001**)**. Other available related information was also collected from many other sources, which have direct contact with the project. The followings are the main ministries in Egypt that provide related information with different disciplines:

- *Ministry of Water Resources and Irrigation (**MWRI**)*
- *Ministry of Agriculture and Land Reclamation (**MALR**)*
- *Ministry of Environment (**MOE**)*
- *Ministry of Health and Population (**MOHP**)*
- *Ministry of Housing, Utilities and New communities (**MHUNC**)*

According to the difficulty to access data or even general information from some institutions, the collected information has different levels of accuracy. In some cases there were some contradictions between the data coming from different sources. However, in such cases, the data provided by MWRI were considered. The collected information covered the following items:

- Project area (location, topography, climatic conditions…etc.);
- Current and expected environmental problems;
- General project requirements;
- Main water bodies in the catchment area;
- The environmental values for each water body concerned with its main uses;
- Current monitoring activities, data availability and possible sources of information;
- Available information about water quantity and quality;
- Soil information;
- Agricultural practices;
- Irrigation and drainage systems;
- Social and economical conditions and
- Water quantity/quality management plans

2.2.2 Developing Brief Description of the System

The second step was, developing general description of the project to be provided to the monitoring team and some pre-selected stakeholders. This was to ensure that they have preliminary understanding of the system. The description included brief statements about:

- Project area (location, geology, climatic conditions…etc.);
- General project requirements;
- Main water bodies in the catchment area;

- Main sources of water pollution
- Overview of some WQPs
- Available sources of information

Annex 2-1 presents a brief description of the El-Salam Canal Project including map of the catchment area and schematic diagram for the project main (current and expected) water resources. Special attention was given for the Hadus drainage system as the main focus of this study.

2.2.3 Stakeholder Analysis

2.2.3.1 Stakeholder Groups

Many actors influence the WQM network for El-Salam Canal Project as well as the project itself. Their different interests, potentials, deficiencies and other characteristics should play role in designing, implementing and operating the network. The main objective of the stakeholder analysis is to identify those people/institutions who have an interest in, or are affected by, the project. As described in the Zielorientierte Projektplanung ***(ZOPP)***[2]***,*** each of these groups was analyzed in relation to the following criteria:

- Main problems facing them
- Main interests related to the project
- Capacity to actively participate in the process
- Main stumbling blocks (weaknesses)
- Links between them and any other stakeholders

The analysis results showed that the major stakeholders (Figure 2-1), who might be able to actively participate in the process of re-design of the WQM network for El-Salam Canal project, could be grouped as followings:

- **Ministry of Water Resources and Irrigation (MWRI)**

Under Law 12/1984, the MWRI has the overall responsibility for appropriating and distributing water and for managing drainage, groundwater and the Mediterranean coastline. In addition, under Law 48/1982, the Ministry has the responsibility for controlling the inflow of pollutants into public waterways, and the Egyptian Public Authority for Drainage Projects (**EPADP**) implements and enforces these laws on drainage water (APRP, 1998). Among

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[2] **Zielorientierte Projektplanung*****, ZOPP (***Objectives-oriented Project Planning) is one of the most commonly used project design and management tool amongst the international development community. It is used as a tool to plan new projects or programs, to manage the development process throughout a project's cycle (Helming S. and Göbel M., 1997).

many departments in EPADP, The Drainage Advisory Service (**DAS**) introduces guidance to the land users related to agricultural drainage.

The Irrigation Department (**ID**) in MWRI operates and maintains public canals. The Irrigation Improvement Project (**IIP**) is a socio-technical irrigation improvement process involving the development of farmer participation in improvements and the subsequent management of improved systems. Under the umbrella of IIP, the primary mission of the Irrigation Advisory Service (**IAS**) is to facilitate and assist private water users to establish, maintain, and manage their own sustainable water user associations (**WUAs**) for improving irrigation performance.

The Mechanical and Electrical Department (**MED**) is responsible for installing, operating and maintaining all irrigation and drainage pumping stations.

The National Water Research Center (**NWRC**) conducts research on water related issues including the re-use of drainage flow (World Bank, 1997).

The MWRI with the Canadian International Development Agency (**CIDA**) are funding The National Water Quality and Availability Management (**NAWQAM**) Project. The NAWQAM goal is to develop an effective and coordinated national system for sustainable water resources management in Egypt. NAWQAM is composed of five components, four of which relate to WQ and availability activities that are undertaken. These five components are:

1. Component 1000, which is responsible for the National WQM activities. The implementing agency is the Drainage Research Institute (DRI), NWRC.
2. Component 2000, which is responsible for the Water Availability Management activities. The implementing agency is the Planning Sector (**PS**), MWRI.
3. Component 3000, which is responsible for the Drainage Water Re-use and Pilot Schemes activities. The implementing agency is the EPADP in collaboration with DRI.
4. Component 4000, which is responsible for the Information Communications Management. The implementing agency is the NWRC.
5. Component 5000, which is responsible for Project Management and Administration. The implementing agency is NWRC and The Prairie Farm Rehabilitation Administration (**PFRA**).

The NWRC of MWRI is the Egyptian executing agency for the project. The Prairie Farm Rehabilitation Administration (PFRA)-Agriculture and Agri-Food Canada is the Canadian executing agency (NAWQAM, 2003).

- **Ministry of Agriculture and Land Reclamation (MALR)**

The Ministry of Agriculture and Land Reclamation (**MALR**) is responsible for policy development and implementation on farm production and cropping patterns. Within the MALR, the Executive Agency for Land Improvement Projects (**EALIP**) and the Public Authority for Land Reclamation in New Valley and other desert areas (**PALR**) are involved in water conservation. The General Authority for Rehabilitation Projects and Agricultural Developments (**GARPAD**) is responsible for the design and implementation of desert reclamation schemes, which are subsequently transferred either to Public Sector Agricultural Companies or the private sector. The Agricultural Advisory Service (**AAS**) is responsible mainly to consult all the agricultural activities in the farms such as introducing new cultivation methods, presenting high yielding crop varieties and recommending the appropriate cultivation practices in relation with the local farm conditions. This institution has now great experiences gained through working many years side by side with farmers. The Agriculture Research Center (**ARC**) includes 16 research institutes, 5 laboratories, and 36 research stations. Among these institutes, the Soil and Water Research Institute (**SWRI**) has a research capability in land improvement by increasing drainage efficiency and optimising water use. The General Authority for Fish Resources Development (**GAFRD**) is also working under the umbrella of MALR (APRP, 1998) and (World Bank, 1997).

- **Ministry of Environment (MOE)**

The Egyptian Environmental Affairs Agency (**EEAA**) is the representative agency, which has a coordination role in all aspects of environmental protection, such as legislation, environmental impact assessment, monitoring and dissemination of information (APRP, 1998).

- **Ministry of Health and Population (MOHP)**

The Ministry of Health and Population (**MOHP**) is responsible for setting standards for potable water sources, drain water that is mixed with other water and discharges from municipal and industrial treatment plants and from river vessels. It is also entrusted with the monitoring of municipal and industrial effluents (APRP, 1998).

The department responsible for the environmental protection within the MOHP is the General Department of Environmental Health (**GDEH**). It has been established and is functioning in accordance with the Presidential decree No. 2703 of 1966 concerning the establishment of the Water Higher Committee in the MOHP. The Minister of Health's decrees No. 569 of 1979 and No. 93 of 1987 and the "Preventive Medical Care Instructions

Manual" issued in 1965 summarize the tasks and responsibilities of the General Department of Environmental Health (MWRI, 2002).

- **Ministry of Housing, Utilities and New Communities (MHUNC)**

The Ministry of Housing, Utilities and New Communities (**MHUNC**) is implementing a national strategy to expand the capacities of the municipal water treatment facilities and provide adequate sanitation facilities. The level of implementing this national strategy based mainly on the availability of funds needed for constructing the new facilities. The National Organization for Potable Water and Sanitary Drainage (**NOPWASD**) is a national authority having a legal personality within the MOHNS (MWRI, 2002).

- **Ministry of Industry (MOI)**

The General Organization for Industry (**GOFI**) is responsible for planning the prevention or treatment of industrial effluent (APRP, 1998).

- **Principal Groups of Beneficiaries**

1. New Land Beneficiaries (NLB)

The distribution of the reclaimed lands within the project is a process to be continued. The following section was quoted from the World Bank/Arab Republic of Egypt, 1997 staff report:

*“Since 1988 one key element of GARPAD's new land allocation policy has been the **Mubarak Program**, under which young jobless university and high school graduates receive a plot of 5 feddans of reclaimed land and one house in a village built by GARPAD. They reimburse LE 10,000 over 30 years, without interest and including a 3 year grace period. In addition, they receive during the first year of settlement LE 50/month. Graduates receive the land with tertiary irrigation and drainage works completed as well as the first leaching done by GARPAD. The Mubarak Program is linked to the broader government policy of phasing out guarantee of public sector employment to graduates. Open unemployment in Egypt is concentrated (75 percent) among young people, 90 percent of whom have a university or high school diploma. In the East Delta project area, about 25 percent of the land has been allocated to graduates under this program”. “A total of 203,000 feddans of reclaimed land has been distributed among two principal groups of beneficiaries. **Poor farmers** have been allocated 128,850 feddans, or 64 percent of the total reclaimed area, on concessional terms, while **investors** have been allocated 74,100 feddans, or 36 percent of the reclaimed area, on commercial terms.” “The **poor farmers**, totaling about 26,000 families. They comprise three sub-groups: **smallholders** (6,800), who will cultivate 30,800 feddans; **land reclamation cooperative members** (10,450) who will cultivate*

51,500 feddans; and ***secondary school and university graduates*** *(9,300) who will cultivate 46,550 feddans.*"

"*About 7,000 families in the target groups are, however, largely settled in the area. These include smallholders (5,000) of whom 2,000 in Mataria have been cultivating land for about 8 years with drainage water. The remainders live along the main drains (Bahr El Baqar, Hadus, Ramsis and Serw). Some graduates are now settling in South Hussainya; where water is available they have begun leaching, cultivation and small livestock operations.*"

2. Old Land Beneficiaries (OLB)

The farmlands along the Nile and in the Delta normally called "Old Lands''. In general, the farmers in those areas have great experiences in all agriculture activities. These experiences have been gained through many decades.

Depending on the warm climate, water availability along the Nile, and exceptionally fertile soils, they grow a rich variety of crops, including grains, cotton, barsim (clover), legumes, fruits, and vegetables. They can also manage to practice double and multiple cropping, which effectively doubled the arable area.

Table 2-1: Targeted distribution of beneficiaries among the first phases of the scheme- (World Bank, 1997)

Scheme	Graduates		Small Holders		Cooperatives		Investors		Total	
	No. (fed)	Area (fed)	No.	Area	No.	Area	No.	Area	No.	Area
Mataria			2,000	8,000					2,000	8,000
North Hussainya	1,800	9,000	2,640	13,200			550	7,800	4,990	30,000
South Hussainya	2,540	12,700					2,000	44,300	4,540	57,000
South Port Said	568	2,850	257	1,600	8,000	34,000	175	1,000	9,000	39,450
South Port Said Plain	2,700	13,500	1,100	5,500	2,450	17,500	2,035	20,500	8,285	57,000
Um El-Reesh	1,700	8,500	775	2,500			33	500	2,508	11,500
Total	9,308	46,550	6,772	30,800	10,450	51,500	4,793	74,100	31,323	202,950

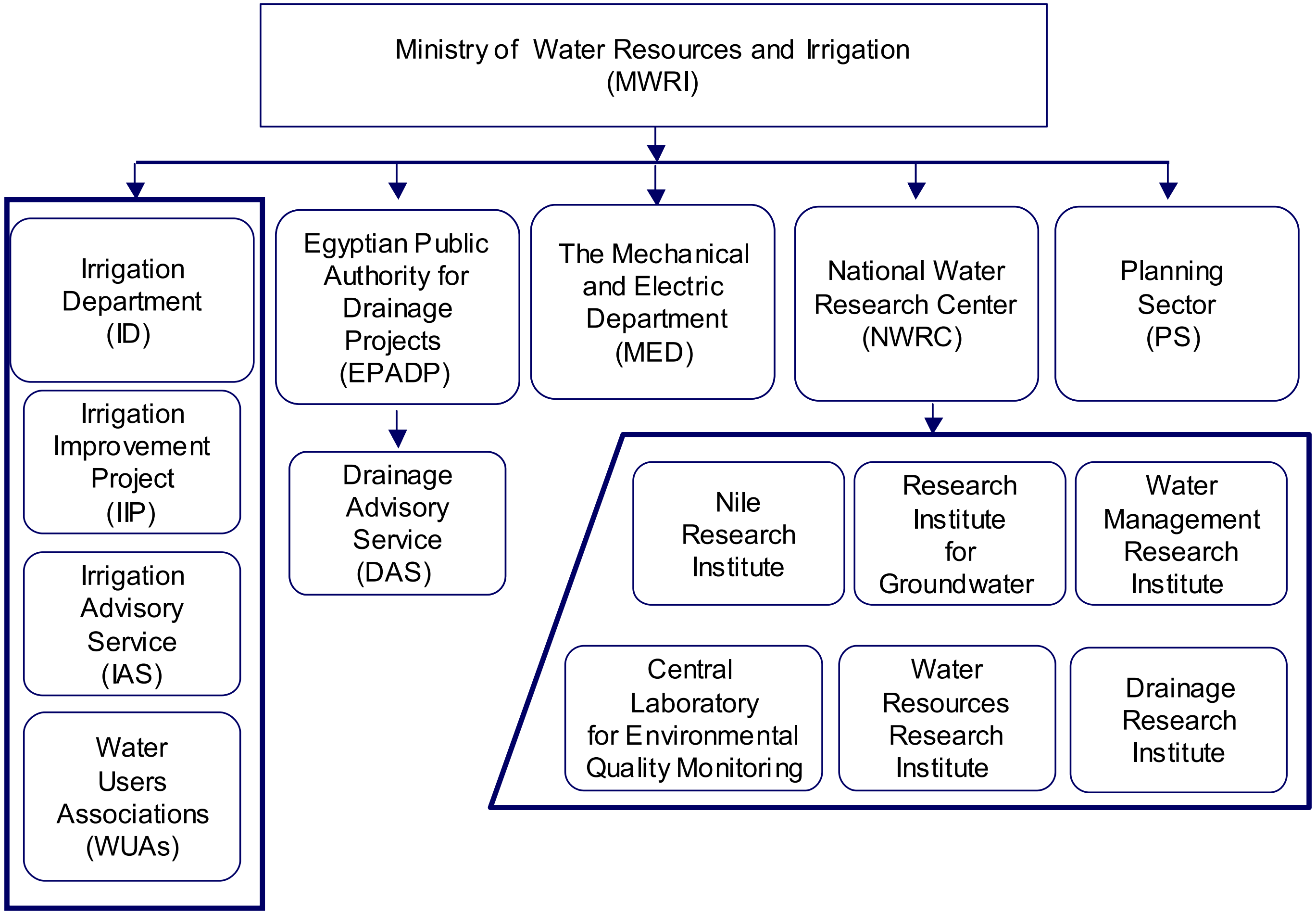

Figure 2-1A: MWRI major stakeholders

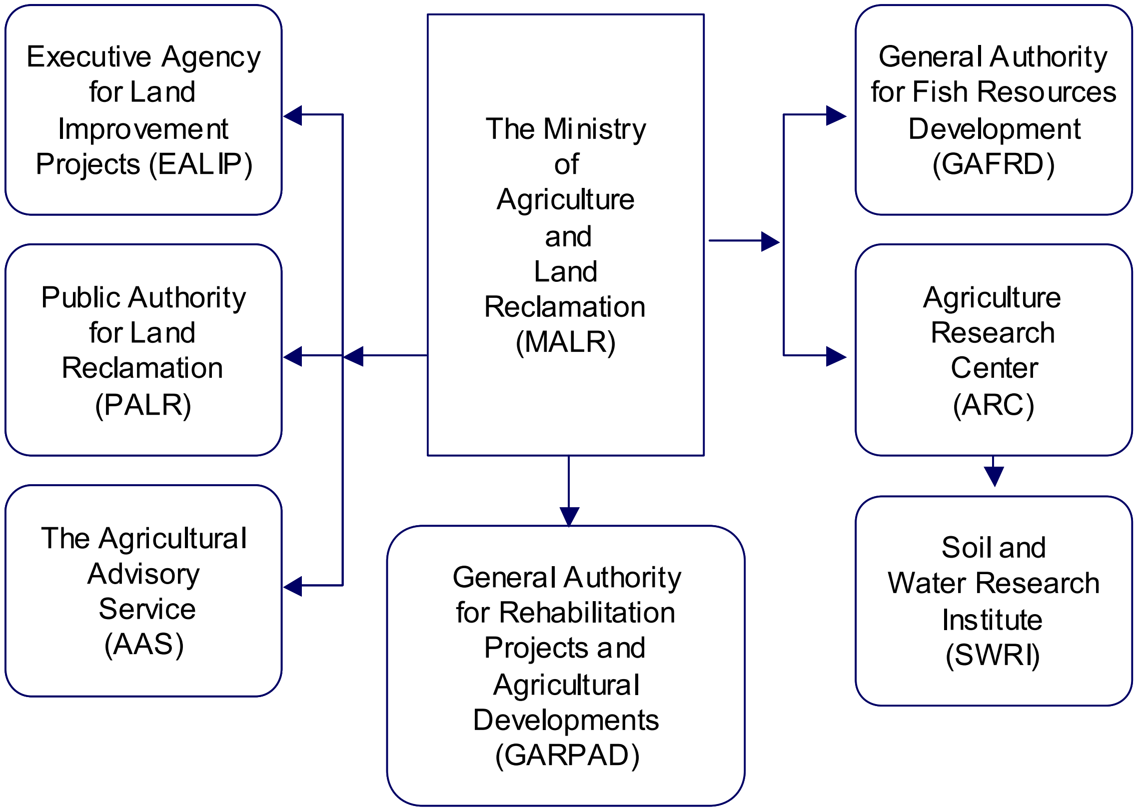

Figure 2-1B: MALR major stakeholders

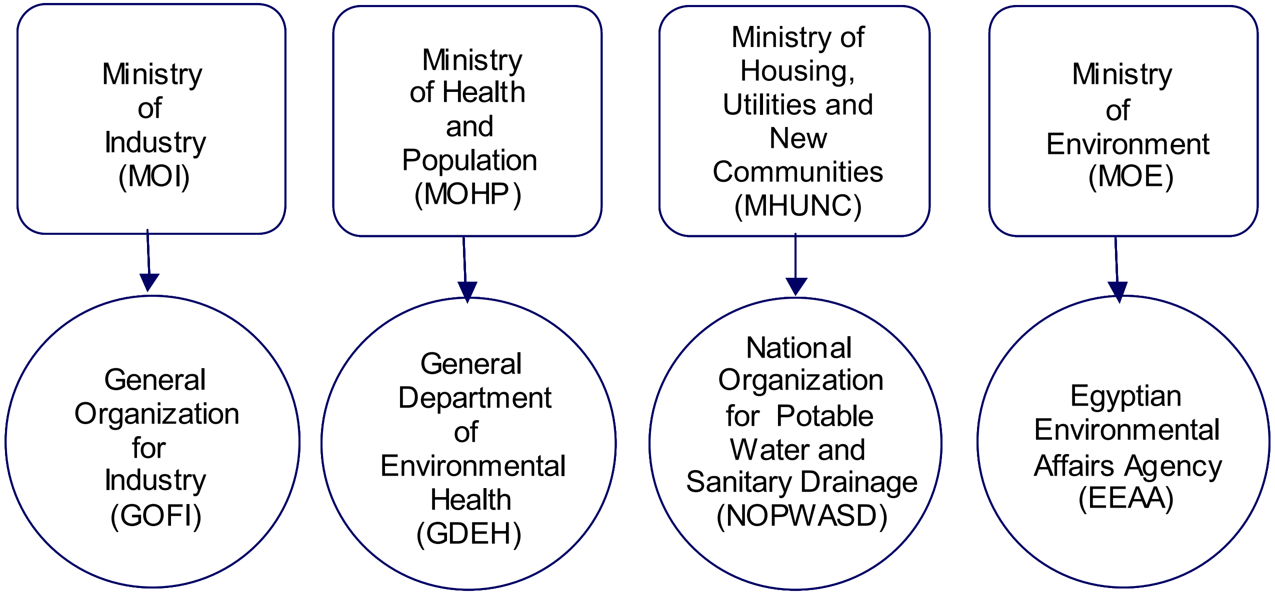

Figure 2-1C: MOI, MOHP, MOHUNC and MOE major stakeholders

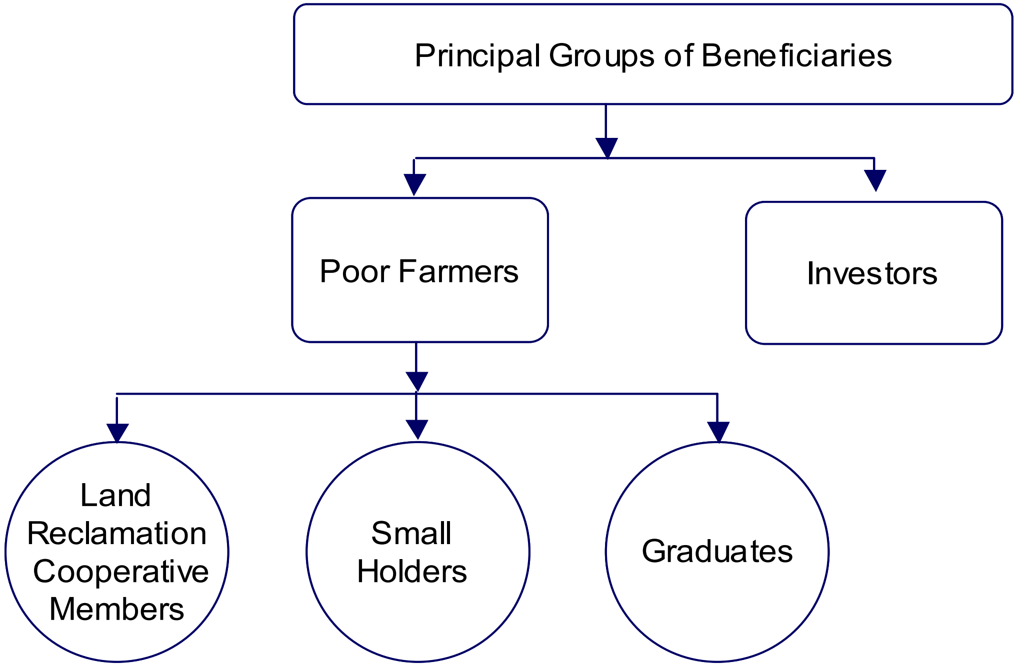

Figure 2-1D: Principal groups of beneficiaries

2.2.3.2 Stakeholder Participations

After defining the target stakeholder groups and their representatives, questionnaires in form of matrices (***Stakeholders/Objectives Matrix)*** in addition to the project brief description (Annex 2-1) were provided. In general, valuable information and even some data were exchanged through this process. It has to be mentioned here that most of the participants showed high willingness to contribute not only in this study but also for further involvement.

However, ensuring effective contributions in any activities in the future concerning the WQM requires that the target stakeholders (representatives) should know what they are being asked to do, why it is important, how the process is going to work and how they will provide input to the process. Questionnaires, informative sessions, meetings, brochures and advertisements can be used to raise awareness of the WQ issues and provide general information about the monitoring system.

2.2.3.3 Stakeholders/Objectives Matrix (SOM)

In order to identify the general monitoring objectives, the ***Stakeholders/Objectives Matrix (SOM)*** was developed. The most common monitoring objectives, which are well known in many other WQM schemes (section 2.1.1), were put in the first column. Every stakeholder group has two columns in the matrix. The first column “**To use**” represents the case if the stakeholder group uses the data produced by the monitoring network in any activities while the second “**To be informed**” represents the case when the group is only interested in having access to the final information product such as yearbooks or scientific reports. Extra rows were added in order to permit the stakeholder representatives to add any specific monitoring objectives (more than the objectives mentioned before), which may cover their different areas of interests. For every monitoring objective, the participants were asked to give two values (for every stakeholder group) in the two columns “to use” and “to be informed”. Table 2-2 presents the possible values and its related meanings.

The total number of the main project stockholder’s representatives who participated in this process was 26. Five participants represented each of The Ministry of Water Resources and Irrigation (**MWRI**), The Ministry of Agriculture and Land Reclamation (**MALR**) and The Ministry of Environment (**MOE**). Only three participants represented each of the New Land Beneficiaries (**NLB**), Old Land Beneficiaries (**OLB**) and The Ministry of Health and Population (**MOHP**). Due to the lake of good communications, one participant represented each of The Ministry of Housing, Utilities and New Communities (**MHUNC**) and The Ministry of Industry (**MOI**).

In general, the selection process of the participants inside each ministry were not fully random, many factors were playing different roles in the selection process such as:

- Job descriptions of the participants and their ability to cooperate,
- Their environmental background,
- Their personal relations with the author and
- The limitation in time and finance to increase the number of participants.

Annex 2-2 presents the Stakeholder Objective Matrices (**SOM**) filled by representatives from the **MWRI, MALR, MOE, MOHP, MHUNC, MOI, NLB** and **OLB**.

Table 2-2: The interpretation for the possible values in the Stakeholder/Objective Matrix (SOM)

Possible Value	"To use"	"To be informed"
"0"	The stakeholder group does not use the data*.	The stakeholder group does not need the information**.
"1"	The group rarly uses the data.	The group rarly needs the information.
"2"	The group sometimes uses the data.	The group sometimes needs the information.
"3"	The group usually uses the data.	The group usually needs the information.
"-"	The participant does not know.	The participant does not know.

* Data produced by the WQM network in relation with a certain monitoring objective

** Information produced by the WQM network in relation with a certain monitoring objective

2.2.3.4 Stakeholders/Objectives Matrix Analysis

The following section describes the SOM analysis steps, which were carried out to identify the WQM objectives for the El-Salam Canal Project. These steps were as follow:

- Calculate "**Averages for Weighted Totals (X)**"

It is almost true that the information provided by a participant from a stakeholder group about the WQ data/information required for this group is comparatively reliable and has more value (weight) than his information about any other groups.

In order to change this qualitative fact to quantitative measure, all values related to the home stakeholder group of the questioned participants were multiplied by numeric weight (in this research, selected to be "2").

Then, for each objective in every **SOM**, the sum of all values given by the participants was calculated (**Weighted Totals**).

Finally, for each stakeholder group, by calculating the "**Averages for Weighted Totals**", an average **SOM** for each group was developed.

- Calculate "**Overall Weighted Average (Y)**"

Due to the unequal numbers of participants in every stakeholder group, the numbers of participants from every stakeholder group were used as a weight to calculate the overall weighted averages.

Then, the priority points were calculated by transferring the overall weighted averages to percentages from total.

2.3 MONITORING OBJECTIVES RESULTS AND DISCUSSIONS

Table 2-3 shows the average for weighted totals results of the objectives matrices filled by the stakeholders. This section presents detailed results of the previous analysis.

- **Results for the case of "TO USE":**

The final priority list developed by the stakeholder representatives indicates that:

- The highest priority level was given to the following WQM network objectives: "assess compliance with standards" (15%); "define WQ problems" (13%); "detect possible trends in WQ with respect to time and space" (12%) and "conduct research" (10%);

- The moderate priority level was given for “facilitate impact assessment studies”, “determine fate and transport of pollutants”, “measure effectiveness of conservation practices”, “make waste-load allocations” and “validate & calibrate models and establish a database for the planning and development of water resources” with average points (8%) and
- The lowest priorities were given to “facilitate baseline information” and “assure a publicly credible basis for controversial decisions” with average points (5%).
- **<u>Results for the case of “TO BE INFORMED”:</u>**

The final priority list developed by the stakeholder representatives indicates that:

- The highest priority level was given to the following WQM network objectives: “assess compliance with standards” (15%); “detect possible trends in WQ with respect to time and space” (13%) “Define WQ problems” (13%); and “conduct research” (12%);
- The moderate priority level was given for “facilitate impact assessment studies”, “determine fate and transport of pollutants”, “measure effectiveness of conservation practices”, “make waste-load allocations” and “validate & calibrate models and establish a database for the planning and development of water resources” with average points (8%) and
- The lowest priority level was given to “facilitate baseline WQ information” and “assure a publicly credible basis for controversial (hot) decisions” with average points (4%).

Table 2-3: The averages for weighted totals calculated for the objectives matrices filled by the stakeholder representatives

Water Quality Monitoring Objectives	Averages for Weighted Totals $(X)^*$																Overall Weighted Average $(Y)^{**}$		Priority Points	
	Stakeholders Groups																			
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB					
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	14.6	20.0	15.6	19.4	19.8	20.4	8.4	10.4	13.0	17.0	14.0	19.0	7.8	12.6	8.8	12.4	13.5	17.0	15%	15%
Facilitate impact assessment studies	10.6	15.8	9.6	14.2	14.4	15.8	6.2	7.4	9.0	11.0	8.0	11.0	0.0	0.6	1.4	3.6	8.2	11.0	9%	10%
Facilitate baseline water quality information (Survey monitoring).	5.0	7.8	7.0	8.0	10.4	11.6	4.0	6.4	9.0	11.0	8.0	10.0	0.0	0.0	1.0	1.6	5.5	7.0	6%	6%
Determine fate and transport of pollutants	9.8	13.8	8.4	10.8	11.2	12.2	6.0	7.2	10.0	11.0	9.0	10.0	0.0	0.0	0.0	0.0	7.1	8.7	8%	8%
Measure effectiveness of conservation practices	7.8	9.6	9.6	12.0	11.8	13.0	5.4	6.2	12.0	13.0	9.0	12.0	0.0	0.0	0.0	0.0	7.0	8.3	8%	8%
Make waste-load allocations	10.0	14.4	6.6	8.2	9.8	9.4	5.8	7.6	8.0	10.0	7.0	7.0	0.0	0.0	0.0	0.0	6.3	7.7	7%	7%
Validate & calibrate models and establish a database for the planning and development of water resources	7.0	9.0	8.6	10.2	10.0	9.0	4.8	6.0	10.0	15.0	9.0	9.0	0.0	0.0	0.0	0.0	6.2	7.0	7%	6%
Conduct research	11.6	17.4	11.0	15.0	11.4	14.0	6.8	8.8	11.0	13.0	10.0	14.0	5.8	8.8	4.4	6.8	9.3	12.8	10%	12%
Define water quality problem	14.8	18.0	11.4	14.8	16.0	17.6	7.6	9.2	12.0	14.0	10.0	14.0	8.0	10.0	6.0	8.2	11.5	13.9	13%	13%
Detect possible trends in water quality with respect to time and space;	14.4	18.8	12.4	17.0	15.2	17.0	6.6	8.6	16.0	18.0	15.0	18.0	4.8	7.6	3.6	7.0	11.0	14.2	12%	13%
Assure a publicly credible basis for controversial (hot) decisions.	7.2	3.2	4.0	5.6	4.2	4.2	0.0	0.0	0.0	0.0	6.0	6.0	0.0	0.0	0.0	0.0	3.2	2.7	4%	2%
No. of Participants	5		5		5		3		1		1		3		3		26			

$(X)^*$: All values related to the home group of the questioned participants were multiplied by numeric weight (equal "2").
$(Y)^{**}$: The no. of participants from every group were used as a weight to calculate the overall weighted averages for the (X) values

- **Discussion and Conclusion**

- It is clear that the analysis results for both cases "TO USE" and "TO BE INFORMED" are almost identical.
- The WQM objectives can be easily divided into three groups, high, intermediate and low priority levels.
- Reviewing the interpretation of each WQM objective can lead to a new system of objectives classification. According to this system, the objectives can be classified into three timely scaled classes: design oriented, short-term deductible and long-term deductible objectives.
- The **Design Oriented Objectives:** on the time scale, they are the objectives that cover the current description of the WQ status in the project area and have direct influences on identifying the other main items of the network design such as monitoring locations, sampling frequency and monitored parameters.
- The Design Oriented Objectives may include "facilitate baseline WQ information (survey monitoring)", "assess compliance with standards", "define WQ problems", "determine fate and transport of pollutants" and "make waste-load allocations".
- According to the priority list, the design-oriented objectives included the three priority levels (2 high, 2 moderate and 1 low).
- The **Short Term deductible Objectives,** they are the objectives that can be achieved after **few** years from executing the monitoring scheme.
- The Short Term Deductible Objectives can include "validate & calibrate models and establish a database for the planning and development of water resources" and "facilitate impact assessment studies".
- According to the priority list, the Short Term Deductible objectives have moderate priority levels.
- The **Long Term deductible Objectives,** they are the objectives that can be achieved after **many** years from executing the monitoring scheme.
- The Long Term Deductible Objectives can include "conduct research", "detect possible trends in WQ with respect to time and space", "measure effectiveness of conservation practices" and "assure a publicly credible basis for controversial (hot) decisions".
- According to the priority list, the Long Term Deductible Objectives included the three priority levels (2 high, 1 moderate and 1 low).

Table 2-4 shows the summery of the SOMs analysis results including the three categories of the WQM objectives for El-Salam Canal project.

The percentage of the total priority points given for the “Design Oriented Objectives” was almost 50%. The other 50% were given for the deductible objectives; distributed as almost 16% for the “Short Term Objectives” and 34% for the “Long Term Objectives” (Figure 2-2).

In general, the objectives under the title “**Design Oriented**” should play the vital role in the designing process but in case of El-Salam Canal network redesign, the objective “Facilitate base line information (survey monitoring)” is no longer valid. This is because of the long monitoring history in many parts in the monitoring network especially old land in Eastern Nile Delta. However, the stakeholder group representatives gave lowest priority points for this objective (only 6% from total points). Consequently, the other four objectives: “Assess compliance with standards”, “Define WQ problems”, “Determine fate and transport of pollutants” and “Make waste-load allocations” were considered as main objectives for the WQM network.

In addition, two deductible monitoring objectives: “Detect Trends” and “ Conduct research” were given high priority levels. Therefore, they have been also considered as main objectives.

However, detecting trends as a statistical design problem has a direct influence on the network design factors especially locating monitoring sites and sampling frequencies. Therefore, it may be also seen as a “design oriented” objective, which can be only achieved after many years of monitoring.

The other objectives that were given intermediate priorities such as “Facilitate impact assessment studies” and “Measure effectiveness of conservation practices were not considered as main objectives. It was decided that they might be covered by the long term objectives “detect trends” and “Conduct research”.

In order to ease transferring these objectives to the other monitoring network design items (monitoring locations, sampling frequencies and monitored parameters), detailed question list was developed (Table 2-5). Each of these questions can indicate certain actions in the design process. Reviewing this question list shows that some questions can fit for more than one objective in the same time. This indicates that some monitoring locations and parameters will serve different objectives.

It has to be mentioned here that some of these questions were suggested to be as extra objectives from the stakeholder representatives during filling the SOMs.

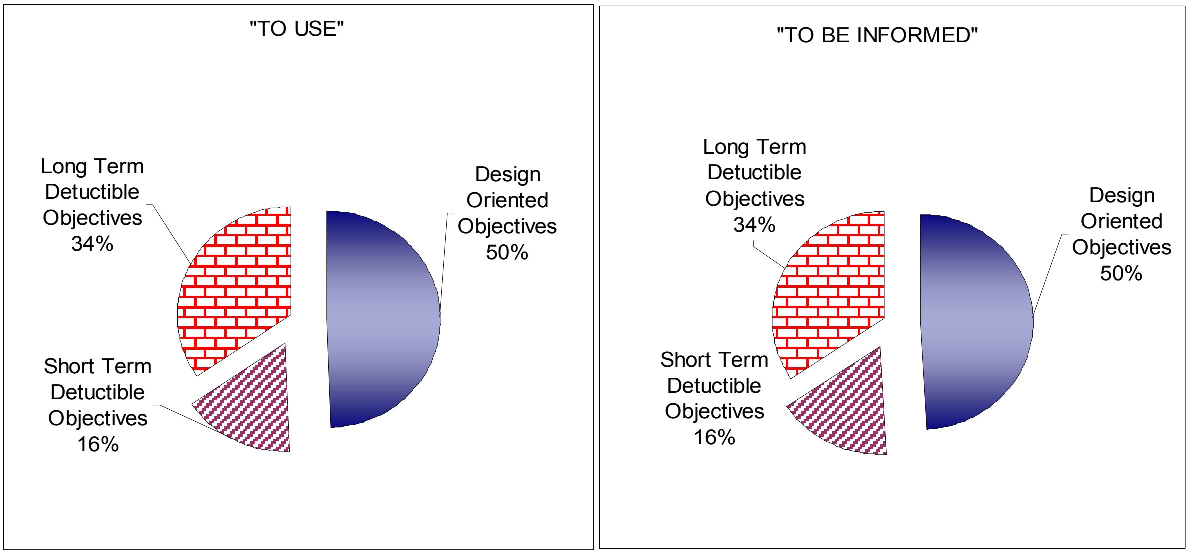

Figure 2-2: The percentages of the priority points given by the stakeholders

- **Summary**

The overall objectives considered to the WQM network for El-Salam Canal Project are as follow:

1. Assess the compliance of the waters used in the project (Nile and main drains) with the standards.
2. Define the current and expected WQ problems for both old and new reclaimed areas related to the project.
3. Determine fate and transport of pollutants from the old land to the new reclaimed areas.
4. Allocate the major sources of pollution in the project area (old and new land).
5. Detect the general nature and trends in the project WQ.
6. Provide WQ data to conduct specific research.

Table 2-4: The priority list of the WQM objectives for El-Salam Canal Project

Water Quality Monitoring Objectives	Overall Weighted Average (Y)**		Priority Points	
	to use	to be informed	to use	to be informed
Design Oriented Objectives				
facilitate baseline water quality information (Survey monitoring).	5.5	7.0	6%	6%
Assess compliance with standards	13.5	17.0	15%	15%
define water quality problem	11.5	13.9	13%	13%
determine fate and transport of pollutants	7.1	8.7	8%	8%
make waste-load allocations	6.3	7.7	7%	7%
Total			49.4%	49.2%
Short Term Deductible Objectives				
validate & calibrate models and establish a database for the planning and development of water resources	6.2	7.0	7%	6%
facilitate impact assessment studies	8.2	11.0	9%	10%
Total			16.2%	16.3%
Long Term Deductible Objectives				
conduct research	9.3	12.8	10%	12%
detect possible trends in water quality with respect to time and space;	11.0	14.2	12%	13%
measure effectiveness of conservation practices	7.0	8.3	8%	8%
assure a publicly credible basis for controversial (hot) decisions.	3.2	2.7	4%	2%
Total			34.4%	34.5%
Grand Total	88.9	110.4	100.0%	100.0%

Note: The “detecting trends” is considered as a “design oriented” objective that can be only achieved after many years of monitoring.

Table 2-5: Detailed questions' list developed for the considered "*Design Oriented*" WQM objectives for the El-Salam Canal Project.

Monitoring Objectives	Detailed Questions
Assess compliance with standards	**Main Question**: Are the water qualities of both Nile and drainage waters complying with the standards related to the different water uses in the project area? **Examples:** 1. Do the salinities of the irrigation waters provided by the project in acceptable levels? 2. Do waters in the network have high Sodium levels? 3. Do waters in the network have specific ion toxicity? 4. Do waters in the network have high nutrintes (nitrates and phosphorus) levels? 5. Do waters in the network have high fecal contamination levels?
Define water quality problems	**Main Question**: What are the current and expected water quality problems in the project area? **Examples:** 1. Does the irrigation water quality provided by the network deteriorate the soil properties in the project area? 2. Is there accumulation of pollutants in the irrigated soils which could deteriorate the ground water in the long run? 3. Does the project irrigation water quality cause or will cause significant reduction in crop productivity in the project area? 4. Is the quality of crops in the project area within acceptable levels? 5. Do the medical records indicate existence of waterborne diseases in the project area (especially the old lands)?
Determine fate and transport of pollutants	**Main Question**: Do the drainage waters transferred from the old to the new lands transport considerable amount of pollution loads? **Examples:** 1. What are the concentrations/loads of the water pollutants in the Nile and drainage waters transferred to the project? 2. Do the mixing ratios between the Nile and drains waters satisfy the planned strategy for the project?
Make waste-load allocations	**Main Question**: What are the major point and nonpoint sources of pollution in the project area (old and new land)? **Examples:** 1. Do industries or/and municipalities that discharge liquid wastes to project water system satisfy the allowable concentrations of particular variables in both effluent and possibly in the receiving waters? 2. Do both surface and ground water in the catchment area of the project suffer from relatively high pesticides contamination? 3. Do farmers in the catchment area overusing phosphorus fertilizers? 4. Do the drained waters to Lake Manzala can lead to eutrophication problems?

CHAPTER 3

3. NETWORK DESIGN FUNDAMENTALS AND STATISTICAL EVALUATION

A WQM network often includes a number of sampling sites, which collect data on particular WQ variables at a specific time intervals. This chapter introduces an overview of two main items in network design process: sampling sites and sampling frequency. For each item, brief descriptions for some recent methods that were employed in network design approaches are presented.

An overview of some statistical methods that will be employed in the following network rationalization process is also presented. In general, it is assumed that the readers have basic statistical knowledge related to the use of statistics in environmental research. Therefore, the main concern here is only to highlight assumptions, limitations and robustness of those methods.

Then, the last part introduces a review of some recent research that employed multivariate statistics in environmental studies.

3.1 SAMPLING SITES

After defining the monitoring objectives, the locations of permanent sampling sites are probably the next most critical design factor in a monitoring program (Cavanagh *et al*., 1998). "*It conveys all the difficulties and the complicated aspects of the design problem; furthermore, it can not be dissociated from other three design criteria, i.e., selection of variables, temporal frequencies and sampling durations*" (Harmancioglu, *et al*., 1999).

The selected sampling locations must be representative sites. The term "representative site" can be simply defined as the point that reflects the actual conditions of water in a certain reach. The main criteria that should be taken into account in locating sampling sites can be summarised as (MDEQ, 1995):

- **Homogeneity**: Well mixing improves the uniform distribution of constituents within the water-body. Stratification may result from natural temperature gradients or different densities of water-body constituents.
- **Characteristics of a water-body**: It can be clearly understood by defining the major water and land uses in the project area.
- **WQ status**: The sampling locations should have the potential for displaying the WQ or biological problems.

- **Discharge measurements:** Pollution loads can be calculated based on the flow measurements.
- **Convenience, accessibility, and practicability:** These factors are important to ensure the continuity of monitoring.

3.2 METHODS FOR LOCATING SAMPLING SITES

3.2.1 Early Practices

> "*Sampling stations should be accessible for all flow conditions that will be sampled*"
> (Stednick, 1991).

The early WQM programs started at sites of easy access or often at stream-flow gauging points, industrialized or highly populated areas, areas with point pollution sources, or areas of intensive land uses (Tirsch and Male, 1984).

With time, more sites were added to include stations "***at points of interest***" such as those located at upstream and downstream of highly polluted areas.

Samplers often prefer to take samples at bridges or other sites, which offer better accessibility conditions. "*A bridge is an excellent place at which to establish a sampling station. It is easily accessible and clearly identifiable, and the station can be precisely described*" (UNEP/WHO, 1996). The only problem is that flow may be modified around jetties or bridges. Also, weirs and similar structures in water streams often alter both the flow and the chemical conditions. In these cases, samples should be taken far enough up- or downstream of such structures (ANZECC & ARMCANZ, 2000).

When accessibility is the unique criterion for site selection, such locations may not add real information for the monitoring program. In addition to "site accessibility", other basic criteria to select monitoring sites were taken into account such as: the locations of polluting sources, representative capacity of the sites, presence of stream-flow stations, transport time from the field to the lab, ease and safety of sampling and availability of required facilities (laboratory, personnel, equipments, etc.) (Lettenmaier 1978, Smith and McBride 1990, USDA 1996 and Harmancioglu, *et al.*, 1999)

Sanders *et al*. (1983) reported that sampling sites could be identified according to some logical basis. "*However, such nonsystematic approaches in the selection of sampling sites are still valid, especially in developing countries where monitoring efforts have not yet evolved into a network*" (Harmancioglu, *et al.*, 1999).

3.2.2 Site Selection to Comply with Monitoring Objectives

There are many factors play different roles in selecting sampling sites. Some of these factors are the monitoring objectives, knowledge of the geography of the watercourse system, water uses and sources of pollution.

Harmancioglu, *et al.*, 1999 stated, "*The most reasonable approach to allocation of sampling sites seems to be the selection of locations so as to comply with the objectives of monitoring*".

Site selection can be classified as a two-step process: the selection of the sampling sites followed by the selection of the sampling stations (Canter, 1985; Ponce, 1980; Sanders, *et al.* 1983).

- **Sampling Site (macro-location):** identifies the areas within the watershed from which samples can be taken and is sometimes called a "macro-location". The selection of sampling sites is determined mainly based on the monitoring objectives.
- **Sampling Station (micro-location):** identifies the exact monitoring location and is sometimes called a "micro- location". It is independent of the monitoring objectives and a function of the hydraulic and mixing characteristics of the stream.

However, transferring the monitoring objectives to concrete sampling sites is not an easy task because of the difficulty of identifying the objectives precisely and in some cases, the existence of field constrains. If the monitoring program has many objectives, then more difficulty will be expected. In this case, allocations of monitoring resources (such as finance, personnel, equipments, etc.) must be made between the objectives (Sanders *et al*, 1983).

The following section will introduce some monitoring activities when sampling sites were proposed in relation with some WQM objectives.

Beckers *et al.*, 1972 selected sampling sites as a function of possible stream standards violations or as a function of stream segments below outfalls. Ward, 1973, reported the importance of objectives priority list prepared by the policy makers to determine the allocation of the monitoring resources as a governing factor for sites selection.

According to Cavanagh *et al.* (1998), the followings are the monitoring objectives and the related guidelines, which were considered during the design process of the *WQM Program in British Columbia*:

- "Check compliance with standards", for this monitoring objective, sites should be located at: the mouths of main tributaries, upstream and downstream from industrial projects, resource extraction activities, waste outfalls, and urban centers, at points of major water withdrawals, and/or jurisdictional boundaries (provincial, international).

- "Detect trends", the location of the site(s) within each watershed should be selected to provide an indication of change in the WQ within the basin as a whole. The sites should be located within the stream (mainstream points) and at the outlet of the watershed.
- "Survey monitoring", the site should be at the mouth of the stream to detect as many integrated inputs as possible.
- "Impact assessment", the monitoring program should be implemented prior to the initiation of a project that its impact is under assessment. In this program, baseline data will be collected at all sites chosen. At least one control site should be located immediately upstream the proposed project location. The distance between the upstream (control) site and the first downstream (treated) site should be minimal. This reduces the possibility of other non-project inputs confounding the data.
- "Define WQ problem", the problem definition should be clear before installing the monitoring program. In some cases, monitoring programs monitor a trend toward an expected WQ problem. For example, Ehrman, *et al.*, 1990 investigated the trend of ground WQ in Nebraska towards violating the standards.

According to Sanders *et al.* (1983), there are other non-systematic approaches to identify macro-location. These approaches are based mainly upon: percentage of areal coverage, density of some indicators of population, and overall discharge of pollutants. Some researchers introduced the first two items as "drainage characteristics".

It has to be mentioned here that the objectives of the monitoring network not only influence the determination of the number and location of sampling sites but also the type of data needed, the length of recordation required, and the sampling frequency (Moss, Lettenmaier, *et al.* 1978; Reinelt, *et al.* 1988; Ward 1989).

3.2.3 Systematic Approaches

Horton (1945) assigned each small tributary (which has no more branches or branches with minimum discharges) the order of one, a stream that is fed by only first order tributaries the order of two, and so on. Based on this approach, Sharp (1970; 1971) suggested that stream order could be viewed as a degree of uncertainty and, therefore, can be used to locate sampling sites.

Sanders *et al.* (1983) selected sampling sites on the basis of the number of contributing tributaries. Next, they modified the same method by considering the pollutant discharges as external tributaries. They used three approaches to identify macro-locations by using: the number of contributing tributaries, the number of pollutant discharges and measures of BOD loadings. "*These approaches, although each may produce a rather different system of stations, work pretty well in initiating a network when no data or very limited amounts of data are available.*" (Harmancioglu *et al*., 1999).

Harmancioglu and Alpaslan, (1992) proposed the use of the entropy theory to decide upon the required numbers and locations of stations. Entropy is a measure of the degree of uncertainty of random hydrological processes. According to this theory, decisions may be taken to reduce the number of stations where information is redundant or to increase sampling sites at regions where additional information is required (Harmancioglu, *et al*., 1999). The entropy-based approach can be only applied for normal or lognormal data in the multivariate case. It does not handle "*very well*" other skewed distributions (Yang and Burn 1994). However, in a study to investigate the effect of the data distribution types on the entropy methods used to design network problems for selecting the priority stations in the Kızılırmalk Basin (multivariate case), Sarlak N. and A. Ü. Sorman (2006) indicated that data distribution types are "very important" for these methods.

The use of "kriging" as a non-statistical optimisation technique has been adapted to surface WQ, precipitation networks, precipitation chemistry, and stream flow (Hughes and Lettenmaier 1981; Ben-Jemaa, Marino, *et al*. 1995 and Christensen, Phoomiphakdeephan, *et al*. 1997). The "kriging" method is data dependent therefore; it can be effectively applied only if the number of observations is big enough.

Olbert *et al*. (2001) presented an analysis procedure for remote sensing data obtained by the Compact Airborne Spectrographic Imager with a neural network cluster algorithm using self-organizing feature maps to optimize the number and location of water sampling stations.

Caeiro, *et al*., (2003) selected a subset of monitoring sampling stations based on locations from an extensive estuarine sediment campaign. In this campaign 153 sites were sampled in the Sado estuary (southern Portugal). Simulated annealing algorithm and Metropolis iterative improvement procedure was used to iteratively improve the mean square error of estimation, by removing one station at a certain time and estimating it by indicator kriging using the remaining stations in the subset, within a controlled non-exhaustive looping scheme. The model results indicated 60 stations design to be optimal. The results also indicated that 17 additional stations should be added to the monitoring scheme to fulfill the objectives of monitoring.

Odom (2003) employed a simulated annealing algorithm using the variable costs of the network and the results of multivariate data techniques (mainly principle component and cluster analyses) to identify an optimized subset of the existing sampling sites based on a maximization of benefits. He identified an optimized network consisting of 67 of the existing 83 sampling sites and provided a basis for an ordered discontinuation of sampling sites by identifying the best ten-site monitoring network through the best 70-site monitoring network.

Dobbie *et al*. (2003) recommended that the number of the monitoring sites at Fitzroy River estuary could be reduced to seven out of 15 locations based on a combination between univariate and multivariate statistical techniques. The univariate exploration consisted of quantitative summaries, box-plots and Spearman’s rank correlation. The multivariate pattern analysis was used to display and summarize a set of multivariate measurements and thus provide a basis for pattern interpretation. Pattern analyses consisted of two approaches, ordination and clustering. Principal Component Analysis (PCA) was used to display the similarity amongst both the sites and the sampling times on a single graphical representation, known as a Bi-plot. Cluster Analysis was used to summarize the WQ data by assigning sites or sampling times to groups.

Sigua, and Tweedale (2004) employed multivariate/multi-parametric data analyses (principal component analysis PCA; cluster analysis CA and kriging analysis KA) in assessing redesigned effectiveness of the WQM program in the Indian River Lagoon, Florida. The analysis covered some WQ variables (salinity, dissolved oxygen, turbidity and total phosphorus). The PCA for these data identified the principal variable(s) responsible for inter-segment variability. The grouping of 'like' stations or a segmenting of each of the lagoon reaches, based on PCA was confirmed by CA and KA. They divided each reach into segments based on a visual discrimination of WQ differences between station groupings aided by spatial and temporal data distribution plots. The WQ data for each reach was also assumed to be normally distributed and have independence of observation and homogeneity of variance over the period of record.

In a study aimed to search for the optimal relocation strategy of WQM stations in the Kao-Ping River Basin (South Taiwan), Ning and Chang (2005) introduced a multi-objective evaluation that is equivalent to a basin-wide assessment for WQM. They presented an approach of how to integrate an optimization scheme of compromise programming with QUAL2E simulation analysis for WQM network assessment. The compromise programming looked for a set of compromise solutions based on five planning objectives (objectives functions: the monitoring sites for lower compliance areas of WQ, important locations with regard to attainable water uses, lower degradation areas of specific pollutants, regions of higher population density, and upstream districts of potable water intakes) and set of constraints (the budget limitations, equity implications, and detection sensitivity in the water environment). Comparison of planning outcomes of compromise programming was carried out against previously achieved analyses by using weighted programming and fuzzy programming (Ning and Chang, 2002, 2004). They did not find obvious difference between the planning alternatives produced by the weighted and compromise approaches.

Zeng and Rasmussen (2005) presented a strategy to reduce the measured parameters, locations, and frequency without compromising the quality of the monitoring program of Lake Lanier, Georgia, USA. WQ data collected from 17 lake and 10 tributary sites were used in conjunction with multivariate statistical techniques to improve the utility of collected data by identifying key parameters and monitoring locations. Firstly, Factor Analysis was used to identify the key parameters of WQ variations for both lake and tributary sites. Secondly, Cluster Analysis was applied to reduce the number of parameters and stations, which frees up resources for increasing monitoring in other areas.

It has to be mentioned here that most of these approaches provide a scientific basis for selecting sampling sites; however, the designer's judgment is equally important. Thus, "*the problem is as much an art as it is a science.*" (Harmancioglu, *et al*., 1999).

3.3 SAMPLING FREQUENCY

How often WQ samples should be collected? This is what is meant by determination of sampling frequency. It is an important issue since confidence intervals of estimates are a function of samples taken. The frequency of sampling significantly affects the sampling costs and can be treated objectively using statistical methods. Therefore, it is probably the network design aspect, which received most attention from the researchers. Other network design issues tend to be more subjective (Sanders *et al*, 1983). In general, the main factors that affect the selection of sampling frequencies are:

- Monitoring objectives;
- Variability in "population" being sampled;
- Required information;
- Expected statistical analyses and accuracy levels;
- Required cost and available budget;
- Number of sampling sites within the network and
- Ability of laboratory and personnel to process samples.

(Whitfield, 1988, Cavanagh *et al*., 1998, Ward *et al*. 1990, ANZECC & ARMCANZ, 2000 and RIZA, 2000)

3.4 METHODS FOR DETERMINIG SAMPLING FREQUENCY

3.4.1 Sampling Frequency to Comply with Monitoring Objectives

In general, the monitoring objective “compliance with standards” may probably require a high sampling frequency over a short period of time. Cavanagh *et al.*, 1998 indicated that the sampling frequencies should be higher during the low flow periods when the waste concentrations are high. The required information that involves detecting compliance with standards can be related to sampling frequency via a percentile approach to compliance assessment (Ward *et al.*, 1990). The frequency of compliance monitoring should be approximately equal to the probability of exceeding a standard.

In many environmental problems, determining whether a time series observations of a random variable generally increase or decrease is needed. The rate of change, in terms of changes in some central value of the distribution such as a mean or median is also required (Helsel and Hirsch, 2002). There are two approaches most commonly used to detect trends in WQ variables. The first is called ***linear/gradual or monotonic*** trend; which consists of a process deals with mean level that varies gradually throughout the data record. This approach, always involves a regression analysis. The second is ***step or sudden*** trend; which consists of a sudden change in the mean level of a process at the midpoint of the data series (Lettenmaier, 1976 and Darken, 1999).

The information goals that involve detecting trends over time can be related to sampling frequency via the power of trend test (Ward *et al*. 1990). Detecting trends in WQ requires monitoring for long periods (ten years or more) in order to ensure that true trends are achieved. The sampling frequencies for this objective generally vary between weekly to monthly.

In general, stations allocated to detect trends need fewer samples than these allocated to other monitoring objectives. Therefore, stations designed to detect standard violations will detect trends, but those detecting trends will not necessarily be able to detect stream standard violations (GAO, 1981).

Automated WQM is required when the monitoring objective is to investigate a mechanism controlling certain WQ changes (USDA, 1996).

“*It is essential that the monitoring program minimizes variability through time. Therefore, as much as possible, the program should remain consistent in terms of frequency, location, time of day samples are collected, and the collection and analytical techniques that are used*” (Cavanagh *et al.*, 1998).

3.4.2 Statistical Methods

Sampling frequency determination methods in WQM vary with the statistical objectives of the monitoring program. There are three statistical objectives that received more attentions related to this issue. These objectives are: detecting compliance with standards, determination of the true mean values of WQ variables and detecting trends (Sanders *et al*, 1983, USDA, 1996, Harmancioglu, *et al.*, (1999). The following sections summarize some approaches developed to deal with those issues.

3.4.2.1 Checking Compliance with Standards

This section is quoted from The US Environmental Protection Agency website presenting the documentation of Sampling Frequency Estimator application (EPA, 2005).

“Mace (1964) and Ward et al. (1990) described an approach for estimating the sample size required to control the risk for type I and type II errors when assessing the proportion of time that a criterion was exceeded. The approach is applicable when individual values are reduced to a nominal scale. In other words, values are determined to be either "above" or "below" a criterion.”

“*An iterative approach is used to estimate a number of exceedances (e) in a specified number of samples (n) that satisfies the following formulae*,”

$$1 - B(e;n, 1 - P^{*}) <= \alpha \qquad \text{Equation 3-1}$$

$$\beta = B(e;n, 1 - P) \qquad \text{Equation 3-2}$$

Where:

- *B is the cumulative binomial probability. Tables for this probability can be found in standard texts but usually only n up to 20, and p in increments of 0.05. Therefore, using an algorithm to obtain B for any values of e, n and p* is recommended.*
- *P* is the proportion of time that concentrations must be within the criterion and*
- *P is a selected proportion associated with an unacceptable frequency of exceedances.*

“Ward et al. (1990) suggest the use of operating characteristic curves, like those shown in Figure 3-1*, to depict the relative power of various sample sizes at a given confidence level.”*

“If the risk of a type I error is fixed at 0.10 and the constituent is required to be in compliance 90% of the time, the relative risks of committing a type II error may be observed from the graph. For example, if the constituent is within the limit only 80% of the time (p = 0.8), the risks associated with a type II error are about 70%, 40%, and 10% for sample sizes of 10, 30, and 100, respectively.”

"In Sample Size Estimator, an arcsin normal approximation is applied, as described by Mace (1964) and Klotz and Meyer (1985) to estimate the required sample size"

$$n = \left[\frac{z_\alpha + z_\beta}{2\arcsin\sqrt{p} - 2\arcsin\sqrt{p^*}}\right]^2$$ Equation 3-3

Where "Z_α *and* Z_β *are quantiles from the standard normal distribution, p* is the proportion associated with a null hypothesis and p is a selected proportion associated with an alternate hypothesis."*

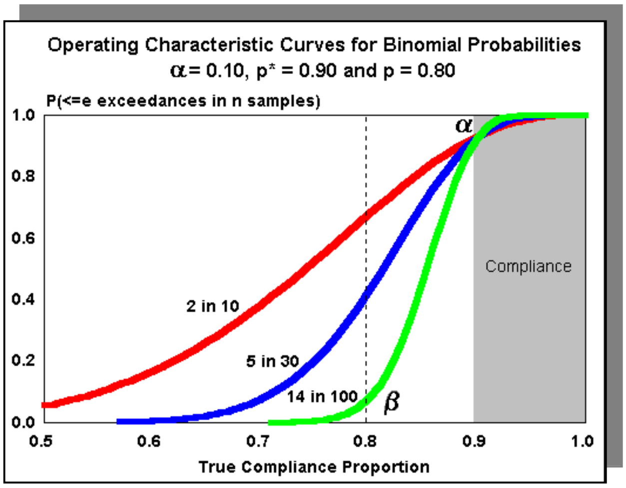

Figure 3-1: An example of operating characteristic curves (EPA, 2005)

3.4.2.2 Determination of the True Mean Values of Water Quality Variables

Sanders and Adrian (1978) developed a statistical method to determine sampling frequency based on the expected half-width of the confidence interval of the mean value. They investigated the relation between sampling frequency and the expected half width of the confidence interval of the random component of an annual mean variable concentration. The confidence interval can be understood as the probability that the population mean of a random variable will lie within a certain interval around the sample mean. The confidence interval can be expressed as:

$$[x - Z_{\alpha/2}\ \mathrm{var}\ (x)^{1/2} \quad \leq \quad \mu \quad \leq \quad x + Z_{\alpha/2}\ \mathrm{var}\ (x)^{1/2}]$$ Equation 3-4

Where:	x	Sample mean.
	$Z_{\alpha/2}$	Standard normal deviate corresponding to a probability of $\alpha/2$
	μ	Population mean.
	var (x)	Variance of the sample mean.

According to this method, the sample size can be calculated from the relationship:

$$n \geq \left(\frac{t_{\alpha/2} * S}{E} \right)^2 \qquad \text{Equation 3-5}$$

Where:
n required sample size
$t_{\alpha/2}$ Student's 't' at n-1 degrees of freedom and confidence level (α)
S estimate of the population standard deviation
E allowable difference from the mean (accepted error)

The previous equation based on three assumptions (Sanders *et al*, 1983):

- ***The population variance is known.*** This maybe valid when extensive data records are available for estimation of the population variance.
- ***The observations are independent***. This maybe valid when samples are spaced one month or more apart.
- ***The sample mean is normally distributed***. This is valid with large samples sizes. According to the *Central Limit Theorem*, if the samples are large enough, the distribution of sample mean will follow a Gaussian distribution even if the population is not Gaussian (Bendat and Piersol, 1971).

Equation 3-5 can be used only in case of series of random events where, the confidence interval of the mean decreases (more accurate) as the number of samples increases. Unfortunately, most WQ time series are not random but include significant seasonal variation and serial correlation. However, Sanders and Adrian (1978) applied a methodology for the case of stream-flows due to the lack of sufficient WQ data for statistical analysis. They first removed the effect of trends, seasonality and serial correlations. Next, the sample variance of residuals were computed and plotted against the sampling interval. The sample variance of residuals stabilized after a certain sampling interval and approached a limiting value. After a certain sampling interval, the variance became almost constant and independent of the sampling interval.

This is a necessary condition so that the analysis of the relationship between the expected confidence interval of the mean and the number of samples per year becomes theoretically valid (Harmancioglu, *et al*., 1999).

3.4.2.3 Detecting Trends

Many hydrologic data sets on which trend analysis is performed are actually pairs of time series such as precipitation and flow, flow and concentration, concentration of one constituent versus concentration of another (Helsel and Hirsch, 2002). Most time series patterns can be described in terms of three basic components (Sanders *et al*, 1983):

- **Trend component**; it represents a general systematic linear or nonlinear component that changes over time and does not repeat within the time range captured by the available data.
- **Seasonal component**; by which the variable repeats itself in systematic intervals over time. Therefore, the approximate level of a variable can be predicted for a given time of the year. This predictable variation can be described by a deterministic function and then removed from the data.
- **Stationary series**; it represents the purely random variation component in the original time series and can be obtained by extracting both seasonal and linear trend components. Stationary means that all statistical parameters such as mean, variance, etc. are constant (independent of time).

Census-I method is the common (classical) technique to isolate the previous components. This technique is described in detail in Makridakis *et al*. (1983).

Another important determining factor while dealing with time series is **serial correlation**. It occurs when successive data values are not statistically independent. This is the case when records are taken close enough in time. One method of describing this process is a plot of the autocorrelation function (**ACF**) against the lag time, which is called correlogram. The values of the correlogram function should range from –1 to +1. A value of one indicates a perfect correlation, while a zero indicates no correlation. Since seasonality and trends affect the correlogram function, the time series should be detrended and deseasonalized before creating the correlogram (Ibrahim, 1996).

Since, the trend detection problem is basically a statistical hypothesis-testing problem, the effective sample sizes that ensure proper use of statistical methods are required. Collecting too large sample sizes means wasting of resources while too small sample sizes bypass some important events and then reduce the reliability and utility of the information gained (Quimpo and Yang 1970 and Cochran, 1977).

Based on parametric trend test, Lettenmaier, 1976 proposed a methodology to determine optimum sampling intervals for actual WQ data. This approach was later applied by Schilperoort *et al.* (1982) in an optimization process to determine optimum sampling intervals when detecting WQ trends was the objective of the monitoring network.

Odom, 2003 applied this method using weekly stream sampling data from the Noland Divide watershed. He used the number of samples obtained as an approximate upper limit of a proposed sampling frequency.

The following section presents a brief description for the proposed methodology to determine the effective number of samples per year for the monitoring objective "detecting linear trend". Ward (1990), Harmancioglu, *et al*. (1999) and Odom (2003) presented similar description for the method proposed by Lettenmaier (1976).

The hypotheses to be verified are as follow:

H_o : there is no trend

H_1 : there is trend

The power function of a classical t-test precented by Lettenmaier, 1976 is

$$1-\beta=F_g(N_t-Z_{(1-\alpha/2)}) \qquad \text{Equation 3-6}$$

Where:

$1-\beta$: The probability of rejecting H1 when H1 is not true (the power of the test)

F_g : Cumulative distribution function of the standardized normal variate

N_t : Measure of trend magnitude (dimensionless) takes into account the trend level and the length of the series

$Z_{(1-\alpha/2)}$: Quantile of the standard normal distribution for a probability of non-exceedence (1-α/2).

For the linear trend the expression of N_t is (Lettenmaier, 1976):

$$N_t=\frac{|Tr|\sqrt{n}}{\sigma_\varepsilon\sqrt{12}} \qquad \text{Equation 3-7}$$

Where:

T_r : Absolute value of the change in beginning and ending predicted values along a regression line for a period of study.

σ_ε : Standard deviation of the residuals (random component of the time series)

n : Total number of independent samples needed for a period of study.

If the power of test (1-*β*) is fixed at 0.9, the equation 3-6 can be simplified to

$$N_t - Z_{(1-\alpha/2)} = 1.282$$

Substituting that in equation 3-7, then the sample size N* related to a trend level (T_r/σ_ε) can be expressed as (N* = n in equation 3-7):

$$N^*=\frac{12(1.282+Z_{1-\alpha/2})^2}{\left(\frac{Tr}{\sigma_\varepsilon}\right)^2} \qquad \text{Equation 3-8}$$

This is the total number of independent samples needed for a period of study Again; one has to remember that the previous equations are valid only for independent samples. The effective number of samples per year can be calculated from Equation 3-9.

$$\frac{1}{n^*} = \frac{1}{n} + \frac{2}{n^2} \sum_{k=1}^{n-1} (n-k) ACF_k \qquad \text{Equation 3-9}$$

Where:

k : Lag number or interval of time between successive observation

n : Number of samples per year based on a proposed sampling frequency

n^* : Effective number of samples taken per year

ACF_k : Autocorrelation coefficient for lag k

These formulas were developed under the assumption that the data series follows normal distribution. However, Lettenmaier (1976) accepted some non-normality in his data.

3.5 PRINCIPELES IN STATISTICAL EVALUATION

3.5.1 Parametric and Nonparametric Approaches

The effective monitoring network is the mechanism, which collects representative samples (quality data) from the water system (population). Then, statistics help drawing conclusions for the entire population (Steele et al., 1960).

In general, there are two basic statistical approaches, which have been developed in order to draw conclusions about populations from samples. These are parametric and nonparametric statistics.

Parametric Statistics assume that the populations follow a special distribution, known as the Gaussian (bell shaped or normal) distribution. The name comes from the fact that the information contained in the data is summarized by parameters, usually the mean and standard deviation. Through this assumption, statistical tests can help drawing conclusions about the mean and other properties of the population. The Gaussian distribution plays a central role in the parametric statistics because of a mathematical relationship known as the ***Central Limit Theorem***. According to this theorem, if the samples are large enough, the distribution of sample mean will follow a *Gaussian distribution* even if the population is not Gaussian. Since most statistical tests are concerned about differences between means, the theorem allows these tests to work well even when the populations are not Gaussian. However, the sampling size has to be reasonably large depending on how far the population distribution differs from the Gaussian distribution (Bendat and Piersol, 1971).

Nonparametric Statistics do not assume that data follow a Gaussian distribution and do not rely on the estimation of parameters (mean or standard deviation) describing the distribution of the variable of interest in the population (Zar, 1984).

In this approach, values are ranked from low to high and the analyses are based on the distribution of ranks (Conover and Iman, 1981). Ranking eliminates the impact of outliers in the tail regions of distributions. The term "*Nonparametric*" or (distribution free) was first used by Wolfowitz (1942).

For each general type of parametric test, there is at least an equivalent nonparametric one. In general, these tests can be categorized into three main groups (StatSoft, Inc., 1995): tests of differences between groups (independent samples), tests of differences between variables (dependent samples) and tests of relationships between variables.

- **Tests for differences between independent groups** compare the mean values of two samples for some variable of interest.
- **Tests for differences between dependent groups** compare two variables measured in the same sample.
- **Tests for relationships between variables** compute correlation coefficients to express a relationship between different variables.

Table 3-1 presents a brief guide to the classification of some of the main tests dealing with the previous categories. In general, the nonparametric tests are less powerful than the parametric ones. With large sample sizes the difference in power is minor. Nonparametric tests have little power to detect differences with small samples (EPA, 1998). The choice between parametric or nonparametric tests is based on the expected distribution of the data involved.

"*If similar data in the past were normally distributed, a parametric procedure would usually be selected. If data were expected to be non-normal, or not enough is known to assume any specific distribution, nonparametric tests would be preferred*" (Helsel, 2002).

Since each parametric or nonparametric test has its peculiar sensitivities and blind spots, the researcher has to select carefully the most suitable one for his analysis. This problem is more obvious in nonparametric approaches. For Example, the Kolmogorov-Smirnov two-sample test is not only sensitive to differences in the location of distributions (for example, differences in means) but is also greatly affected by differences in their shapes.

Table 3-1: Guide to the classification of some hypothesis tests (Helsel, 2002)

PARAMETRIC	NONPARAMETRIC (exact)
Two Independent Data Groups	
Two-sample t-test	Rank sum test or Mann-Whitney or Wilcoxon-Mann-Whitney or Wald-Wolfowitz runs test or Kolmogorov-Smirnov two-sample test.
Matched Pairs of Data (dependent variables)	
Paired t-test	Wilcoxon signed-rank test or McNemar's Chi-square test
More than Two Independent Data Groups	
One-way Analysis of Variance (ANOVA)	Kruskal-Wallis test
More than Two Dependent Data Groups	
Analysis of Variance without replication	Friedman test
Correlation between Two Continuous Variables	
Pearson's r or linear correlation	Kendall 's tau
Relation between Two Continuous Variables	
Linear Regression test for slope = 0	Mann-Kendall test for slope = 0

3.5.2 Wilcoxon Signed Rank Test

This section will focus on the Wilcoxon signed rank test as a nonparametric test, which is developed by Wilcoxon (1945). It is used to determine whether the median difference between paired observations equals zero. It may be used to test whether the median of a single data set is significantly different from zero.

- **ASSUMPTIONS, LIMITATIONS AND ROBUSTNESS**

1. The two underlying distributions are assumed to have the same shape and dispersion, so that one distribution differs by some fixed amount when compared to the other distribution.
2. Although no particular distributions are assumed for the two variables, the population distribution of the paired differences is assumed to be symmetric.
3. The magnitude of differences in matched observations can be ordered in a meaningful manner.
4. The matched pair test requires that the two samples are associated in some meaningful way.
5. The Wilcoxon signed rank test may produce misleading results if many data values are the same. In this case their relative ranks will be the same, and this has the effect of diluting the statistical power of the test.
6. The Wilcoxon signed rank test is slightly less likely to reject the null hypothesis when it is false than the t-test (slightly less powerful than t-test).
7. The test is relatively robust to outliers, because the ranks rather than observations are used for the analysis. This limits the influence of outliers because a given data point can be no more extreme than the first or last rank.

"*…. Comparing the means of monthly observations from one year to the next would be a two-sample test. Months are not paired well from year to year because of climate differences. However, comparing the means of monthly observations from adjacent watersheds for the same year would be a paired sample test. The two adjacent watersheds would be similarly affected by climate from month to month during the year*"(USDA, 2002). The effectiveness of pairing can be tested by calculating the Spearman correlation coefficient (r_s) and a corresponding P value. If (r_s) is positive and P is small, the two groups are significantly correlated. This justifies the use of a paired test (InStat, Inc., 1990).

3.5.3 Factor Analysis (FA)

Factor analysis (FA) as a statistical multivariate technique reduces the number of dimensions necessary to describe the relationships among a set of variables. It simply can be described as a data reduction procedure whereby the pattern of relationships among a set of variables is identified. There are basic 5 assumptions needed to use factor analysis. These assumptions are (Morrison *et al*, 1990):

1. **Normality:** each observed indicator should be normally distributed. If this assumption is violated, the solution may be degraded, but it may still be worthwhile.
2. **Linearity:** the relationships among the pairs of variables must be linear.
3. **Factorability of R**: the correlation matrix should be examined before the analysis. If the matrix reflects no correlations greater than 0.3, the use of FA should be reconsidered.
4. **Sample size:** the minimum sample size can be based on a ratio between the number of participants per variable used. This ratio has been suggested to be as low as 2 participants to every one variable to 20 to 1. Some researches suggested 10 to 1.
5. **Multivariate normality:** all variables and all linear combinations of variables are normally distributed. This assumption is an extension of the “Normality” assumption.

3.5.3.1 Principle Component Analysis (PCA)

The method of extracting factors from a set of data identifies the type of factoring. Principal Components Analysis (PCA): by far is the most common form of factor analysis. PCA seeks a linear combination of variables such that the maximum variance is extracted from them. It then removes this variance and seeks a second linear combination, which explains the maximum proportion of the remaining variance, and so on. This is called the principal axis method and results in orthogonal (uncorrelated) factors.

Apart from the computational aspects, the extraction of principal components basically amounts to a variance maximizing rotation of the original variable space. For example, in a scatter plot (for only two variables) one can think of the regression line as the original X axis, rotated so that it approximates the regression line. However, for more than two variables, the logic of rotating the axes so as to maximize the variance of the new factor remains the same. This is called variance-maximizing rotation (**Varimax**).

After the first factor has been extracted, that is, after the first line has been drawn through the data, another line is defined that maximizes the remaining variability, and so on. The consecutively extracted factors are orthogonal (uncorrelated) because each factor is defined to maximize the variability that is not captured by the earlier factor (StatSoft, Inc., 1995).

3.5.4 Cluster Analysis (CA)

A common question facing researchers in many disciplines is how to classify observed data into meaningful structures. Factor analysis is able to examine how much variance is shared by several variables and how much this variance is unique. Then it clusters variables together that share the same variance. In other words, it is a process of clustering variables that look as they explain the same variance. "*In essence, cluster analysis is similar technique except that rather than trying to group together variables, we are interested in grouping case*s" (Field, 2000).

There are mainly three techniques can cluster observations: hierarchical, non-hierarchical, and fuzzy. The hierarchical methods (used in this study) most commonly use agglomerative techniques where each observation starts in a cluster by itself (n observations = n clusters).

$$d_{rs} = \{ (x_r - x_s)' (x_r - x_s) \}^{1/2} \qquad \text{Equation 3-10}$$

As the algorithm progresses, observations are joined based on a proximity measure until there is only one cluster composed of all the observations (n clusters = 1). Different variations of proximity measures are used for each technique. One such proximity measure is Euclidean distance (Odom, 2003).

It can be described as the geometric distance in the multidimensional space between two objects. Smaller distances indicate more similarities. However, this measure is heavily affected by variables with large size or dispersion differences. Then the Euclidean distances will be inaccurate. As such it is especially important to standardize scores before proceeding with the analysis. It is especially important if variables have been measured on different scales (Field, 2000). In addition to the Euclidean distance, there are many other measures such as Squared Euclidean distance, City-block (Manhattan) distance, Chebychev distance, Power distance and Percent disagreement.

At the first step, when each object represents its own cluster, the distances between those objects are defined by the chosen distance measure. Then, the next step is to determine when two clusters are sufficiently similar to be linked together.

The most common methods of hierarchical clustering are (StatSoft, Inc., 1995):

- **Single linkage (nearest neighbor):** the distance between two clusters is determined by the distance of the two closest objects (nearest neighbors) in the different clusters.
- **Complete linkage (furthest neighbor):** the distances between clusters are determined by the greatest distance between any two objects in the different clusters.

- **Un-weighted pair-group average:** the distance between two clusters is calculated as the average distance between all pairs of objects in the two different clusters.
- **Weighted pair-group average:** this method is identical to the un-weighted pair-group average method, except that in the computations, the size of the respective clusters (i.e., the number of objects contained in them) is used as a weight.
- **Un-weighted pair-group centroid:** the centroid of a cluster is the average point in the multidimensional space defined by the dimensions. In a sense, it is the center of gravity for the respective cluster. In this method, the distance between two clusters is determined
- **Ward's method:** This method is different from all other methods because it uses an analysis of variance approach to evaluate the distances between clusters. In short, this method attempts to minimize the Sum of Squares of any two (hypothetical) clusters that can be formed at each step.

3.5.5 Multivariate Analysis of Variance (MANOVA)

Multivariate analysis of variance (**MANOVA**) determines the effect of multiple independent variables or a multi-level independent variable on multiple dependent variables simultaneously. It is an extension of the analysis of variance (**ANOVA**) whose main purpose is to investigate the significant differences between means. This is achieved by dividing the total variance into:

- Component due to true random error (i.e., within- groups);
- Components due to differences between means.

These latter variance components are then tested for statistical significance, and, if significant, the null hypothesis of no differences between means is rejected and the alternative hypothesis (the means, in the population, are different from each other) is accepted. However, the main reasons to use MANOVA instead of applying multiple ANOVAs are:

- MANOVA demonstrates the interaction effects between the dependent and independent variables and determine which factor is significantly important.
- MANOVA protects against Type I errors (rejecting a true null hypothesis) that might occur if multiple ANOVAs were applied independently.
- Multiple univariate measures (multiple ANOVAs) do not equal multivariate measures (MANOVA) because they do not take co-linearity (correlations among the dependent variables) into consideration.

- MANOVA provide univariate information on the effect of the independent variable(s) on each dependent variable.

There are three basic assumptions needed to use MANOVA. These assumptions are (Field, 2000):

1. **Normality:** It is assumed that the dependent variable is measured on at least an interval scale level. Moreover, the dependent variable should be normally distributed within groups. In general, the F test is remarkably robust to deviations from normality if skewness rather than outliers causes it. However, outliers should be excluded before performing MANOVA.
2. **Homogeneity of Variances:** It is assumed that the variances in the different groups of the design are identical; this is called the homogeneity of variances assumption. However, the F statistic is quite robust against the violations of this assumption.
3. **Homogeneity of Variances and Covariances:** In multivariate designs, since there are multiple dependent variables, it is also required that their inter-correlations (covariances) are homogeneous. The effect of violating this assumption is unclear but as a general rule of thumb, when sample sizes are equal then this violation effect can be ignored and the robustness of Hotellings's and Pillai's statistics as indicators of group differences can be assumed.

3.5.6 Discriminant Function Analysis (DFA)

In order to clarify the nature of the relationships between dependent variables, MANOVA analysis can be followed by Discriminant Function Analysis (DFA). For the purpose of this study, the DFA was used to determine which variables (WQPs) discriminate between two or more naturally occurring groups (monitoring sites). It has to be mentioned here that DFA can be considered as the reverse of MANOVA. Therefore, In MANOVA, the independent variables are the groups and the dependent variables are the predictors but in DFA, the independent variables are the predictors and the dependent variables are the groups.

In simple words, discriminant function (also called canonical root) can be thought of as (and is analogous to) multiple regression equation. It is a latent variables which is created as a linear combination of discriminating (independent) variables, such as:

$$DF = a + b_1 * x_1 + b_2 * x_2 + \ldots + b_m * x_m \qquad \text{Equation 3-11}$$

Where a is a constant, b_1 through b_m are the discriminant coefficients (analogous to regression coefficients) and x_1 through x_m are discriminating variables. The number of discriminant functions is the lesser of:

- (The number of categories in the grouping variable – 1) or
- (The number of discriminating variables)

The discriminant functions are orthogonal (uncorrelated) to each other. This means that their contributions to the discrimination between groups will not overlap.

Computationally, DFA determines the successive functions and canonical roots (the eigen-values associated with the respective discriminant/canonical function). The order of the discriminant functions is determined by investigating some optimal combination of variables so that the first function provides the most overall discrimination between groups, the second provides second most, and so on.

The contribution of each variable to the discrimination between groups is determined by the discriminant coefficients (b_1 to b_m) for each variable in each discriminant function (can be also standardized). The larger coefficient (or the standardized coefficient) indicates greater contribution of the respective variable.

The nature of the discrimination for each discriminant (canonical) function can be determined by looking at the means for the functions across groups or plotting the individual scores for the discriminant functions.

3.6 MULTIVARIATE ANALYSES AND ENVIRONMENTAL MONITORING

In general, univariate, bivariate and multivariate statistical analyses have been used to deal with different WQ data types. Most of these focused on univariate and bivariate data. "*Ideally, users of statistical methods find the greatest ease when the WQ data are linear, normal, independent and identically distributed with no outliers. However, this is almost never the case*" (Odom, 2003)

Many approaches have treated WQM design problems with different data types such as non-normal data, non-linear, seasonal, outliers, dependent, irregular spaced intervals, missing data, and serial correlated (Lettenmaier 1978; Lettenmaier 1979; Moss 1979; Whitfield 1983; Ward and Loftis 1986; Whitfield 1988; Somerville and Evans 1995, Thas, Van Vooren, *et al*. 1998, Husain 1989, Harmancioglu and Alpaslan 1992).

Multivariate techniques, both computational and graphical, have been applied to many environmental studies. These techniques, capable of distinguishing complex relations among many variables and can be useful for source-identification problems (Spruill *et al*, 2002). This section presents some literatures when multivariate techniques were employed to examine phenomena associated with the environmental quality.

Steinhorst and Williams (1985) used multiple analysis of variance, canonical analysis, and DA to discriminate ground water sources and to differentiate WQ associated with particular aquifers in basalt flows and interbeds in south-central Washington.

Ross and Ruiz (1996) studied the distribution and status of five plant taxa-Indigofera keyensis, Chamecrista lineata var. keyensis, Chamaesyce deltoidea subsp. serpyllum, Melanthera parvifolia, and Linum arenicola in the Florida Keys. The study was undertaken in order to assess the need for conservation efforts. First they examined patterns in the transect and sub-transect means of each plant and habitat variable throughout the study area through tabular or graphic means.

Secondly, they applied PCA to the habitat variables, reducing their dimensionality and creating four orthogonal, easily interpretable composite variables. Then, the differences in the PCA factor scores were tested via MANOVA, ANOVA, and the Scheff multiple-comparison test. They also developed discriminant functions from the Big Pine Key data set, which could be used to predict the presence or absence of the four plants, and these functions were applied to habitat data from Cudjoe, Little Pine, No Name, and Sugarloaf Keys.

Multivariate and principal component statistical analyses were used to identify the relations between physical and chemical variables in urban and agricultural soils in north Jordan (Salman and Abu Ruka'h 1999).

Qian and Anderson (1999) used Regression-Tree models to identify factors that affect pesticide concentrations in the Willamette River basin in Oregon.

Macro-invertebrate assemblages and environmental variables were evaluated as part of the Idaho statewide surface WQM program during 1996–98. Two assessment approaches were used to evaluate the macro-invertebrate data collected from Idaho Rivers; biological metrics and multivariate statistical analyses. The multivariate analyses consisted of PCA, de-trended correspondence analysis (DCA), and canonical correspondence analysis (CCA). PCA was used to summarize subsets of environmental data by identifying groups of variables that were highly correlated and was also used to evaluate relations among macro-invertebrate metrics. DCA was used to identify major patterns in macro-invertebrate assemblages and to determine whether the species data generally followed a unimodal pattern for further analysis by CCA. CCA was used to evaluate the degree to which environmental variables were associated with macro-invertebrate taxa and abundances (USGS, 2001).

Robertson *et al*. (2001) used regression trees to identify important environmental variables that affect nutrient concentrations in watersheds in the upper Midwest. The purpose of this study was to apply tree-based classification methods to (i) determine which WQ variables, both with and without 15N, could be used to identify the source of nitrate contamination with 80% or better success using selected chemical characteristics of the water sample from five known source categories, and (ii) determine if the chemical characteristics of water samples collected from wells in the North Carolina Coastal Plain and contaminated with nitrate can be used to identify the nitrate source.

Frapporti *et al*. (2001) used “fuzzy c-means clustering” to classify water types in the Netherlands and to identify the biogeochemical processes that dominate for each type. They grouped individual monitoring sites, based on the concentrations of the major ions, into well-defined water types. The data set contained over 46.000 samples, taken at 2278 location in the Netherlands in the period 1978 to 1991. The analysis covered the WQPs ammonium, bicarbonate, calcium, chloride, chlorophyll-a, Secchi visibility, iron, Kjeldahl nitrogen, magnesium, nitrate, potassium, sodium, sulphate, ortho-phosphate, oxygen and oxygen saturation, pH, silica and total phosphorus.

Lane *et al*. (2001) presented preliminary results of an attempt to develop an Index of Biotic Integrity (IBI) of phytoplankton communities for the Chesapeake Bay and its tributaries. Prior to developing a phytoplankton IBI, a MANOVA and canonical DA was employed to determine which stations within the current monitoring system could be used to represent reference conditions i.e. those stations exhibiting the least relative impact with respect to WQ conditions. This characterization was performed using surface WQPs that were believed to directly affect phytoplankton community composition: dissolved oxygen, secchi depth, water temperature, pH, total nitrogen, total phosphorus and total suspended solids.

Nagelkerke and Densen (2001) used PCA and CA, first to identify the variables that govern most of the diversity within and between fish communities and then to classify these communities. These two factors (effective classification of fish communities and the identification of key variables) are very important for the installment of informative and cost-effective fish monitoring programs.

Spruill *et al*, 2002, developed two statistical classification-tree models from 48 water samples containing nitrate from five sources (fertilizer on crops, fertilizer on golf courses, irrigation spray from hog (Sus scrofa) wastes, and leachate from poultry litter and septic systems) to determine if the nitrate sources in ground water could be classified with 80% or greater success. Both models were able to distinguish all five source categories with better than 80% overall success and with 71 to 100% success in individual categories using the learning samples. Classification-tree models showed great potential in identifying sources of contamination and the important variables in the source-identification process.

Lowell and Culp (2002) used multivariate analyses (multi-dimensional scaling ordination) and data sub-sampling to investigate long-term patterns in benthic invertebrate community structure downriver of a large pulp mill in southern British Columbia. They sub-sampled the full data set spanning 20 years to produce a series of smaller data sets, each simulating a sampling frequency of once every three years. The ordination of the sub-sample data sets showed that an average of 71% of the important taxa and 50% of the important physicochemical variables highlighted in the full analysis were missed in the subset analyses. These results underscored the importance of ensuring adequate temporal replication of sampling effort when a major goal is to directly measure or test for temporal patterns of stressor impacts.

Using principle components analysis, Patrick J. Phillips *et al*. (2002) found that pesticides in surface waters of New York State frequently occur in particular combinations that can be quantitatively expressed as five principal components. Those components reflect the five most common associations among 11 pesticides that were detected most frequently in a June through July 1997 survey of New York streams. The five principal components, in aggregate, account for about 80 percent of the variation in ranked concentrations of pesticides in the original data. These results indicated that the principal component analysis can be used to: (1) identify common mixtures present in surface waters, (2) relate these mixtures to patterns of land use and agricultural applications of pesticides, and (3) indicate regions where these mixtures of pesticides are commonly found.

In order to evaluate impacts of moist-soil habitat management on WQ and biological communities in wetland areas at the Strawberry Plains Audubon center in Holly Springs, Ervin *et al*. (2003) analyzed WQ field parameters data using repeated-measures multivariate analysis of variance (RM-MANOVA), PCA and CA to determine which parameters contributed most to differences among sites and to determine which sites were most similar to one another.

Bowling *et al*. (2003) investigated the impacts of cattle grazing on foreshore lands at Glennies Creek Storage after a major cyanobacterial bloom occurred there in November 1998. Analysis of Variance (ANOVA) was used to test for the effects of grazing and position in relation to the shore for individual WQ variables. The analysis was performed as an ANOVA with multiple strata, taking into consideration the spatial and temporal sampling design. MANOVA was also used to test effects on variation in all variables jointly.

Coad (2003) used the hierarchical clustering (classification) and multi-dimensional scaling (ordination) to analyze the community composition of the macro-invertebrate and diatom data produced by Hornsby Shire Council’s WQM program. The main objective of the report was to assess the WQ in the monitoring sites. Classification analysis aimed to determine ‘natural groups’ of samples, where samples within a group are more similar to each other than samples in other groups. Using the ordination technique, samples with similar species composition were located together within the ordination diagrams, whereas samples located well apart were not similar.

Roman *et al*. (2003) used multivariate analyses to analyze differences among selected watersheds in Puerto Rico using various multivariate techniques based on long-term WQ data. FA was performed to reduce the number of chemical constituents and to eliminate data redundancy. CA was then used to group watersheds with similar WQ characteristics. Finally, a DA was performed to relate the WQ clusters to different physical parameters and generate equations to predict WQ characteristics at unmonitored watersheds.

In a study to determine the generalized level of mercury contamination in sediment, water, and biota of multiple trophic levels across the Vermont and New Hampshire Lakes region, Kamman *et al*. (2004 A and B) used univariate and MANOVA to determine whether significant variation in water and sediment chemistry could be attributed either to the years in which the samples were collected (1998 vs. 1999), or to sample replication. They also used Principal Components Analysis to reduce the dataset (33 parameters) to account for simultaneous covariance among parameters that jointly influence concentrations of HgT, meHg, and sediment HgT, and tissue Hg, and to control for the occurrence of spurious correlations. Classification analysis using linear discriminant functions were used to allocate fillet tissue HgT concentrations to two classes one meeting the standard, and the second failing it.

Andre St-Hilaire *et al*. (2004) investigated the presence of significant variance among 36 stations in most WQPs measured in the Richibucto River drainage basin, including the estuary, in New Brunswick, Canada. They applied PCA to identify the processes explaining the observed variance in WQ. They recommended that WQPs that were found to explain most of the variance should be monitored more closely, as they are key elements in understanding the variability in WQ in the Richibucto drainage basin. Using CA, they identified areas with high phosphorous and nitrate concentrations in the basin. They were mostly found in areas of peat runoff, tributaries receiving treated municipal effluent, and lentic zones upstream of culverts. One-way analysis of variance (ANOVA) on ranks was used in this study to compare medians of the measured parameters at each sampled station. The Kruskal-Wallis ANOVA tested the hypothesis that samples are drawn from distributions with the same median.

De Vlaming, V. *et al* (2004), assessed benthic macro-invertebrate (**BMI**) community structure and physical stream habitat conditions in several agriculture-dominated and effluent-dominated waterways of the lower Sacramento River watershed. They applied Analysis of Variance (ANOVA) to distinguish the environmental variables and BMI metrics associated with the site groups identified by CA. PCAs and multivariate linear models were also applied to identify environmental variables accounting for most of the variability. In a complimentary analysis, they conducted a MANOVA and developed a linear model to examine the statistical significance of relationships between BMI metrics and environmental variables.

Eleria *et al*. (2005) developed ordinary least squares and multivariate linear/multivariate logistic regression models to predict fecal coliform bacteria concentrations and the probabilities of exceeding the Massachusetts recreation standard for bacteria based on meteorological conditions and streamflow measurements at Charles river basin.

CHAPTER 4

4. SAMPLING SITES FOR HADUS DRAIN MONITORING NETWORK

This chapter presents the employed methods and obtained results during assessing Hadus drain sampling sites (one of the main feeders of the El-Salam Canal Project). These methods were employed for 36 WQPs measured during the period from August 1997 to January 2005. The detailed information about the data availability for these sites is presented in Annex 4-1.

According to the preliminary investigations of the available data, it was decided to perform the analyses on three data sets: *monthly measurements*, *yearly averages* and *total means*. The last two sets were abstracted from the original data (monthly measurements of WQPs in Hadus drain network).

Figure 4-1 shows a flowchart for the analyses steps indicating the different data types that were used for each step. In general, the flowchart includes two main parts as following:

1. Preliminary Analyses

- Spatial analysis
- Data inspection
- Data screening and detecting outliers
- Descriptive statistics
- Check normality
- Check dependency

2. Similarity Analyses

- WQPs means (FA, PCA, CA and DFA)
- WQPs yearly averages (MANOVA and DFA)
- WQPs monthly measurements (nonparametric comparisons, correlation, regression and Key Players analyses)

4.1 PRELIMINARY ANALYSES

4.1.1 Spatial Analysis

The WQM sites in Hadus drain were divided into four site groups (Figure 4-2) based on the spatial characteristics of the monitoring sites such as geographical position, surrounding conditions and the direction of flow. This step ensures that the locations in every site group have similar environmental properties that may affect the WQ in the system.

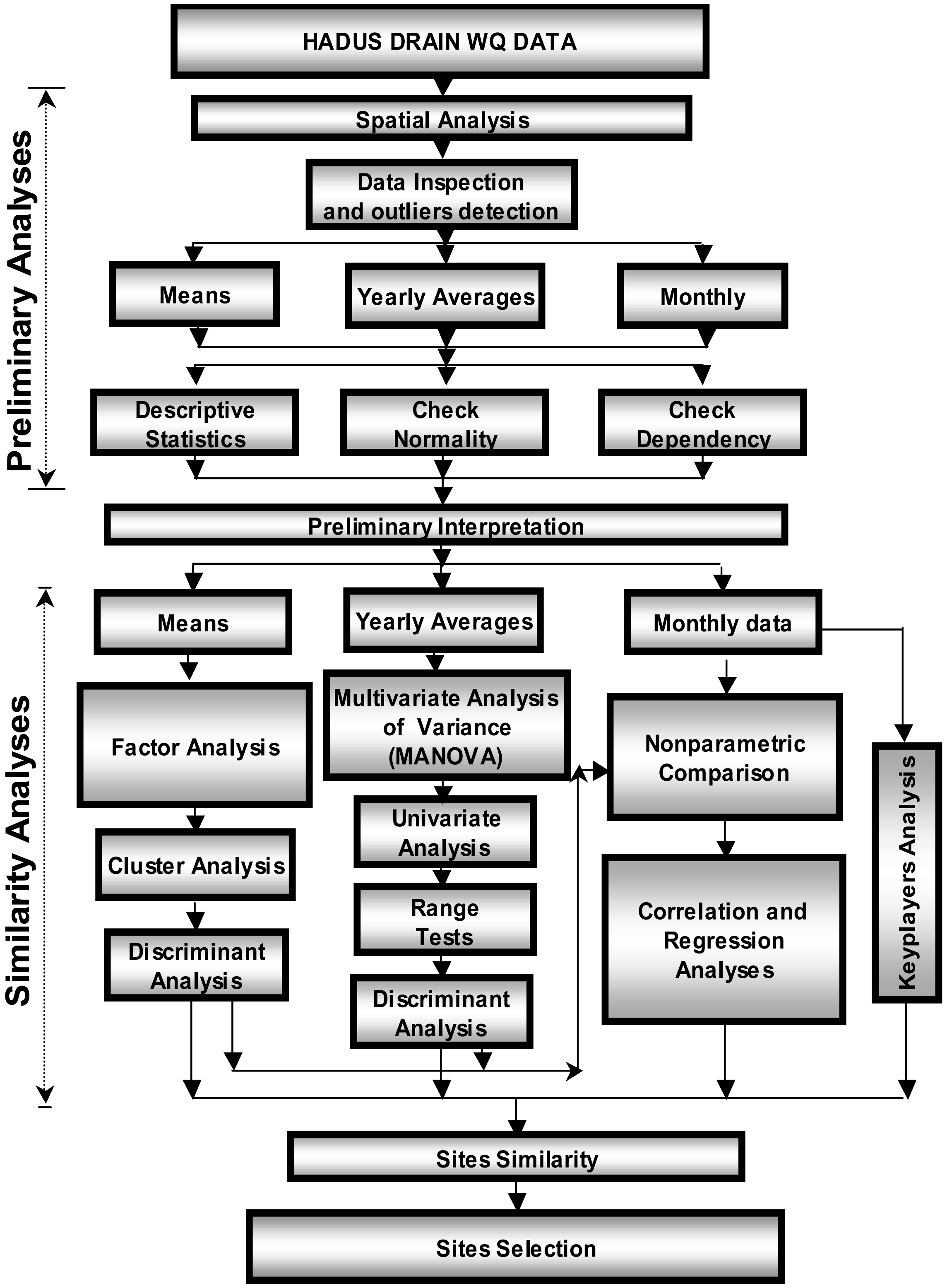

Figure 4-1: Flowchart of statistical analyses applied on the WQ measurements in Hadus drain

In addition, the relationships that may be detected between the WQPs in these monitoring sites can be easily understood.

However, this limits the process of detecting similarities within each site group and avoids sites that are significantly far from each other and/or separated by crucial tributaries (in the distances between them). For the last cases, one cannot easily exclude any of those sites based on the detected similarities.

These site groups are as following (Table 4-1):

- **Site Group 1:** includes EH14, EH02, EH18 and EH03.
- **Site Group 2:** includes EH04, EH05, EH15 and EH06.
- **Site Group 3:** includes EH07, EH08, EH09 and EH10.
- **Site Group 4:** includes EH11, EH16, EH12 and EH17.

Table 4-1: Monitoring sites in Hadus drain system

LOCATIONS	CODE	LOCATION TYPE
Gemeeza Bridge	EH14	Open Location
Hanut P.S.	EH02	Reuse
Additional Point between Hanut and Sadaqa Pump stations	EH18	Open Location
Sadaqa P.S.	EH03	P.S.
Nizam Bridge	EH04	Open Location
Nizam P.S.	EH05	P.S.
El-Dawar Bridge	EH15	Open Location
Beni Ebid P.S	EH06	Reuse
Additional Qassabi P.S.	EH07	P.S.
Main Qassabi P.S.	EH08	P.S.
Genina P.S.	EH09	Reuse
Erad P.S.	EH10	P.S.
Bahr Hadus Bridge	EH11	Open Location
Saft P.S.	EH12	30 % Reuse
El-Rian drain	EH16	Open Location
New Bahr Hadus Outfall to Salam Canal (El-Salam 3 P.S.)	EH17	Irrigation P.S.

Note: P.S. = Pump Station

(Source: DRI internal data)

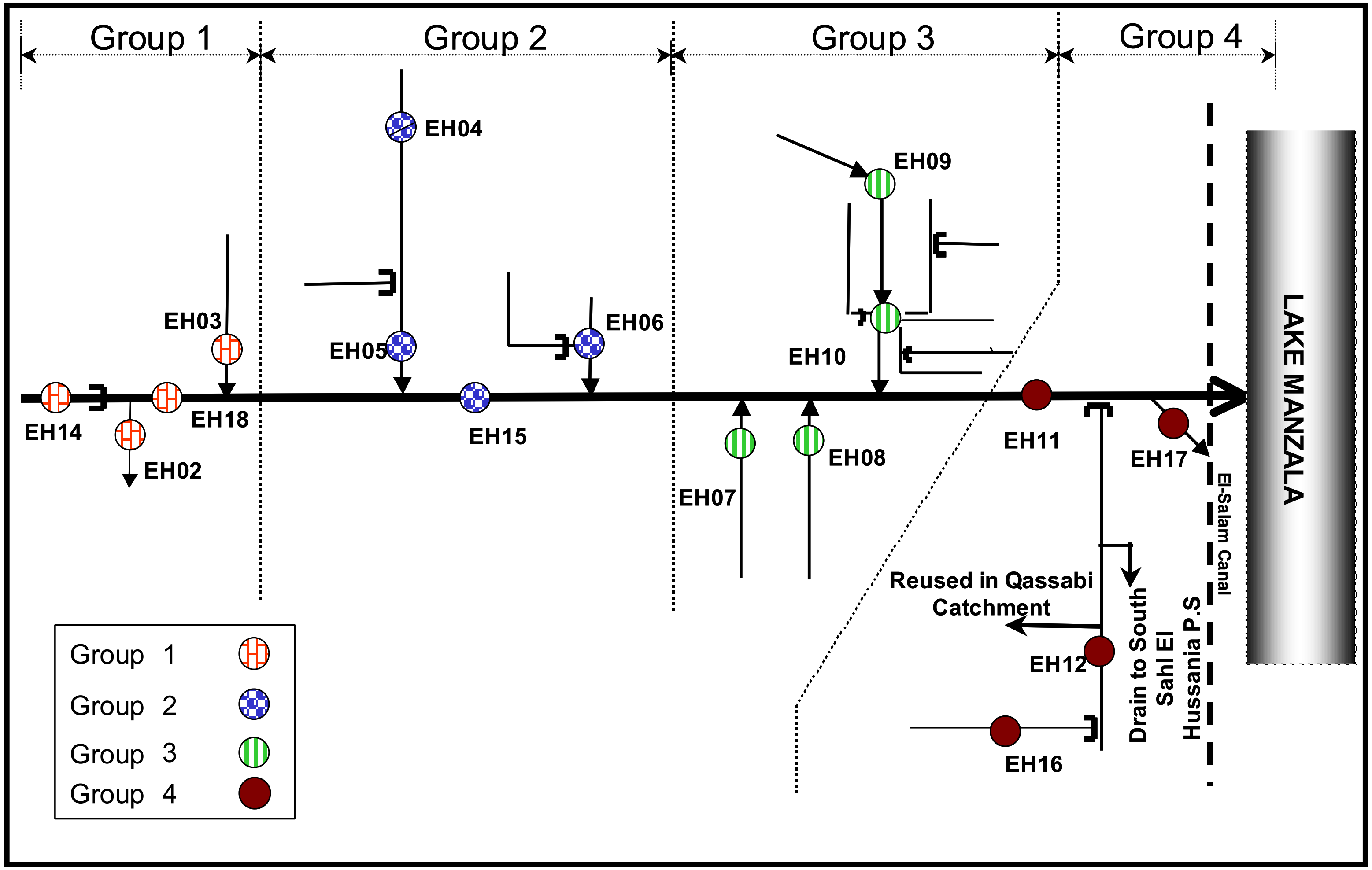

Figure 4-2: Grouping Hadus drain WQM sites

4.1.2 Data Screening and Detecting Outliers

Box and Whisker plot indicates the maximum and minimum measurements (Min/Max, shown as whiskers), the 25th and 75th percentiles (shown as a box), and the median (indicated by a line across the box). The box length is the inter-quartile range, which contains 50% of the measurements. The plots present also the extreme values, which can be divided to:

- **Outliers**: cases with values between 1.5 and 3 box lengths from the upper or lower edge of the box (inter-quartile range).
- **Extremes:** cases with values more than 3 box lengths from the upper or lower edge of the box.

The outliers and extremes that were detected in the Hadus drain data were checked with the DRI team. Consequently, it was decided to exclude some extremes from further analysis (Table 4-2).

Table 4-2: Extreme values that have been excluded from further analysis

Paramters	Locations	Extremes	Units	Date
TSS	EH18	1512	mg/l	Apr-99
N-NH4	all locations		mg/l-N	Nov-02
N-NO3	EH16	170	mg/l-N	Apr-03
Fe	EH15	5.77	mg/l	May-02
Ni	EH15	0.625	mg/l	Feb-04
Ni	EH05	0.333	mg/l	May-01
Zn	EH12	34.8	mg/l	Jan-03
Pb	EH12	1.3	mg/l	Jan-03
TP	EH12	6.64	mg/l	May-03
DO	EH14	43	mg/l	Apr-05
TN	EH16	221.04	mg/l	Apr-03
TN	all locations		mg/l	Nov-02

(Source: DRI internal data)

Annex 4-2 shows the Box and Whisker plots that were carried out for the monthly measurements of WQPs in Hadus drain monitoring sites for the period from August 1997 till January 2005 after removing the extremes in Table 4-2.

4.1.3 Descriptive Statistics, Check Normality and Dependency

- **Descriptive statistics**

Annex 4-3 shows summary statistics for the WQPs in Hadus drain during the period from August 1997 till January 2005 (after excluding the extremes in Table 4-2). The summery includes sample size, mean, minimum, maximum, standard deviation, range, standard error of the mean, and kurtosis and skewness with their standard errors.

- **Check Normality**

In order to check whether the data sets for Hadus WQPs follow normal distribution, the Kolmogorov-Smirnov statistics with a Lilliefors significance level for testing normality were carried out. In addition, the Shapiro-Wilk statistics were calculated especially for the cases when sample size did not exceed 50.

The normal probability and Box-Whisker plots were also carried out for the total WQ means (**Means**) to support the visual judgment of the normality and explore whether some locations can be considered as extremes.

The normality tests were also applied for both; the yearly averages for all WQPs with respect to the monitoring sites (**Yearly Avg.**) and the monthly measurements (**Monthly**). The yearly average results were divided into four parts based on the spatial characteristics of the monitoring sites.

Annex 4-4A, B and C show the output for all the previous data sets; Means, Yearly Avg. and Monthly respectively for the WQPs in Hadus drain.

- **Check Dependency**

In order to check the occurrence of linear associations between the parameters, Kendall 's tau correlation coefficients for the monthly measurements in Hadus drain monitoring sites, were calculated. For every site group, the correlations were investigated for the sites, which have similar conditions.

Annex 4-5 (A, B, C and D) shows the results of the non-parametric correlation analysis (Kendall ‘s tau test) for the three data sets (total means, yearly averages and monthly).

4.2 PRELIMINARY RESULTS

The following sections introduce some findings, which were obtained from the previous data analyses.

4.2.1 Data Inspection

- The outfalls to Hadus main drain at EH07, EH08, EH10 and EH12 have relatively higher salt levels comparing to the preceding monitoring sites. This may be the reason for high salt levels in the later sampling sites at the main drain (EH11 and EH17).
- The metal parameters; Fe, Mn and Br show higher levels at all Hadus sampling sites comparing to Cu, Zn, Pb and Ni.
- The average Fe measurements at all sampling sites were higher than 0.36 mg/l (EH18). The maximum mean was recorded at sampling sites EH04 and EH05 (0.58 mg/l).
- The average Mn measurements were higher than 0.21 mg/l. The maximum means were recorded at the sampling sites EH09 and EH10 (0.44 and 0.46 mg/l).
- The average Br measurements were higher than 0.15 mg/l. The maximum mean was recorded at the sampling site EH09 (0.42 mg/l).
- The means of the metal measurements Cd, Cu, Zn, Pb and Ni at all Hadus sampling sites were less than 0.1 mg/l.
- For the means, the monitoring location EH04 can be seen as an extreme location for the WQPs Coli, BOD, COD, Br, Temp and DO.
- For the means, the monitoring location EH09 has high N-NO_3 and TN levels while EH08 and EH15 have high K and Pb levels respectively.

4.2.2 Check Normality

A. "Means"

- Both Kolmogorov-Smirnov and Shapiro-Wilk tests indicated that 20 WQPs follow the normal distribution. These parameters are as follow: BOD, COD, TSS, TVS, N-NO_3, N-NH_4, P, Cd, Cu, Fe, Mn, Zn, Pb, pH, Temp, DO, Turb, Visib, TP and TN.
- Although Kolmogorov-Smirnov test results considered that Coli, Br, EC, TDS, Na, K, Cl, SAR and Adj_SAR follow normal distribution, Shapiro-Wilk tests indicated non-normality.
- Both Kolmogorov-Smirnov and Shapiro-Wilk tests indicated that seven WQPs differ from normal distribution. These parameters are Ca, Mg, SO_4, Sal, Fecal, Ni and SO_{4_m}.

B. “Yearly Averages”

Site group 1 (EH14, EH02, EH18 and EH03):

- For each monitoring site in group 1, both Kolmogorov-Smirnov and Shapiro-Wilk tests indicated that 23 parameters follow normal distribution. These parameters are BOD, COD, TSS, TVS, N-NH_4, Mn, Br, pH, EC, TDS, Ca, Mg, Na, K, SO_4, Cl, SAR, Adj. SAR, Temp, Sal, Turb, Fecal and Tp.
- Both tests indicated that the yearly averages for (N-NO_3, Cd, Zn, Pb, TN and Ni at EH14), (Fe and Zn at EH02), (N-NO_3 and Visib at EH18), and (Coli, N-NO_3, Cd, and Fe at EH03) differ from normal distribution.
- Shapiro-Wilk test results considered that (Pb at EH02), (DO at EH18) and (SO_{4_m} at EH03) follow normal distribution while Kolmogorov-Smirnov test indicated non-normality.
- Although Kolmogorov-Smirnov tests results considered that (Cu, DO and SO_4 at EH14), (N-NO_3 and Cd at EH02), (Cd at EH18) and (Zn at EH03) follow normal distribution, Shapiro-Wilk tests indicated non-normality.

Site group 2 (EH04, EH05, EH06 and EH15):

- For each monitoring site in group 2, both Kolmogorov-Smirnov and Shapiro-Wilk tests indicated that 13 parameters follow normal distribution. These parameters are as follow: Cu, Fe, pH, TDS, Ca, Mg, K, SO_4, Cl, DO, Visib, Tp and Ni.
- Shapiro-Wilk test results considered that (EC at EH04), (BOD, TVS, Mn, Na and SAR at EH06) and (SO_4 at EH15) follow normal distribution while Kolmogorov-Smirnov tests indicated non-normality.
- Although Kolmogorov-Smirnov test results considered that (TN at EH04), (Sal at EH05), (COD and N-NH_4 at EH06) and (Br, Turb and TN at EH15) follow normal distribution, Shapiro-Wilk test indicated non-normality.

Site group 3 (EH07, EH08, EH09 and EH10):

- For each monitoring site in group 3, both Kolmogorov-Smirnov and Shapiro-Wilk tests indicated that 17 parameters follow normal distribution. These parameters are COD, Cu, Fe, Mn, Br, pH, EC, TDS, Na, SO_4, Cl, Temp, Sal, DO, Turb, TP and TN.
- For all monitoring sites in this group, both Kolmogorov-Smirnov and Shapiro-Wilk tests indicated that N-NO_3, Cd and Zn do not follow normal distribution.
- Although Kolmogorov-Smirnov test results considered that (BOD and N-NH_4 at EH07), (BOD and K at EH08), (BOD and SAR at EH09) and (Ca, Mg and SO_{4_m} at EH10) follow normal distribution, Shapiro-Wilk test indicated non-normality.

Site group 4 (EH11, EH16, EH12 and EH17):

- For each monitoring site in group 4, both Kolmogorov-Smirnov and Shapiro-Wilk tests indicated that 18 parameters follow normal distribution. These parameters are BOD, Cu, Mn, Zn, Br, pH, EC, TDS, Na, SO_4, Cl, SAR, Adj.SAR, Temp, Sal, Turb, Visib and TN.
- For all monitoring sites in this group, both Kolmogorov-Smirnov and Shapiro-Wilk tests indicated that N-NO_3 did not follow normal distribution.
- Shapiro-Wilk test results considered that (Fe at EH11), (TSS and TVS at EH12), (Pb. Mg and Ni at EH16) and (Coli and Pb at EH17) follow normal distribution while Kolmogorov-Smirnov test indicated non-normality.
- Although Kolmogorov-Smirnov test results considered that (BOD, N-NH_4, Cd, K and Fecal at EH17) follow normal distribution, Shapiro-Wilk test indicated non-normality.

C. Monthly

- Kolmogorov-Smirnov test results indicated that most of the WQPs in Hadus drain differ from normal distribution.

4.2.3 Check Dependency

A. Means

- Except Br, most of the metals have insignificant correlations with the other WQPs.
- Most of the other WQPs are significantly correlated and most of their correlations are significant at 0.01 level of confidence.
- The parameters TN and N-NO_3 are significantly correlated at 0.01 level of confidence and they do not have correlation with any other parameter.

B. Yearly Averages

Site group 1 (EH14, EH02, EH18 and EH03):

- For the WQPs TP, TN, Ni, SO_{4_m} and Fecal (number of replicates do not exceed 5), the monitoring locations have insignificant correlations.
- For the WQPs P, Br, Mn and Na, the monitoring locations have insignificant correlations.
- For the other parameters, most of the monitoring locations have significant correlations.

Site group 2 (EH04, EH05, EH06 and EH15):

- As in site group 1, the monitoring locations have insignificant correlations for the WQPs TP, TN, Ni and Fecal (number of replicates do not exceed 5).
- There were not enough data to perform the correlation analysis for the parameter P.
- For Br, Sal, DO and Turb, the monitoring locations showed insignificant correlations.

- For the other WQPs, most of the monitoring locations have significant correlations.

Site group 3 (EH07, EH08, EH09 and EH10):

- For the WQPs Fecal, TP, Ni and SO_{4_m} (replicates do not exceed 5), the monitoring locations have insignificant correlations.
- There were not enough data to perform the correlation analysis for the parameter P.
- For the WQPs Br and Cl, the monitoring locations have insignificant correlations.
- For the other WQPs, most of the monitoring locations have significant correlations.

Site group 4 (EH11, EH16, EH12 and EH17):

- For the WQPs Fecal, TP and SO_{4_m} (replicates do not exceed 5) the monitoring locations showed insignificant correlations.
- There were not enough data to perform the correlation analysis for the parameter P.
- For the WQPs Mn, Zn, Br and DO, the monitoring locations showed insignificant correlations.
- For the other WQPs, most of the monitoring locations have significant correlations.

C. Monthly

- Within each site group and almost for all WQPs, the monitoring locations have significant correlations between each other and most of these correlations are significant at 0.01 level of confidence.

4.3 SIMILARITY ANALYSIS

4.3.1 Means

The following sections present the analyses procedures which were carried out for the total WQ means (Means) to find out the possible similarities in Hadus drain monitoring sites. From now on, the term "**Means**" will indicate the total averages of the WQPs measured during the period from August 1997 to January 2005.

4.3.1.1 Factor Analysis and Principle Components

According to the information extracted from the preliminary results (section 4.2), the WQPs BOD, COD, TSS, TVS, N-NH_4, P, pH, Temp, DO, Turb, Visib and TP follow the basic assumption of Factor Analysis (**FA**) therefore, further analysis will be focused only on them.

In order to identify the principle components of the previous parameters, the statistical software SPSS was used. The method of extraction was selected as "*Principle Components (**PC**)*". The extraction eigen-values were decided to be greater than 0.7 to increase the variability explained.

Normally, un-rotated solutions are hard to be interpreted because variables tend to load on multiple factors. Therefore, ***Varimax*** as a common orthogonal rotation method was selected. In many cases, rotated solution yields results, which make it as easy as possible to identify each variable with a single factor.

The following section presents the detailed SPSS outputs for the examined WQPs in Hadus drain monitoring sites. Table 4-3 shows the **correlation matrix**, which describes the bi-variate relations involving all the examined WQPs, which were introduced to the **PCA**. The values within the matrix are the correlation coefficients between each pair of variables. It can be easily seen that high correlation coefficients exist indicating data factorability.

Table 4-4 shows the **communalities box**, which includes two communality values for each variable. The *initial* value indicates the variance for the variable in standard score form (1.00 for all variables). Once the number of factors has been accounted for, these values are lowered.

Therefore, the *extraction* column in Table 4-4 reflects the proportion of variance accounted for each variable by the factors. It is clear that the variances accounted by the factor analysis vary within range of high values (0.8 to 0.97). This indicates that the FA is accounting for much of the variance associated with that variable and also means that the variables have much in common with each other.

Table 4-3: The correlation matrix in SPSS outputs for some WQPs measured in Hadus drain monitoring sites

Parameters	BOD	COD	TSS	TVS	N-NH_4	P	pH	Temp	DO	Turb	Visib	TP
BOD	1.00	0.99	-0.61	-0.58	0.47	0.77	-0.73	0.68	-0.90	-0.32	0.10	0.92
COD	0.99	1.00	-0.61	-0.58	0.53	0.79	-0.73	0.63	-0.89	-0.31	0.09	0.92
TSS	-0.61	-0.61	1.00	0.98	-0.68	-0.80	0.82	-0.54	0.63	0.90	-0.78	-0.64
TVS	-0.58	-0.58	0.98	1.00	-0.68	-0.76	0.79	-0.50	0.60	0.87	-0.78	-0.60
N-NH_4	0.47	0.53	-0.68	-0.68	1.00	0.74	-0.75	0.27	-0.44	-0.57	0.38	0.44
P	0.77	0.79	-0.80	-0.76	0.74	1.00	-0.87	0.65	-0.72	-0.59	0.37	0.78
pH	-0.73	-0.73	0.82	0.79	-0.75	-0.87	1.00	-0.66	0.70	0.66	-0.42	-0.71
Temp	0.68	0.63	-0.54	-0.50	0.27	0.65	-0.66	1.00	-0.71	-0.46	0.23	0.70
DO	-0.90	-0.89	0.63	0.60	-0.44	-0.72	0.70	-0.71	1.00	0.33	-0.07	-0.93
Turb	-0.32	-0.31	0.90	0.87	-0.57	-0.59	0.66	-0.46	0.33	1.00	-0.92	-0.34
Visib	0.10	0.09	-0.78	-0.78	0.38	0.37	-0.42	0.23	-0.07	-0.92	1.00	0.10
TP	0.92	0.92	-0.64	-0.60	0.44	0.78	-0.71	0.70	-0.93	-0.34	0.10	1.00

Table 4-4: The communalities box in SPSS output for some WQPs measured in Hadus drain monitoring sites

Parameters	Initial	Extraction
BOD	1.00	0.93
COD	1.00	0.94
TSS	1.00	0.97
TVS	1.00	0.94
N-NH_4	1.00	0.93
P	1.00	0.88
pH	1.00	0.86
Temp	1.00	0.80
DO	1.00	0.91
Turb	1.00	0.97
Visib	1.00	0.97
TP	1.00	0.93

Table 4-5 shows the *total variance explained* (eigen analysis) for the examined WQPs in Hadus drain. This table presents the eigen-values for the analysis and the estimates of the variance accounted for.

The first three principle components that explain almost 92% of the total variability were extracted. The rotated *components matrix* (Table 4-6**)** shows that the first principle component is mainly affected by the Temp, Nutrients (TP) and oxygen budget (BOD, COD, DO). The second component is affected by the water clarity and suspended solids (TSS, TVS, Turb and Visib). Also, Nutrients (N-NH_4) affects the third component**.**

Table 4-5: Total variance explained in SPSS output for some WQPs in Hadus drain

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.99	66.57	66.57	7.99	66.57	66.57
2	2.29	19.06	85.63	2.29	19.06	85.63
3	0.75	6.23	91.86	0.75	6.23	91.86
4	0.42	3.50	95.36			
5	0.17	1.42	96.78			
6	0.14	1.14	97.92			
7	0.13	1.08	99.00			
8	0.06	0.50	99.49			
9	0.04	0.33	99.83			
10	0.01	0.11	99.94			
11	0.01	0.05	99.99			
12	0.00	0.01	100.00			

Table 4-6: Rotated component matrix in SPSS output for some WQPs in Hadus drain

Parameters	1	2	3
BOD	0.92	-0.11	0.27
COD	0.90	-0.08	0.36
TSS	-0.46	0.79	-0.37
TVS	-0.42	0.79	-0.38
N-NH_4	0.23	-0.35	0.87
P	0.66	-0.39	0.53
PH	-0.62	0.47	-0.51
Temp	0.81	-0.35	-0.15
DO	-0.92	0.13	-0.20
Turb	-0.18	0.95	-0.20
Visib	-0.07	-0.98	0.08
TP	0.93	-0.14	0.23

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

4.3.1.2 Hierarchical Cluster Analysis (HCA)

The scores of the first three components for 16 sampling sites in Hadus drain were passed to the *CLASSIFY* module in SPSS. Due to the reason that sample size was less than 200, the hierarchical cluster analysis procedure was selected. As a first trial, solutions with 3, 4, 5 and 6-clusters were requested based on the *nearest neighbor* clustering method.

Table 4-7 shows that, for all the requested solutions, the monitoring locations EH04, EH16 and EH17 differ from each other and differ from the rest of Hadus monitoring sites except EH16, which does not differ from others in the 3-clusters solution. This indicated the importance of repeating the analysis after excluding EH04, EH16 and EH17 in order to better declare the similarity of the other 13 locations.

4.3.1.3 Discriminant Function Analysis (DFA)

In order to test the discriminating ability of the clusters that were presented before, Discriminant analysis (**DA**) module in SPSS was used. As an example, Figure 4-3 shows the Canonical Discriminant Function plots which present the principle component scores in relation with cluster groups and centroids for the 4- and 6-clusters solutions.

Table 4-7: Cluster memberships assuming different number of clusters in SPSS output for all Hadus drain sampling sites

Locations	No. of Clusters			
	6 Clusters	5 Clusters	4 Clusters	3 Clusters
EH14 .	1	1	1	1
EH02	2	2	1	1
EH18	2	2	1	1
EH03	3	2	1	1
EH04	4	3	2	2
EH05	3	2	1	1
EH15	2	2	1	1
EH06	3	2	1	1
EH07	3	2	1	1
EH08	3	2	1	1
EH09	3	2	1	1
EH10	3	2	1	1
EH11	3	2	1	1
EH16	5	4	3	1
EH12	3	2	1	1
EH17	6	5	4	3

The analysis results support the previous obtained from the cluster analysis where the monitoring locations EH04, EH16 and EH17 are different from the other locations.

The cluster analysis was again performed with the same conditions after removing the monitoring locations EH04, EH16 and EH17. Table 4-8 shows the cluster memberships of all Hadus drain sampling sites assuming different number of clusters. The table indicates that the previous three locations are extremes.

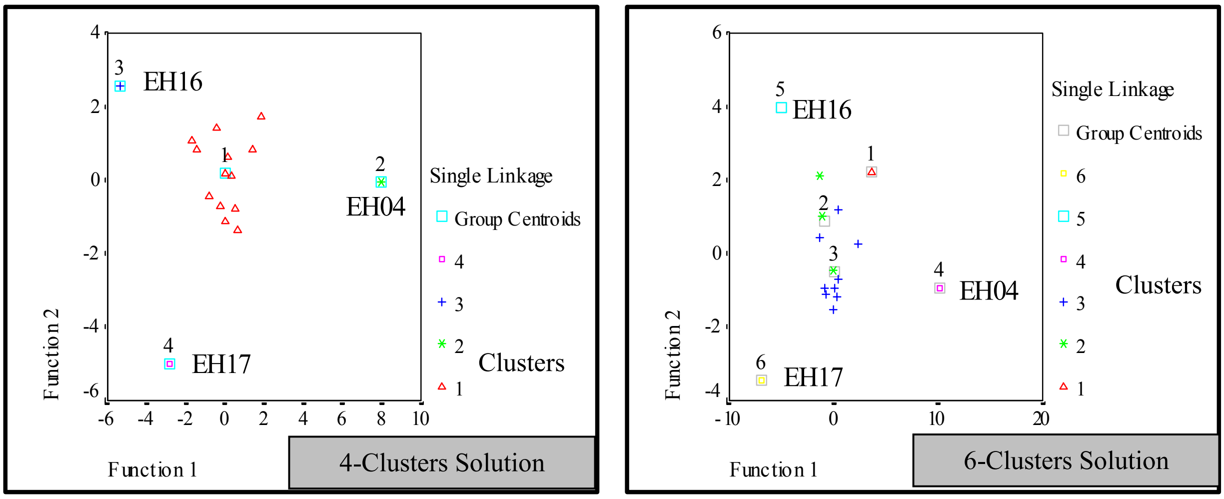

Figure 4-3: Canonical Discriminant Functions plots (principle component scores in relation with cluster groups and centroids)

Table 4-8: Cluster memberships of 13 sampling sites in Hadus drain

Spatial Grouping	Locations	No. of Clusters			
		6 Clusters	5 Clusters	4 Clusters	3 Clusters
Group 1	EH14 .	1	1	1	1
	EH02	2	2	1	2
	EH18	3	3	1	2
	EH03	4	4	3	3
Group 2	EH04	Extreme			
	EH05	5	5	4	3
	EH15	2	2	2	2
	EH06	5	5	4	3
Group 3	EH07	6	5	4	3
	EH08	6	5	4	3
	EH09	5	5	4	3
	EH10	4	4	4	3
Group 4	EH11	4	4	4	3
	EH16	Extreme			
	EH12	6	5	4	3
	EH17	Extreme			

Figures 4-4 and 4-5 plot the previous results for the two solutions 6 and 4 clusters indicating the location pairs, which were seen as possible similar. For the 6-clusters solution, these pairs are EH05&EH06 and EH07&EH08. While for the 4-clusters solution these pairs are EH14&EH02, EH14&EH18, EH02&EH18, EH05&EH06, EH07&EH08, EH07&EH09, EH07&EH10, EH09&EH10 and EH11&EH12.

It has to be mentioned here that these results ignored the similarities between the locations that lie in different site groups such as those found between: EH03, EH10 and EH11 (6-clusters solution) or EH05, EH07 and EH12 (4-clusters solution). This is due to the fact that they are significantly far from each other and/or separated by crucial tributaries (in the distances between them).

However, the term possible similar was used to stress the fact that these results obtained from analyzing only 12 (out of 36) WQPs that were able to participate in this approach. These 12 WQPs included 6, 3 and 3 physical, nutrients and oxygen budget respectively. The rest failed to fulfill the required assumptions. In general, ***salts***, ***metals*** and ***bacterial indicators*** were missed.

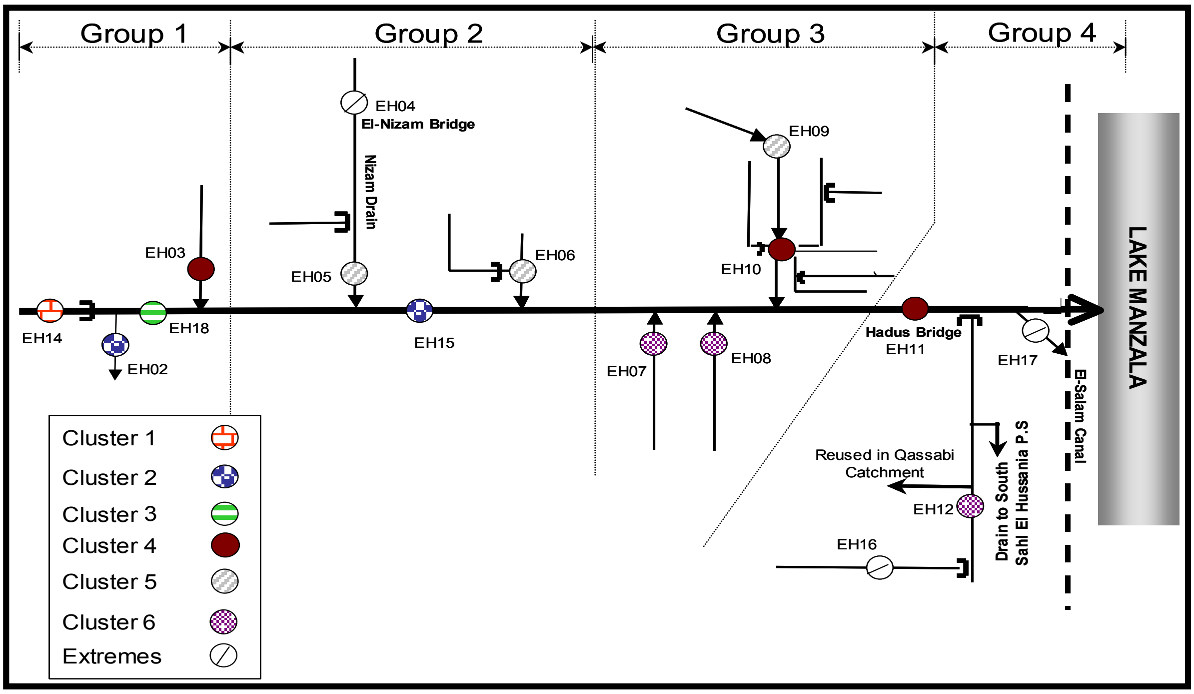

Figure 4-4: Water quality clusters in Hadus drain monitoring sites (6-clusters solution)

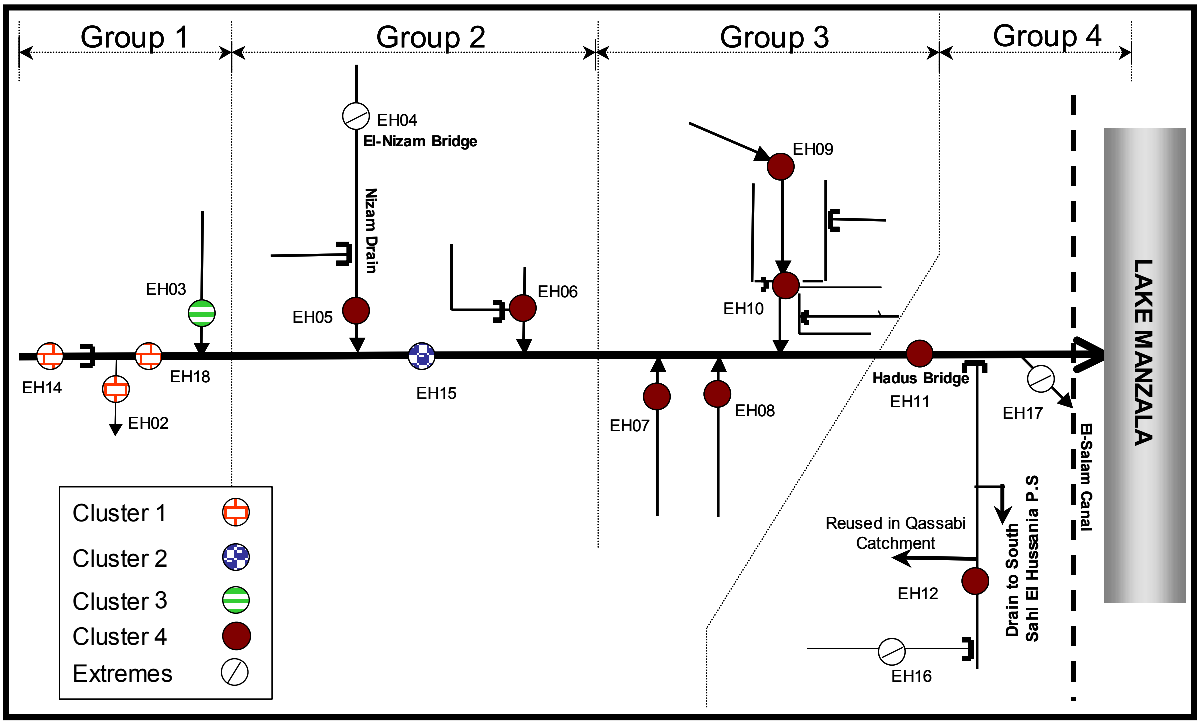

Figure 4-5: Water quality clusters in Hadus drain monitoring sites (4-clusters solution)

4.3.2 Yearly Averages

Recalling the spatial analysis in section 4.1.1, the monitoring sites in Hadus drain were divided into four site groups. Every site group includes four locations. As an example, this section presents the detailed results of the analysis procedures (MANOVA and DA), which were carried out for eight years averages (August 1997 to January 2005) of some WQPs measured at the site group 1. In addition, summary results for all site groups are also included. Annex 4-6 presents the detailed SPSS outputs of the previous analyses that were employed for all site groups.

4.3.2.1 Results and Interpretation for Site Group 1

4.3.2.1.1 Multivariate Analysis of Variance (MANOVA)

Recalling the information presented in section 4.2.2, for each monitoring site in this group (EH14, EH02, EH18 and EH03), both Kolmogorov-Smirnov and Shapiro-Wilk tests indicated that **23** WQPs follow normal distribution. These parameters are BOD, COD, TSS, TVS, $N\text{-}NH_4$, Mn, Br, pH, EC, TDS, Ca, Mg, Na, K, SO_4, Cl, SAR, Adj. SAR, Temp, Sal, Turb, Fecal and Tp. The MANOVA was carried out for all the previous parameters except Mn, Br, Fecal and TP, which have many missing data. The reason for excluding these parameters is to obtain equal sample sizes. In general, most of these 19 parameters have significant correlations (section 4.2.3).

This section presents the MANOVA outputs using SPSS Software. Table 4-9 shows the *multivariate test statistics*, Pillai's Trace, Wilks' lambda, Hotelling's Trace and Roy's Largest Root (at 95% confidence level).

For the purpose of site similarity assessment, the "Locations" effects (Table 4-9) are of interest because it can indicate whether the monitoring sites have influences on the measured WQPs or not. The column of real interest in analysis interpretation is the one containing the significance values of these statistics. For these data, Pillai's trace (sig. = 0.029) and Wilks' lambda, Hotelling's Trace and Roy's Largest Root (sig. < 0.05). This means that all of them indicated that the monitoring locations have significant influences on the WQPs.

However, given what is known about the robustness of Pillai's trace when sampling sizes are equal, the conclusion of significant differences between monitoring sites will be trusted. It has to be mentioned here that the previous results clarified neither the nature of the influences of the monitoring sites on the WQPs nor which parameters are significantly influenced by the differences in locations. To determine the nature of the effect, SPSS provides univarite tests. The univariate test statistics provided by SPSS are Levene's test of equality of variances and tests of between-subjects effects. The following section presents the output results of these two univarite tests.

Table 4-9: SPSS output of the multivariate test statistics for the yearly average data of some WQPs measured in site group 1

Effect		Value	F	Hypothesis df	Error df	Sig.	Noncent. Parameter	Observed Power
Intercept	Pillai's Trace	1.00	24605.58	19	10	0.000	467505.95	1.00
	Wilks' Lambda	0.00	24605.58	19	10	0.000	467505.95	1.00
	Hotelling's Trace	46750.60	24605.58	19	10	0.000	467505.95	1.00
	Roy's Largest Root	46750.60	24605.58	19	10	0.000	467505.95	1.00
Location	Pillai's Trace	2.23	1.818	57	36	0.029	103.63	0.98
	Wilks' Lambda	0.00	2.934	57	31	0.001	164.99	1.00
	Hotelling's Trace	33.59	5.107	57	26	0.000	291.08	1.00
	Roy's Largest Root	29.21	18.448	19	12	0.000	350.51	1.00

Note: Computed using alpha = 0.05

- **Levene's Test of Equality of Variances**

Table 4-10 shows a summary table of *Levene's test* of equality of variances for each of the dependent variables (WQPs). This is the same as would be found if a one-way ANOVA (univariate analysis) had been conducted on each dependent variable in turn (Field, 2000). In this summary table, the F statistic and the degrees of freedom (df_1) and (df_2) are used to calculate the significance values. If the significance value is small (<0.05) then the null hypothesis of equal error variances across groups is rejected and the assumption is violated.

It can be concluded from Table 4-10 that the assumption of equal variances is met for the WQPs BOD, COD, TSS, TVS, N-NH_4, pH, Ca, K, SO_4, Cl, Adj_SAR, Temp and Turb.

- **Tests of Between-Subjects Effects**

In essence, this table provides information about univariate effect of the independent variable on each of the dependent variables separately. This test should only be examined if the multivariate test is significant. The next part of the SPSS univariate analysis output contains the ANOVA summary table for each of the dependent variables. Table 4-11 shows part of the output, which concerns the monitoring locations.

It is clear that, the dependent variables EC, TDS, Na, SAR, Sal, Cl and Adj_SAR are affected by the independent variable (monitoring locations) (sig. < 0.05). In other words, there are differences in the means of the examined WQPs due to the effect of changing the monitoring locations.

In the meantime, the means of the parameters Mg, BOD, COD, TSS, TVS, N-NH_4, pH, Ca, K, SO_4, Temp and Turb have insignificant differences between the monitoring locations. At this point, the following points can be concluded:

- There are significant differences in the WQPs due to the effect of the monitoring locations.
- The parameters Mg, BOD, COD, TSS, TVS, N-NH_4, pH, Ca, K, $SO_{4,}$ Temp and Turb show insignificant differences between the monitoring locations.
- The parameters EC, TDS, Na, SAR, Sal, Cl and Adj_SAR have significant differences between the monitoring locations.
- **Range Tests and Pair-Wise Multiple Comparison**

Once differences among the means have been detected, post hoc range tests and pair-wise multiple comparisons can determine which means differ. Range tests (post hoc) identify homogeneous subsets of means that are not different from each other. Pair-wise multiple comparisons test the difference between each pair of means, and yield a matrix where asterisks indicate significantly different means at an alpha level of 0.05.

Recalling the result of Levene's Test of Equality of Error Variances (Table 4-10), the data of EC, TDS, Mg, Na, SAR and Sal violated the assumption of equal variances. Therefore, the range test Tamhane’s T2 was considered for them (differences among the means have been detected).

This is due to that Tamhane’s T2 test does not assume equal variances. For the WQPs Cl and Adj_SAR (differences among the means have been detected) the range test LSD (Least Significant Difference) was considered.

Table 4-12 shows the Range test details in SPSS output. The differences (between means) followed by (*) are significant at the 0.05 level.

It is clear that the monitoring location EH03 differs significantly from the other three locations. This is only for the 7 parameters EC, TDS, Mg, Na, SAR, Cl, Adj_SAR and Sal.

Also, it can be seen that for all the 19 examined parameters, the monitoring locations EH02, EH14, EH18 have insignificant differences except SAR which shows significant difference between EH14 and EH18.

Table 4-10: SPSS output for Levene's Test of Equality of Error Variances for the yearly average data of some WQPs measured in site group 1

Parameters	F	df_1	df_2	Sig.
BOD	1.853	3	28	0.160
COD	0.919	3	28	0.444
TSS	2.188	3	28	0.112
TVS	2.803	3	28	0.058
$N\text{-}NH_4$	0.034	3	28	0.991
pH	1.127	3	28	0.355
EC	10.805	3	28	0.000
TDS	4.280	3	28	0.013
Ca	0.515	3	28	0.675
Mg	4.611	3	28	0.010
Na	5.010	3	28	0.007
K	1.316	3	28	0.289
SO_4	0.467	3	28	0.708
Cl	1.949	3	28	0.145
SAR	4.649	3	28	0.009
Adj_SAR	2.460	3	28	0.083
Temp	0.402	3	28	0.752
Sal	4.773	3	28	0.008
Turb	0.132	3	28	0.940

Note: Computed using alpha = 0.05

Table 4-11: SPSS output results of the Tests of Between-Subjects Effects for the yearly averages data of some WQPs measured in site group 1

Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power
BOD	2151.41	3	717.14	0.583	0.631	1.75	0.16
COD	3971.93	3	1323.98	0.339	0.797	1.02	0.11
TSS	20383.74	3	6794.58	0.933	0.438	2.80	0.23
TVS	378.51	3	126.17	1.231	0.317	3.69	0.29
$N\text{-}NH_4$	3.52	3	1.17	0.036	0.991	0.11	0.06
pH	0.03	3	0.01	0.754	0.530	2.26	0.19
EC	1.31	3	0.44	23.123	0.000	69.37	1.00
TDS	498161.99	3	166054.00	24.993	0.000	74.98	1.00
Ca	0.86	3	0.29	0.576	0.636	1.73	0.15
Mg	1.20	3	0.40	1.414	0.260	4.24	0.33
Na	75.21	3	25.07	30.391	0.000	91.17	1.00
K	0.02	3	0.01	0.644	0.593	1.93	0.17
SO_4	0.91	3	0.30	0.203	0.893	0.61	0.08
Cl	93.26	3	31.09	23.123	0.000	69.37	1.00
SAR	15.21	3	5.07	26.254	0.000	78.76	1.00
Adj_SAR	91.37	3	30.46	18.943	0.000	56.83	1.00
Temp	0.30	3	0.10	0.147	0.931	0.44	0.07
Sal	0.56	3	0.19	32.465	0.000	97.39	1.00
Turb	1262.97	3	420.99	1.409	0.261	4.23	0.33

Note: Computed using alpha = 0.05

Table 4-12: Range tests (post hoc) results in MANOVA SPSS output which were carried out for some WQPs in site group 1

Dependent Variable	Range Test	(I) Locations	(J) Locations	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
EC	Tamhane	EH02	EH03	-0.41 *	0.07	0.007	-0.70	-0.12
			EH14	0.11	0.07	0.070	-0.01	0.24
			EH18	0.03	0.07	0.990	-0.11	0.17
		EH03	EH14	0.52 *	0.07	0.001	0.23	0.82
			EH18	0.44 *	0.07	0.004	0.15	0.73
		EH14	EH18	-0.08	0.07	0.347	-0.22	0.05
TDS	Tamhane	EH02	EH03	-260.05 *	40.76	0.002	-420.19	-99.92
			EH14	61.67	40.76	0.320	-31.80	155.13
			EH18	6.52	40.76	1.000	-93.05	106.09
		EH03	EH14	321.72 *	40.76	0.000	164.14	479.30
			EH18	266.57 *	40.76	0.002	107.60	425.54
		EH14	EH18	-55.15	40.76	0.380	-143.56	33.27
Na	Tamhane	EH02	EH03	-3.06 *	0.45	0.002	-4.97	-1.15
			EH14	0.94	0.45	0.088	-0.11	1.98
			EH18	0.24	0.45	0.981	-0.81	1.29
		EH03	EH14	3.99 *	0.45	0.000	2.12	5.87
			EH18	3.30 *	0.45	0.002	1.42	5.18
		EH14	EH18	-0.70	0.45	0.071	-1.44	0.04
Cl	LSD	EH02	EH03	-3.35 *	0.58	0.000	-4.53	-2.16
			EH14	1.10	0.58	0.067	-0.08	2.29
			EH18	0.35	0.58	0.547	-0.83	1.54
		EH03	EH14	4.45 *	0.58	0.000	3.26	5.64
			EH18	3.70 *	0.58	0.000	2.51	4.89
		EH14	EH18	-0.75	0.58	0.206	-1.94	0.44
SAR	Tamhane	EH02	EH03	-1.33 *	0.22	0.006	-2.27	-0.38
			EH14	0.49	0.22	0.057	-0.01	1.00
			EH18	0.14	0.22	0.952	-0.36	0.64
		EH03	EH14	1.82 *	0.22	0.001	0.89	2.75
			EH18	1.46 *	0.22	0.004	0.53	2.39
		EH14	EH18	-0.36 *	0.22	0.021	-0.67	-0.04
Adj_SAR	LSD	EH02	EH03	-3.26 *	0.63	0.000	-4.56	-1.96
			EH14	1.17	0.63	0.075	-0.13	2.47
			EH18	0.37	0.63	0.561	-0.93	1.67
		EH03	EH14	4.43 *	0.63	0.000	3.14	5.73
			EH18	3.64 *	0.63	0.000	2.34	4.93
		EH14	EH18	-0.80	0.63	0.218	-2.10	0.50
Sal	Tamhane	EH02	EH03	-0.27 *	0.04	0.000	-0.42	-0.13
			EH14	0.06	0.04	0.244	-0.03	0.16
			EH18	0.01	0.04	1.000	-0.09	0.12
		EH03	EH14	0.34 *	0.04	0.000	0.20	0.48
			EH18	0.29 *	0.04	0.000	0.14	0.43
		EH14	EH18	-0.05	0.04	0.421	-0.14	0.04

(*) The mean differences are significant at the 0.05 level.

4.3.2.1.2 Discriminant Function Analysis (DFA)

The main terms related to DFA in this section are:

- **Independent variables** (WQPs): These are the discriminating variables or "predictors".
- **Dependent variable** (monitoring locations): This is the grouping variable, which is the object of classification efforts.
- **Discriminant function**: It is a latent variable, which is created as a linear combination of discriminating (independent) variables.

This section presents the DFA outputs using SPSS Software. Table 4-13 shows the two initial statistics from the discriminant (canonical) functions analysis, which was carried out for some WQPs in Hadus drain site group 1. The first statistics are the *Eigen-value*s of the discriminant functions. They reflect the importance ratio of the dimensions, which classify cases of the dependent variable. This is because they reflect the percents of variance explained in this variable, cumulating to 100% for all functions. The first function is the largest and most important, the second is next most important and so on.

The second statistics are the Wilks' lambda statistics that are used to test the significance of the discriminant function as a whole. In SPSS, the Wilks' lambda table has a column labeled "Test of Function(s)" and a row labeled "1 through n" (where n is the number of discriminant functions). Wilks' lambda ranges between 0 and 1. Values close to 0 indicate different group (locations) means. Values close to 1 indicate that group means are not different (equal to 1 indicates all means are the same). A chi-square transformation of Wilks' lambda is used along with the degrees of freedom to determine significance. Small significance value indicates that the locations differ. If the significance value is large, this indicates that they do not differ. A significant lambda means one can reject the null hypothesis that the locations have the same mean discriminant function scores and conclude the model is discriminating.

Table 4-13 shows Wilks' lambda, which has the values (0.004), degrees of freedom (57) and significance value (0.00) for the first function. These values are (0.116), (36) and (0.23) for the second function respectively. The important point to note from Table 4-13 is that only the first function is significant. The other functions are not. Therefore, the differences between locations shown by the MANOVA can be explained in terms of one underlying dimension.

The next important part of the SPSS output includes two items: the *standardized canonical discriminant function coefficients* and *structure matrix*. The first indicates the relative contribution of each variable to the respective discriminating function. Another way of investigating the relationship between dependent variables and discriminant functions is to look at the structure matrix.

Table 4-13: Canonical discriminant functions analysis in SPSS output for some WQPs in site group 1

Eigen-values

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	29.21	86.97	86.97	0.98
2	3.44	10.23	97.19	0.88
3	0.94	2.81	100.00	0.70

Wilks' lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 3	0.004	108.45	57.00	0.000
2 through 3	0.116	41.99	36.00	0.227
3	0.515	12.94	17.00	0.740

The structure matrix contains within-group correlations of each predictor variable (WQP) with the canonical function. For each variable, an asterisk marks its largest absolute correlation with one of the discriminant functions. With each function, these marked variables are then ordered by the size of the correlation.

For the purpose of the analysis here, it is clear that both items (the standardized canonical discriminant function coefficients and structure matrix) can provide similar information in different forms. Therefore, only the information gained by the structure matrix will be presented in Table 4-14. In general, the independent variables, which have high discriminant function correlations, contribute most to the dependent variable separation.

The main concern here is only the first discriminating function because it is the only significant one. It is clear that all the correlation coefficients are relatively small (less than or equal 0.34).

Table 4-15 shows the values of the functions (variates) centroids for each grouping variable (location). It is clear that the first function (variate) discriminates the monitoring location EH03 from the other three locations. The second and third functions (variates) seem to discriminate EH02 and EH18 respectively (the second and third functions are insignificant).

Table 4-14: Structure matrix in SPSS output for some WQPs in site group 1

Variables	Function		
	1	2	3
BOD	0.34 *	-0.03	-0.01
COD	0.33 *	0.02	-0.01
TSS	0.31 *	0.05	-0.02
TVS	0.30 *	-0.02	-0.04
N-NH_4	0.29 *	0.00	0.00
pH	0.29 *	0.03	0.02
EC	0.26 *	0.04	0.01
TDS	0.07 *	0.00	-0.07
Ca	0.05 *	-0.03	0.02
Mg	0.04 *	-0.03	-0.02
Na	-0.01 *	0.01	-0.01
K	0.05	-0.16 *	0.10
SO_4	0.01	0.06 *	0.00
Cl	0.05	-0.02	-0.15 *
SAR	0.03	-0.10	-0.15 *
Adj_SAR	-0.04	0.00	0.13 *
Temp	0.06	-0.03	-0.10 *
Sal	-0.03	-0.01	0.07 *
Turb	0.03	-0.01	-0.05 *

(*) Largest absolute correlation between each variable and any discriminant function

The relationship between the variates and the grouped factors (locations) is also visualized using a combined groups plot (Figure 4-6). This graph plots the variate scores for each dependent grouped by the grouping factor and the average variate scores for each group (centroids).

Noting the positions of the centroids, it is clear that variate 1 discriminates EH03 (with largest horizontal distances between centroids).

Table 4-15: The values of the function (variate) centroids in SPSS output for some WQPs in site group 1

Locations	Function		
	1	2	3
EH02	-1.67	2.62	0.71
EH03	8.57	-0.60	0.09
EH14	-4.51	-2.19	0.71
EH18	-2.38	0.16	-1.51

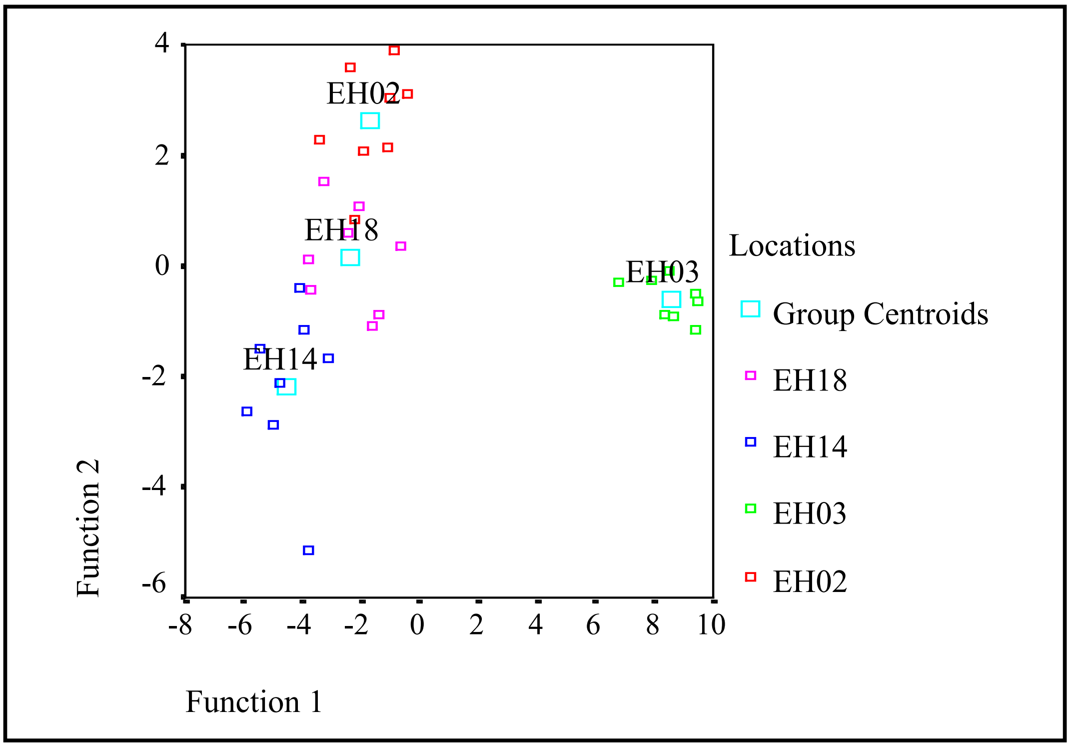

Figure 4-6: Combined group plot in SPSS output for some WQPs in site group 1

Table 4-16 shows the overall classification results. This table measures the degree of success of the classification for the investigated sample. It simply answers the question how well can the discriminant functions predict to which group a particular case belongs. Therefore, the number and percentage of cases correctly classified and misclassified are displayed. In this sample, for each monitoring location (EH14, EH02, EH18 and EH03) 8 cases (100%) were correctly classified.

Table 4-16: The overall classification results in SPSS output for some WQPs in site group 1

	Locations	Predicted Group Membership				Total
		EH02	EH03	EH14	EH18	
Count	EH02	8	0	0	0	8
	EH03	0	8	0	0	8
	EH14	0	0	8	0	8
	EH18	0	0	0	8	8
%	EH02	100%	0	0	0	100%
	EH03	0	100%	0	0	100%
	EH14	0	0	100%	0	100%
	EH18	0	0	0	100%	100%

4.3.2.2 Summary Results for All Site Groups

- **Site Group 1**

1. The *MANOVA* and *DFA* were carried out for **19** WQPs. These parameters are BOD, COD, TSS, TVS, N-NH_4, pH, EC, TDS, Ca, Mg, Na, K, SO_4, Cl, SAR, Adj. SAR, Temp, Sal and Turb. Most of these parameters have significant correlations.
2. The *multi-variate tests* indicated that the monitoring locations have significant influences on the WQPs (*Pillai's trace*, F(57,36)= 1.82 and Sig. = 0.029).
3. *Levene's test* of equality of variances indicated that the assumption of equal variances was met for the parameters BOD, COD, TSS, TVS, N-NH_4, pH, Ca, K, SO_4, Cl, Adj_SAR, Temp and Turb. In the meantime, the data of EC, TDS, Mg, Na, SAR and Sal violated the assumption.
4. *Tests of between-subjects effects* indicated that there are insignificant differences between the monitoring locations in site group 1 for the parameters Mg, BOD, COD, TSS, TVS, N-NH_4, pH, Ca, K, SO_4, Temp and Turb. In contrary, there are significant differences for EC, TDS, Na, SAR, Sal, Cl and Adj_SAR due to the effect of changing the monitoring locations.
5. The range test *Tamhane's T2* does not assume equal variances. Therefore, it was considered for the parameters EC, TDS, Na, SAR and Sal (differences among the means have been detected). For Cl and Adj_SAR (differences among the means have been detected) the range test *LSD* (Least Significant Difference) was considered.
6. For all the 19 WQPs, the monitoring locations EH02, EH14, EH18 have insignificant differences except SAR which shows significant difference between EH14 and EH18.
7. For the WQPs (EC, TDS, Mg, Na, SAR, Cl, Adj_SAR and Sal), the monitoring location EH03 differs significantly from the other three locations.
8. The first discriminant function accounts for 86.97% of variance compared to the second function, which accounts only for 10.23%. The third function is the smallest and accounts only for less than 3% of the total variance.
9. The next part of the output shows Wilks' lambda, which has the values (0.004), degrees of freedom (57) and significance value (0.00) for the first discriminating function. These values are (0.116), (36) and (0.23) for the second function respectively.
10. The important point to note here is that only the first discriminating function is significant and the other functions are not.

11. The results of the *Structure Matrix* for the first discriminating function show that all the correlation coefficients are relatively small (less than or equal 0.34).
12. Recalling the values of the functions (variates) *centroids* for each grouping variable (location), it is clear that the first function (variate) discriminates the monitoring location EH03 from the other three locations. The second and third functions (variates) seem to discriminate EH02 and EH18 respectively (but the second and third functions are insignificant).
13. The relationship between the variates and the grouped factors (locations) is also visualized using a *combined groups plot* (Figure 4-6). Noting the positions of the centroids, it is clear that variate 1 discriminates EH03 (with largest horizontal distances between centroids).
14. The overall classification results show that the discriminant functions correctly classified 8 cases (100%) for each monitoring location (EH14, EH02, EH18 and EH03).

- **Site Group 2**

1. The *MANOVA* and *DFA* were carried out for **11** WQPs. These parameters are Cu, Fe, pH, TDS, Ca, Mg, K, SO_4, Cl, DO and Visib. Most of these parameters have significant correlations.
2. The *multi-variate tests* indicated that the monitoring locations have significant influences on the WQPs (*Pillai's trace* F(33,60)=3.88 and sig. =0.000).
3. *Levene's test* of equality of variances indicated that the assumption of equal variances is met for the parameters Cu, Fe, pH, K, SO_4, Cl and Visib. In the meantime, the data of TDS, Ca, Mg, and DO violate the assumption.
4. *Tests of between-subjects effects* indicated that there are insignificant differences between the monitoring locations in site group 2 for the parameters Cu, Fe, pH, K, SO_4 and Visib. Also, there are significant differences for the parameters TDS, Ca, Mg, Cl and DO due to the effect of changing the monitoring locations.
5. The range test *Tamhane's T2* was considered for the parameters TDS, Ca. Mg and DO (differences among the means have been detected). For the WQP Cl (differences among the means have been detected) the range test *LSD* (Least Significant Difference) was considered.
6. It can be also seen that for all the examined parameters, the pairs EH04&EH05 and EH04&EH15 have insignificant differences except only one parameter (DO). Again, the pair EH05&EH15 has insignificant differences except only one parameter (TDS).

7. Out of 11 parameters, EH06 differs significantly from the location EH04, EH05 and EH15. The parameters TDS, Ca, Cl and DO are the reasons for these differences.
8. The first discriminant function accounts for 61.25% of variance compared to the second function, which accounts only for 33.6%. The third function is the smallest and accounts only for 5.15% of the total variance.
9. The next part of the output shows Wilks' lambda, which has the values (0.021), degrees of freedom (33) and significance value (0.000) for the first discriminating function. These values are (0.146), (20) and (0.001) for the second function respectively.
10. The first two discriminating functions are significant while the third function is not.
11. The results of the *structure matrix* for the first discriminating function show that the highest correlation coefficients for TDS and Cl are 0.62 and 0.58 respectively indicating more contribution for discriminating the locations within the first function. For the second function, DO with correlation coefficient (-0.6) contribute mainly for the discrimination process.
12. The first function (variate) discriminates the monitoring location EH06 from the monitoring locations EH04 and EH05. The second function (variate) discriminates EH04 and EH05. The third function is insignificant.
13. The relationship between the variates and the grouped factors (locations) is also visualized using a *combined groups plot*. Noting the positions of the centroids, it is clear that the largest horizontal distances between centroids are between EH04&EH06 and also between EH05&EH06. The largest vertical distance between centroids is between EH04&EH05.
14. The overall *classification results* show that the discriminant functions correctly classified 8 or 100% of the cases for each monitoring locations (EH05, EH06 and EH115). Only one case in EH04 was incorrectly classified. However, almost 97% of original grouped cases were correctly classified.

- **Site Group 3**

1. The *MANOVA* and *DFA* were carried out for **13** WQPs. These parameters are: COD, Cu, Fe, pH, EC, TDS, Na, SO_4, Cl, Temp, Sal, DO and Turb. Most of these parameters have significant correlations.
2. The *multi-variate tests* indicated that the locations have significant influences on the WQPs (*Pillai's trace* F(39,54)=2.491 and sig. =0.001).

3. *Levene's test* indicated that the assumption of equal variances is met for the parameters COD, Cu, Fe, pH, TDS, SO_4, Temp, DO and Turb. In the meantime, the data of EC, Na, Cl and Sal violate the assumption.
4. *Tests of between-subjects effects* indicated that there are insignificant differences between the monitoring locations in site group 3 for the parameters COD, Cu, Fe, pH, Temp and Turb. Also, there are significant differences for the dependent variables EC, TDS, Na, SO_4, Cl, Sal and DO.
5. The range test *Tamhane's T2* was considered for the parameters EC, Na, Cl and Sal (differences among the means have been detected) and the range test *LSD* (Least Significant Difference) was considered for the TDS, SO_4 and DO (differences among the means have been detected).
6. For all the examined parameters, the pair EH07&EH10 has insignificant differences. All the other pairs have significant differences for 7 WQPs except the pair EH07&EH08, which has significant differences in only 6 parameters. These 7 parameters are EC, TDS, Na, SO_4, Cl, Sal and DO.
7. The first discriminant function accounts for 86.92% of variance compared to the second function, which accounts only for 11.72%. The third is the smallest and accounts only for 1.36% of the total variance.
8. The results show the Wilks' lambda, which has the values (0,009), degrees of freedom (39) and significance value (0.000) for the first discriminating function. These values are (0.202), (24) and (0.056) for the second function respectively.
9. The first two discriminating functions are significant. The third function is not (sig.=0.857).
10. The *structure matrix* for the first discriminating function shows that the highest correlation coefficients for TDS and Sal are 0.69 and 0.64 respectively. The correlation coefficients for EC and Na are higher than 0.5. This indicates that they have more contribution for discriminating the locations within the first function. For the second function, DO and Turb with correlation coefficients (0.22, 0.2 respectively) contribute mainly for the discrimination process.
11. The first function (variate) discriminates the monitoring locations EH08 and EH09 from the monitoring locations EH07 and EH10. The second functions (variates) discriminates EH07 from the other three locations.

12. Noting the positions of the centroids in the *combined groups plot,* it is clear that the largest horizontal distance between centroids is between EH08 and EH09 and the largest vertical distances are between EH07 and the other locations.
13. The *overall classification* results show that the discriminant functions correctly classified 8 or 100% of the cases for each monitoring locations (EH07, EH08, EH09 and EH10).

- **Site Group 4**

1. The *MANOVA* and *DFA* were carried out for **15** WQPs. These parameters are BOD, Cu, Zn, pH, EC, TDS, Na, SO_4, Cl, SAR, Adj_SAR, Temp, Sal, Turb and Visib. Most of these parameters have significant correlations.
2. The *multi-variate tests* indicated that the monitoring locations have significant influences on the WQPs (*Pillai's trace* F(45,48)=2.978 and sig. =0.000).
3. *Levene's test* of equality of variances indicated that the assumption of equal variances is met for the WQPs BOD, Cu, pH, EC, TDS, Na, SO_4, Cl, SAR, Adj_SAR, Temp, Sal and Visib. In the meantime, the data of Zn and Turb violate the assumption of equal variances.
4. *Tests of between-subjects effects* indicated that there are insignificant differences between the monitoring locations in site group 4 for the WQPs BOD, Cu, pH and Temp. Also, there are significant differences for Zn, EC, TDS, Na, SO_4, Cl, SAR, Adj_SAR, Sal, Turb and Visib due to the effect of changing the monitoring locations.
5. The range test *Tamhane's T2* was considered for the parameters Zn and Turb (differences among the means have been detected). For the parameters Cu, EC, TDS, Na, SO_4, Cl, SAR, Adj_SAR, Sal and Visib (differences among the means have been detected) the range test *LSD* (Least Significant Difference) was considered.
6. For all the examined parameters, the pair EH11&EH17 has insignificant differences. The pair EH12&EH17 has significant differences for only 3 parameters (Sal, Turb and Visib). All other pairs have significant differences for 6 to 10 WQPs.
7. The first discriminant function accounts for 84.27% of variance compared to the second function, which accounts only for 10.39%. The third function is the smallest and accounts only for 5.34% of the total variance.
8. The output shows Wilks' lambda, which has the values (0,006), degrees of freedom (45) and significance value (0.000) for the first discriminating function. These values are (0.132), (28) and (0.031) for the second function respectively.

9. The first two discriminating functions are significant. The third function is not (sig.=0.187).

10. The *structure matrix* for the first function shows that the highest correlation coefficients for Sal, TDS and EC are 0.34, 0.33 and 0.33 respectively indicating more contribution for discriminating the locations within this function. For the second function, Turb and Visib with correlation coefficients (-0.39, 0.37 respectively) contribute mainly for the discrimination process.

11. The first function (variate) discriminates the monitoring location EH12 and EH16 from the monitoring locations EH11 and EH17. The second functions (variates) discriminates EH12 and EH17 from the other locations.

12. The relationship between the variates and the groups is visualized using a *combined groups plot*. Noting the positions of the centroids, it is clear that the largest horizontal distance between centroids is between EH12 and EH16. The largest vertical distance between centroids is between EH12 and EH17. It is clear that the monitoring locations EH11 and EH17 have insignificant distances in both horizontal and vertical direction.

13. The *overall classification* results show that the discriminant functions correctly classified 8 cases (100%) for the monitoring locations EH12 and EH16. For EH11 and EH17, they classified 7 cases (87.5%) per each. However, 93.8% of all original grouped cases were correctly classified.

Figures 4-7 plots the previous results for the four site groups indicating the location pairs, which were seen as *possible similar*. These pairs are EH14&EH02, EH14&EH18, EH02&EH18, EH04&EH05, EH04&EH15, EH05&EH15, EH07&EH10 and EH11&EH17.

Again, the term “*possible similar*” was used to stress the fact that these results obtained from analyzing only 19, 11, 13 and 15 (out of 36) WQPs for the four site groups 1, 2, 3 and 4 respectively.

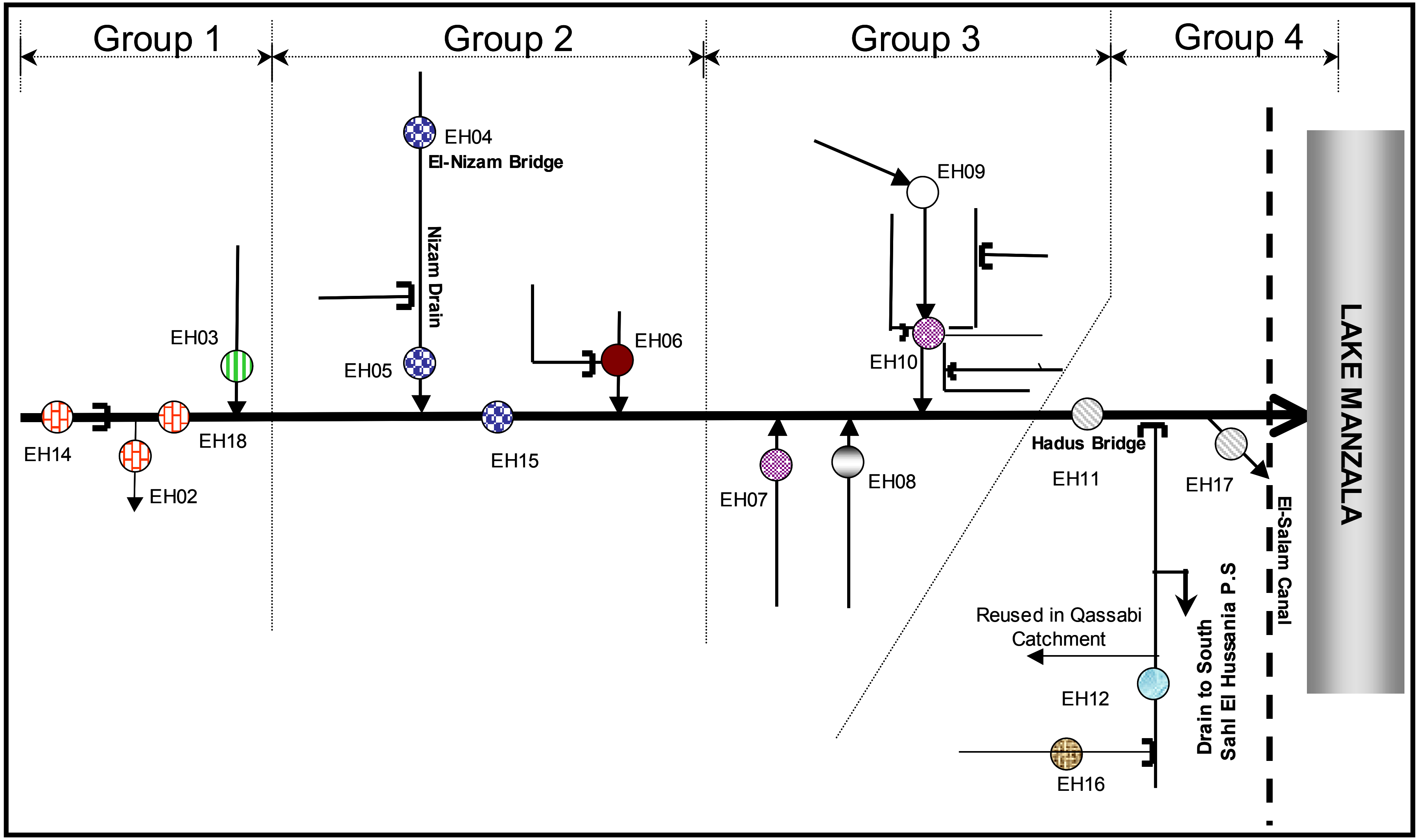

Figure 4-7: Water quality clusters in Hadus drain monitoring sites (Yearly Avgs.)

4.3.3 Monthly Data

This section presents the results of the nonparametric comparisons, detecting correlations and regression analyses applied for the monthly measurements of 36 WQPs in Hadus drain monitoring network (Monthly). The analysis covered the available data for the period from August 1997 to January 2005.

4.3.3.1 Results and Interpretation

4.3.3.1.1 Nonparametric Comparisons

Recalling Section 4.2.2 for the monthly measurements in Hadus monitoring sites, Kolmogorov-Smirnov test results indicated that most of the WQPs differ from normal distribution. Therefore, the nonparametric Wilcoxon signed rank test for matched pairs was employed to determine whether the median difference between monthly observations from adjacent monitoring sites in Hadus drain equals zero.

The effectiveness of pairing can be noticed by recalling Annex 4-5 wherein the monitoring locations (in each site group and almost for all WQPs) have significant correlations between each other. This justifies the use of a paired test (InStat, Inc., 1990 and USDA, 2002).

Table 4-17 presents a result summary of the Wilcoxon signed rank test applied for some WQM locations in Hadus drain. The combinations of location pairs were selected based on three criteria:

- **Means and Yearly Avgs. Results**

The previous two approaches (Means and Yearly Avgs.) indicated similarities between some locations related with some WQPs. Unfortunately, the rest of these parameters failed to fulfill the required assumptions. Therefore, only pairs that show significant similarities in at least one approach (Means and/or Yearly Avgs.) were again selected to be analyzed using all the measured parameters.

Consequently, the focus was only on the monitoring sites, which were seen as *possible similar*. In addition, two other pairs (EH17&EH12 and EH16&EH12) were also analyzed due to the relative importance of the monitoring locations EH12 and EH17, which were similar for 12 (out of 15) WQPs participated in the Yearly Avgs. Approach.

- **Geographical Layout**

The location pairs were selected from only the adjacent monitoring sites. Most likely they have the same environmental conditions, which may affect the WQ in the system. This is also one of the assumptions required for applying the Wilcoxon signed rank test for matched pairs.

- **Flow Direction**

Almost all the pairs were selected with the direction of flow. In some cases some pairs were chosen to close (logically) the information circle within one site group. The following example illustrates what the information circle means. Figure 4-8 shows the first four locations in Hadus drain monitoring sites (site group 1). It is clear from the flow direction that there are direct flows between the pairs EH14&EH02 and EH14&EH18. Therefore, initially these two pairs were selected for analyzing by the nonparametric test for matched pairs. The logic question might be raised about the pair EH02&EH18. Then the latest pair was also analyzed in spite of the fact that no direct flow between EH02 and EH18.

Although, the locations EH05&EH06 (in 4- and 6-clusters solutions) and EH11&EH12 (in 4-clusters solution) were seen as similar in the Mean approach, they were not considered in the nonparametric Wilcoxon signed rank test for matched pairs. This is due to the flow direction criterion where no flow from EH05 can reach to EH06 or from EH11 to EH12.

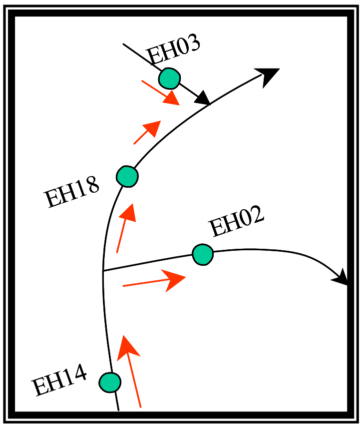

Figure 4-8: Hadus drain site group 1

As a result of the previous criteria, the site similarities that may be detected between the adjacent monitoring sites can be easily understood. Annex 4-7 shows the significant statistics (sig) for Wilcoxon signed rank test while comparing the monthly measurements of 36 WQPs for some adjacent monitoring sites in Hadus drain.

According to Chapman (1992), there are basic WQPs (called also background quality) have to be identified to assess the suitability of water for use and also to detect future trends. Table 4-17 shows a summary result for Wilcoxon signed rank tests. The table divides the WQPs into two categories:

- The first (***Base parameters)*** includes 18 variables: BOD, COD, TSS, N-NO_3, N-NH_4, P, pH, EC, Ca, Mg, Na, K, SO_4, Cl, Temp, DO, Turb and Visib.

- The second (***Other parameters)*** includes 18 variables: Coli, TVS, Cd, Cu, Fe, Mn, Zn, Pb, Br, TDS, SAR, Adj. SAR, Sal, Fecal, TP, TN, Ni and SO_{4_m}.

The following notes can be concluded:

- **Site group 1**:

1. The percentage of similar parameters to the total number of WQPs varied from 53% to 89% with an average of 76%.
2. The percentage of similar base parameters varied from 56% to 94% with an average of 70%.
3. The percentage of similar other parameters varied from 50% to 83% with an average of 63%.

- **Site group 2:**

1. The percentage of similar parameters to the total number of WQPs varied from 50% to 75% with an average 60%.
2. The percentage of similar base parameters varied from 50% to 67% with an average 57%.
3. The percentage of similar other parameters varied from 50% to 83% with an average of 63%.

- **Site group 3:**

1. The percentage of similar parameters to the total number of WQPs varied from 33% to 61% with an average of 51%.
2. The percentage of similar base parameters varied from 28% to 56% with an average of 47%.
3. The percentage of similar other parameters varied from 39% to 67% with an average of 56%.

- **Site group 4:**

1. The percentage of similar parameters to the total number of WQPs varied from 42% to 56% with an average of 47%.
2. The percentage of similar base parameters varied from 33% to 50% with an average of 41%.
3. The percentage of similar other parameters varied from 50% to 61% with an average of 54%.

Table 4-17: Summary results for Wilcoxon signed rank test applied for some WQM sites in Hadus drain

	EH02 - EH14	EH18 - EH14	EH18 - EH02	EH05 - EH04	EH15 - EH04	EH15 - EH05
Other Parameters						
No. of similar Other Parameters	10	9	15	10	9	15
Total no. of Other Parameters	18	18	18	18	18	18
%	56%	50%	83%	56%	50%	83%
Base Parameters						
No. of similar Base Parameters	11	10	17	10	9	12
Total no. of Base Parameters	18	18	18	18	18	18
%	61%	56%	94%	56%	50%	67%
All Parameters						
Total No. of similar parameters	21	19	32	20	18	27
Total %	58%	53%	89%	56%	50%	75%

	EH08 - EH07	EH09 - EH07	EH10 - EH07	EH10 - EH09	EH17 - EH11	EH12 - EH16	EH17 - EH12
Other Parameters							
No. of similar Other Parameters	12	7	10	11	9	9	11
Total no. of Other Parameters	18	18	18	18	18	18	18
%	67%	39%	56%	61%	50%	50%	61%
Base Parameters							
No. of similar Base Parameters	10	5	9	10	7	6	9
Total no. of Base Parameters	18	18	18	18	18	18	18
%	56%	28%	50%	56%	39%	33%	50%
All Parameters							
Total No. of similar parameters	22	12	19	21	16	15	20
Total %	61%	33%	53%	58%	44%	42%	56%

4.3.3.1.2 Correlation and Regression Analyses

Pearson correlation and then linear regression analyses were applied (using monthly data) for all the location pairs, which passed the Wilcoxon signed rank test [4]. The main objectives of these two steps were to detect and then visualize the relationships between the members of each location pair according to the different WQPs. This is important especially for getting information about the dissimilar parameters declared by parametric (MANOVA and DA) and/or nonparametric (Wilcoxon signed rank test) analyses.

It has to be noted that the correlation analysis results in Annex 4-5A, B, C and D show the non-parametric correlation analysis (Kendall 's tau test), which deals with the ranks rather than the original data.

Figure 4-9 shows the results of both correlation and linear regression analyses applied for the pair EH18&EH02. Annex 4-8 shows the analyses results for the other pre-selected pairs.

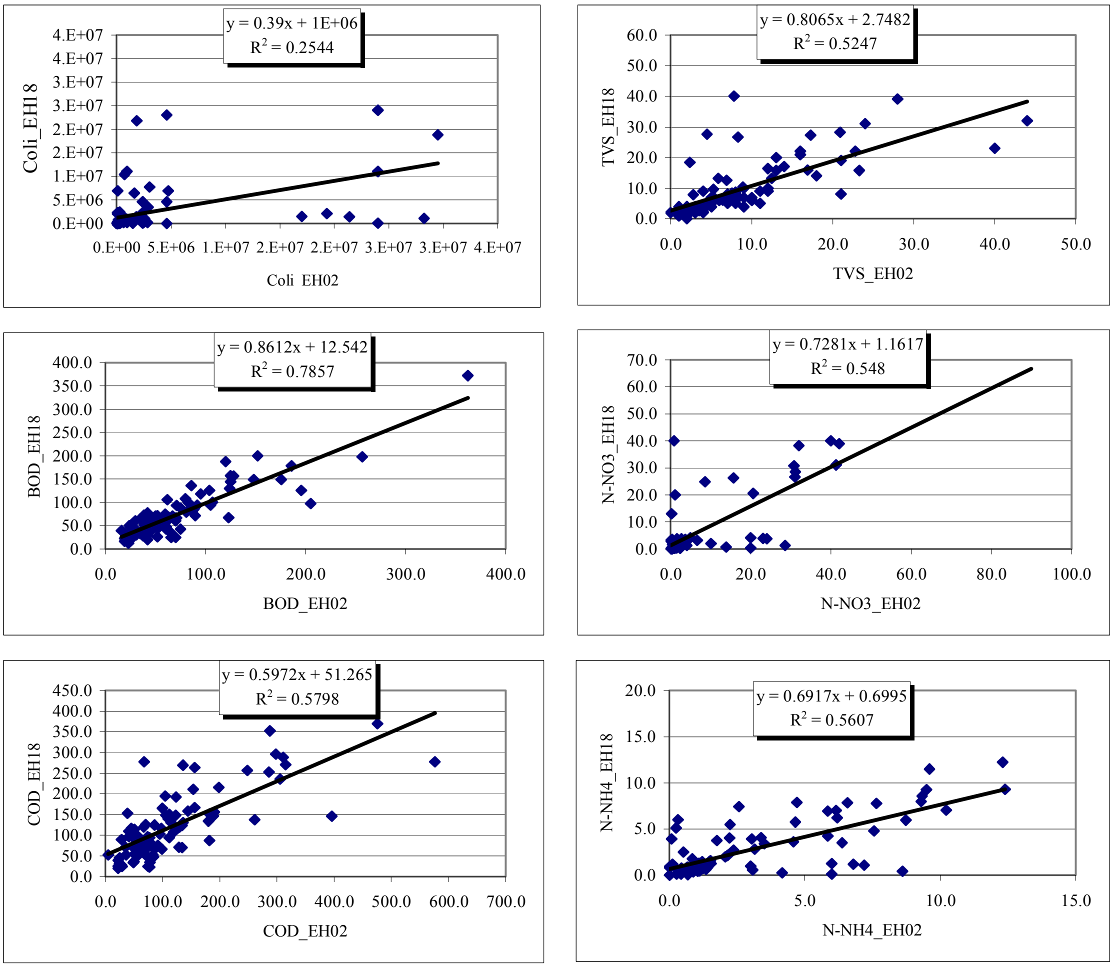

Figure 4-9: Correlation and regression analyses for the WQPs in location pair EH02&EH18

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[4] The location pair EH10&EH11 was also analyzed while investigating the WQP relations between EH10 and EH09 (Annex 4-10 section 2.2).

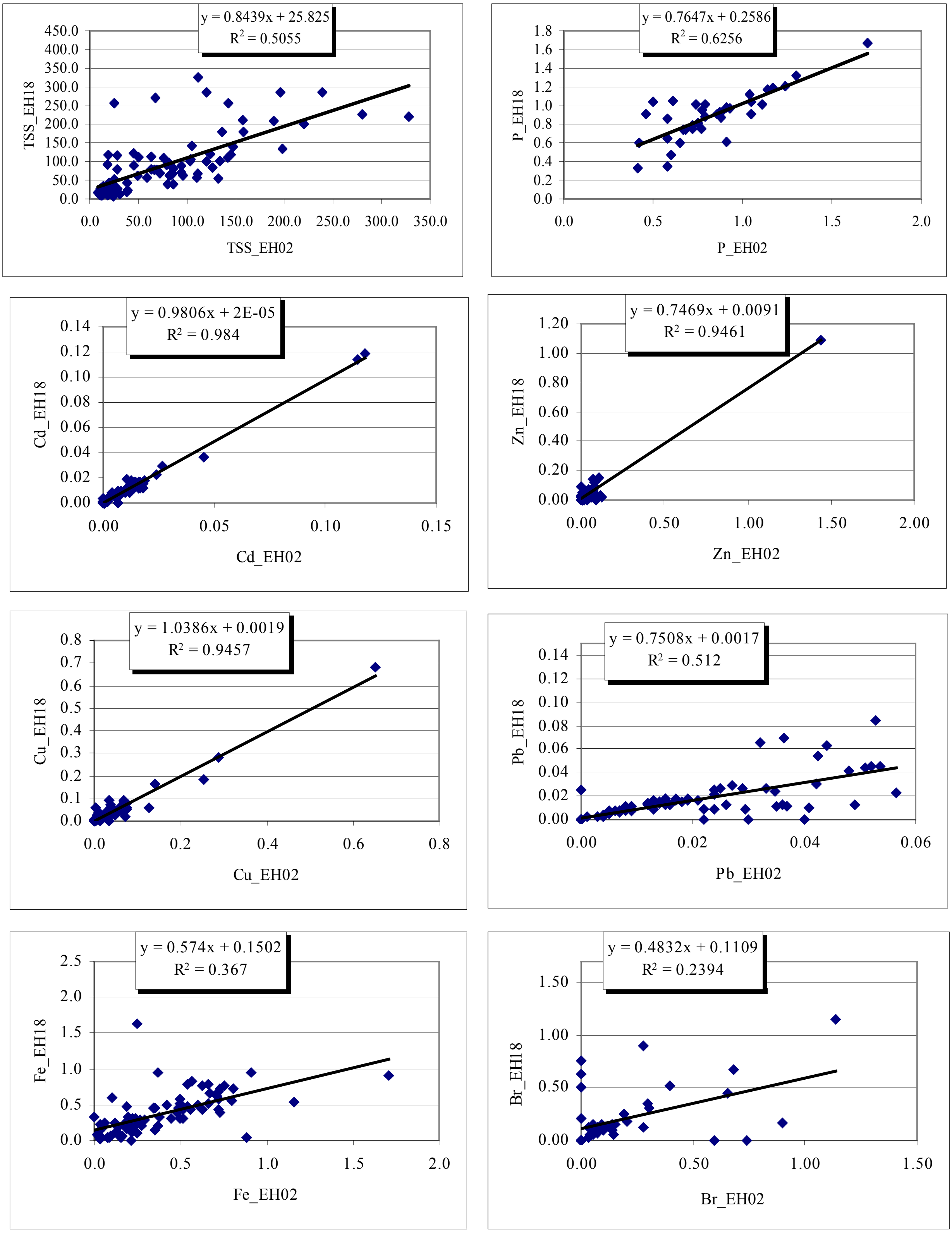

Figure 4-9 Cont.: Correlation and regression analyses for the WQPs in location pair EH02&EH18

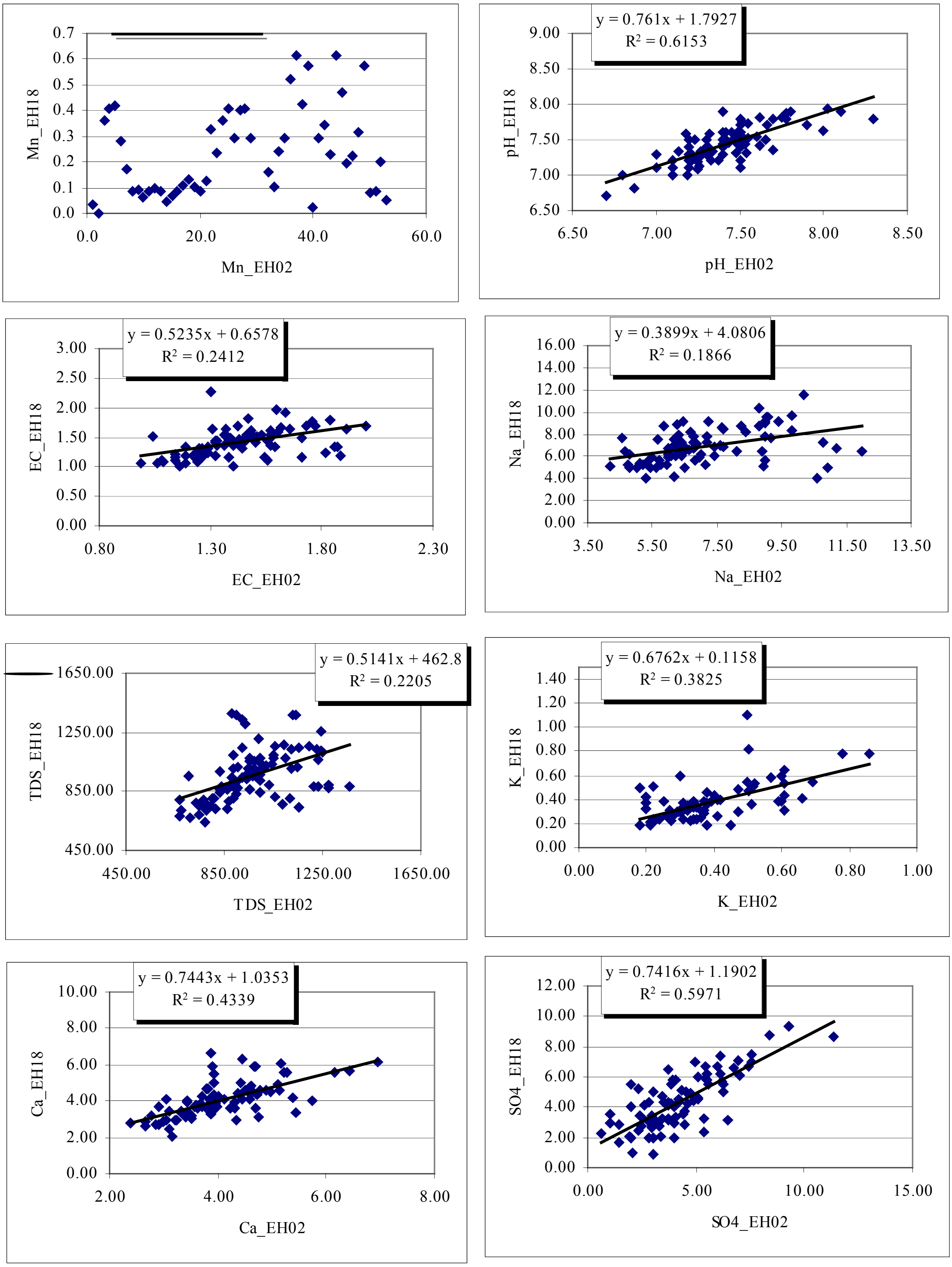

Figure 4-9 Cont.: Correlation and regression analyses for the WQPs in location pair EH02&EH18

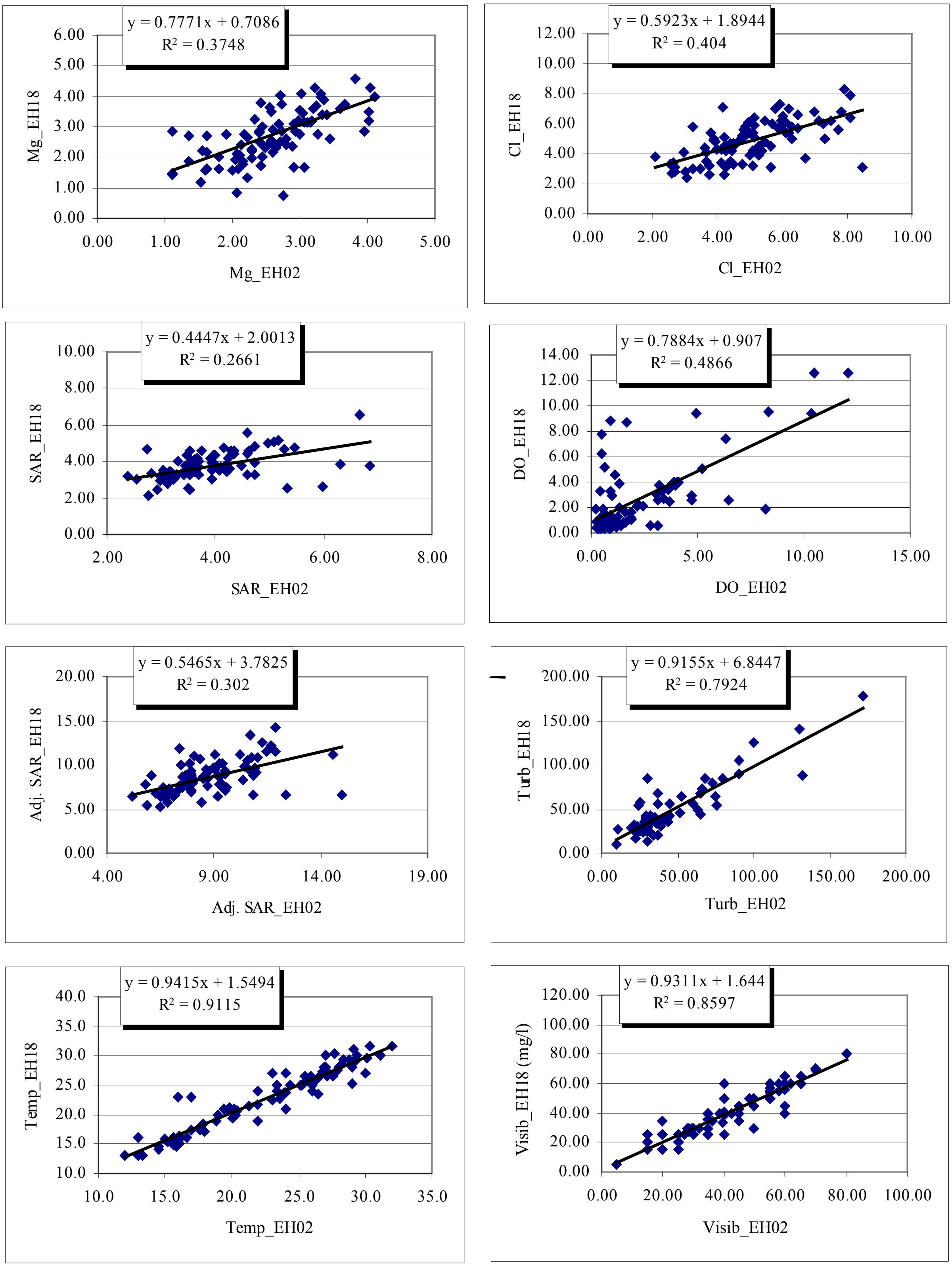

Figure 4-9 Cont.: Correlation and regression analyses for the WQPs in location pair EH02&EH18

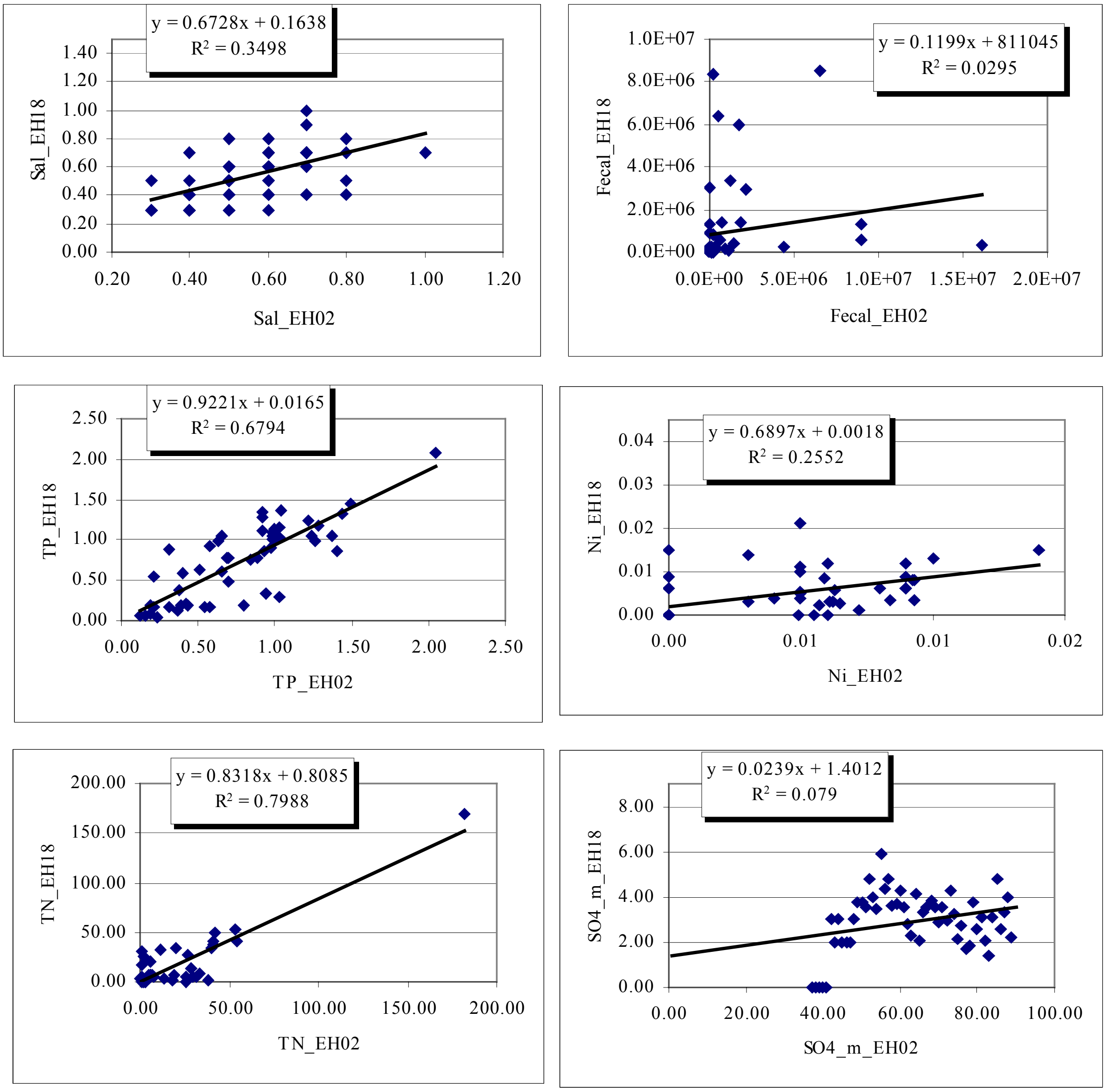

Figure 4-9 Cont.: Correlation and regression analyses for the WQPs in location pair EH02&EH18

4.3.3.1.3 Key Players and Monitoring Objectives

The aim of this section is to identify the most crucial tributaries (**Key Players**), which have greatest influences on the Hadus drain system. The identification process was carried out in the light of the proposed network objectives. The considered objectives were:

1. Assess compliance with standards,
2. Define WQ problems,
3. Determine fate and transport of pollutants,
4. Make waste-load allocations,
5. Detect trends and
6. Determine water quantities

Percentile analysis was carried out using some WQPs measured at Hadus drain monitoring sites. These parameters were selected based on the common quality standards in Egypt (mainly Law 48 of 1982 for drainage water reuse and ambient drainage water or FAO standards for irrigation water)[5].

The selected parameters can be categorized into six groups (parameter groups): oxygen budget (BOD, COD and DO), salts (EC, TDS and SAR), nutrients (N-NO_3, N-NH_4 and TP), physical parameters (Turb, pH and Temp), bacterial indicator (Coli) and heavy metals (Cu, Fe, Mn, Zn and Pb).

The locations EH18, EH15, EH11 and EH17 as checking points (main stream locations) were the main concern of the correlation analysis. Pearson correlation coefficients were calculated to investigate the possible influences of the other locations on these checking points. Figure 4-10 shows the percentile and correlation analyses for the oxygen budget parameters as an example while Annex 4-9 presents the detailed results of the other examined parameters.

Considering the monitoring objective “**Assess compliance with standards** “, the following observations can be reported:

- For BOD, COD, TDS, N-NH_4 and Coli, all monitoring locations are violating Law 48 standards.
- According to FAO standards, most of TDS measurements can be considered as fair water except EH08, which can be described as poor water for irrigation.

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[5] Law no. 48 of 1982 concerns the pollution protection of the River Nile and the water channels in Egypt. It can be found in the FAO website under the address: http://faolex.fao.org/docs/texts/egy18642.doc

- For DO and Turb, most of the monitoring locations are violating the standards.
- For EC, SAR, TP and Fe, most of the monitoring locations are complying with the standards. The TP measurements at all locations after EH15 are complying with the standards. 75% percents of all Fe measurements at all locations are complying with the standards.
- For $N\text{-}NO_3$, pH, Temp, Cu, Mn, Zn and Pb, all the monitoring locations are complying with the standards.

It has to be mention here that the location is considered as complying with standards when 90% percents of all measurements were within the acceptable levels.

Considering the other monitoring objectives "**Define WQ problems, Determine fate and transport of pollutants and Make waste-load allocations**", the following observations can be reported:

Drain part A (from Hadus starting point to EH18)

- It is clear that there are insignificant differences between the monitoring sites EH14, EH02 and EH18 for all the previous WQPs. Their correlation coefficients are relatively high.
- As a general conclusion, one monitoring location can sufficiently describe the quality of this part of the drain. Logically, this location can be EH18 as a checking point, which combine information about all the previous sites. In contrary, EH02 was selected as an official reuse pumping station. This will insure the continuation of a long history of water quantity and quality records at this location.

Drain part B (from EH18 to EH15)

- **Oxygen Budget**: The water flows through the monitoring locations EH03 and EH05 (relatively better quality) seem to neutralize those pass EH04 (worst quality along the drain). Their discharges are somehow near to each other. Their influences on the monitoring site EH15 are almost equal. The correlation results support this conclusion.
- **Salts**: The water flows through the monitoring locations EH04 and EH05 seem to eliminate the effect of the higher salt levels at EH03 (relatively lower quality). The analysis shows insignificant median change in salts levels between EH18 and EH15 (1%, -3% and 7% for EC, TDS and SAR respectively). The correlation results indicate that EH03 has the lowest influence on EH15.
- **Nutrients**: The distributions of $N\text{-}NO_3$ and $N\text{-}NH_4$ are similar along this part of the drain. Considering only those two parameters, the influences of EH03, EH04 and EH05 on the

monitoring site EH15 are almost equal and one monitoring location can sufficiently describe their levels. The TP results show that EH04 and EH05 have the highest influences on EH15.

- **Physical Parameters**: The water flows through the monitoring locations EH18, EH03 and EH05 seem to neutralize those pass EH04 (higher Turb levels). The Turb results show that EH18 and EH03 have the highest influences on EH15. The distributions of pH and Temp are almost similar along this part of the drain.
- **Bacterial Indicator:** There are unclear interactions between the monitoring locations in this part of the drain. The correlation results indicate that EH18, EH03 and EH05 have the highest influences on EH15.
- **Heavy Metals:** There are insignificant differences between the median values of all the metals in this part of the drain. The correlation results indicate that EH04 and EH05 have the highest influences on EH15.

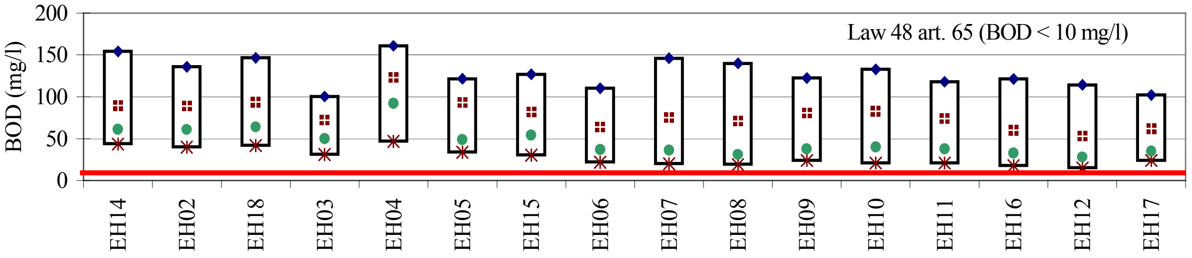
Drain part C (from EH15 to EH11)

- **Oxygen Budget**: For BOD and COD, there are similar distributions at the locations EH15, EH06, EH07, EH08, EH09 and EH10. The location EH09 has relatively lower DO levels and insignificant influence on EH11 due to its low discharges reaching to Hadus main drain (most of its water is reused before EH10). The correlation coefficient between DO measurements at EH09 and EH11 does not exceed 0.01 supporting the previous field observations.
- **Salts**: The water flows through the monitoring locations EH07 and EH08 raise the salts levels at the monitoring location EH11 (comparing to the salt levels at EH15). The percentages of median changes are 63%, 53% and 48% for EC, TDS and SAR respectively. The higher correlation coefficients between EH07, EH08 with EH15 are supporting the previous conclusion.
- **Nutrients**: The distributions of N-NO_3 and N-NH_4 are almost similar along this part of the drain. The TP results show that EH10 has the highest influence on EH15.
- **Physical Parameters**: The water flows through the monitoring locations EH06, EH07, EH08 and EH10 raise the Turb levels at the monitoring location EH11 comparing to their levels at EH15. The percentage of median change is almost 12%. The distributions of pH and Temp are almost similar along this part of the drain.
- **Bacterial Indicator:** There are unclear interactions between the monitoring locations in this part of the drain.

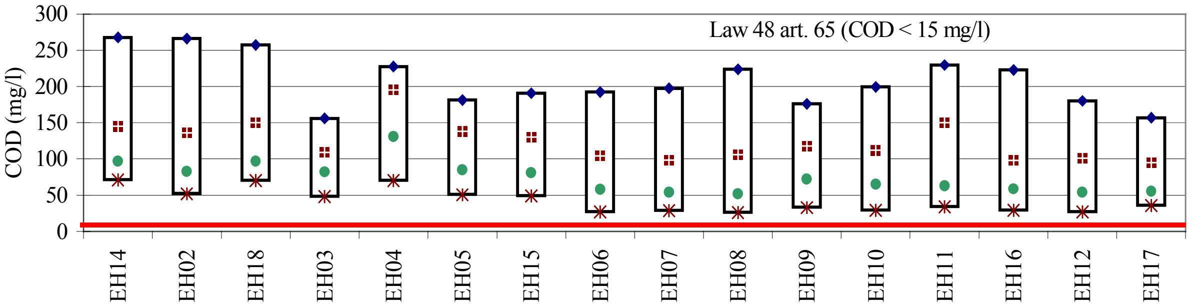
- **Heavy Metals:** There are unclear interactions between the monitoring locations in this part of the drain.

<u>Drain part D (from EH11 to EH17)</u>

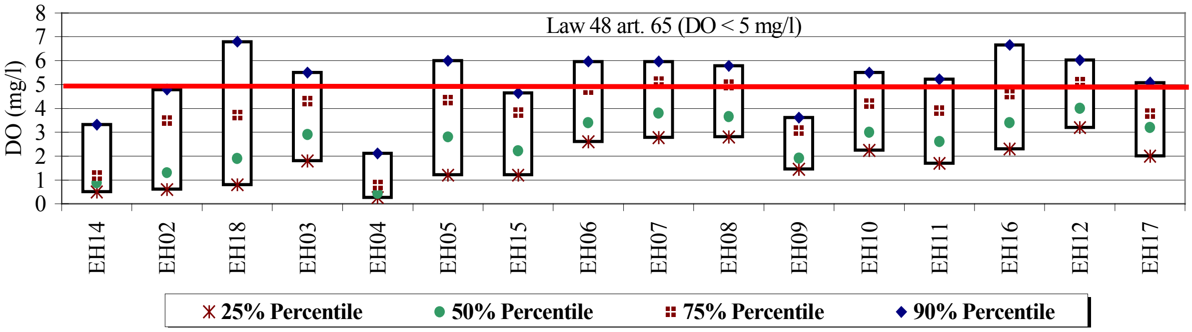
- **Oxygen Budget**: The monitoring locations EH11 and EH12 have the highest influence on EH17 due to their high discharges. This is explained by the high correlation coefficients for those sites with EH17. The percentages of median changes between EH11 and EH17 are 7%, 12% and 22% for BOD, COD and DO respectively.
- **Salts**: In addition to EH11, the monitoring location EH12 has the highest influence on EH17 due to its high discharges with relatively high salts levels. This is explained by the high correlation coefficients for this site and EH17. The percentages of median changes between EH11 and EH17 are 7%, 11% and 15% for EC, TDS and SAR respectively. Low discharges from EH16 may be the reason of its minor influence on EH17.
- **Nutrients**: The distributions of N-NO_3 and N-NH_4 are almost similar along this part of the drain. The TP correlation results show that only EH11 has the high influence on EH17.
- **Physical Parameters**: In addition to EH11, the monitoring location EH12 has the highest influence on EH17. This is explained by the high correlation coefficients between EH12 and EH17.
- **Bacterial Indicator:** There are unclear interactions between the monitoring locations in this part of the drain.
- **Heavy Metals:** In general, there are unclear interactions between the monitoring locations in this part of the drain. Except Zn and Pb, EH12 seems to have the highest influences on EH17.



	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
EH18	0.95	0.89	1.00													
EH15	0.64	0.65	0.62	0.54	0.62	0.54	1.00									
EH11	0.62	0.60	0.58	0.53	0.60	0.44	0.79	0.76	0.87	0.85	0.89	0.87	1.00			
EH17	0.37	0.38	0.35	0.34	0.52	0.42	0.62	0.68	0.78	0.80	0.73	0.77	0.80	0.69	0.83	1.00



	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
EH18	0.86	0.76	1.00													
EH15	0.73	0.58	0.61	0.61	0.68	0.62	1.00									
EH11	0.77	0.64	0.60	0.70	0.69	0.64	0.81	0.80	0.86	0.86	0.84	0.86	1.00			
EH17	0.65	0.61	0.54	0.41	0.60	0.51	0.64	0.76	0.66	0.75	0.67	0.71	0.71	0.65	0.66	1.00



	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
EH18	0.66	0.70	1.00													
EH15	0.04	0.17	0.31	0.21	0.13	0.22	1.00									
EH11	-0.02	0.17	0.08	0.29	-0.06	0.35	0.46	0.17	0.47	0.48	0.01	0.55	1.00			
EH17	-0.13	-0.03	-0.05	0.04	-0.22	0.08	0.23	0.06	0.11	0.11	0.22	0.11	0.26	-0.07	0.14	1.00

Figure 4-10: Percentile and correlation analyses for some WQPs measured at Hadus drain monitoring locations

4.4 SIMILARITY RESULTS

4.4.1 Statistical Analyses

The main objective of this section is to determine for each location pair, the number of similar, correlated and dissimilar-uncorrelated parameters. The determination process is performed in sequence where the number of correlated parameters is determined after excluding the similar parameters that may have also significant correlations. For example, when the number of similar and correlated parameters are 10 and 16, this means that out of 36 (the total number of participated parameters) there are 10 similar and out of the other 26 there are 16 correlated and 10 dissimilar-uncorrelated.

The problem is that the statistical approaches (Means, Yearly avg. and Monthly) produced different results. Some parameters were employed for more than one approach, which might lead to inconsistent numbers of similar, correlated and dissimilar-uncorrelated parameters.

In such cases, the minimum numbers of repeated parameters that are reported at least in two different approaches will be considered. For example, assuming that the numbers of similar parameters that employed in three approaches were 5, 8, and 10 but only 4 were ***repeated*** in two approaches then the number of similar parameters will be 4.

As an Example, the following section presents the findings of site similarity within *site group 1* based on the statistical analyses (three approaches: Means, Yearly Avgs. and Monthly) . Annex 4-10 presents the site similarity results for the other three site groups (2, 3 and 4).

For site group 1, the 36 parameters employed in the statistical analyses can be divided into 4 parameter groups A1, B1, C1 and D1 as followings:

- ***Parameter Group (A1)*** includes 8 parameters namely BOD, COD, TSS, TVS, $N\text{-}NH_4$, pH, Temp and Turb. These 8 parameters participated in three approaches (Means, Yearly Avg. and Monthly). The 4-clusters solution and MANOVA indicated that there are insignificant differences between the monitoring locations EH14, EH02 and EH18.
- However, the nonparametric comparisons did not differ significantly from these results. Only, Turb and pH were dissimilar for the monitoring locations EH02 and EH14. Also, TSS, TVS, Temp and Turb were not similar for the monitoring locations EH18 and EH14. The Pearson correlation coefficients (R) for theses parameters are as followings:

		Turb	pH
R (Pearson)	EH02-EH14	0.737^{**}	0.802^{**}

		TSS	TVS	Temp	Turb
R (Pearson)	EH18-EH14	0.833^{**}	0.845^{**}	0.990^{**}	0.709^{**}

- ***Parameter Group (B1)*** includes 11 parameters namely EC, TDS, Ca, Mg, Na, K, SO_4, Cl, SAR, Adj. SAR and Sal. These 11 parameters participated only in two approaches (Yearly Avg. and Monthly).
- The MANOVA and the nonparametric comparisons indicated that there are insignificant differences between the monitoring locations EH02 and EH18.
- In the two approaches, 4 out of the 11 parameters (Ca, Mg, K and SO_4) were similar for the monitoring locations EH02 and EH14. The Pearson correlation coefficients (R) for the other 7 parameters are as followings:

	EC	TDS	Na	Cl	SAR	Adj. SAR	Sal
R (Pearson)	0.494^{**}	0.572^{**}	0.466^{**}	0.535^{**}	0.482^{**}	0.494^{**}	0.449^{**}

- In the two approaches, 3 out of the 11 parameters (Ca, K and SO_4) were similar for the monitoring locations EH18 and EH14. Also, they indicated that SAR was dissimilar for the same pair. However, the Pearson correlation coefficients (R) for the dissimilar parameters are as followings:

	EC	TDS	Mg	Na	Cl	SAR	Adj. SAR	Sal
R (Pearson)	0.780^{**}	0.844^{**}	0.653^{**}	0.749^{**}	0.769^{**}	0.731^{**}	0.727^{**}	0.807^{**}

- ***Parameter Group (C1)*** includes 4 parameters namely P, DO, Visib and TP. These 4 parameters participated in the two approaches (Means and Monthly). For the pairs (EH14&EH02 and EH02&EH18), the two approaches showed different results. Only Visib measurements were similar in both approaches for the location pair EH02&EH18. For the pair EH14&EH18, both approaches indicated that P and Visib were similar. However, the Pearson coefficients (R) for these parameters are as followings:

		P	DO	Visib	TP
EH02-EH14	R (Pearson)	0.735^{**}	0.704^{**}	0.677^{**}	0.099
EH18-EH14		0.656^{**}	0.661^{**}	0.730^{**}	0.670

"**" Correlation is significant at the 0.01 level.

		P	DO	Visib	TP
EH02-EH18	R (Pearson)	0.791**	0.698**	0.927**	0.824**

- ***Parameter Group (D1)*** includes 13 parameters namely Coli, N-NO_3, Cd, Cu, Fe, Mn, Zn, Pb, Br, Fecal, TN, Ni and SO_{4_m}. These 13 parameters participated only in the last approach (Monthly). For each pair (EH14&EH02, EH14&EH18 or EH02&EH18), there were ten similar parameters. However, the Pearson correlation coefficients (R) for the other three parameters are as followings:

EH02-EH14	R (Pearson)	Coli	Fe	Mn
		0.054	0.612**	0.181
EH18-EH14	R (Pearson)	Coli	Fe	Fecal
		0.407**	0.623**	0.426**
EH02-EH18	R (Pearson)	Cu	Mn	Br
		0.407**	0.623**	0.426**

Summary

Table 4-18 shows the summary results of the similarity analysis (section 4.3), which were employed for 36 WQPs, measured at site group1.

- The location pair EH02&EH14 has 20 similar WQPs, 13 correlated at 0.01-confidence level and 3 dissimilar-uncorrelated parameters.
- The location pair EH14&EH18 has 19 similar WQPs, 16 correlated at 0.01-confidence level and 1 dissimilar-uncorrelated parameters.
- The location pair EH02&EH18 has 30 similar WQPs, 6 correlated at 0.01-confidence level and 0 dissimilar-uncorrelated parameters.

Table 4-19 presents the relations between the monitoring location EH02 and the other two locations EH14 and EH18 concerning the 36 WQPs employed in the statistical analyses.

Based on the statistical analysis, the monitoring locations EH14 and EH18 can be excluded without loosing substantial information. Most of the variability related to these two locations can be easily obtained from the monitoring location EH02.

"**" Correlation is significant at the 0.01 level.

Table 4-18: Similarity analyses summary results for 36 WQPs measured at the possible similar pairs in site group 1

	Water Quality Parameters			
	EH14 -EH02			
	Group A1	Group B1	Group C1	Group D1
Means	8S	-	4S	-
Yearly Avg.	8S	11S	-	-
Monthly	6S+2C	4S + 7C	3C + 1NS_NC	10S + 1C + 2NS_NC
Similar Parameters	6	4	0	10
Correlated	2	7	3	1
Dissimilar - Uncorrelated	0	0	1	2
Total No. of Parameters	8	11	4	13

	EH14 - EH18			
	Group A1	Group B1	Group C1	Group D1
Means	8S	-	4S	-
Yearly Avg.	8S	10S + 1NS	-	-
Monthly	4S + 4C	3S + 8C	2S + 1C + 1NS_NC	10S + 3C
Similar Parameters	4	3	2	10
Correlated	4	8	1	3
Dissimilar - Uncorrelated	0	0	1	0
Total No. of Parameters	8	11	4	13

	EH02 - EH18			
	Group A1	Group B1	Group C1	Group D1
Means	8S	-	4S	-
Yearly Avg.	8S	11S	-	-
Monthly	8S	11S	1S + 3C	10S + 3C
Similar Parameters	8	11	1	10
Correlated	0	0	3	3
Dissimilar - Uncorrelated	0	0	0	0
Total No. of Parameters	8	11	4	13

"S"	Similar parameters	"NC"	Uncorrelated
"NS"	Dissimilar	"NS_NC"	Dissimilar-Uncorrelated
"C"	Correlated	"-"	Not participated in the related approach

Table 4-19: The relations between the monitoring location EH02 and the other two locations EH14 and EH18

Parameters	Group 1	
	EH14-EH02	EH18-EH02
BOD (mg/l)	S	S
COD (mg/l)	S	S
TSS (mg/l)	S	S
TVS (mg/l)	S	S
N-NO_3 (mg/l)	S	S
N-NH_4 (mg/l)	S	S
Cd (mg/l)	S	S
Zn (mg/l)	S	S
Pb (mg/l)	S	S
Ca (meq/l)	S	S
Mg (meq/l)	S	S
K (meq/l)	S	S
SO_4 (meq/l)	S	S
Temp (C^o)	S	S
Fecal(MPN/100ml)	S	S
TN (mg/l)	S	S
Ni (mg/l)	S	S
SO_{4_m} (meq/l)	S	S

Parameters	Group 1	
	EH14-EH02	EH18-EH02
Mn (mg/l)	NS-NC	C

Parameters	Group 1	
	EH14-EH02	EH18-EH02
P (mg/l)	C	C
DO (mg/l)	C	C

Parameters	Group 1	
	EH14-EH02	EH18-EH02
Fe (mg/l)	C	S
pH	C	S
EC (dS/m)	C	S
TDS (mg/l)	C	S
Na (meq/l)	C	S
Cl (meq/l)	C	S
SAR	C	S
Adj_SAR	C	S
Sal	C	S
Turb (NTU)	C	S
Visib (Cm)	C	S

Parameters	Group 1	
	EH14-EH02	EH18-EH02
Coli (MPN/100ml)	NS-NC	S

Parameters	Group 1	
	EH14-EH02	EH18-EH02
Cu (mg/l)	S	C
Br (mg/l)	S	C

Parameters	Group 1	
	EH14-EH02	EH18-EH02
TP (mg/l)	NS-NC	C

“S”	Similar parameters	“NC”	Uncorrelated
“NS”	Dissimilar	“NS_NC”	Dissimilar-Uncorrelated
“C”	Correlated		

4.4.2 Key Players and Monitoring Objectives Analysis

The following section presents the findings of the site similarity results within site group 1 based on the analysis of crucial tributaries (Key Players) and monitoring objectives. Annex 4-10 presents the site similarity results for the site groups 2, 3 and 4.

- For BOD, COD, TDS, N-NH$_4$ and Coli, all monitoring locations in site group 1 violate Law 48 (local standards). There are insignificant differences between the monitoring sites EH14, EH02 and EH18 for most of the examined WQPs. Their correlation coefficients are relatively high. Selecting EH02 for the final network (as an official reuse pumping station) may insure the continuation of a long history of water quantity and quality records at this location.
- EH03 is essential for the monitoring objectives "***Make waste-load allocations***" and "***Determine Water Quantities***" in order to facilitate the calculation of pollutant loads, which are added to the system. EH03 also seems to be a Key Player concerning some quality indicators such as oxygen budget, salts, nutrients and physical parameters.
- For the other monitoring objectives and when EH15 (main stream point) is monitored, EH03 can be excluded based on the correlation analysis, which shows high correlation between EH03 and EH15 in relation with some parameters such as BOD, COD, EC, N-NO$_3$, N-NH$_4$, Temp, Cu and Fe. In the meantime, the parameters TDS, SAR, TP, pH, Turb, Coli, Zn and Pb show lesser correlation but the coefficients remain statistically significant.

4.5 SITES SELECTION FOR THE FINAL NETWORK

The results of the Key Players, monitoring objectives and statistical analyses can be summarized using the schematic diagrams in Figures 4-11 to 4-18. It is clear that every diagram proposes different combinations of sampling sites. In order to overcome this problem, checklist was employed. It contains mainly three items: *Monitoring location*, *Monitoring objectives* and *Statistical approaches.* Then, for every monitoring objective and statistical approach, the monitoring sites were assigned based on the similarity results presented in section 4.4 and Annex 4-10.

In general, the decisive factors concerning the continuity or discontinuity for any monitoring site in Hadus drain networks can be summarized as followings:

1. Results of the different statistical approaches
2. Key Players and monitoring objectives

3. Field observations and previous experiences
4. Location history in the current program
5. First priorities for reuse pump stations
6. Higher priorities for mainstream locations (checkpoints) and
7. High priorities for downstream locations.

When any location was selected, a value of “1” was given for the related selection reason. Then general sums were calculated. The sums of the values coming from the statistical approaches were multiplied by 6 in order to give equal weight for both monitoring objectives and statistical approaches in the list. These sums may indicate the priority of the monitoring location to be a member of the final monitoring network. Table 4-20 shows the monitoring objectives/locations checklist.

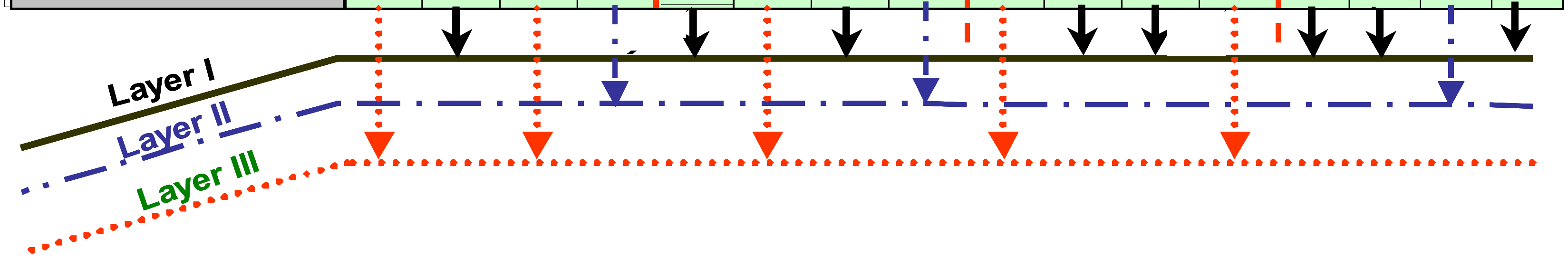
According to the final priorities indicated by the checklist, the monitoring network can be divided into three layers (Figure 4-18).

- **Layer I** has the highest priority levels and includes 8 monitoring locations (EH02, EH04, EH15, EH08, EH09, EH11, EH12 and EH17).
- **Layer II** has the second priority levels and includes 3 monitoring locations (EH03, EH06, and EH16).
- **Layer III** has the lowest priority levels and includes 5 monitoring locations (EH14, EH18, EH05, EH07 and EH10).

It has to be mentioned that some decisions concerning the presence of a location in the monitoring objectives part in the checklist were taken in the light of the statistical results. As an example, although both EH07 and EH08 can be considered as Key Players (crucial tributaries) in Hadus system, one can recognize that EH08 was given higher priority where the number of similar parameters between EH07 and EH08 are 23 and the other dissimilar parameters are mainly due to the higher salts levels at EH08. Most of these parameters (EC, TDS, Na, K, Ca, SO_4, Mg, Cl, SAR and Adj. SAR) are significantly correlated with the EH07 measurements and there are significant regression equations to describe their relations.

Table 4-20: Monitoring objectives/locations checklist for allocating monitoring sites

	Group 1				Group 2				Group 3				Group 4			
Monitoring Locations	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH12	EH16	EH17
Monitoring Objectives																
Assess compliance with standards		1			1		1			1	1		1			1
Define water quality problems		1			1		1			1	1		1	1		1
Determine fate and transport of pollutants		1			1		1			1			1	1		1
Make waste-load allocations		1		1	1	1	1	1	1	1	1	1	1	1	1	1
Detect trends		1			1		1			1	1		1	1		1
Determine Water Quantities	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
SUM	1	6	1	2	6	2	6	2	2	6	5	2	6	5	2	6
Statistical Approaches																
Means, Yearly Avg. and Monthly		1		1	1		1	1		1	1		1	1	1	1
6 * SUM	0	6	0	6	6	0	6	6	0	6	6	0	6	6	1	6
General SUM	1	12	1	8	12	2	12	8	2	12	11	2	12	11	8	12



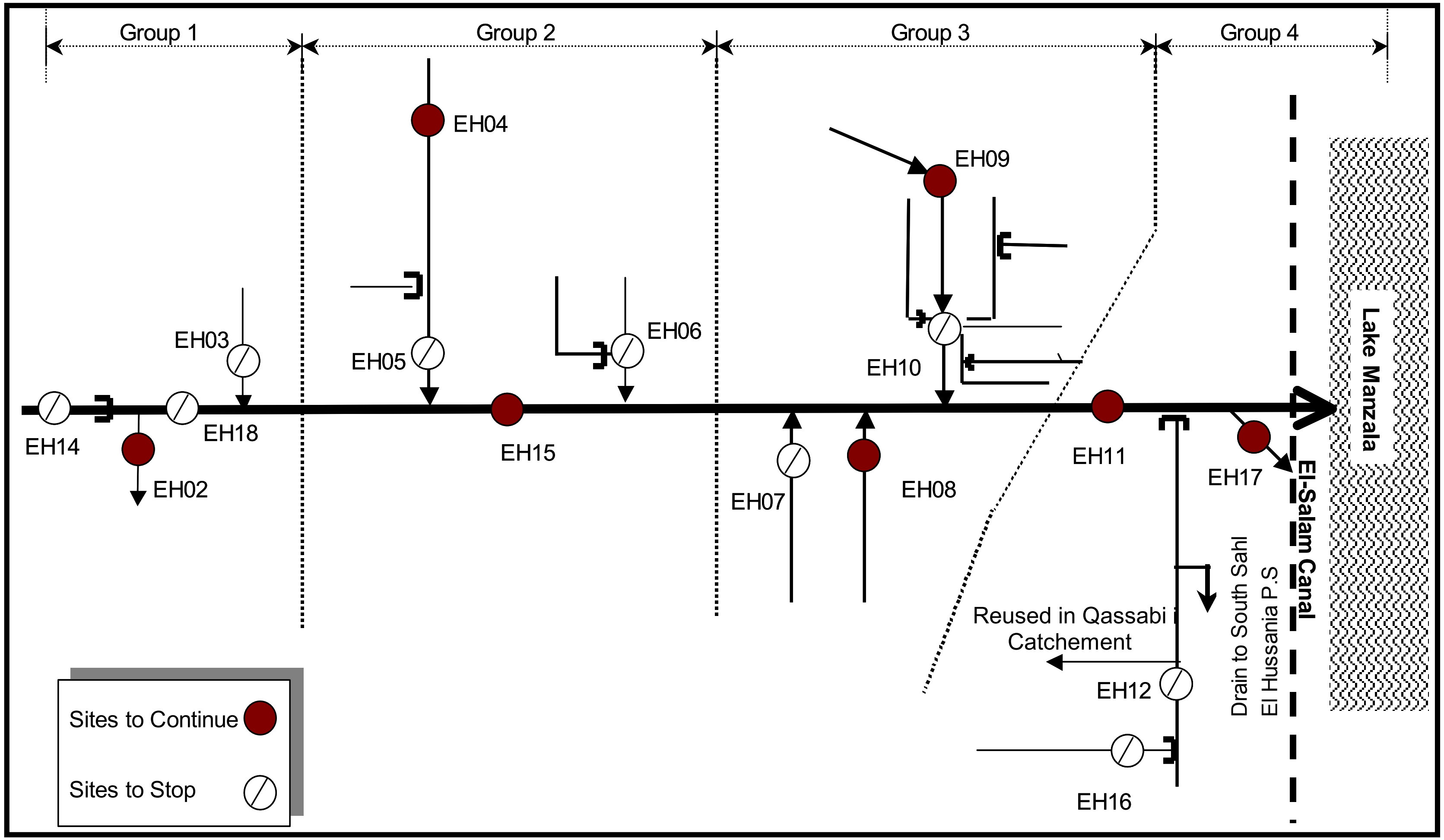


Figure 4-11: Hadus drain monitoring sites based on the monitoring objective

„Assess compliance with standards"

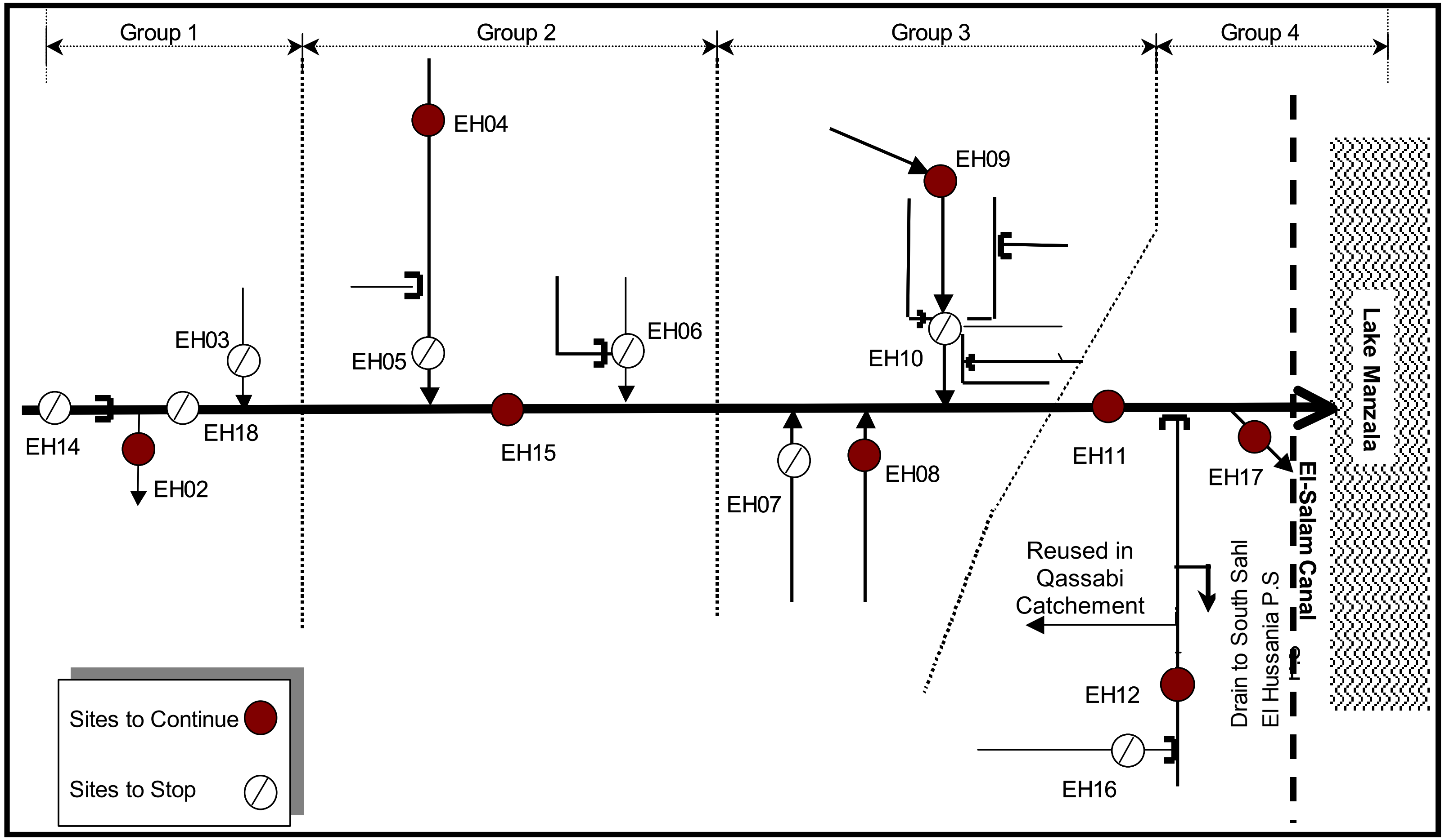


Figure 4-12: Hadus drain monitoring sites based on the monitoring objective

„Define WQ problems“

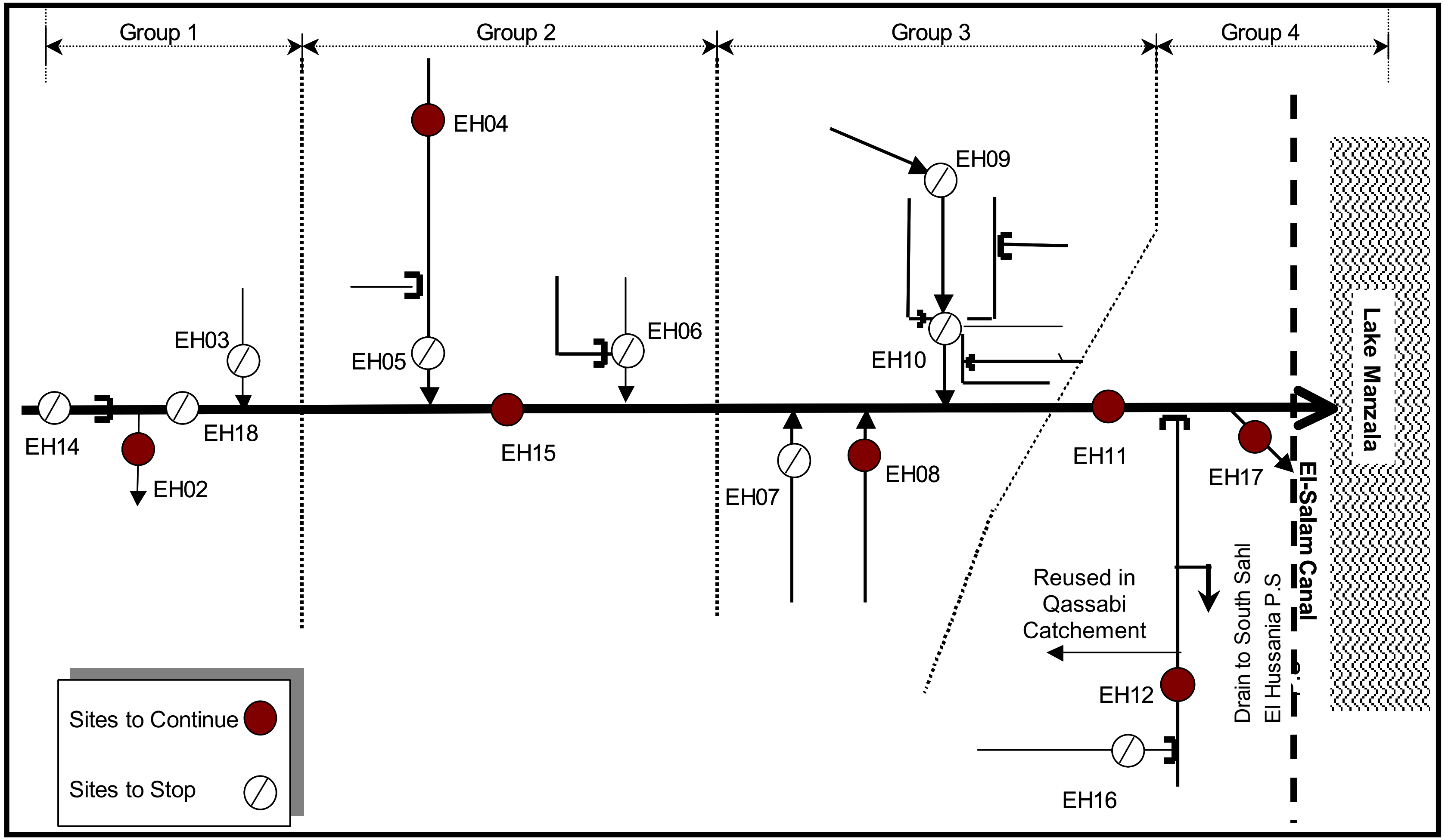


Figure 4-13: Hadus drain monitoring sites based on the monitoring objective

„Determine fate and transport of pollutants“

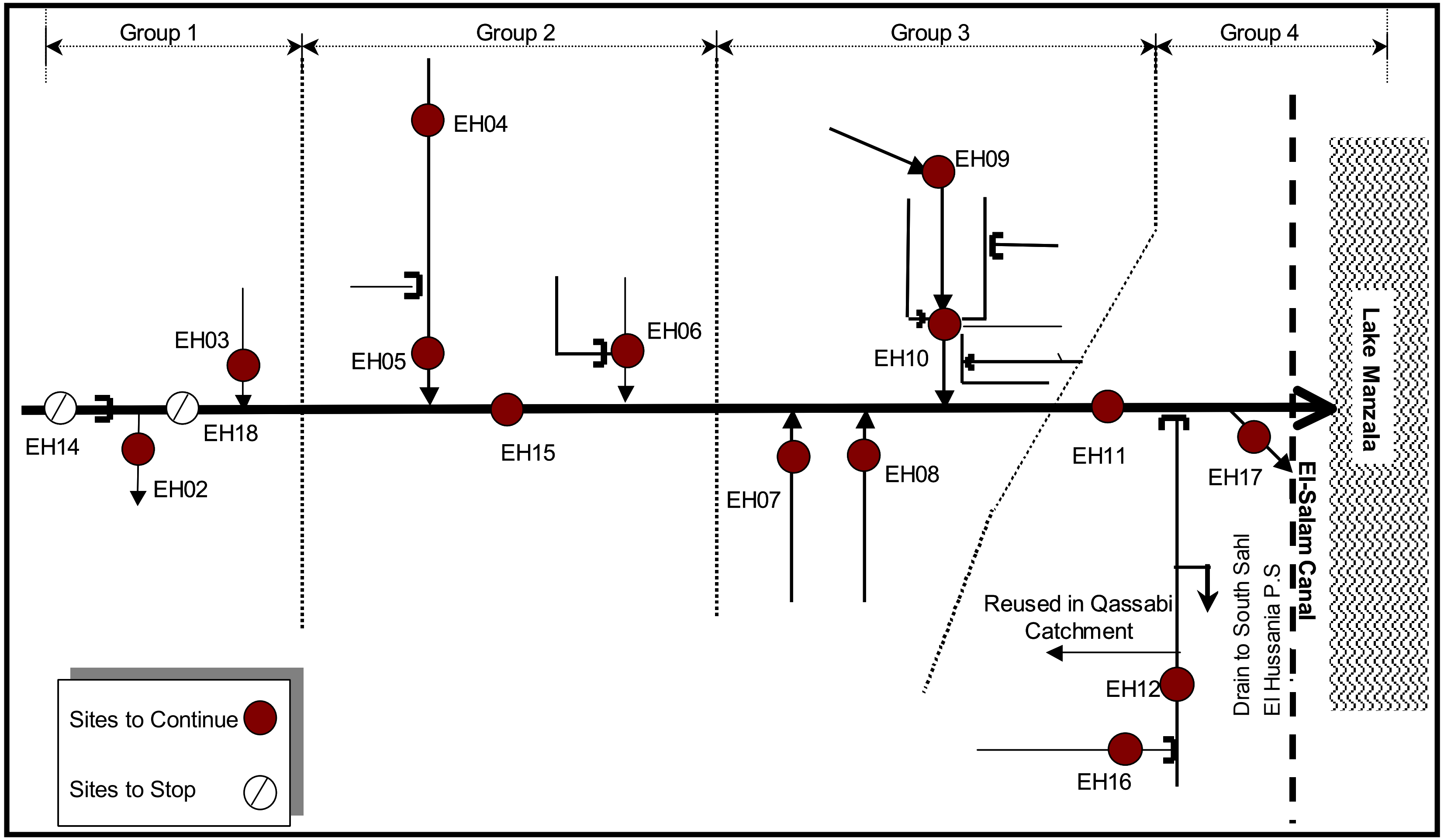


Figure 4-14: Hadus drain monitoring sites based on the monitoring objective

„Make waste-load allocations"

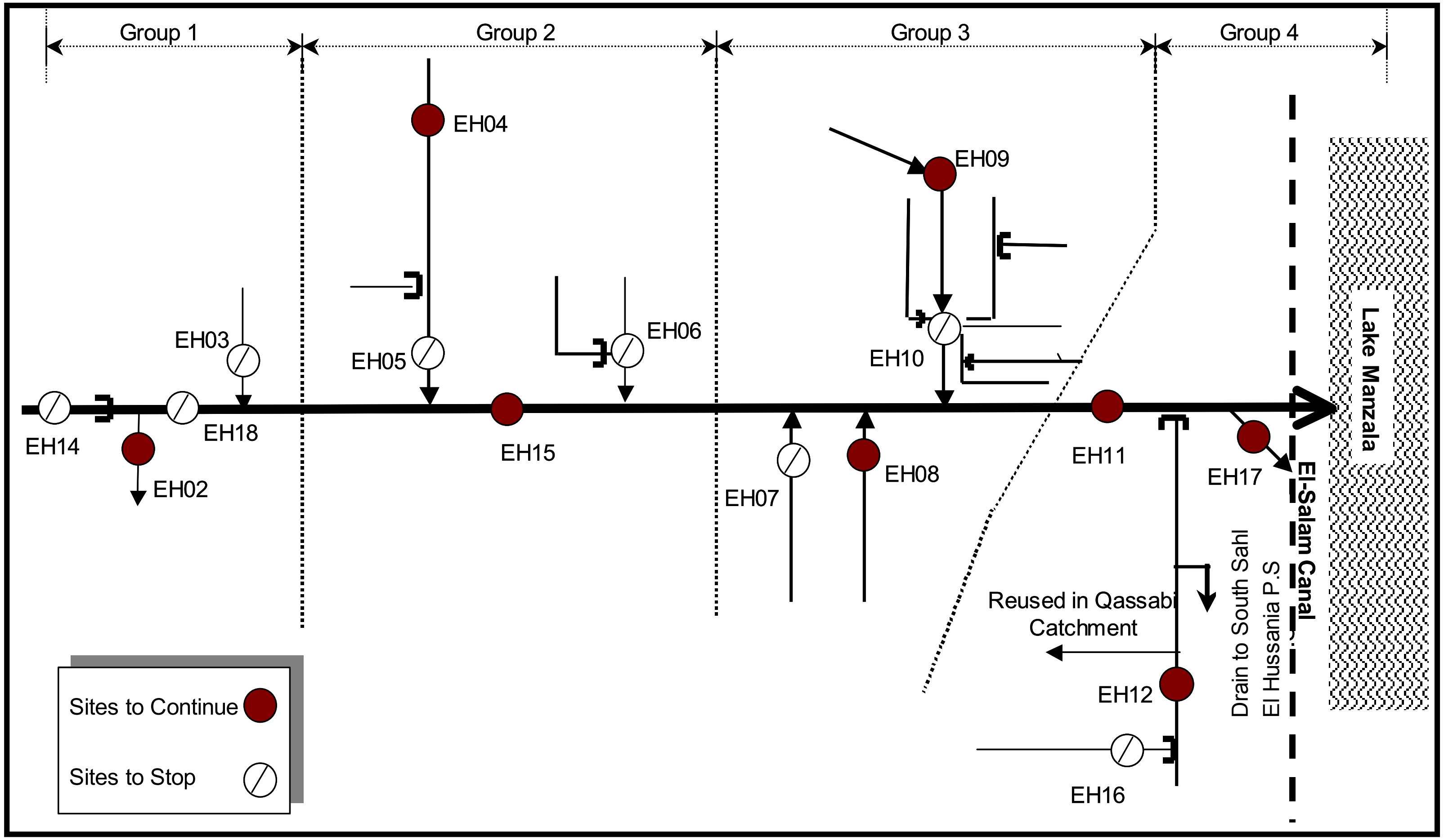


Figure 4-15: Hadus drain monitoring sites based on the monitoring objective

„Detect trends“

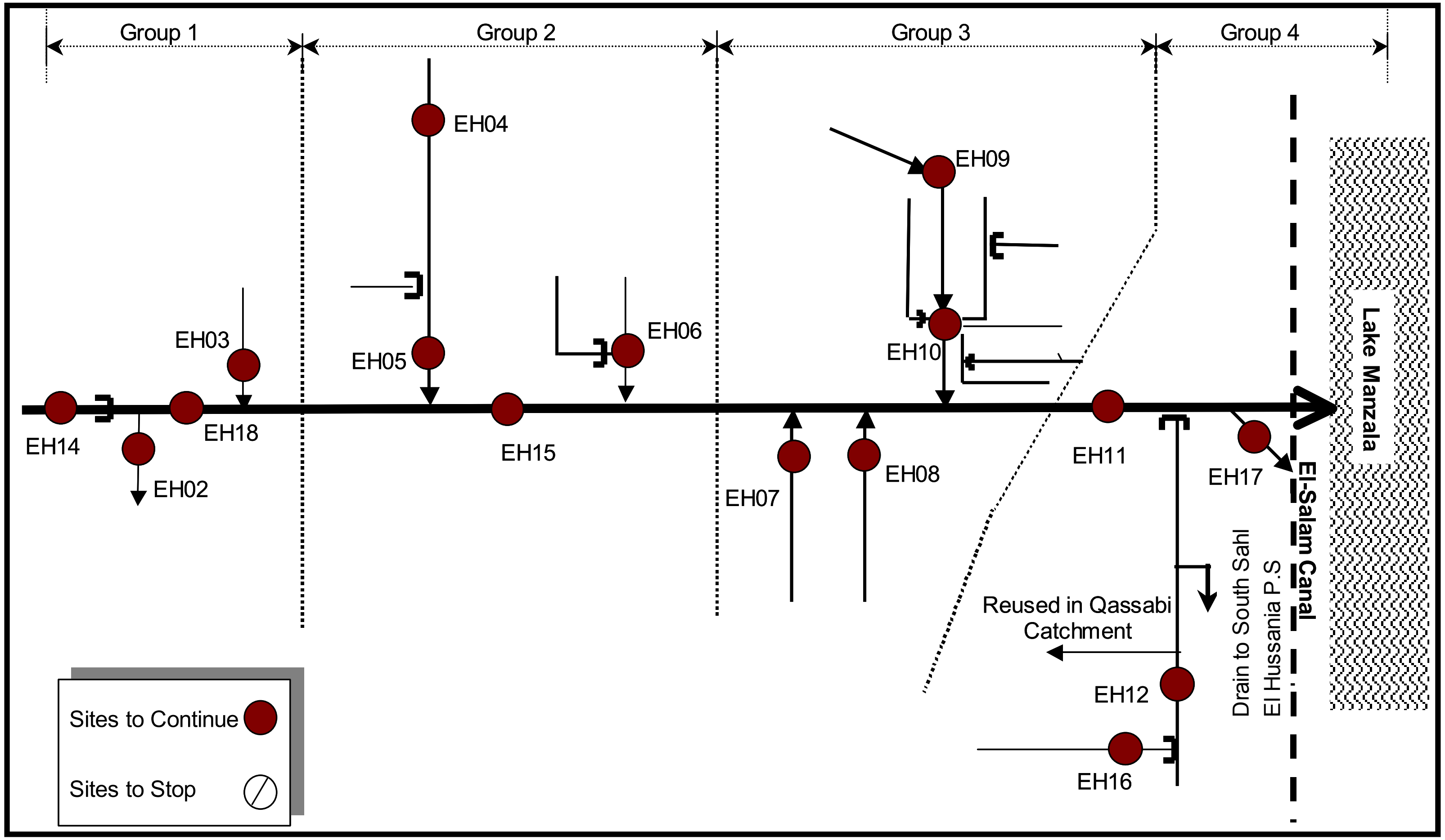


Figure 4-16: Hadus drain monitoring sites based on the monitoring objective

„ Determine Water Quantities“

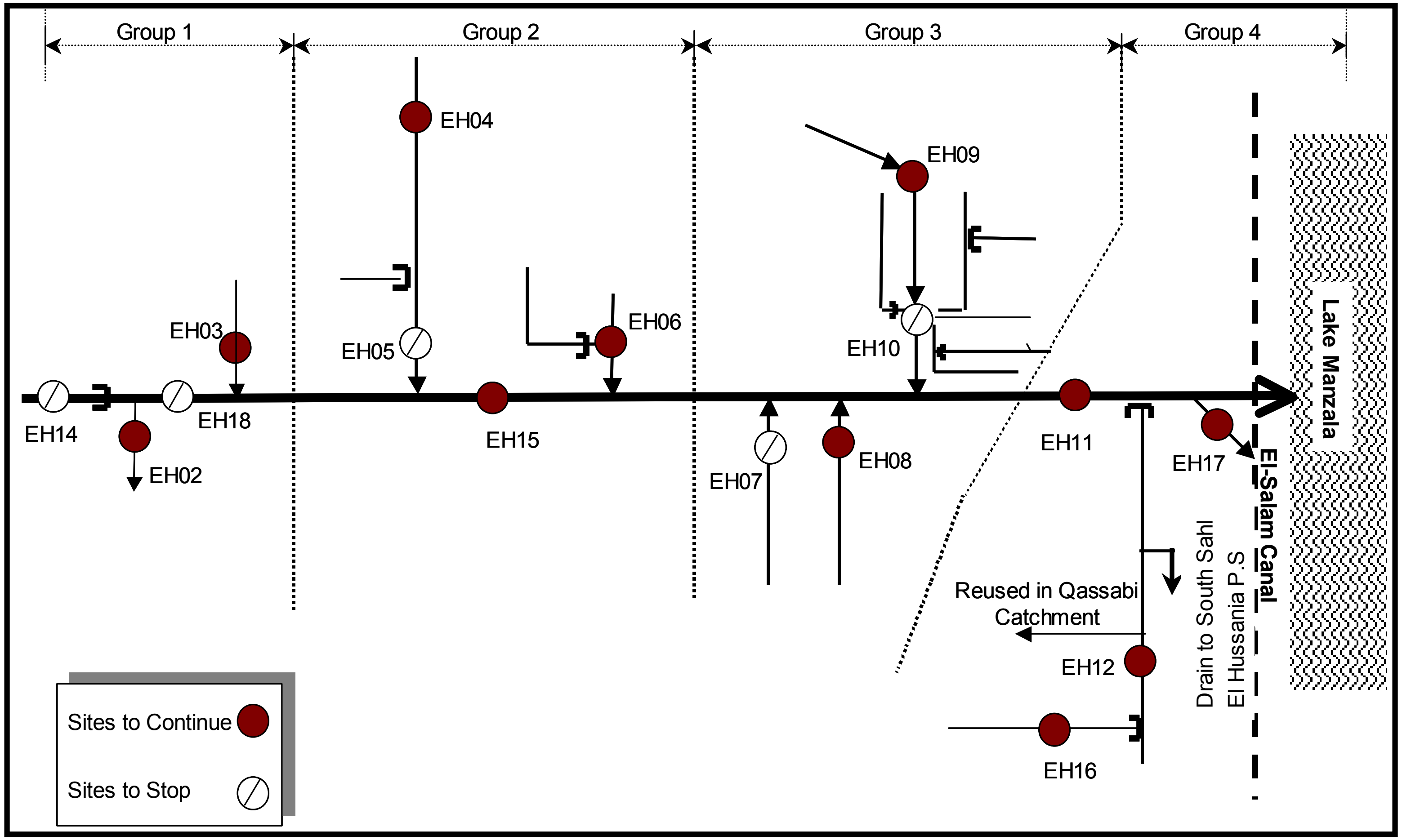


Figure 4-17: Hadus drain monitoring sites based on different statistical analyses

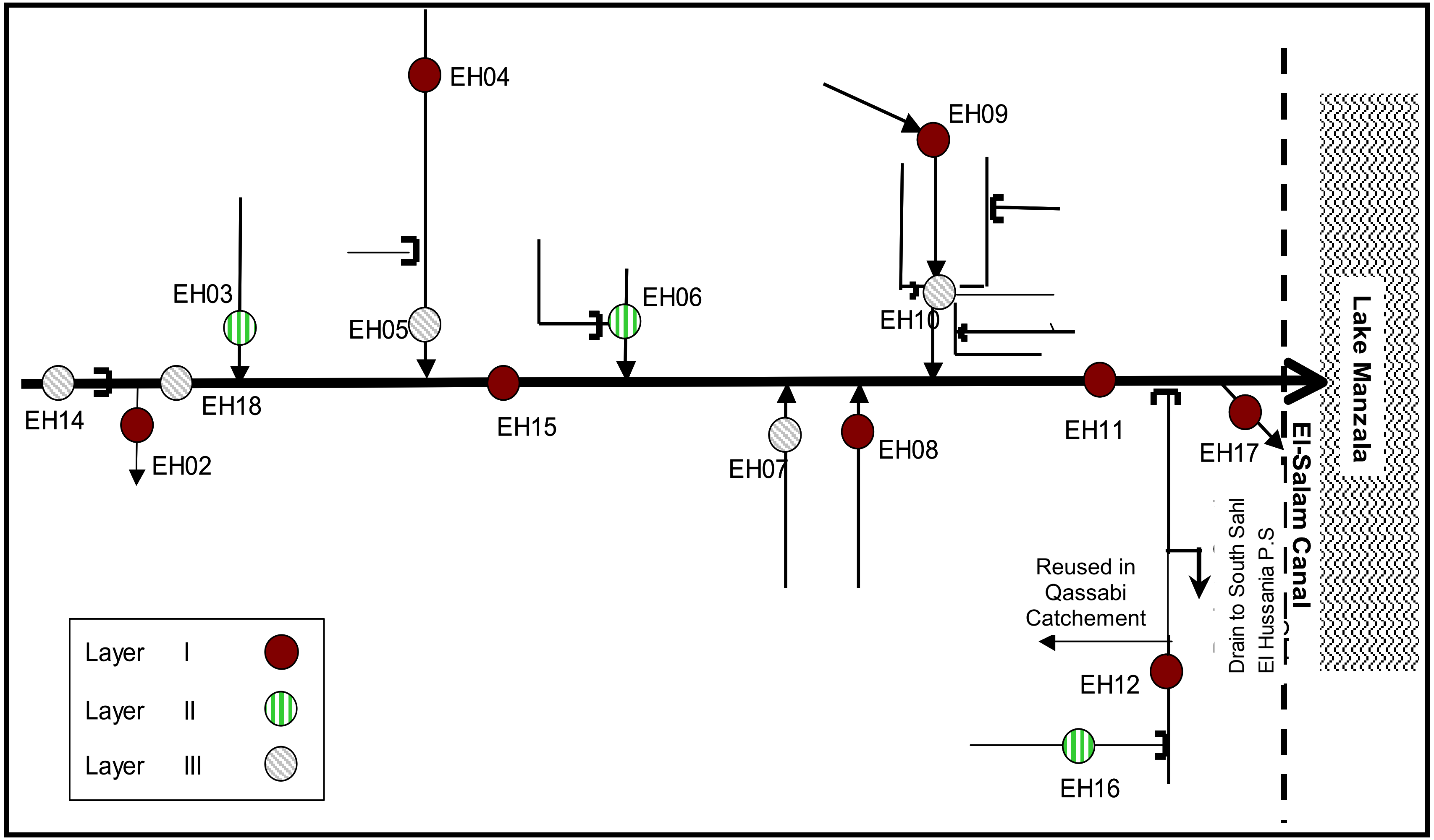


Figure 4-18: Final selection for the proposed WQM network in Hadus drain

4.6 SUMMARY AND DISCUSSION

This section presents a summary for the three different approaches (Means, Yearly Averages and Monthly), which were used in this study to locate sampling sites for Hadus drain monitoring network. In the first approach (Means), the total means (as a measure of central tendency) for some WQPs, which fulfilled the required assumptions for principle components, cluster and discriminant analyses, were used to investigate the similarity between the monitoring sites in the current network of Hadus drain. The followings are some observations obtained during applying this approach for Hadus drain network:

- Using multivariate techniques helped to deal with many variables simultaneously and distinguishing complex relations among them.
- Using central tendency measure such as means compressed the available data of a long period (August 1997 to January 2005 - monthly records). This compression may hide significant variability especially for water systems as Hadus drain where many environmental (human and natural) aspects are playing (randomly or/and systematically) significant roles with respect to the point and non-point pollution sources.
- Only 12 (out of 36) WQPs were able to participate in this approach (Means). These parameters included 6 physical-, 3 nutrients- and 3 oxygen budget parameters. The rest failed to fulfill the required assumptions. In general, ***salts***, ***metals*** and ***bacterial indicators*** were missed in this approach.
- Recalling the clustering results, one can also recognize that for example, the locations EH05 & EH11 or EH03 & EH11 were in the same cluster for the 4 and 6 clusters solutions respectively in spite of the fact that they are significantly far from each other and there are many Key Players (such as EH07 and EH08 for salts levels) in the distances between them. Therefore, no one can easily exclude one of the locations based on these results.
- The decision concerning the presence or absence of any monitoring location is based (only) on the different water quality levels. The dimension concerning the ***monitoring objectives*** is not clearly involved.

In order to reduce the effect of some of these problems, the multivariate analysis of variance (MANOVA) followed by Discriminant analysis (DA) and range tests, were carried out for the yearly averages (**Yearly Avg.)** of some WQPs to find out the possible similarity in WQM sites in Hadus drain. The analyses were applied for the four site groups. The followings are some observations concerning this approach:

- This approach (like the previous one) is based on multivariate parametric statistical tests, which may also indicate powerful results.
- It facilitates detailed information about the participated parameters in relation with the monitoring locations. Firstly, it indicates the significant or insignificant differences between the locations based on these parameters. Then, it can also identify which parameters are the reasons of the similarity or dissimilarity.
- The WQM sites in Hadus drain were divided into four site groups based on their spatial characteristics such as geographical position, surrounding conditions and the direction of flow. These may ensure that the locations in every site group have similar environmental properties, which may affect the WQ in the system. As a result, the relationships that can be detected between the WQPs in these sites can be easily understood.
- This approach improves the problem of compressing information but does not really solve it. There is still some variability lost due to the yearly averaging.
- For the four site groups (1, 2, 3 and 4), the numbers of participated parameters were 19, 11, 13 and 15 respectively.
- For the four site groups (1, 2, 3 and 4), the numbers of participated ***salts*** parameters were 11, 6, 5 and 7 respectively.
- ***Metal*** parameters were only missed in the analysis of site group 1. For the other site groups, 2 metal parameters participated in each.
- ***Nutrients*** were missed in the site groups 2, 3 and 4. Only N-NH_4 was included in site group 1.
- ***Bacterial indicators*** were missed in all site groups.
- Again, the decision concerning the presence or absence of any monitoring location is based (only) on the different water quality levels. The dimension concerning the ***monitoring objectives*** is not clearly involved.

At this point, one can recognize that there are still three main problems. The first is the problem of compressing information by taking averages (total or yearly), which may hide some important variability. The second is the absence of some parameters such as the bacterial indicators. The third is related to the dimension of monitoring objectives.

The main reason of the first two problems is the non-normality of most of the WQPs. However, these can be solved through two different techniques. The first is to perform data transformation (such as taking the normal logarithm which is common in WQ studies) to be near to the normal distribution. Then the parametric statistical tests may be applied. In the case of Hadus drain, using this technique to deal with 36 parameters most of their probability distributions differ from each other and differ from normal distribution will not be an easy task. Therefore, as a second alternative, non-parametric statistical tests were used. The common belief is that they have less power than the parametric ones. However, they are relatively easier to be used and can afford reasonable power if the examined data are fulfilling the required assumptions.

The nonparametric Wilcoxon signed rank test for matched pairs was selected to determine if the median difference between monthly observations from adjacent monitoring sites in Hadus drain equals zero. The information obtained from the previous two approaches was used to identify the effective pairing. The pairs that show significant similarities in at least one approach (Means and/or Yearly Avgs.) were again selected to be analyzed using all the measured parameters. As a result, the focus was only on the monitoring sites, which were seen as (possible) similar. In addition, two other pairs (EH17&EH12 and EH16&EH12) were also analyzed due to the relative importance of the monitoring locations EH12 and EH17.

However, it was never the case that two monitoring sites have similarity in all 36 examined parameters. The maximum number of similar parameters (32) was reported in the Monthly approach between the monitoring sites EH02 and EH18. This number was again reduced (to only 30) in the final assessment of the three approaches where the Means and Monthly approaches showed different results for the parameters DO and TP (Annex 4-10). Therefore, correlation and then regression analyses were performed to improve basically the information about those dissimilar parameters. Correlation and regression analyses were also carried out for the other similar parameters to help keeping track with the monitoring sites that may be removed (in the future) from the network.

Till this point, the absence of monitoring objectives role in the site selection process was an existed problem. This problem may be solved by identifying the most crucial tributaries (***Key Players***). They have the greatest influences on the Hadus drain system. This identification process was carried out in the light of some expected objectives of the monitoring network.

Percentile analyses were carried out using some WQPs measured at Hadus drain monitoring sites. These parameters were selected based on some quality standards (mainly Law 48 art. 65 for drainage water to be re-used and art. 68 for ambient drainage water or FAO standards for irrigation water).

However, in addition to the network proposed by the statistical analyses, every monitoring objective proposed different combinations of sampling sites (different networks).

In order to have unique combination of sampling sites, a checklist was implemented. This checklist contains mainly three items: Monitoring locations, Monitoring objectives and Statistical approaches. Then, for every monitoring objective and the statistical approach, the monitoring sites were assigned.

According to the final priorities indicated by the checklist, the monitoring network can be divided into three layers (Figure 4-18).

- **Layer I** has the highest priority levels and includes 8 monitoring locations (EH02, EH04, EH15, EH08, EH09, EH11, EH12 and EH17).
- **Layer II** has the second priority levels and includes 3 monitoring locations (EH03, EH06, and EH16).
- **Layer III** has the lowest priority levels and includes 5 monitoring locations (EH14, EH18, EH05, EH07 and EH10).

CHAPTER 5

5. SAMPLING SITES VALIDATION

Before putting recommendations concerning the proposed number of locations in Hadus WQM program, the reliability of the site similarity results (Chapter 4) has to be scientifically validated. This is to ensure that the recommended program will produce the information required to achieve the monitoring objectives. In general, the validation techniques have to be independent from the data analysis procedures.

5.1 VALIDATION METHODOLOGY

In a similar study, Y. Ouyang (2005) divided the monitoring sites for the main stem of the lower St. Johns River in Florida, USA, into two groups: principal and non-principal stations. He used a simple methodology to validate his results by comparing the WQ data with and without the non-principal stations. Two cases were developed for the comparison. Firstly, the data from the principal stations was used to formulate four relationships by regression:

1. Dissolved organic carbon (DOC) versus watercolor;
2. Chlorophyll a versus total phosphorous (TP);
3. Biochemical oxygen demand (BOD) versus total organic carbon (TOC) and
4. Chlorophyll a versus total dissolved nitrogen (TDN).

Then, the previous relationships were reformulated by regression using all data (principal and non-principal stations). This was to determine whether the addition of data from the non-principal stations improved the regression relationships or not.

To test the statistical significance of R^2 values produced by the regression analysis in the previous two cases (using data from principal sites only or all data), a t-test analysis was performed with a 5% level of significance. The test rejected the hypothesis of equal means, indicating that the R^2 values from the principal stations data were statistically better than those data from all stations.

However, there is one main argument concerning the sensitivity of using this technique in such comparisons. This is the case when a relation between two parameters is strong enough to minimize or even eliminate the effect of adding or removing some locations in the analysis. This means that whatever the number of locations considered, the relation between the parameters will not have a significant change.

For a system like Hadus drain which works as a collective water body, strong correlations (relations) are expected. This may reduce the sensitivity of the previous validation method. Therefore, the validation process of the results presented in chapter 4 includes three main steps described in the following sections.

5.1.1 Regression analysis

In this step, three cases were developed to compare the WQ data coming from the different monitoring layers described in section 4.5. These cases are:

Case I: Using data from 8 sites (Layer I);

Case II: Using data from 11 sites (Layer I and II) and

Case III: Using data from 16 sites (layers I, II and III).

In all previous cases, the linear regression analysis was employed to formulate the following WQ relationships (well known as significantly correlated parameters):

- Biological oxygen demand (BOD) versus chemical oxygen demand (COD)
- Total suspended solids (TSS) versus total volatile solids (TVS)
- Electrical conductivity (EC) versus total dissolved salts (TDS)
- Sodium (Na) versus chloride (Cl)

The one-way analysis of variance (ANOVA) was employed for the Pearson correlation coefficients (R^2) obtained from the regression. This was to investigate if there were significant differences between the three cases I, II and III.

5.1.2 Box-plots and Descriptive Statistics

In this step, Box-plots and common descriptive statistics were employed for the previous three cases (Case I, II and III) using the eight parameters (BOD, COD, EC, TDS, Na, Cl, TSS and TVS) analyzed in the regression analysis. In general, the output of this step may be useful to have an insight vision for the data coming from the previous cases (I, II and III). This is especially important for the cases where strong relations between the WQPs are detected by the regression analysis and it can help to avoid misleading results.

5.1.3 Multiple Regressions

In this step, linear multiple regression models were employed using three WQPs (BOD, TSS and TDS) in order to formulate the relationships between the monitoring locations in Hadus drain within the reach between the two open locations El-Dawar Bridge (EH15) and Bahr Hadus Bridge (EH11) (Figure 5-1). Recalling section 4.5, the three locations (EH15, EH08 and EH09) represent the monitoring sites in Layer I. While EH06 represents the sites in Layer II and finally EH07 and EH10 represent Layer III.

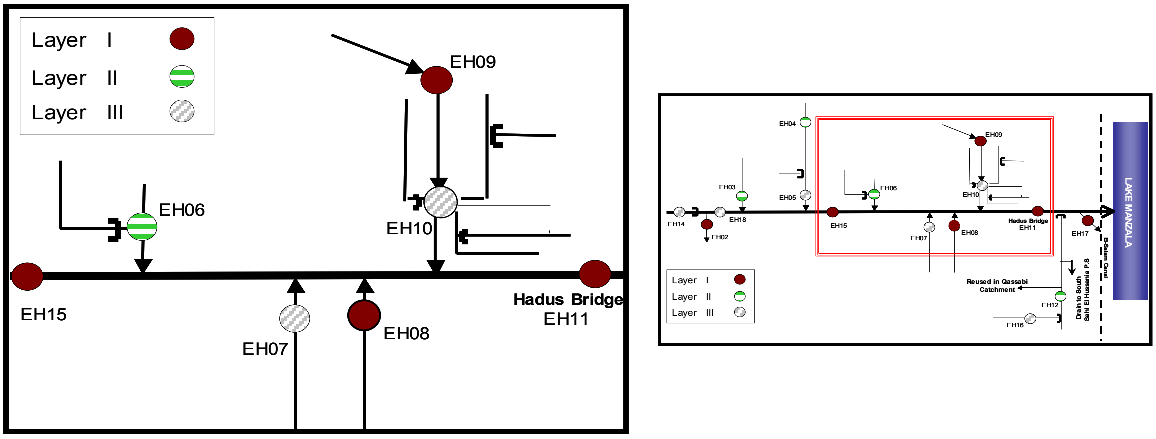


Figure 5-1: Hadus drain monitoring locations between EH15 and EH11

The procedure can be summarized as following:

1. Application of linear multiple regression analyses in order to describe the levels of the three parameters (BOD, TSS and TDS) at EH11 as functions of the same parameters measured at the other locations (EH15, EH08, EH09, EH06, EH07 and EH10).
2. Estimation of these parameters at EH11 using the original datasets of the other **six** locations (measured during the period from August 1997 till January 2005).
3. Repeating steps 1 and 2 but after removing the monitoring locations EH07 and EH10 from the original (measured) datasets.
4. Comparing (visually and statistically) between the information (estimated parameters for EH11) obtained using the original data set where EH07 and EH10 were measured and the information obtained when they were excluded.

5.2 VALIDATION RESULTS

5.2.1 Regression Analysis

This section presents the results of the linear regression analyses performed in order to formulate some WQ relationships (BOD-COD, TSS-TVS, EC-TDS and Na-Cl) in Hadus drain monitoring sites. However, for every relation, three cases (I, II and III) were developed as mentioned before.

Table 5-1 and Figures 5-2 to 5-5 show that the Pearson correlation coefficients (R^2) vary within narrow ranges for the three cases I, II and III. However, for all relations except BOD-COD, case II (11 sites) has the highest correlation coefficients.

This may indicate that removing the monitoring sites from Layer III (5 out of 16 locations) will not significantly reduce (but even slightly improve) the information obtained by the regression analyses.

Table 5-1: Pearson correlation (R^2) values for some WQ relations in Hadus drain

	BOD-COD	TSS-TVS	EC-TDS	Na-Cl
Case_I	0.8121	0.8293	0.8121	0.9143
Case_II	0.8030	0.8343	0.9217	0.9199
Case_III	0.7881	0.8311	0.9168	0.9156

One can easily recognize that reducing the number of monitoring sites from 11 to only 8 causes reductions in the correlation coefficients indicating losses of variability (information) that can be grasped by the regression.

For the relation BOD-COD, the correlation coefficients have an inverse relation with the number of considered monitoring sites. The values of R^2 increase while the number of monitoring sites decrease. There are two possible interpretations for this result:

1. There are many ***similar*** locations that have strong relation between BOD and COD levels. Therefore, the reduction in the monitoring sites from 16 to 11 or even to only 8 did not significantly reduce (but even slightly improve) the information obtained by the regression analysis; or/and
2. The relation between BOD and COD is strong enough to minimize the effect of removing some locations in the analysis.

However, one-way analyses of variance (ANOVA) that can detect significant differences between the means of more than 2 variables were employed for the cases I, II and III using the Pearson correlation coefficients (R^2). The output results are presented in Table 5-2. The ANOVA significant value (0.7986) is greater than 0.05 indicating that there are insignificant differences between the mean values of the R^2 for the cases I, II and III. This indicates that reducing the number of monitoring sites from 16 to 11 or even 8; has insignificant effect on the power of information produced by the regression analysis.

Table 5-2: The ANOVA output results for the Pearson correlation coefficients (R^2) applied for the cases I, II and III.

	Sum of Squares	df	Mean Squares	F	Sig.
Between Groups	0.0016	2	0.0008	0.2306	0.7986
Within Groups	0.0308	9	0.0034		
Total	0.0324	11			

5.2.2 Box-Plots and Descriptive Statistics

This section presents the Box-plots and some descriptive statistics that were employed for the eight parameters (BOD, COD, EC, TDS, Na, Cl, TSS and TVS) used in the previous regression analysis. For every parameter, three cases (I, II and III) were developed as mentioned before. Figure 5-6 presents the Box-plots employed for the previous cases. Visually, one can easily recognize that reducing the number of monitoring sites from 16 to 11 and then to only 8 has insignificant influences on the parameters TSS and TVS. This is not the case for BOD, COD, EC, TDS, Na and Cl where significant influences can be seen due to the reduction of sampling sites to only eight.

In general, one can conclude that reducing the number of monitoring sites to 11 (Layer I and II) may be sufficient to obtain most of the information produced by the current monitoring program (16 locations). The descriptive statistics presented in Table 5-3 support the same conclusion.

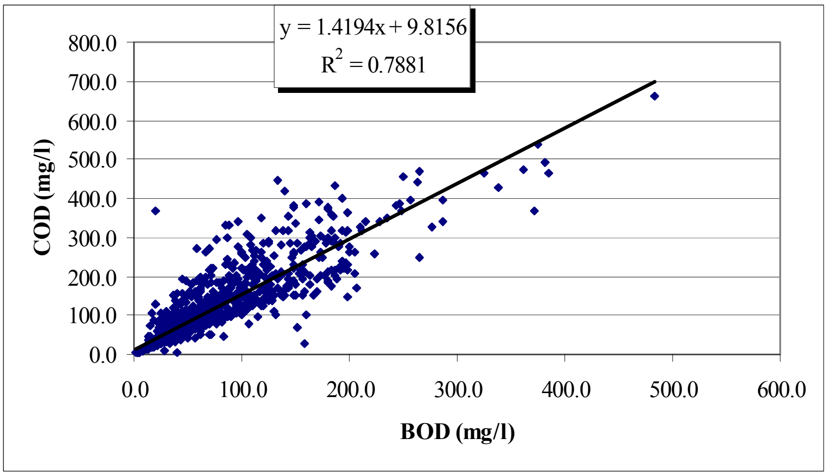


Figure 5-2A: Regression analysis for BOD and COD using **16** sites (case III)

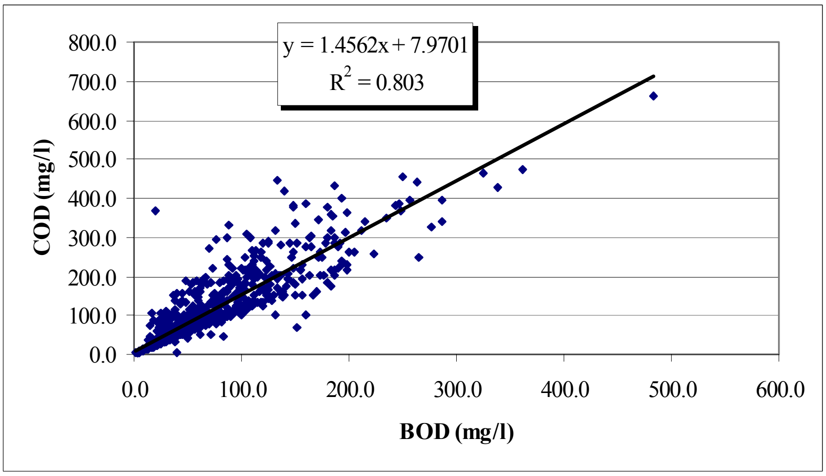


Figure 5-2B: Regression analysis for BOD and COD using **11** sites (case II)

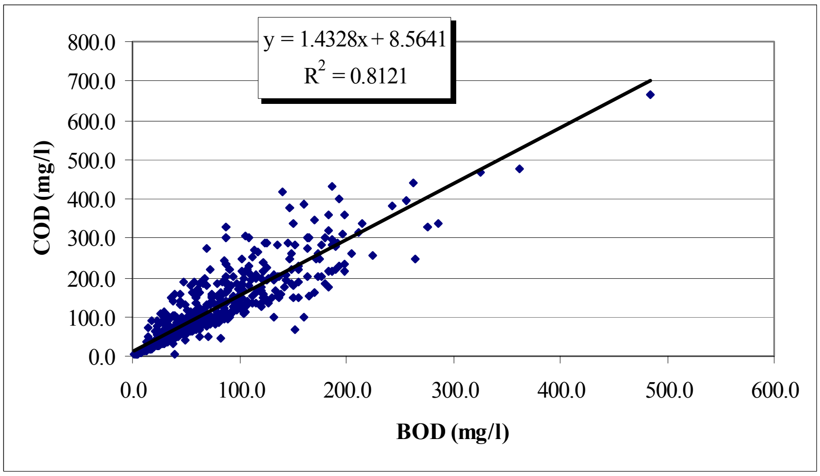


Figure 5-2C: Regression analysis for BOD and COD using **8** sites (case I)

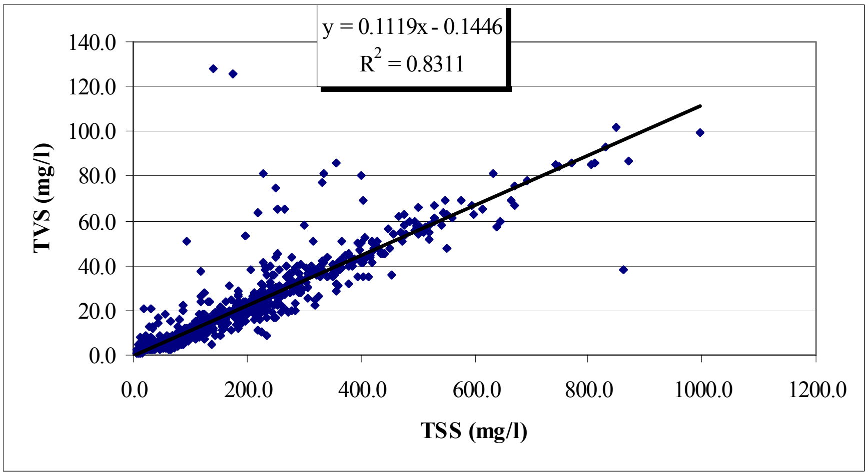


Figure 5-3A: Regression analysis for TSS and TVS using **16** sites (case III)

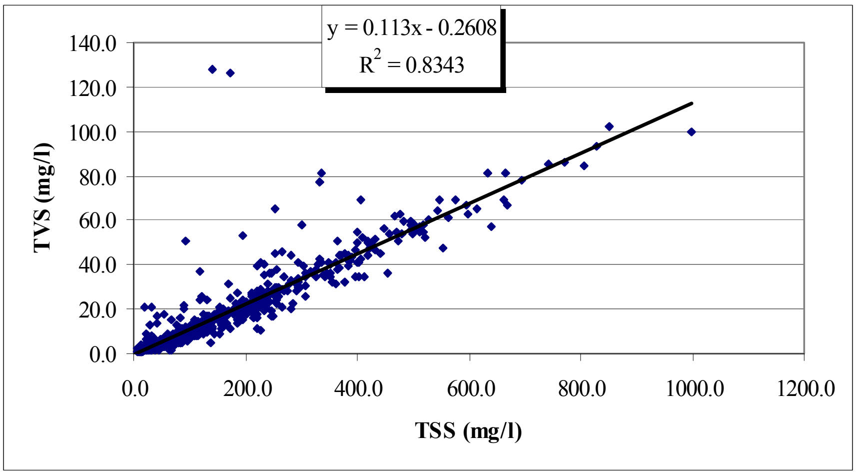


Figure 5-3B: Regression analysis for TSS and TVS using **11** sites (case II)

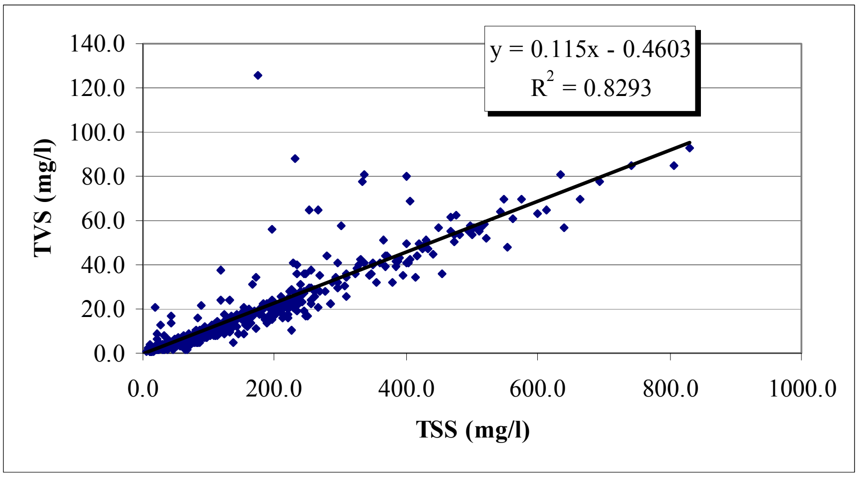


Figure 5-3C: Regression analysis for TSS and TVS using **8** sites (case I)

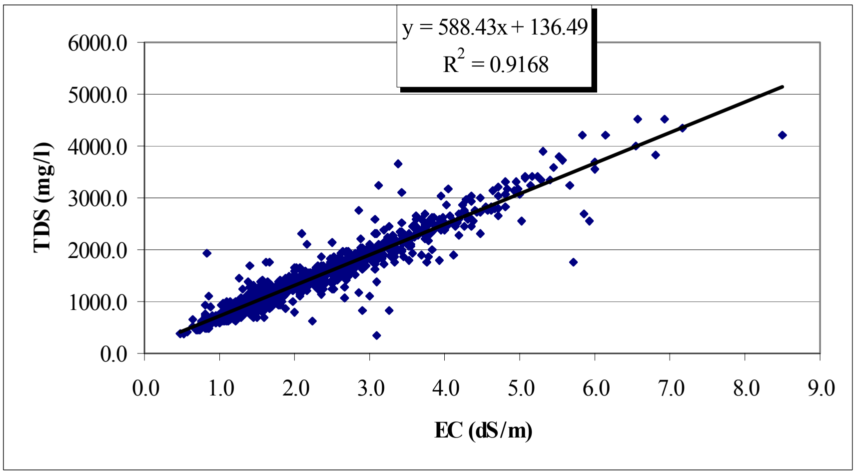


Figure 5-4A: Regression analysis for EC and TDS using **16** sites (case III)

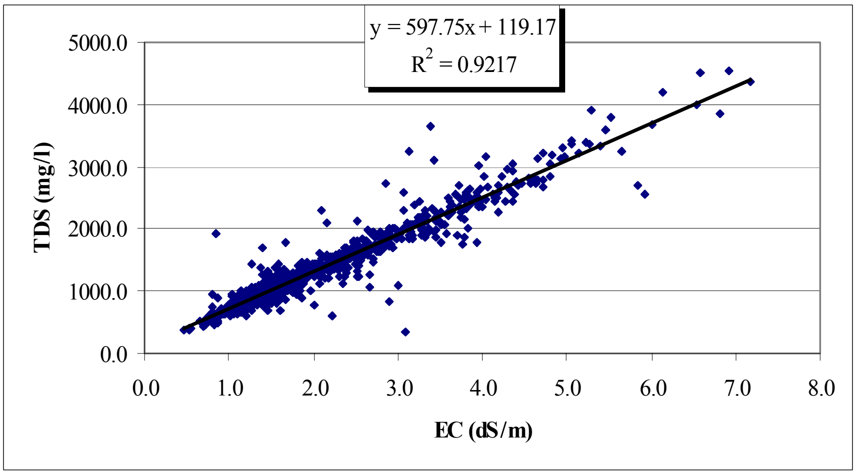


Figure 5-4B: Regression analysis for EC and TDS using **11** sites (case II)

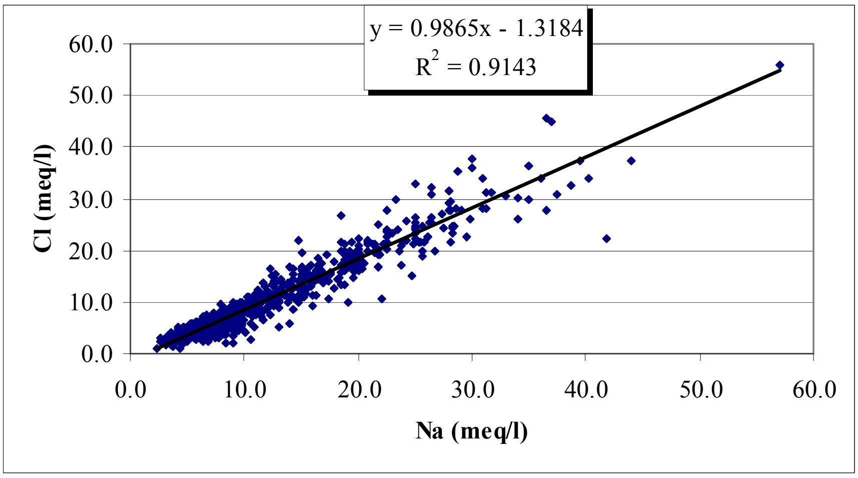


Figure 5-4C: Regression analysis for EC and TDS using **8** sites (case I)

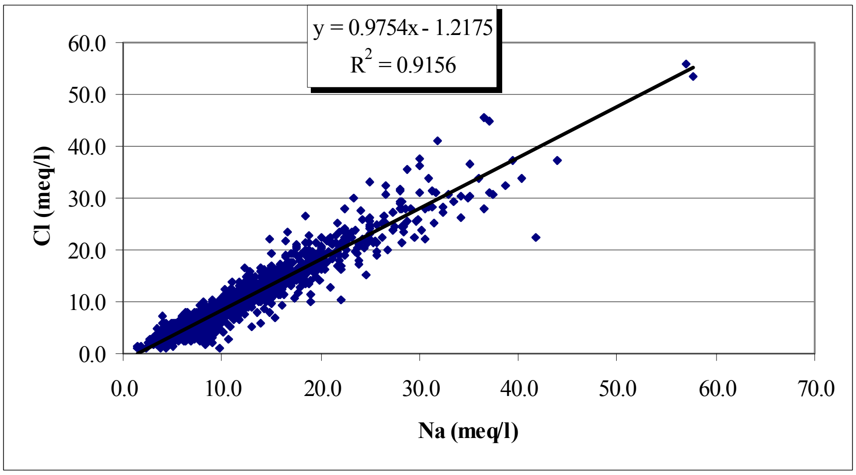


Figure 5-5A: Regression analysis for Na and Cl using **16** sites (case III)

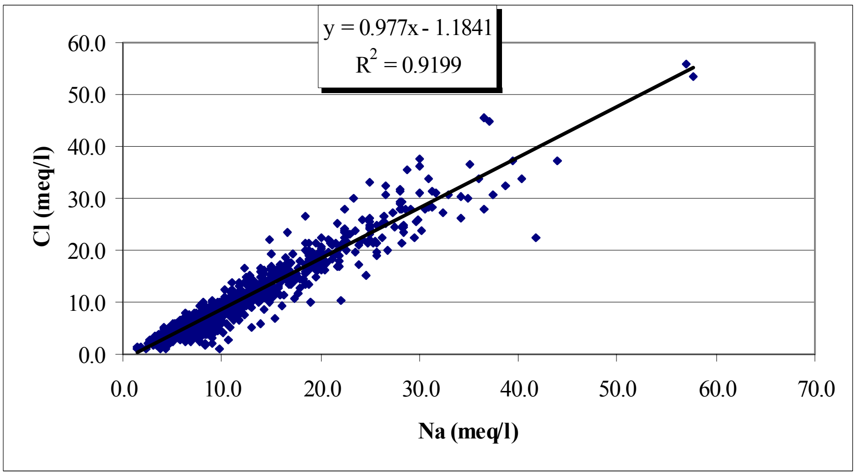


Figure 5-5B: Regression analysis for Na and Cl using **11** sites (case II)

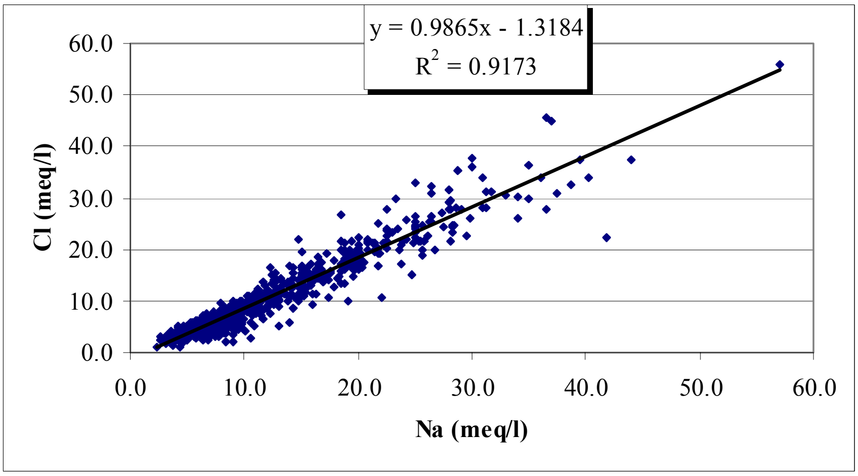


Figure 5-5C: Regression analysis for Na and Cl using **8** sites (case I)

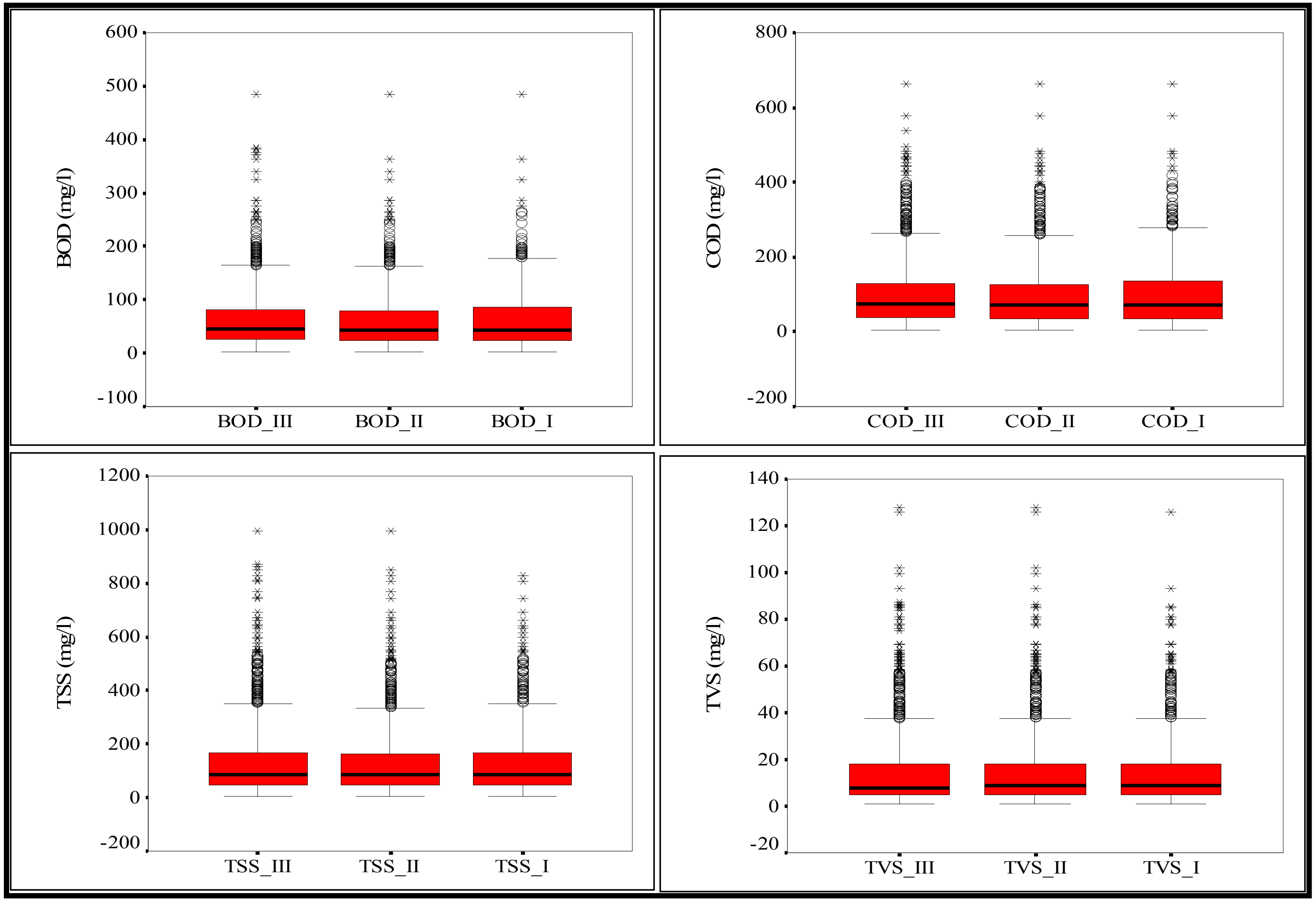


Figure 5-6: Box-plots for some WQPs for the three cases I, II and III

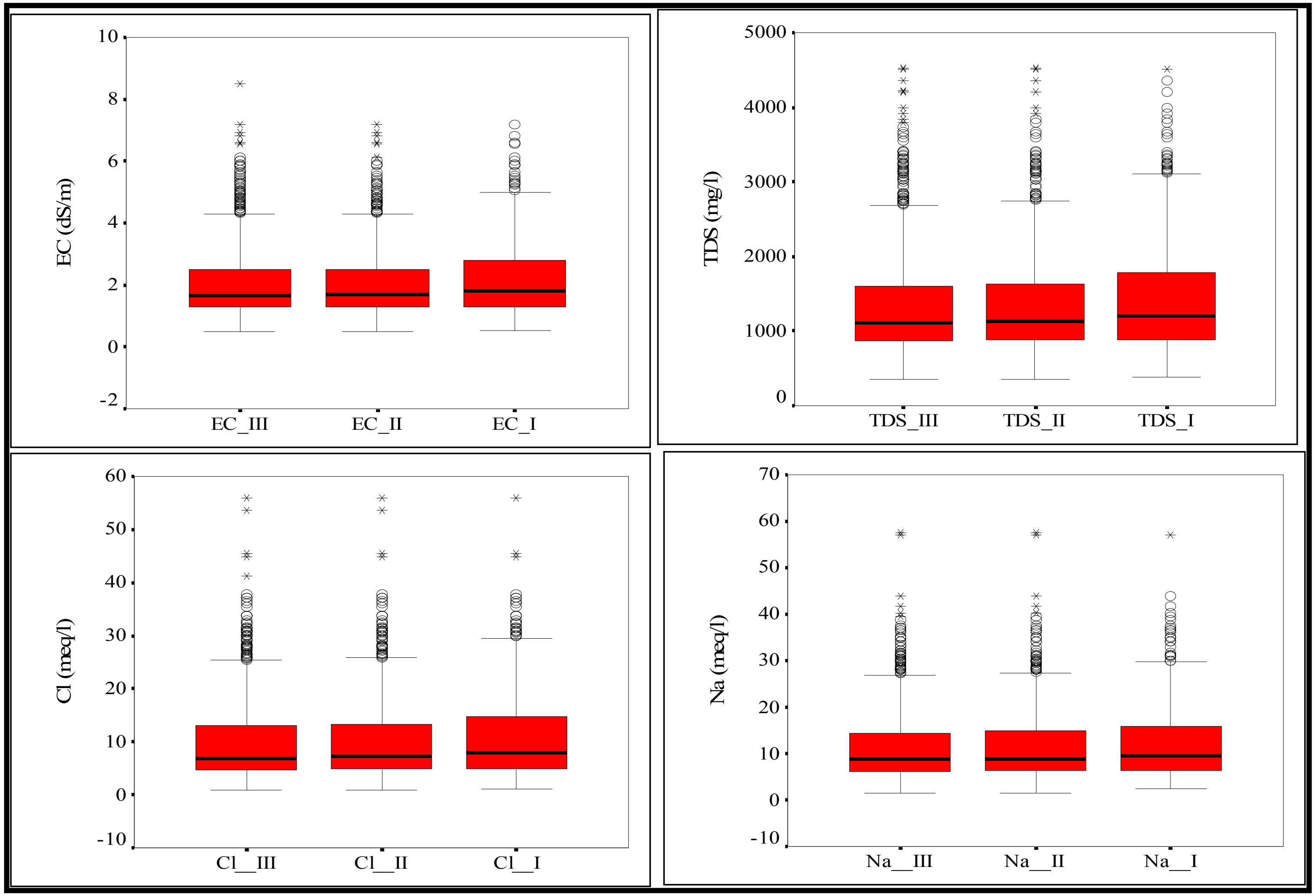


Figure 5-6 Cont.: Box-plots for some WQPs for the three cases I, II and III

Table 5-3: Descriptive statistics for some WQPs for the cases I, II and III

Parameters	N	Range	Minimum	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
					Statistic	Std. Error		Statistic	Std. Error	Statistic	Std. Error
BOD_III	1422	482.1	2.0	484.1	61.9	1.4	54.2	2.2	0.1	7.9	0.1
BOD_II	982	482.1	2.0	484.1	60.0	1.7	53.4	2.2	0.1	7.7	0.2
BOD_I	712	482.1	2.0	484.1	62.2	2.0	54.6	2.1	0.1	7.7	0.2
COD_III	1433	660.0	3.0	663.0	98.8	2.3	88.4	1.9	0.1	4.5	0.1
COD_II	988	660.0	3.0	663.0	96.4	2.8	89.0	2.0	0.1	4.9	0.2
COD_I	718	660.0	3.0	663.0	98.9	3.4	89.9	1.9	0.1	5.0	0.2
TSS_III	1430	993.8	3.0	996.8	130.5	3.5	133.3	2.3	0.1	6.7	0.1
TSS_II	987	993.8	3.0	996.8	132.1	4.2	132.8	2.3	0.1	6.5	0.2
TSS_I	717	826.4	3.0	829.4	131.9	4.9	131.1	2.0	0.1	4.7	0.2
TVS_III	1427	127.2	0.8	128.0	14.6	0.4	16.4	2.4	0.1	7.5	0.1
TVS_II	984	127.2	0.8	128.0	14.8	0.5	16.7	2.5	0.1	8.2	0.2
TVS_I	715	125.0	1.0	126.0	14.8	0.6	16.5	2.3	0.1	6.6	0.2
EC_III	1389	8.0	0.5	8.5	2.0	0.0	1.0	1.6	0.1	3.4	0.1
EC_II	959	6.7	0.5	7.2	2.0	0.0	1.1	1.5	0.1	2.5	0.2
EC_I	701	6.7	0.5	7.2	2.2	0.0	1.1	1.3	0.1	1.5	0.2

Table 5-3 Cont.: Descriptive statistics for some WQPs for the cases I, II and III

Parameters	N	Range	Minimum	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
					Statistic	Std. Error		Statistic	Std. Error	Statistic	Std. Error
TDS_III	1430	4176.0	352.0	4528.0	1318.6	16.9	640.7	1.6	0.1	3.1	0.1
TDS_II	984	4176.0	352.0	4528.0	1339.0	21.3	667.4	1.5	0.1	2.7	0.2
TDS_I	714	4129.4	380.6	4510.0	1411.1	26.5	708.0	1.3	0.1	1.7	0.2
Na__III	1430	56.3	1.4	57.7	11.1	0.2	7.0	1.8	0.1	4.3	0.1
Na__II	984	56.3	1.4	57.7	11.5	0.2	7.4	1.8	0.1	4.5	0.2
Na__I	714	54.6	2.4	57.0	12.2	0.3	7.8	1.5	0.1	2.6	0.2
Cl__III	1430	54.9	1.0	55.9	9.7	0.2	7.1	1.7	0.1	4.1	0.1
Cl__II	984	54.9	1.0	55.9	10.0	0.2	7.5	1.8	0.1	4.2	0.2
Cl__I	714	54.8	1.0	55.9	10.8	0.3	8.0	1.5	0.1	2.6	0.2

5.2.3 Multiple Regression

This section presents the multiple regression results for the case study explained in section 5.1.3. The objective of this case study is to investigate if the information added by measuring at the stations EH07 and EH10 (representing Layer III) can be obtained from the other neighbor locations. More specifically, it is to investigate the hypothesis, which assumes that the monitoring stations EH08 and EH09 already produce most of the information obtained by measuring at EH07 and EH10.

Table 5-4 presents the regression analysis results for the monitoring pairs EH07&EH08 and EH09&EH10 (Annex 4-8C1 and 4-8C4). The table includes the linear regression equations and the Pearson correlation Coefficients (R) for the WQPs BOD, TSS and TDS. The selection of these three parameters was based on two factors. Firstly, these parameters were employed for the previous validation methods (regression analysis, Box-plots and descriptive statistics). This may ensure integrated interpretation for the overall results of the three validation methods. Secondly, they represent three different cases concerning the power of the regression equations. One can easily recognize that the BOD correlations between the monitoring sites within each pair (EH07&EH08 and EH09&EH10) have relatively high R coefficients (0.8599 and 0.8787) then TSS (0.6753 and 0.7827). The TDS represents the cases where the correlation coefficients (0.5474 and 0.2914) are relatively small although the correlations are still statistically significant.

Table 5-4: The regression analysis results for the monitoring pairs EH07&EH08 and EH09&EH10 concerning the parameters BOD, TSS and TDS

Parameters	Regression Equation	R	X	Y
BOD	y = 0.7399x + 10.609	0.8599	EH08	EH07
	y = 1.1214x - 2.2097	0.8787	EH09	EH10
TSS	y = 0.6759x + 49.296	0.6753	EH08	EH07
	y = 0.8886x + 22.477	0.7827	EH09	EH10
TDS	y = 0.6323x + 148.31	0.5474	EH08	EH07
	y = 0.3859x + 1543.8	0.2914	EH09	EH10

Table 5-5 presents the output results of the multiple regression analyses that describe the BOD, TSS and TDS levels at the monitoring site EH11 as functions of the other sites. For every parameter, two cases were developed as following:

- ***Case A***: EH11 was introduced as a dependent variable while the locations EH15, EH06, EH07, EH08, EH09 and EH10 were independents.
- ***Case B***: EH11 was introduced as a dependent variable while the locations EH15, EH06, EH08 and EH09 were independents (EH07 and EH10 were excluded).

Figures 5-7 A, B and C introduce graphical presentations of the previous two cases. Figure 5-7A presents a visual comparison between a measured parameter at EH11 and the estimated values of the same parameter using real measurements for the other six sites (*Case A*). Figure 5-7B presents the same comparison for the second case where EH07 and EH10 were excluded. Finally, Figure 5-7C was developed in order to visualize the effect of removing EH07 and EH10 on the final information obtained from the analysis. The X-axis represents an estimated parameter where real measurements for 6 locations were employed (*Case A*) while the Y-axis represents the same estimated parameter but after excluding EH07 and EH10 (*Case B*).

The results show that measuring BOD, TSS and TDS at only 4 locations were able to produce 99.9%, 94.0% and 91% (respectively) of the total information that can be produced by measuring at 6 locations. In general, one can conclude that the two stations EH07 and EH10 (representing Layer III) do not significantly improve the information quality obtained from the other 4 sites located within the reach between the two open locations EH15 and EH11.

Table 5-5: The multiple regression results describing BOD, TSS and TDS at EH11 as functions of other monitoring sites

BOD (6 locations are measured)						
Intercept	*Coefficients*					
	EH15	EH06	EH07	EH08	EH09	EH10
-4.2628	0.2067	0.2595	-0.0329	0.1820	0.4187	0.0220
Multiple Regression Statistics						
Multiple R	R^2	Adjusted R^2	Standard Error		Observations	
0.943	0.889	0.8813	18.2952		90	
BOD (4 locations are measured, EH07 and EH10 are excluded)						
Intercept	*Coefficients*					
	EH15	EH06	EH07	EH08	EH09	EH10
-4.0688	0.1992	0.2653	-	0.1739	0.4195	-
Multiple Regression Statistics						
Multiple R	R^2	Adjusted R^2	Standard Error		Observations	
0.943	0.889	0.8839	18.0935		90	

TSS (6 locations are measured)						
Intercept	*Coefficients*					
	EH15	EH06	EH07	EH08	EH09	EH10
-1.0218	0.0930	-0.0943	0.1045	0.2896	0.0523	0.4577
Multiple Regression Statistics						
Multiple R	R^2	Adjusted R^2	Standard Error		Observations	
0.882	0.777	0.7611	69.1520		90	
TSS (4 locations are measured, EH07 and EH10 are excluded)						
Intercept	*Coefficients*					
	EH15	EH06	EH07	EH08	EH09	EH10
0.7582	0.0463	0.0781	-	0.5474	0.1600	-
Multiple Regression Statistics						
Multiple R	R^2	Adjusted R^2	Standard Error		Observations	
0.836	0.700	0.6855	79.3480		90	

TDS (6 locations are measured)						
Intercept	*Coefficients*					
	EH15	EH06	EH07	EH08	EH09	EH10
-228.1816	0.2237	0.0633	0.1274	0.3376	0.0319	0.1736
Multiple Regression Statistics						
Multiple R	R^2	Adjusted R^2	Standard Error		Observations	
0.839	0.704	0.6825	215.9850		90	
TDS (4 locations are measured, EH07 and EH10 are excluded)						
Intercept	*Coefficients*					
	EH15	EH06	EH07	EH08	EH09	EH10
-136.5562	0.1717	0.1171	-	0.4966	0.0770	-
Multiple Regression Statistics						
Multiple R	R^2	Adjusted R^2	Standard Error		Observations	
0.802	0.643	0.6262	234.3824		90	

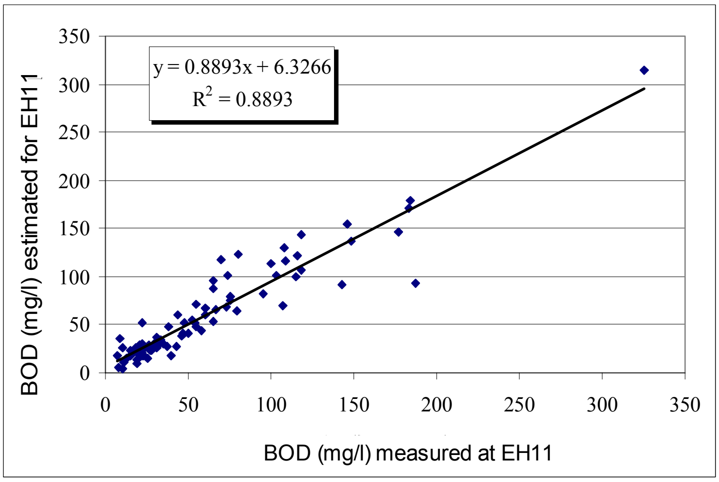


Figure 5-7A1: The measured and estimated BOD levels for the monitoring site EH11 (The estimation based on real measurements at **6** locations)

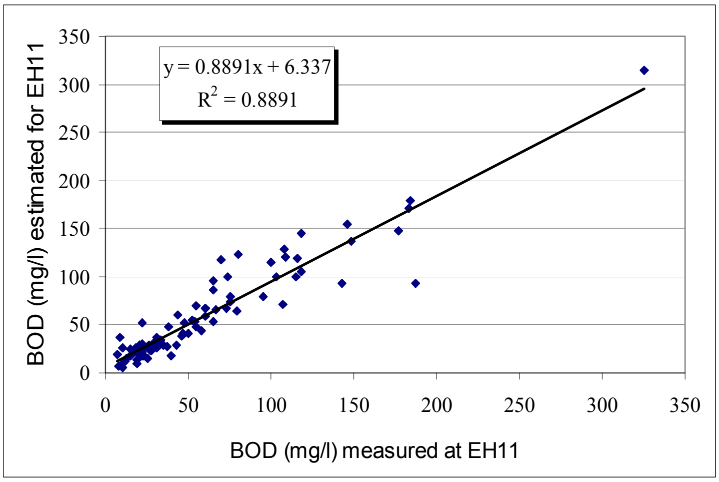


Figure 5-7B1: The measured and estimated BOD levels for the monitoring site EH11 (The estimation based on real measurements at **4** locations)

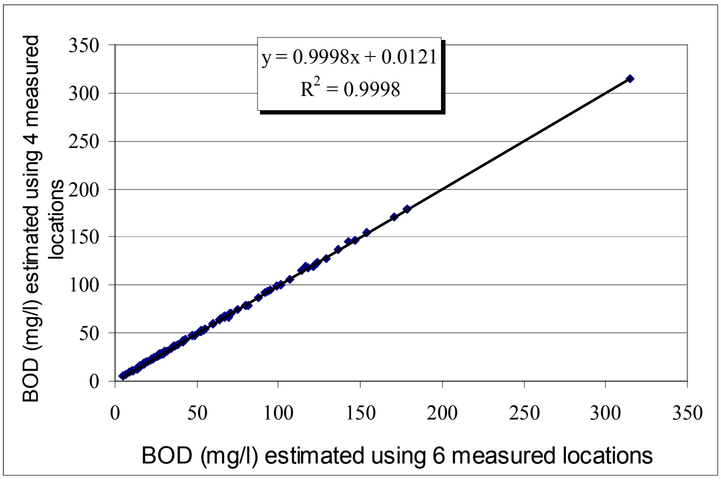


Figure 5-7C1: The BOD levels estimated using measurements at **6** locations versus the BOD levels estimated using measurements at only **4** locations

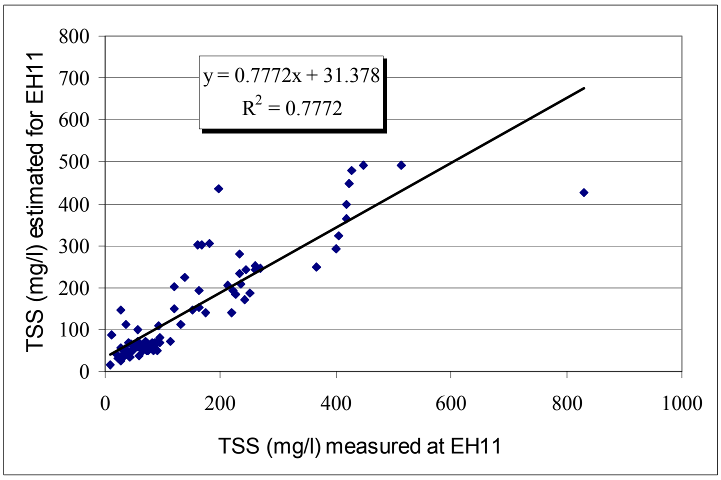


Figure 5-7A2: The measured and estimated TSS levels for the monitoring site EH11 (The estimation based on real measurements at **6** locations)

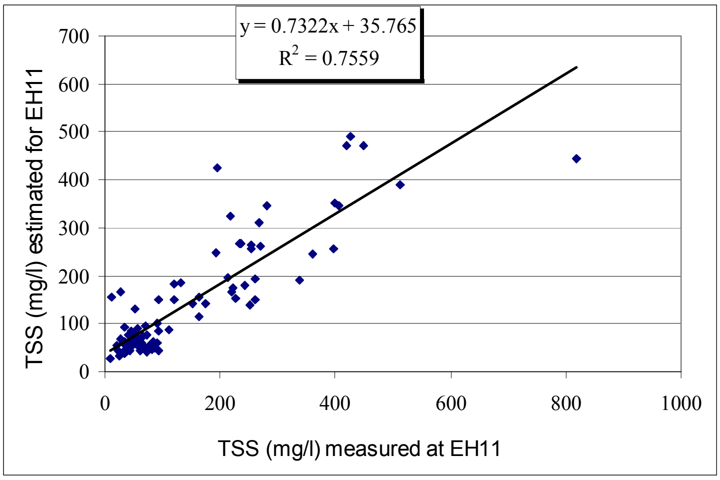


Figure 5-7B2: The measured and estimated TSS levels for the monitoring site EH11 (The estimation based on real measurements at **4** locations)

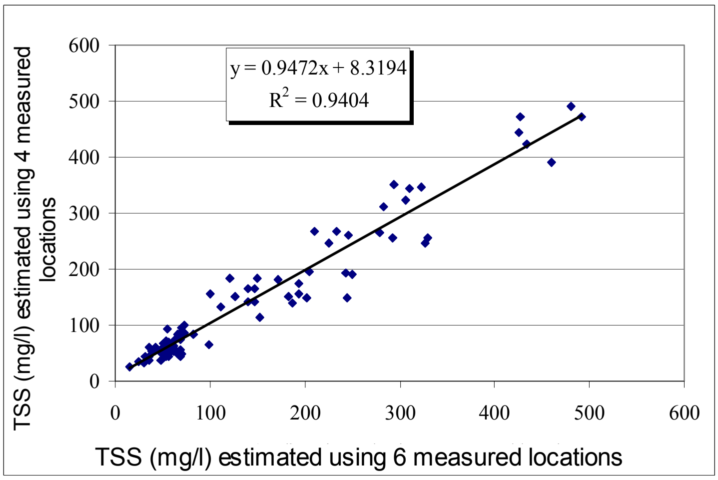


Figure 5-7C2: The TSS levels estimated using measurements for **6** locations versus the TSS levels estimated using measurements for only **4** locations

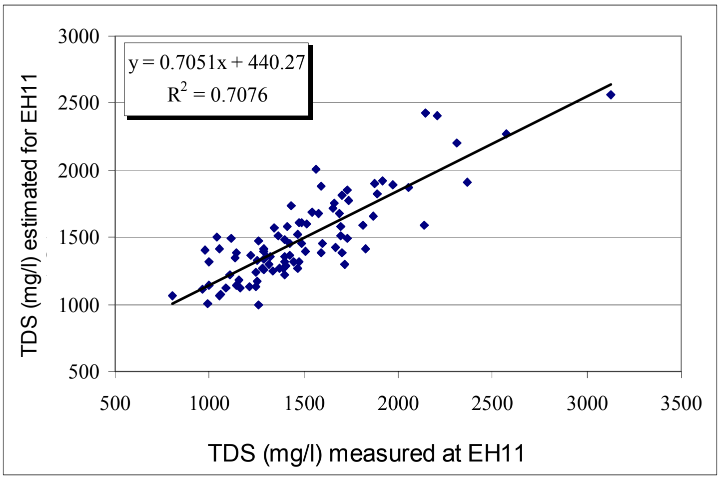


Figure 5-7A3: The measured and estimated TDS levels for the monitoring site EH11 (The estimation based on real measurements at **6** locations)

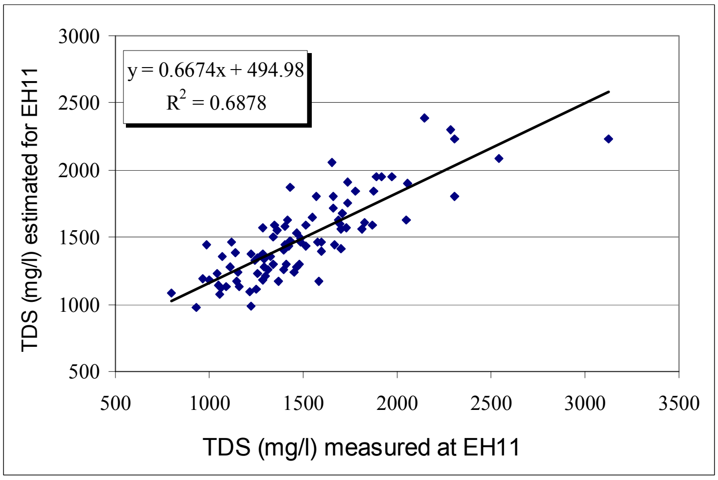


Figure 5-7B3: The measured and estimated TDS levels for the monitoring site EH11 (The estimation based on real measurements at **4** locations)

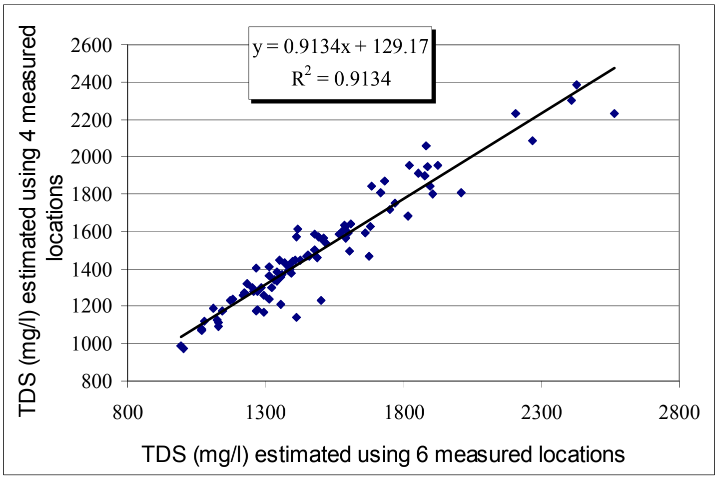


Figure 5-7C3: The TDS levels estimated using measurements for **6** locations versus the TDS levels estimated using measurements for only **4** locations

5.3 SUMMARY AND DISCUSSION

According to the final results obtained in section 4.5, Hadus drain monitoring network was divided into three layers (Figure 4-18). These layers are:

- **Layer I**: eight locations (EH02, EH04, EH15, EH08, EH09, EH11, EH12 and EH17);
- **Layer II**: three locations (EH03, EH06, and EH16) and
- **Layer III**: five locations (EH14, EH18, EH05, EH07 and EH10).

Validating these results was to ensure that any decision concerning the proposed program would not affect its ability to accomplish the monitoring objectives. Therefore, three integrated validation methods were employed. The first method (regression analysis) was to investigate the effect of the number of monitoring locations on some well-known WQ relations. The linear regression analysis was used to formulate the four relationships (BOD-COD, TSS-TVS, EC-TDS and Na-Cl). This formulation process was carried out using three cases: data from 8 sites (Layer I), 11 sites (Layer I and II) and 16 sites (Layers I, II and III).

In this method the focus was on the WQ relations. The Pearson correlation coefficients (R) were used as measures to test the effect of changing the number of monitored sites. The results indicated that there are insignificant differences between the mean values of the R^2 for the three cases. This indicates that reducing the number of monitoring sites from 16 to 11 or even 8 has insignificant effect on the power of information obtained by the regression analysis.

However, the sensitivity of this method may be questionable when the relation between the two parameters is strong enough to minimize or even eliminate the effect of adding or removing some locations in the analysis.

To avoid improper conclusions, Box-plots and some descriptive statistics (second method) were employed for the previous three cases using the eight parameters (BOD, COD, EC, TDS, Na, Cl, TSS and TVS) covered in the regression analysis. The focus here was on the distribution of each parameter rather than its relation with the others. The sizes and positions of the Box-plots were used as measures to investigate the variations of each parameter due to the changes in the number of sites. This visual judgment was supported by the information obtained through the descriptive statistics.

The results show that reducing the number of monitoring sites from 16 to 11 does not significantly affect the distributions of the examined parameters.

Finally, the multiple regression analysis (third method) was employed using three WQPs (BOD, TSS and TDS) in order to formulate the relationships between the monitoring locations in Hadus drain within the reach between the two open locations El-Dawar Bridge (EH15) and Bahr Hadus Bridge (EH11). These parameters at EH11 were estimated using two datasets. They were firstly estimated using data measured at 6 monitoring sites then the analysis was repeated after excluding 2 sites. The estimated parameters for every case were then compared.

The focus here was the information (estimated parameters) that may be produced by the monitoring locations and the Pearson correlation coefficients (R) were used as measures to test the effect of changing the number of monitored sites.

The results show that the two stations EH07 and EH10 (representing Layer III) do not significantly improve the information quality obtained by the other four sites located within the reach between the two open locations EH15 and EH11.

CHAPTER 6

6. SAMPLING FREQUENCY FOR HADUS DRAIN MONITORING NETWORK

Sampling frequency is one of the most important design elements for WQM networks. It significantly affects the sampling cost and can be treated using statistical analyses.

This section presents the sampling frequency evaluation results of the monitoring site “Bahr Hadus Bridge” (EH11). It is the latest open location on the main stream of Hadus drain and was included in the monitoring network **Layer I** with the highest priority level (section 4.5).

6.1 METHODS AND RESULTS

Using the method proposed by Lettenmaier (1976), the sampling frequencies were initially estimated for the 36 WQPs, which were collected (on monthly basis) during the period from August 1997 to January 2005. It has to be mentioned here that the Lettenmaier’s method (1976) was developed under the assumption that the data series follows normal distribution. However, he accepted some non-normality in his data.

Since most of the monthly data (deseasonalised and detrended measurements) used for this analysis did not follow the normal distribution (Annex 6-1), the estimated sampling frequencies had to be evaluated. The evaluation process started with generating new data sets (subsets) from the original data. Then, the common required statistics from the monitoring network were extracted. The different information obtained from different data sets was assessed using visual and statistical comparisons.

The evaluation process was carried out only for the monitored parameters with frequencies less than or equal 12 sample per year where data subsets could be generated from the original data. This process was not possible in case of parameters with frequencies higher than or equal 12 samples per year. In this case, the recommendation was to continue with the current sampling frequency (12 samples per year).

Figure 6-1 shows a flowchart for the analyses procedures, which were carried out in order to recommend the sampling frequencies for 36 WQPs in the monitoring site Bahr Hadus Bridge (EH11). The results can be divided into six sections that present the outcomes of the previous procedures. These sections are as follow:

- Time series Decomposition.
- Autocorrelation functions.
- Effective sampling frequencies.
- Data generation (data subsets).

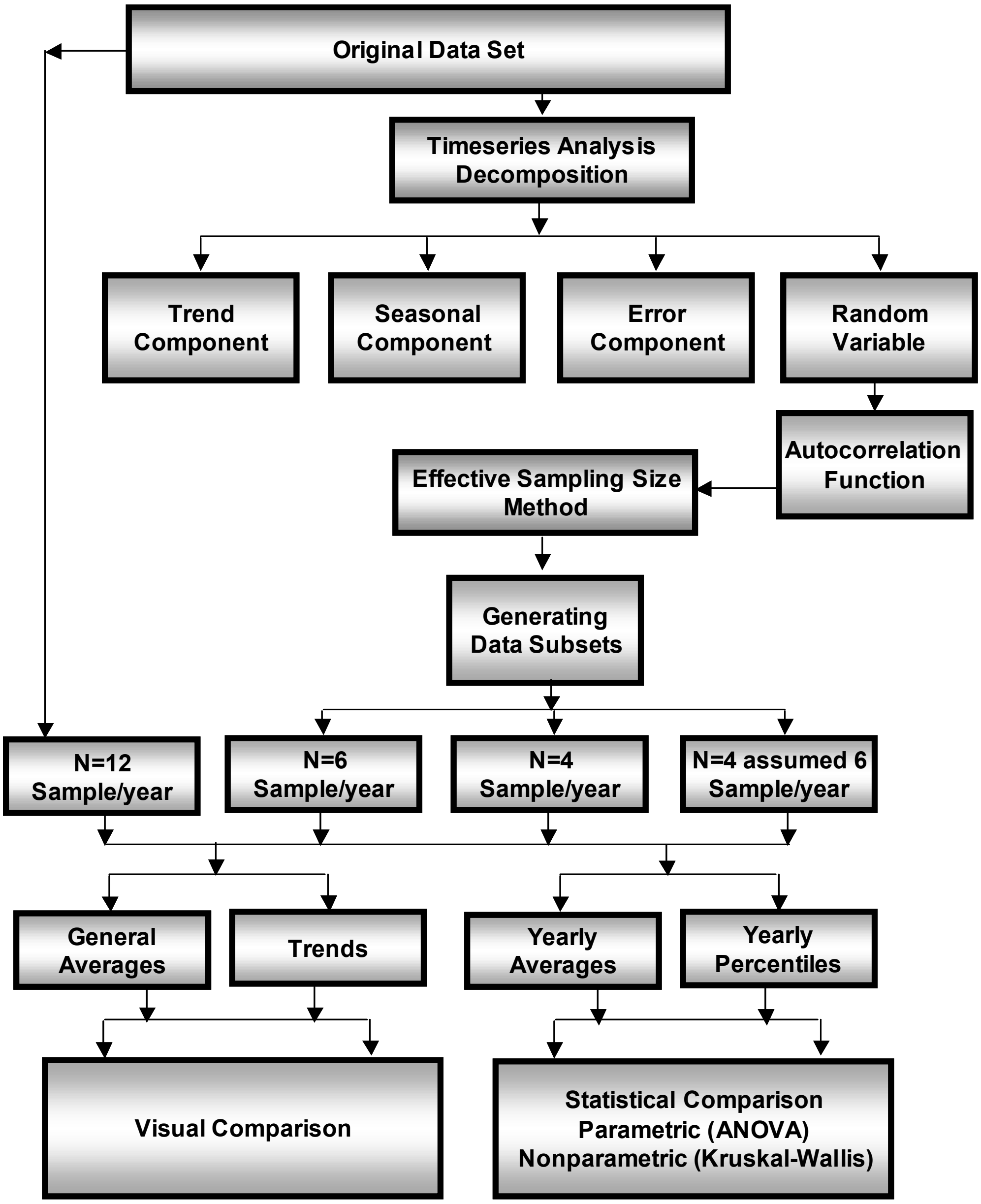


Figure 6-1: Flowchart of the analyses procedures used for estimating sampling frequency for the WQ measurements at Bahr Hadus Bridge (EH11).

- Expected statistics and visual assessment
- Statistical Assessment.

6.1.1 Time Series Decomposition

The main objective of this step is to isolate the basic components of the time series, which include trend, seasonal and random variable components. The information gained from the random variable (stationary series) is more accurate/useful than using the original data set. “Stationary” means that all statistical parameters such as mean, variance, etc. are constant (independent of time).

Census-I method as the most common technique to isolate the previous components was used. As an example, the following section presents the detailed outputs for BOD levels in Bahr Hadus Bridge (EH11) monitoring site. Annex 6-2 presents the MINITAB detailed output for the decomposition process for 36 WQPs measured at the monitoring site EH11. The decomposition process consists of 4 steps:

1. **Isolation of Trend-cycle Component** A trend line was fitted to the original data, using least squares regression. Then, the residuals (de-trended data) were obtained using the „Additive Module“: **Residuals = (Original Series – Trend Component)**.

Figure 6-2 shows the application of the additive module for the BOD measurements in Bahr Hadus Bridge (EH11) respectively.

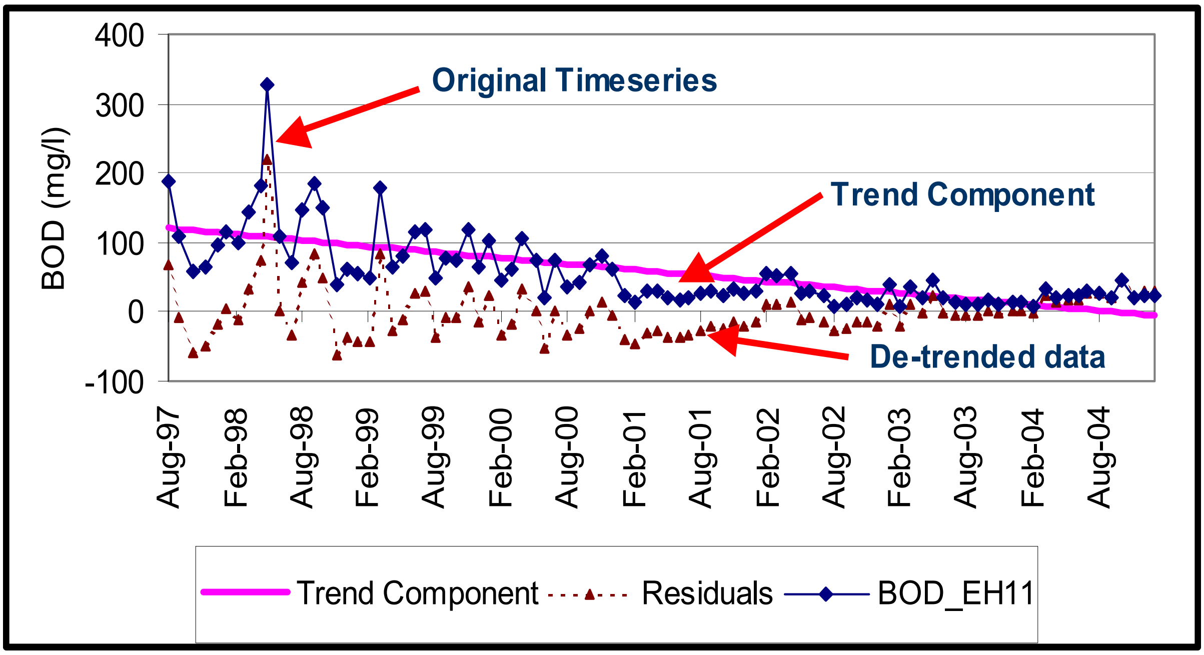


Figure 6-2: De-trending for the BOD measurements at Bahr Hadus Bridge (EH11).

2. **Smoothing the de-trended data** Moving averages were computed for the residuals (de-trended data), with the moving average window width equal to the length of one season. Then, the differences were obtained as following:

Difference = (de-trended data) – (smoothed series).

Figures 6-3 and 6-4 show the smoothing results and the computation of differences using the additive module for the BOD measurements in Bahr Hadus Bridge (EH11) respectively.

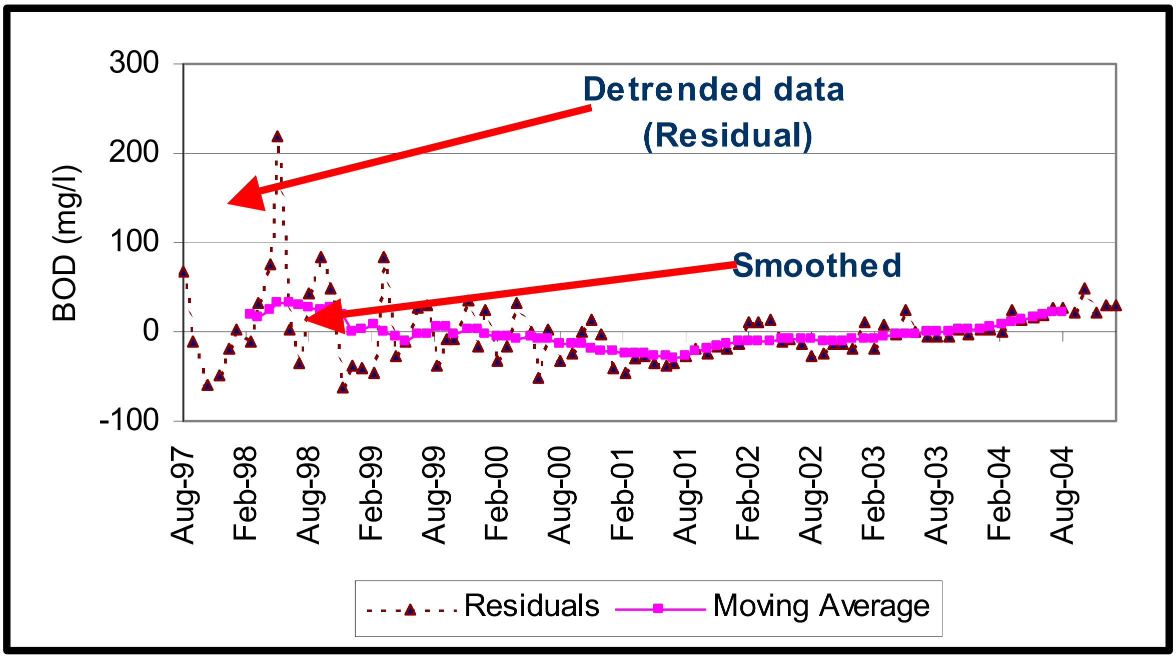


Figure 6-3: Moving average smoothing for the de-trended BOD measurements at Bahr Hadus Bridge (EH11).

3. **Seasonal Component** The seasonal indices (components) were then computed. For each point in the season (every month), the indices were calculated as following

Averages of differences (de-trended – smoothed data)

Figure 6-5 shows the seasonal indices (component) calculated for the BOD measurements in Bahr Hadus Bridge (EH11).

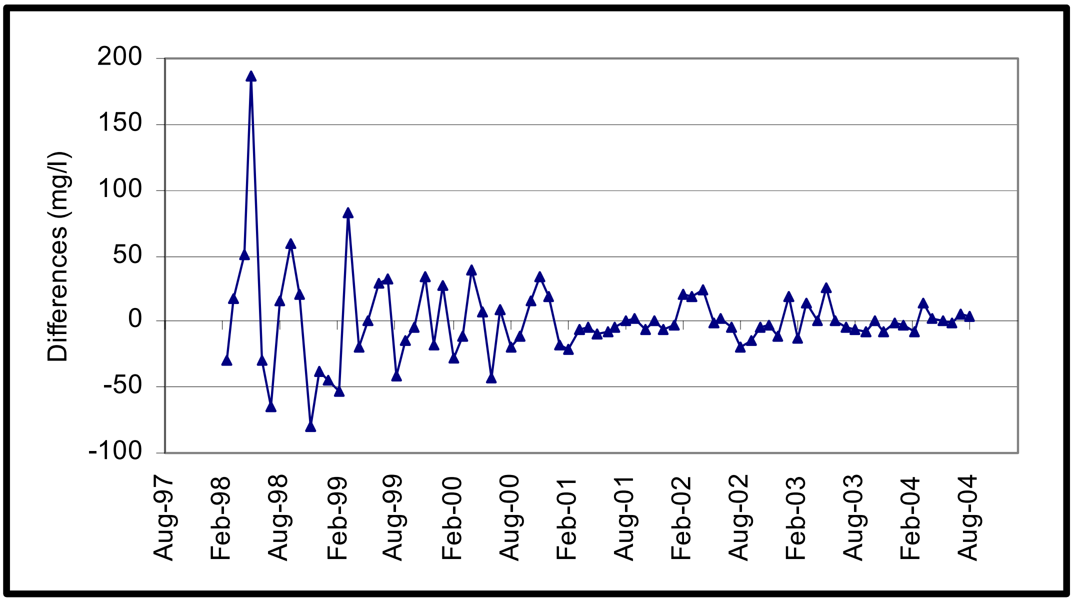


Figure 6-4: Differences (de-trended data – moving averages) for the BOD measurements at Bahr Hadus Bridge (EH11).

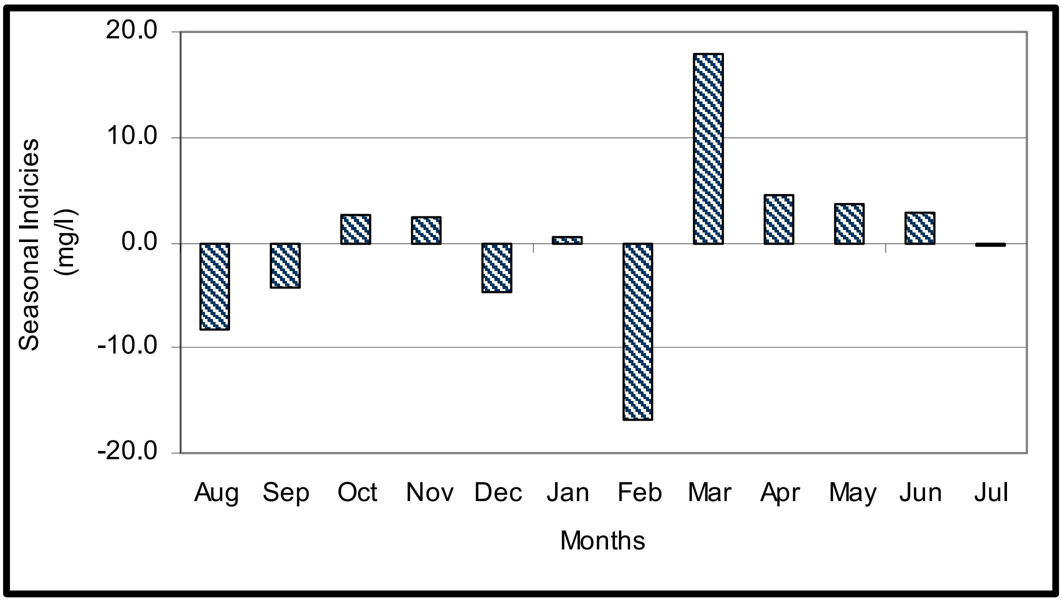


Figure 6-5: Seasonal indices (components) for the BOD measurements at Bahr Hadus Bridge (EH11).

4. **Random Component** This component represents the stationary series, which was calculated by extracting the seasonal component from the de-trended data.

Random component = (De-trended data – Seasonal component).

Figure 6-6 shows the different components of the time series BOD at the monitoring site Bahr Hadus Bridge (EH11) according to the decomposition process, which were carried out using Census-I method.

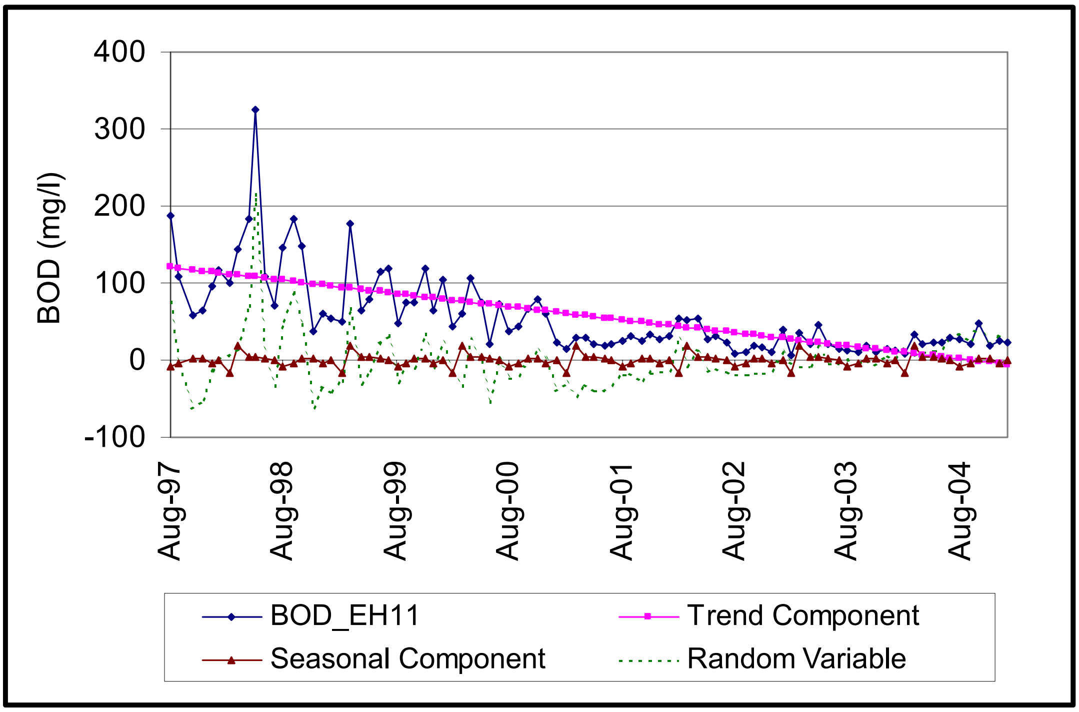


Figure 6-6: Decomposition results of the BOD measurements at Bahr Hadus Bridge (EH11).

6.1.2 Autocorrelation Functions

As a required step for using the Lettenmaier's method (1976), the autocorrelation functions (**ACF**s) for the 36 WQPs measured at EH11 were calculated. The plot of the autocorrelation function (**ACF**) against the lag time is called Correlogram. The values of the Correlogram function vary within range from –1 to +1. A value of one indicates a perfect correlation, while a zero indicates no correlation. It has to be mentioned here that seasonality and trends affect the correlogram function. Therefore, the time series were adjusted (detrended and deseasonalized) before creating the Correlogram. Figure 6-7 shows the Correlogram for the adjusted BOD data at the monitoring site (EH11).

Annex 6-3 presents the Correlograms for the adjusted 36 WQ data measured at the monitoring site (EH11).

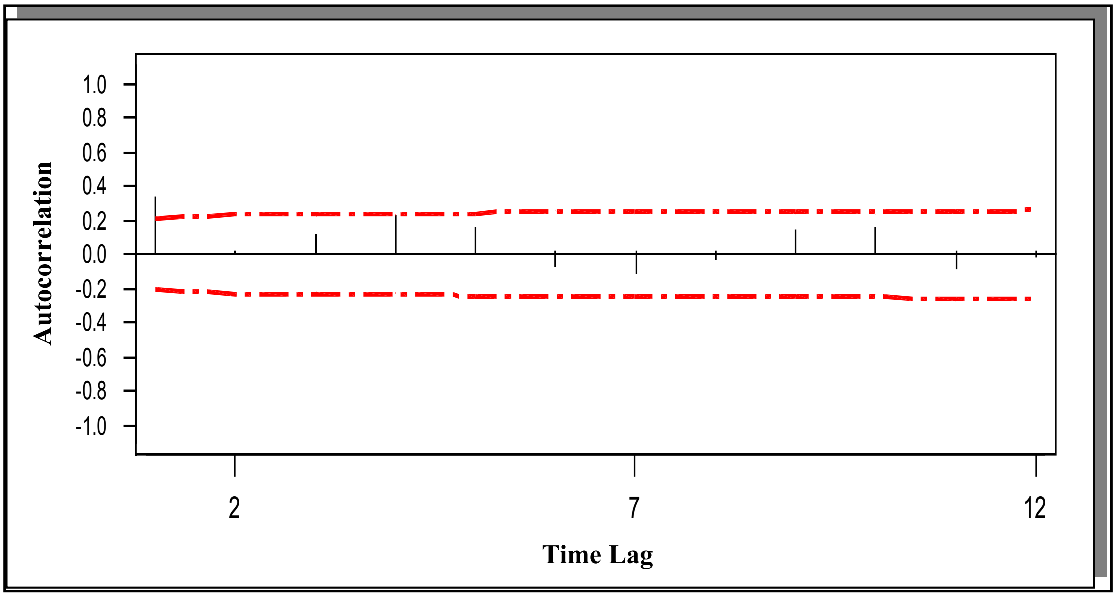


Figure 6-7: The Correlogram for the adjusted BOD measurements at Bahr Hadus Bridge (EH11).

6.1.3 Effective Sampling Frequencies

Recalling section 3.4.2.3, the effective numbers of samples per year were calculated from the following Equation

$$\frac{1}{n^*}=\frac{1}{n}+\frac{2}{n^2}\sum_{k=1}^{n-1}(n-k)ACF_k$$

Where:

k	:	lag number or interval of time between successive observation
n	:	number of samples per year based on a proposed sampling frequency
n^*	:	"effective" number of samples taken per year
ACF_k	:	autocorrelation coefficient for lag k

Table 6-1 presents the results of applying the previous formula for the WQPs measured at EH11. Based on this initial estimation of sampling frequencies, these parameters were categorized into four parameter groups as following:

- **Parameter Group 1** ($n^* \leq 4$ samples per year) includes COD, TSS, TVS, N-NO_3, Pb, Ca, Na, SAR, Adj. SAR, Cl and Visib.
- **Parameter Group 2** ($4 < n^* \leq 6$ samples per year) includes BOD, Cu, Fe, Mn, pH, TDS, K, SO_4, SO_{4_m}. and DO.
- **Parameter Group 3** ($6 < n^* \leq 12$ samples per year) includes Mg, EC, Br, Ni, Sal, Cd, TN, TP, Temp, Fecal, Coli and N-NH_4.

- **Parameter Group 4** (n* > 12 samples per year) includes Zn and P.

Due to the presence of many missing values in the Turb measurements, the calculation of its autocorrelation function was failed. Therefore, It was assumed to be a member in parameter group 4.

Table 6-1: Initial estimation of sampling frequencies for the WQPs measured at Bahr Hadus Bridge (EH11).

Parameters	Sampling Frequency (Samples /year)	Parameters	Sampling Frequency (Samples /year)
Coli (MPN/100ml)	10.80	Ca (meq/l)	3.68
BOD (mg/l)	5.65	Mg (meq/l)	6.58
COD (mg/l)	3.99	Na (meq/l)	3.86
TSS (mg/l)	2.74	K (meq/l)	4.19
TVS (mg/l)	4.00	SO_4 (meq/l)	4.58
$N\text{-}NO_3$ (mg/l)	2.94	Cl (meq/l)	3.91
$N\text{-}NH_4$ (mg/l)	11.25	SAR	3.62
P (mg/l)	25.10	Adj_SAR	3.67
Cd (mg/l)	8.80	Temp (C^o)	10.36
Cu (mg/l)	5.89	Sal	8.35
Fe (mg/l)	4.26	DO (mg/l)	4.44
Mn (mg/l)	5.04	Turb (NTU)	NA
Zn (mg/l)	18.84	Visib (Cm)	1.93
Pb (mg/l)	2.80	Fecal (MPN/100ml)	10.64
Br (mg/l)	7.62	TP (mg/l)	10.33
pH	5.11	TN (mg/l)	9.34
EC (dS/m)	6.69	Ni (mg/l)	8.11
TDS (mg/l)	5.76	SO_{4_m} (meq/l)	5.92

6.1.4 Data Generation (Data Subsets)

Different data subsets were generated from the original measurements in order to facilitate the evaluation process of the information obtained from each set. Since the available data was collected on monthly basis, the generation process was carried out only for the first two groups (n* ≤ 4 and 4 < n* ≤ 6) as following:

1. **Parameter Group 1** (n* ≤ 4)

For this group, the following two possibilities were examined:

- ***Assuming n* = 6 samples per year (every two months):*** two data subsets A and B were generated. The first subset A included measurements started at August till June while the second subset B started at September till July (Figure 6-8). In this case, serial correlation may exist.

- ***Assuming n* = 4 samples per year (every three months):*** three data subsets C, D and E were generated. The first subset C includes the measurements started at August till May, subset D started at September till June and subset E started at October till July (Figure 6-9).

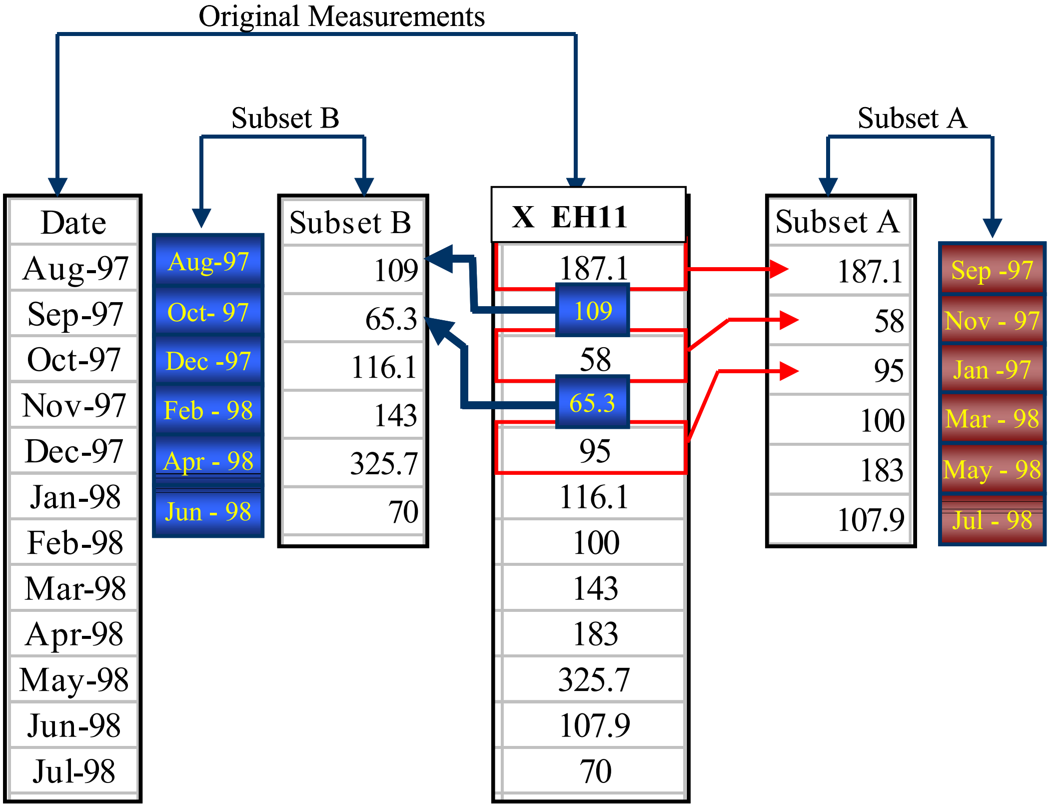


Figure 6-8: Example of data subsets generation from the original measurements X when sampling frequency assumed to be 6 samples per year.

2. **<u>Parameter Group 2</u>** (4 < n* ≤ 6)

For this group, one possibility was examined:

- ***Assuming n* = 6 samples per year (every two months):*** two data subsets A and B were generated as shown in (Figure 6-8).

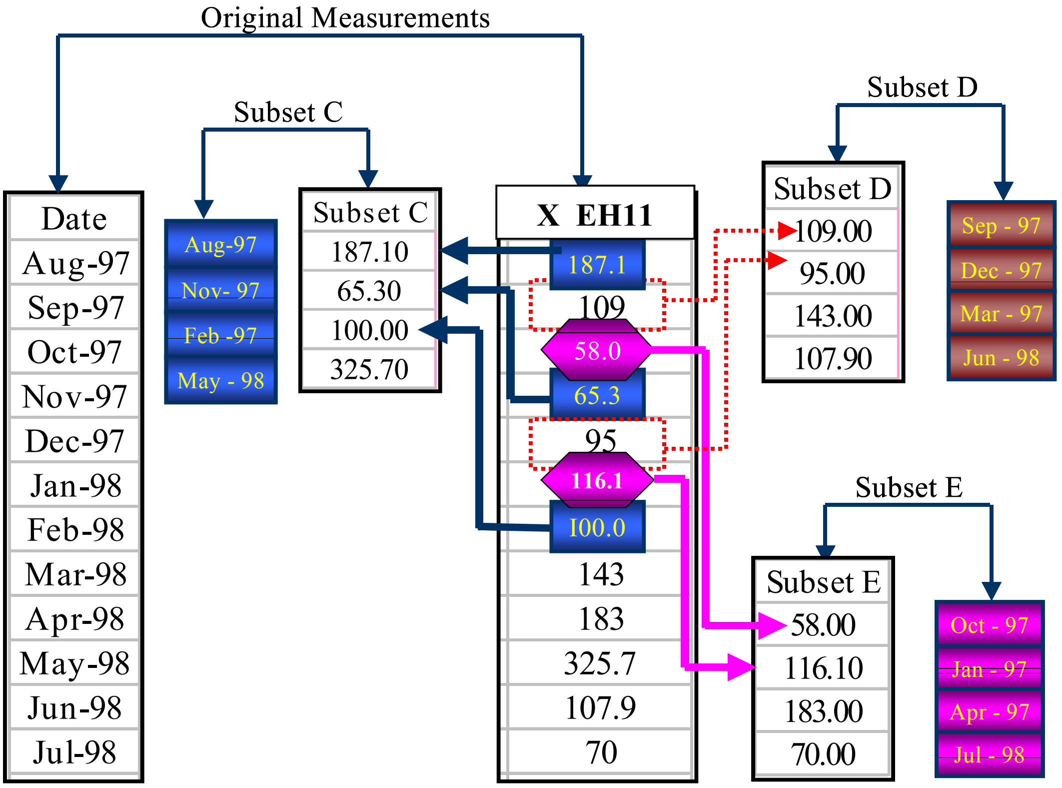


Figure 6-9: Example of data subsets generation from the original measurements X when sampling frequency assumed to be 4 samples per year.

6.1.5 Expected Statistics and Visual Assessment

Some required (expected) statistics from the monitoring network was discussed with the DRI team. As a result, the following statistical items were considered in further analysis:

- **Trend (slope)**: the rate of change for a certain WQP with time. It can be also defined as the slope of the trend component extracted from the time series of that parameter.
- **General Average:** The mean value of the WQ measurements within a period of time. The ***Mean*** is an informative measure of the "central tendency" of the variable and is computed as the sum of the variable divided on the number of cases.
- **Percentiles:** The percentile of a distribution of values is a number X_p such that a percentage p of the population values are less than or equal to X_p. For example, the 25th percentile (also referred to as the 0.25 quantile or lower quartile) of a variable is a value (X_p) such that 25% (p) of the values of the variable fall below that value. Similarly, the 75th percentile (also referred to as the 0.75 quantile or upper quartile) is a value such that 75% of the values of the variable fall below that value and is calculated accordingly.

- **Yearly Averages:** for eight years monitoring, the mean values of the WQ measurements for each year were computed as the sum of the variable divided by the number of samples per year.
- **Yearly Percentiles (90%):** for eight years monitoring, the 90% percentile values of the WQ measurements for each year were computed.

Table 6-2 and Figures 6-10 to 6-15 present examples for the previous statistics obtained from the BOD (mg/l) measured at EH11 ($4 < n^* \leq 6$) where the estimated frequency n^* was assumed to be 6 samples per year.

The previous five items (trend, general averages, percentiles, yearly averages and yearly percentiles) were calculated and then plotted two times for the WQPs in the first parameter group ($n^* \leq 4$). The first time, sampling frequency was assumed to be 6 samples per year. In the second time, it was assumed to be 4 samples per year.

Annex 6-4A shows the detailed output results for the first case ($n^* = 6$) when Annex 6-4B shows the output for the same parameters for the second case ($n^* = 4$).

The same five items were also calculated and plotted for the WQPs in the second parameter group ($4 < n^* \leq 6$) assuming that the sampling frequency was 6 samples per year. Annex 6-5 shows the detailed output results for those parameters.

Table 6-2: Pre-selected statistics for BOD (mg/l) measured at Bahr Hadus Bridge (EH11).

Statistics		12 Samples/year	6 Samples/year	
		Original Data	Subset A	Subset B
Trend	Equation	Yt = 121.26 - 1.41*t	Y = 113.54 - 2.62*t	Y = 130.7 - 3.04*t
	Slope	-1.39	-1.28	-1.48
General Averages	Mean	57.13	53.36	60.89
General Percentiles	25%	21.00	21.00	22.00
	50%	37.35	37.00	36.35
	75%	73.75	65.00	74.43
	90%	118.00	112.16	118.00
Yearly Averages	year 1	130.01	121.83	138.18
	year 2	102.97	97.40	108.53
	year 3	71.99	60.00	83.98
	year 4	36.75	37.83	35.67
	year 5	34.50	36.17	32.83
	year 6	20.67	14.17	27.17
	year 7	18.00	16.17	19.83
	year 8	27.17	33.33	21.00
Yearly 90% Percentiles	year 1	130.01	121.83	138.18
	year 2	102.97	97.40	108.53
	year 3	71.99	60.00	83.98
	year 4	36.75	37.83	35.67
	year 5	34.50	36.17	32.83
	year 6	20.67	14.17	27.17
	year 7	18.00	16.17	19.83
	year 8	27.17	33.33	21.00

Note: The first month of the series has t value equals to 1 and the second equals to 2 and so on.

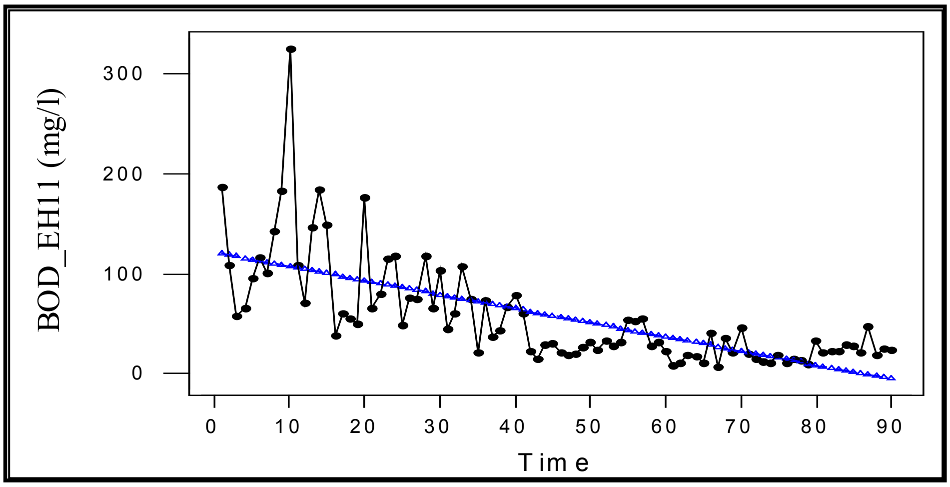


Figure 6- 10: Trend component for the original BOD data at EH11

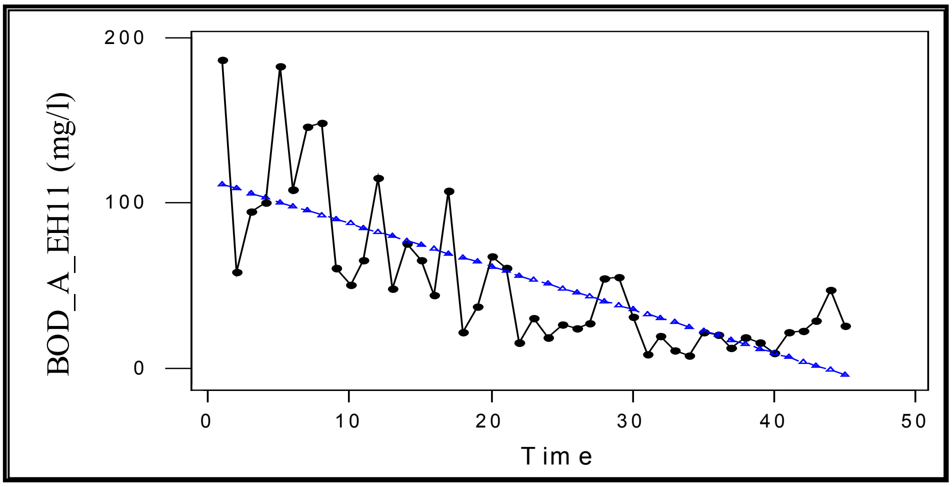


Figure 6- 11: Trend component for the BOD data subset A at EH11.

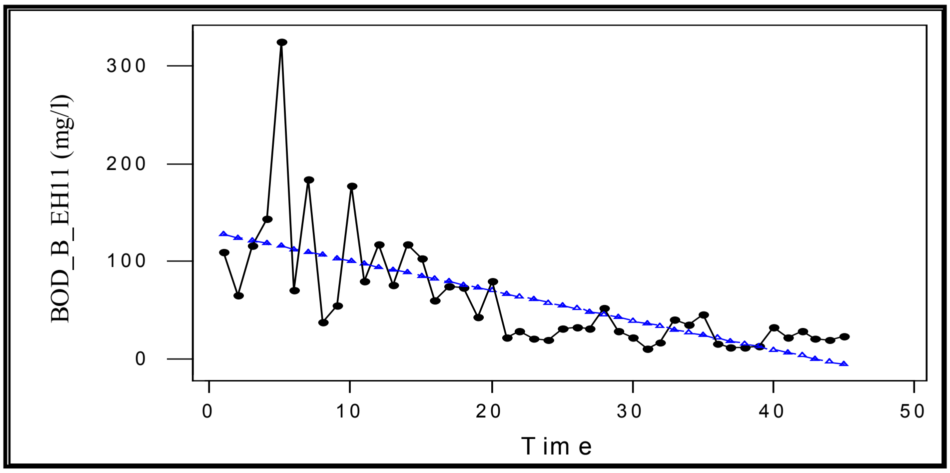


Figure 6- 12: Trend component for the BOD data subset B at EH11.

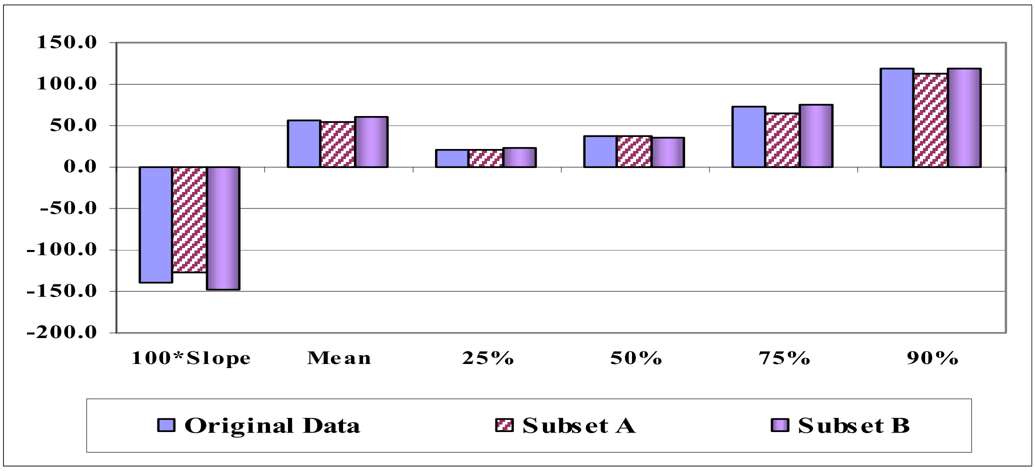


Figure 6- 13: Pre-selected statistics for the BOD original measurements and subsets A&B

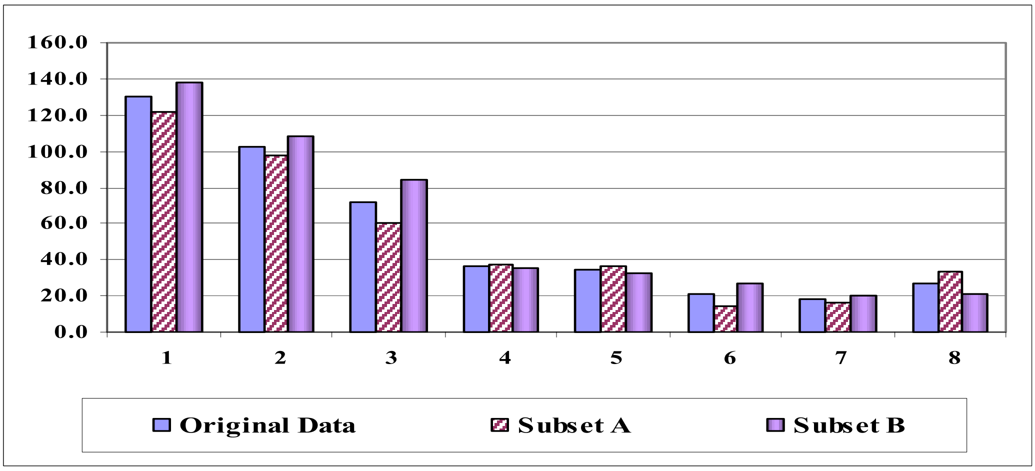


Figure 6- 14: Yearly averages for the BOD original measurements and subsets A&B

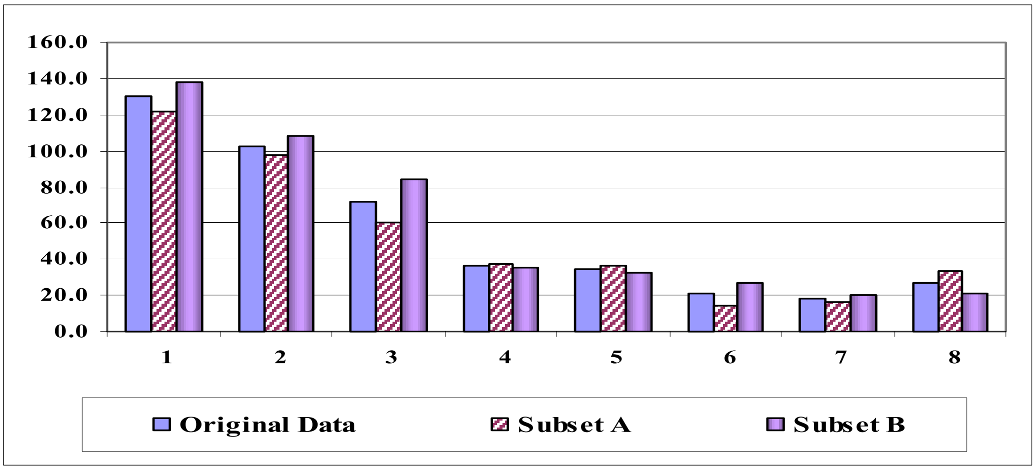


Figure 6- 15: Yearly percentiles for the BOD original measurements and subsets A&B

6.1.6 Statistical Assessment

The analysis of variance (ANOVA) is a parametric test, determining whether population means are equal. ANOVA assumes that the data are normally distributed around their respective means and have equal variance. When data cannot be assumed to be normally distributed or have identical variances, a nonparametric test should be used instead. The Kruskal-Wallis test is the nonparametric equivalent to one-way ANOVA. It compares the medians of groups differentiated by one explanatory variable (one factor) (Helsel and Hirsch, 2002).

In order to investigate significant differences between, yearly averages and 90% yearly percentiles calculated from the original measurement, and same statistics obtained from data subsets A and B ($n^* = 6$) or C, D and E ($n^* = 4$), the previous two tests (one way ANOVA and Kruskal-Wallis test) were carried out.

The process of investigating the previous differences was carried out two times for the WQPs in the first group ($n^* \leq 4$). The first time, sampling frequency was assumed to be 6 samples per year. In the second time, it was assumed to be 4 samples per year. Annex 6-6A shows the detailed output results for the first case ($n^* = 6$) when Annex 6-6B shows the output for the same parameters for the second case ($n^* = 4$).

The same process was also carried out for the WQPs in the second parameter group ($4 < n^* \leq 6$) assuming that the sampling frequency was 6 samples per year. Annex 6-7 shows the detailed output results for the latest case.

Table 6-3 shows an example, which includes the detailed results for the pre-selected tests carried out for the BOD (mg/l) measured at EH11. These tests are the Kolmogorov-Smirnov and Shapiro-Wilk, one-way analysis of variance (ANOVA), test of homogeneity of variances and Kruskal Wallis test.

6.1.7 Summary Results

- **<u>Parameter Group 1</u>** ($n^* \leq 4$)

The pre-selected statistical items (trend, general averages, percentiles, yearly averages and yearly percentiles) were calculated and then plotted two times. The first time, sampling frequency was assumed to be 6 samples per year. In the second time, it was assumed to be 4 samples per year. The followings some observations obtained from the analysis:

- Eleven WQPs are included in this parameter group (COD, TSS, TVS, N-NO_3, Pb, Ca, Na, Cl, SAR, Adj. SAR and Visib).

- When n* assumed to be 6 samples per year, the parameters Na, SAR and Adj. SAR show (relatively) clearer differences in the trend (slope) magnitudes between the three data sets (original data and subsets A and B). Lesser differences can be seen in TVS, Visib, Ca and Cl.
- When n* assumed to be 4 samples per year, the parameters Na and Ca show (relatively) clearer differences in the trend (slope) magnitudes between the four data sets (original data and subsets C, D and E). Lesser differences can be seen in TVS, Pb, Cl, SAR and Adj. SAR.
- In both cases, n* assumed to be 4 and 6 samples per year, almost all parameters did not show clear differences for the mean values of all the data sets.
- When n* assumed to be 6 samples per year, the parameters TSS and TVS show (relatively) clearer differences for the 90% percentile values between the three data sets (original data and subsets A and B).
- When n* assumed to be 4 samples per year, the parameter Pb shows (relatively) clearer differences for the 25% percentile values between the four data sets (original data and subsets C, D and E). Lesser differences can be seen in Pb 50% percentiles and COD at 75% and 90% percentiles.
- When n* assumed to be 6 samples per year, the parameter TVS in the first water year (1997-1998) of measurements shows (relatively) clearer differences in the yearly average values between the three data sets (original data and subsets A and B). Lesser differences can be seen in SAR at the water year (2002-2003). However, both ANOVA and Kruskal-Wallis test results indicate that all differences are insignificant.
- When n* assumed to be 4 samples per year, the parameters TVS (1997-1998) and N-NO_3 (2004-2005) show (relatively) clearer differences in the yearly average values between the four data sets (original data and subsets C, D and E). Lesser differences can be seen in TSS (1999-2000). However, both ANOVA and Kruskal-Wallis test results indicate that all differences are insignificant.
- When n* assumed to be 6 samples per year, the parameter TVS (1997-1998) shows (relatively) clearer differences in the 90% yearly percentile values between the three data sets (original data and subsets A and B). Lesser differences can be seen in TSS (1997-1998 and 1999-2000) and SAR (2002-2003). However, both ANOVA and Kruskal-Wallis test results indicate that all differences are insignificant.
- When n* assumed to be 4 samples per year, the parameters TVS (1997-1998), TSS (1999-2000), SAR (2002-2003), Visib (1997-1998) and N-NO_3 (2004-2005) show

(relatively) clearer differences in the 90% yearly percentile values between the four data sets (original data and subsets C, D and E). However, both ANOVA and Kruskal-Wallis test results indicate that all differences are insignificant.

- **Parameter Group 2** ($4 < n^* \leq 6$)

The same five statistical items were also calculated and plotted for the WQPs in this group ($4 < n^* \leq 6$) assuming that the sampling frequency was 6 samples per year. The followings are some observations obtained from the analysis:

- Ten WQPs are included in this group (BOD, Cu, Fe, Mn, pH, TDS, K, SO_4, SO_{4_m} and DO).
- The parameters TDS and pH show (relatively) clearer differences in the trend (slope) magnitudes between the three data sets (original data and subsets A and B). Lesser differences can be seen in Cu, Fe, SO_{4_m} and DO.
- Almost all parameters did not show clear differences for the mean values of all the data sets.
- The parameter Cu shows (relatively) clearer differences for the 90% percentile values between the three data sets (original data and subsets A and B). Lesser differences can be seen in Fe 75% percentile values.
- The parameter Fe in the water year (2001-2002) shows (relatively) clearer differences in the yearly average values between the three data sets. However, both ANOVA and Kruskal-Wallis test results indicate that all differences are insignificant.
- The parameters TDS (2001-2002) and DO (2003-2004) show (relatively) clearer differences in the 90% yearly percentile values between the three data sets. Lesser differences can be seen in DO (2001-2002). However, both ANOVA and Kruskal-Wallis test results indicate that all differences are insignificant.

Table 6-3: The detailed results for the pre-selected tests carried out for the BOD (mg/l) measured at EH11.

The results of normality tests applied for the yearly averages obtained from the original data set (12 sample/year) and data subsets A and B (6 sample/year).

Parameters	Data group	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
BOD	Original Data	0.205	5	0.200	0.856	5	0.267
	Subset A	0.294	5	0.182	0.742	5	0.038
	Subset B	0.216	5	0.200	0.849	5	0.243

The results of normality tests applied for the the yearly 90% percentiles obtained from the original data set (12 sample/year), data subsets A and B (6 sample/year).

Parameters	Data group	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
BOD	Original Data	0.245	5	0.200	0.930	5	0.523
	Subset A	0.239	5	0.200	0.830	5	0.178
	Subset B	0.219	5	0.200	0.960	5	0.757

Analysis of variance (ANOVA) results for the yearly averages for the WQPs in the second parameter group $(4 < n^* \le 6)$ assuming sampling frequency as 6 samples per year.

Parameters		Sum of Squares	df	Mean Square	F	Sig.
BOD	Between Groups	158.13	2	79.065	0.044	0.957
	Within Groups	37373.37	21	1779.684		
	Total	37531.50	23			

Results of the Test of Homogeneity of Variances

Parameters	Levene Statistic	df1	df2	Sig.
BOD	0.35	2.00	21.00	0.71

Results of the Kruskal Wallis test for the yearly averages for the WQPs in the second parameter group $(4 < n^* \le 6)$ assuming sampling frequency as 6 samples per year.

Parameters	Chi-Square	df	Asymp. Sig.
BOD	0.02	2.00	0.99

Analysis of variance (ANOVA) results for the 90% yearly percentiles for the WQPs in the second parameter group $(4 < n^* \le 6)$ assuming sampling frequency as 6 samples per year.

Parameters		Sum of Squares	df	Mean Square	F	Sig.
BOD	Between Groups	636.74	2	318.372	0.070	0.932
	Within Groups	95294.20	21	4537.819	0.000	
	Total	95930.94	23	0.000	0.000	

Output results for the Test of Homogeneity of Variances

Parameters	Levene Statistic	df1	df2	Sig.
BOD	0.49	2.00	21.00	0.62

Kruskal Wallis tests results for the 90% yearly percentiles for the WQPs in the second parameter group $(4 < n^* \le 6)$ assuming sampling frequency as 6 samples per year.

Parameters	Chi-Square	df	Asymp. Sig.
BOD	0.06	2.00	0.97

CHAPTER 7

7. CONCLUSIONS AND RECOMMENDATIONS

The rationalization process of the Hadus drain WQM network started firstly with assessing and reformulating the current objectives of the network. Then, the monitoring locations were investigated using integrated logical and statistical approaches. Finally, different sampling frequency regimes for the monitoring site “Bahr Hadus Bridge” (latest open location on the main stream) were evaluated using visual and statistical methods.

This section presents the final recommendations for the WQM network for Hadus drain as a main feeder of El-Salam Canal Project.

7.1 MONITORING LOCATIONS

The stakeholder analysis indicated that there are 6 objectives for the WQM network covering the El-Salam Canal Project. These objectives are:

- Assessing the compliance with the standards;
- Defining the current and expected water quality problems;
- Determining fate and transport of pollutants;
- Allocating the major sources of pollution;
- Detecting the general nature and trends and
- Providing data to conduct specific research.

One can easily transfer the previous objectives to 2 integrated activities; water quality and quantity measurements. These measurements are essential for analyzing the pollutants loads and understanding its movements, nature and trends in the water system. Most of the scientific research in the field of water quality employs those measurements to facilitate proper environmental management.

For all the pumping stations within El-Salam Canal project, the Mechanical and Electrical Department under the Ministry of Water Resources and Irrigation (MWRI) collects the basic quantity data namely; water levels at suction and delivery sides, number of operating hours and the electrical power consumption. Then the water quantities can be calculated and then delivered for the Drainage Research Institute (DRI) as an executing institution for the monitoring program. In DRI, these data are frequently employed to update the discharge-head relations (rating curves) obtained using long series of measurements started from 1994. In general, the cost of generating the quantity data is too low comparing to the production cost of the water quality data. Therefore, this research focuses on assessing the WQM network rather than the quantity. It is recommended to continue the water quantity-monitoring program without changes (Figure 7-1).

The results of this research show that the quality network can be divided into three layers (Figure 4-18) as followings:

- **Layer I** has the highest priority level and includes eight monitoring locations (EH02, EH04, EH15, EH08, EH09, EH11, EH12 and EH17).
- **Layer II** has the second priority level and includes three monitoring locations (EH03, EH06, and EH16).
- **Layer III** has the lowest priority level and includes five monitoring locations (EH14, EH18, EH05, EH07 and EH10).

These results were validated using three integrated methods (regression analysis, Box-plots with descriptive statistics and multiple regression) to ensure that any recommendation concerning the proposed program will not significantly affect its ability to accomplish the monitoring objectives. The validation results showed that reducing the number of monitoring sites from 16 to 11 did not significantly affect the information produced by the monitoring network.

Therefore, a monitoring network including 11 (out of 16) sites representing the layers I and II is recommended (Figure 7-2). The monitoring locations in layer III (EH14, EH18, EH05, EH07 and EH10) can be stopped without affecting the information produced by the system.

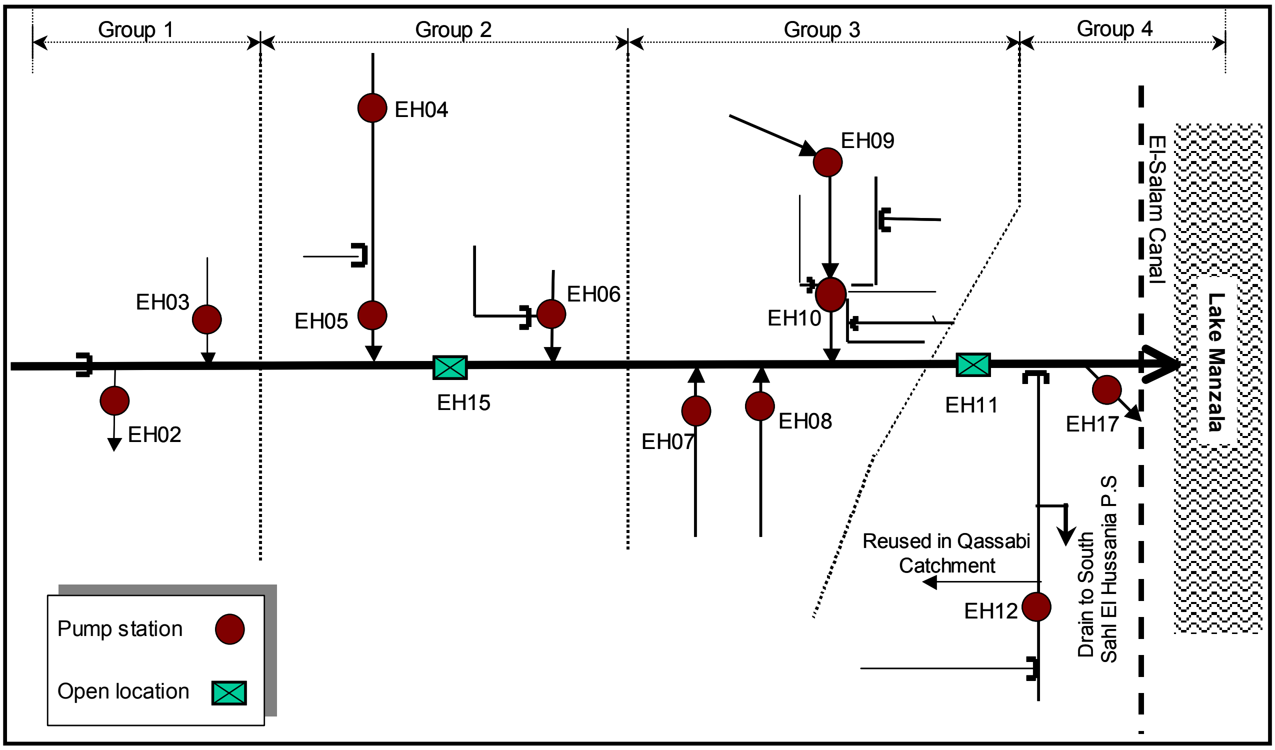


Figure 7-1: The proposed drainage water quantity-monitoring network in Hadus drain

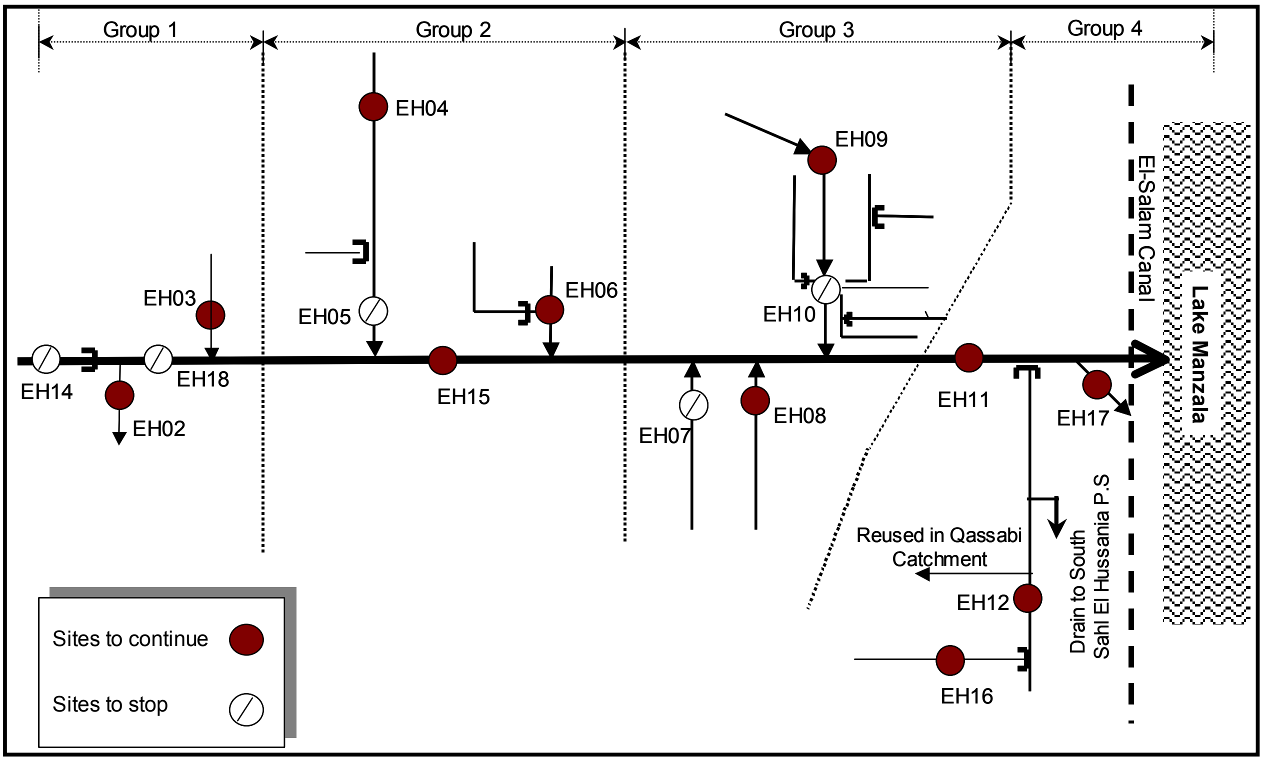


Figure 7-2: The proposed drainage WQM network in Hadus drain

7.2 SAMPLING FREQUENCY

Based on the initial estimation of sampling frequencies (n*) (see section 6.1.3), the WQPs measured at Hadus Bridge were categorized into four parameter groups as following:

- **Parameter Group 1** ($n^* \leq 4$ samples per year) includes COD, TSS, TVS, $N\text{-}NO_3$, Pb, Ca, Na, SAR, Adj. SAR, Cl and Visib.
- **Parameter Group 2** ($4 < n^* \leq 6$ samples per year) includes BOD, Cu, Fe, Mn, pH, TDS, K, SO_4, SO_{4_m} and DO.
- **Parameter Group 3** ($6 < n^* \leq 12$ samples per year) includes Mg, EC, Br, Ni, Sal, Cd, TN, TP, Temp, Fecal, Coli and $N\text{-}NH_4$.
- **Parameter Group 4** ($n^* > 12$ samples per year) includes Zn and P.

Due to the presence of many missing values in the Turb measurements, the calculation of its autocorrelation function was failed. Therefore, It was assumed to be a member in the forth parameter group. Further visual and statistical analyses were employed for the first two-parameter groups using different data subsets that were developed from the original measurements. The objective of these analyses was to ensure that the initial estimation of the sampling frequency could be sufficient to produce most of the information obtained from the current frequency (12 samples/year).

In general, the results indicated that sampling 4 and 6 times a year for the parameter groups 1 and 2 respectively can be sufficient. Nevertheless, it is recommended to have 6 samples per year for 18 WQPs (COD, TSS, TVS, $N\text{-}NO_3$, Pb, Ca, Na, Cl, Visib, BOD, Cu, Fe, Mn, pH, TDS, K, SO_{4_m} and DO). The measured parameter SO_{4m} will automatically replace the SO_4 (calculated). SAR and Adj. SAR also can be calculated from the other parameters.

This may be a conservative frequency for the parameter group 1 where 4 samples per year can be sufficient. However, adding two samples a year more than required may not produce vital problem with serial correlation but can facilitate convenient practice.

For the other fifteen parameters (Mg, EC, Br, Ni, Sal, Cd, TN, TP, Temp, Fecal, Coli and $N\text{-}NH_4$, Zn, P and Turb), It is recommended to continue with twelve samples per year. This frequency is sufficient for the parameter group 3 (13 parameters). For feasibility reasons, although the parameters Zn, P and Turb may require more than 12 samples per year, the current frequency is also recommended.

7.3 FURTHER RESEARCH

- The application of the previous recommendations concerning both monitoring locations and sampling frequency in Hadus drain will lead to a considerable reduction in the total cost of the monitoring program facilitating more fiscal resource, which is a key prerequisite in developing a successful monitoring program. The rescued budget can be redirected to achieve better system performance in terms of improving the current resources and/or to conduct lateral research concerning other important questions such as the high salt levels recorded in the monitoring stations EH07 and EH08. This may require intensive monitoring scheme (for a short period) along these two tributaries (Main Qassabi and El-Qanan drains) to identify the pollution sources and to recommend the possible measures of mitigation.
- The correlation and regression analyses employed in this research call for a detailed study to assess the monitored quality parameters. There are many evidences for strong relations between many of them. This may lead to a significant reduction in the number of measured parameters. In addition, the methods of measurement, the equipments used and the personnel expertises have to be evaluated in relation with the accuracy levels required for the monitoring objectives.
- Also, many anthropogenic chemicals and waste materials, particularly persistent organic and inorganic chemicals, may accumulate in sediments. These sediments become repositories for many of the more toxic chemicals that are introduced into surface waters. Therefore, the feasibility of adding sediment samples to the current monitored parameters has to be evaluated.
- Other important issue that needs to be investigated is the sudden changes (improve) in many WQPs starting from the year 2000.
- In general, it is recommended that the network should be periodically assessed in terms of monitoring sites and sampling frequencies incorporating the new data collected.
- The approach presented in this study can be employed not only for the rest of the El-Salam Canal water resources but also for assessing other parts of the national WQM network in Egypt.

7.4 ENVIRONMENTAL MANAGEMENT

Environmental management is integrated efforts that should be carried out by many entities (stakeholders). The environmental elements, monitoring networks, national/local institutions and beneficiaries are the major actors that monitoring system designers and assessors have to deal with (Figure 7-3). Not only effective communications but also high level of integration between them is required.

Unfortunately, it is always difficult to integrate objectives, plans and activities for many institutions especially in the developing countries. In Egypt, there were numerous trials through many projects to integrate between the different ministries that concern with water sector. The overall impression about the results of these trials could be concluded from the next paragraph:

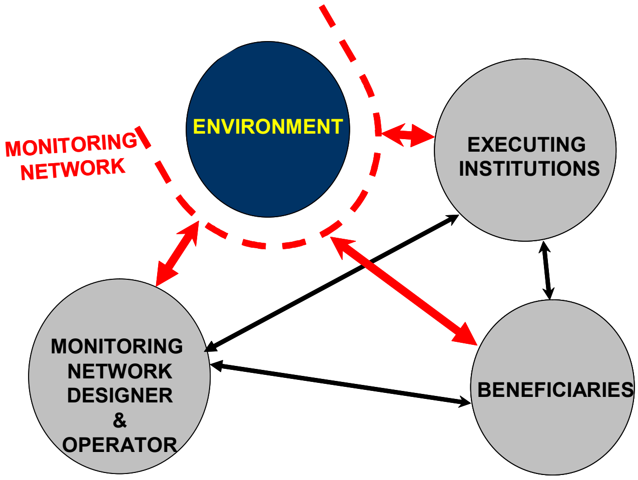


Figure 7-3: Major entities in the environmental monitoring process

"*To ensure proper coordination among the Egyptian Ministries involved in the water sector,* ***the Supreme Committee of the Nile*** *was established. It is supposed to meet on a monthly basis to direct and review different development plans as well as to resolve conflicts; <u>but meetings are irregular and</u> its effectiveness in maintaining coordination among concerned ministries is limited*" (APRP,1998).

It seems to be that starting integration between the ministries by establishing committees where top staff levels should meet is not the effective way. There are daily problems in the field need fast consultation. Therefore, starting with the lowest/widest end of the ministerial pyramid may offer better performance.

To achieve proper mechanism of stakeholders participation in the El-Salam Canal project, the first ministerial staff levels (mainly junior engineers) that have direct contact with the land users were selected to be the steering group. They can be reached easily and they have ***daily*** direct influence (positive or negative) on the land users. This initial selection has mainly three problems:

- These staff levels most likely do not have the power to take ministerial actions if needed. In this case they have to raise the problems to their superiors (intermediate or/and top levels). To avoid any process delay, the higher ministerial levels should facilitate the required actions.
- The lack of appropriate (multi-disciplines) environmental information, which is required to be transferred directly or indirectly to the land users. Therefore, special training should be offered in order to improve their qualifications. The training should stress the concept of participation in environmental management in general and the WQM network design, operation and assessment in particular. The socioeconomic aspects in the project area should be carefully considered.
- Working with these ministerial staff levels means dealing with large number of participants. For this reason, the reclaimed blocks in the new lands can be divided into smaller units and according to the number of feddans which are already reclaimed and the number of land users in the region, a priority list can be prepared in order to provide the engineers and then the land users with the appropriate environmental information. The late priority staff can have (as a preliminary action) a detailed explanation through informative notes. The process will be much easier in the old lands where many areas are already guided from years by many institutions such as:

1. Agricultural Advisory Service (**AAS**) staff.
2. Irrigation Department (**ID**) engineers who are distributed in almost all directorates.
3. Drainage Advisory Services (**DAS**) from EPADP.
4. Irrigation Advisory Services (**IAS**) staff who are available only in the IIP areas.

Local Groups then can be established from the concerned ministerial staff members (minimum MALR and MPWI including the WQM staff) and representatives from the land users. The WQM staff members should be available minimum once a month. The selection of the land users' representatives should include different categories (poor farmers/investors and land owners/labors...etc.). Every local group can represent maximum **500** feddan. The identification of the local groups should take into account the irrigation and drainage systems layout.

The advantage that the local groups are representatives of relatively small areas is that they can easily meet when it is needed. However, they have to have regular meetings minimum every **2** months in order to discuss the problems (if any) and to exchange their ideas and experiences.

The views and discussions raised in the local groups should be recorded. It is useful to establish an **Advisory Committees** to bring together all major interests in one forum to discuss ideas, issues, scientific reports, yearbooks and proposals. These committees should constitute from ministerial senior staff members (**intermediate levels**) and can have regular meetings every **6** months. From the Local Groups, some highly active land users' representatives who have real leading influences on the farmers should be selected to participate in these meetings. Every Advisory Committee can represent maximum **5000** feddan. Then, the **Supreme Committee** can play a vital role in integrating the miniseries objectives, directing and reviewing different plans as well as to resolve conflicts between these activities.

This mechanism sounds to be rather theoretical than practical. For sure, the proper recommendation needs more detailed studies of all the previous experiences gained by many projects trying to achieve better integration between objectives, plans and activities for the different environmental institutions in Egypt. The connections between Local Groups, Advisory Committees and Supreme Committee are also very critical issues.

Therefore, clear and feasible responsibilities have to be settled in advance. Figure 7-4 summaries the proposed stakeholders participation mechanism in WQ management in the El-Salam Canal project area.

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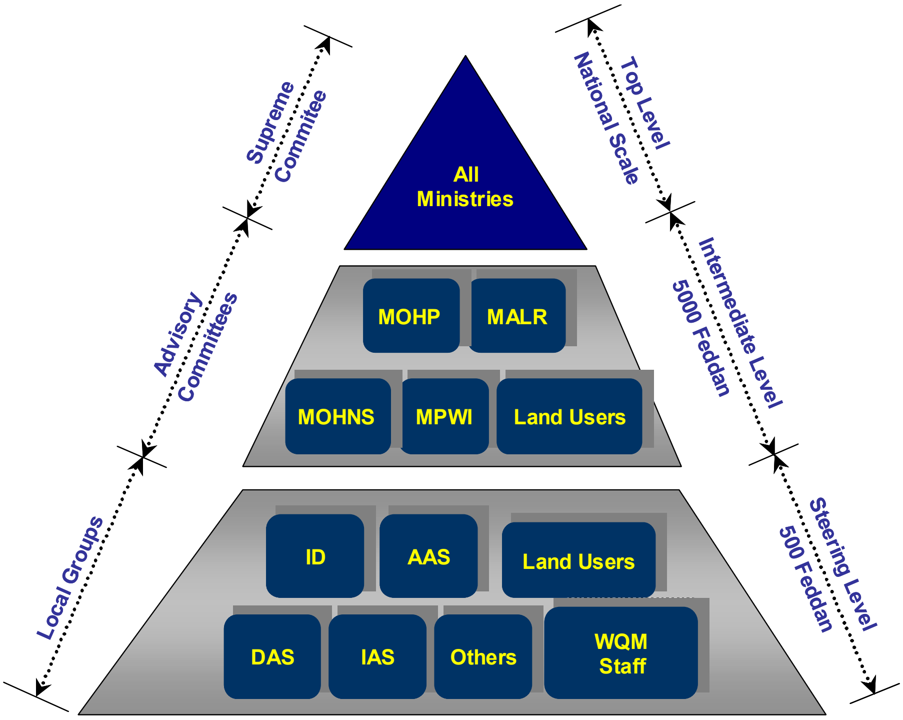

Figure 7-4: The proposed stakeholder participation mechanism

8. SUMMARY

El-Salam Canal Project aims at increasing the Egyptian agricultural productivity through agricultural and stock development by irrigating about 263,500 ha gross of new lands.

In order to stretch the limited water supply to cover these reclaimed areas, fresh River Nile water is augmented with agriculture drainage water from Hadus and Lower Serw drains to meet crop requirements, especially during summer months (peak demand).

With a growing population and intensified industrial and agricultural activities, water pollution is spreading in Egypt, especially in main drains, which receive almost all kinds of wastes (municipal, rural, domestic and industrial wastes).

The medical records indicate that significant numbers of waterborne-disease cases (bilharzias, typhoid, paratyphoid, diarrhoea, hepatitis A, B and C) have been reported in many areas in Egypt (MOHP, 2000).

The National Water Quality Monitoring Program (NWQMP) in Egypt covers the Nile River, irrigation canals, drains and groundwater aquifers to assess the status of water quality for different water uses and users.

The overall objective of this research is to introduce a rationalization technique for the drainage water quality-monitoring network for Hadus drain as a main feeder of El-Salam Canal Project. Later on, this technique can be applied for other parts in the NWQMP.

The rationalization process started firstly with assessing and reformulating the current objectives of the network. Then, the monitoring locations were identified using integrated logical and statistical approaches. Finally, a sampling frequency regime was recommended to facilitate proper and integrated information management.

The monitoring objectives were classified into three classes: design oriented, short-term and long-term deductible objectives. Mainly, the objectives “assess compliance with standards”, “define water quality problems”, “determine fate and transport of pollutants”, “make waste-load allocations” and “detect possible trends” were considered in the redesign process of the network.

A combination of uni-, bi-, and multi-variate statistical techniques supported by spatial and temporal analysis for the important tributaries (key players) in Hadus drain system, were used for locating the monitoring sites. The key players analysis was carried out in the light of monitoring objectives. As a result, the monitoring network was divided into three priority levels (Layers **I**, **II** and **III**) as following:

- **Layer I**: It has the highest priority level and includes eight monitoring locations
- **Layer II**: It has the second priority level and includes three monitoring locations
- **Layer III**: It has the lowest priority level and includes five monitoring locations

Using the method proposed by Lettenmaier (1976), the sampling frequencies were initially estimated and then evaluated for 36 water quality parameters, which were collected on monthly basis during the period from August 1997 to January 2005. The evaluation process was carried out by generating new data sets (subsets) from the original data. Then, the common required statistics from the monitoring network were extracted. The information obtained from different data sets was assessed using visual and statistical comparisons.

Three integrated validation methods were employed to ensure that any decisions concerning the proposed program would not affect its ability to accomplish the monitoring objectives. These validation methods employed: descriptive statistics, regression analysis and linear multiple regression in an integrated approach.

The validation results ensured that excluding the monitoring locations in **layer III** did not significantly affect the information produced by the monitoring network. Therefore, a monitoring network including only 11 sites (out of 16) representing the **layers I** and **II** was recommended.

Based on the evaluation of sampling frequencies, it is recommended to have 6 (instead of 12) samples per year for 18 water quality parameters (COD, TSS, TVS, N-NO_3, Pb, Ca, Na, Cl, Visib, BOD, Cu, Fe, Mn, pH, TDS, K, SO_{4_m} and DO). The measured parameter SO_{4m} will automatically replace the SO_4 (calculated). SAR and Adj. SAR also can be calculated from the other parameters. For the other fifteen parameters (Mg, EC, Br, Ni, Sal, Cd, TN, TP, Temp, Fecal, Coli and N-NH_4, Zn, P and Turb), it is recommended to continue with twelve samples per year.

These recommendations may ensure significant reduction in the total cost of the monitoring network. This facilitates a fiscal resource, which is a key prerequisite in developing a successful program. The rescued budget can be redirected to achieve better performance in terms of improving the current resources.

In addition, a frame of stakeholders-participation mechanism was proposed to not only facilitate a better coordination among the Egyptian Ministries involved in the water sector but also guarantee effective landowners/farmers involvement. However, applying such a mechanism requires more detailed studies of all the previous experiences gained by many projects trying to achieve better integration between objectives, plans and activities for the different environmental institutions in Egypt.

9. ZUSAMMENFASSUNG

Ziel des El-Salam-Kanal-Projekts ist die Steigerung der Leistungsfähigkeit von Ackerbau und Viehzucht in Ägypten durch landwirtschaftliche Entwicklung und Grundlagenverbesserung. Der Schlüssel hierzu liegt in der Bewässserung eines Gesamtgebietes von rund 263,500 ha neu gewonnenen Landes.

Zur Versorgung dieses neu gewonnenen Landes wird das nur begrenzt zur Verfügung stehende Frischwasser aus dem Nil mit Wasser aus den landwirtschaflichen Entwässerungskanälen Hadus und Lower Serw gestreckt, um den Bedarf der Pflanzen, insbesondere während der Spitzenzeiten in den Sommermonaten zu decken.

Durch das Bevölkerungswachstum in Ägypten und dem damit verbundenen Wachstum von Industrie und Landwirtschaft, nimmt auch die Wasserverschmutzung zu, vor allem in den Entwässerungskanälen, wo sich praktisch alle Arten der Verschmutzungen (kommunaler, landwirtschaftlicher, privathaushaltlicher und industrieller Herkunft) nachweisen lassen.

Medizinische Aufzeichnungen weisen darauf hin, dass eine nicht unerhebliche Anzahl von Krankheiten, die mit Wasser in engem Zusammenhang stehen (z. B. Bilharziose, Typhus, Paratyphus, Hepatitis A, B und C) in vielen Gebieten Ägyptens bezeugt sind (MOHP, 2000).

Das staatliche “National Water Quality Monitoring Program” (NWQMP) überwacht den Wasserzustand des Nils, der Be- und Entwässerungskanäle und der Grundwasserreserven und bewertet die Wasserqualität je nach Verbraucher und Verwendungszweck.

Hauptziel der vorliegenden Untersuchung ist die Entwicklung von Rationalisierungsmaßnahmen des Netzwerkes zur Wasserqualitätsüberwachung im Hadus-Kanal, einer Hauptzufuhr des El-Salam-Kanal-Projekts. Die vorgestellten Maßnahmen können später auch in anderen Teilen des NWQMP Anwendung finden.

Im Rationalisierungsprozess wurden zunächst die gegenwärtigen Ziele des Projekts bewertet und neu formuliert. Im zweiten Schritt wurden die Kontrollpunkte unter einheitlich logischen Gesichtspunkten und unter Heranziehung von statistischen Ansätzen festgelegt. Um ein einheitliches und zweckdienliches Informationsmanagement zu gewährleisten, wurde schließlich ein Messfrequenzsystem vorgeschlagen.

Die Ziele der Qualitäskontrolle wurden klassifiziert nach zweckbezogenen und kurz- bzw. langfristig daraus ableitbaren Zielen. Folgende Ziele fanden bei der Neuformulierung des Netzwerks Berücksichtigung: Bewertung der Standardkonformität, Definition der Probleme der Wasserqualität, Bestimmung von Herkunft Stärke, Transport und Verbleib der Verschmutzungen sowie mögliche Trends.

Zur Festlegung der Kontrollpunkte wurden uni-, bi- und multilvariable statistische Methoden zur Auswertung der räumlichen und zeitlichen Analyse der wichtigsten Zweigkanäle (Schlüsselkanäle) im Kanalsystem Hadus gewählt. Die Auswertung der Schlüsselkanäle fand unter dem Gesichtspunkt der Kontrollziele statt. Das Ergebnis war ein Kontrollnetzwerk, das in drei Prioritätsebenen eingeteilt werden kann:

- **Ebene I** mit höchste Priörität, sie umfasst acht Kontrollpunkte
- **Ebene II** mit nachgeordneter Priorität, sie umfasst drei Kontrollpunkte
- **Ebene III** mit der geringsten Priorität, sie umfasst fünf Kontrollpunkte

Nach der von Lettenmaier (1976) vorgeschlagen Methode wurde die Häufigkeit der Probennahmen anfänglich geschätzt und dann anhand der Messungen von 36 Wasserqualitätsparametern, die in monatlichen Messungen in der Zeit von August 1997 bis Januar 2005 erhoben wurden, ausgewertet. Bei diesem Prozess wurden aus den ursprünglichen Daten neue Datensätze (Teilmengen) gewonnen. Daraufhin wurden die allgemein erforderlichen Statistiken aus dem Kontrollnetzwerk abgeleitet. Die Informationen aus den verschiedenen Datensätzen wurden mit Hilfe von optischen und statistischen Vergleichen bewertet.

Um sicher zu stellen, dass eine getroffenen Entscheidung hinsichtlich des vorgeschlagenen Programms nicht die Fähigkeit der Entscheidung, die Kontrollziele zu erfüllen, beeinflussen würde, wurden drei zusammenhängende Methoden zur Prüfung der Stichhaltigkeit angewandt. Diese Methoden verwenden beschreibende Statistiken, Regressionsanalyse und lineare multiple Regression durch integrale Annäherung.

Die Ergebnisse der Stichhaltigkeitsprüfung garantieren, dass die Weglassung der Kontrollpunkte aus Ebene III die aus dem Kontrollnetzwerk gewonnenen Informationen nicht entscheidend beeinflussen. Auf dieser Grundlage wird ein Kontrollnetzwerk vorgeschlagen mit nur 11 von insgesamt 16 Punkten, die die Ebenen I und II repräsentieren.

Die Evaluierung der Messfrequenz legt eine Erhebung von 6 statt 12 Messungen pro Jahr für 18 Wasserqualitätsparameter (COD, TSS, TVS, N-NO_3, Pb, Ca, Na, Cl, Visib, BOD, Cu, Fe, Mn, pH, TDS, K, SO_{4_m} und DO) nahe. Der gemessene Wert für SO_{4_m} ersetzt automatisch den errechneten Wert SO_4. SAR und Adj. SAR können aus den anderen Parametern errechnet werden. Für die anderen fünfzehn Parameter (Mg, EC, Br, Ni, Sal, Cd, TN, TP, Temp, Fecal, Coli und N-NH_4, Zn, P und Turb) wird empfohlen, mit zwölf Proben pro Jahr fortzufahren.

Diese Empfehlungen stellen eine deutliche Verringerung der Gesamtkosten des Kontrollnetzes dar, was wiederum eine Grundvoraussetzung für die Entwicklung eines erfolgreichen Programms ist. Die Einsparungen im Etat können zur Verbesserung der momentanen

Ressourcen wiedereingesetzt werden. Darüber hinaus wird ein Rahmenprogramm für alle beteiligten Interessengruppen vorgeschlagen, das einerseits die Kommunikation zwischen den im Bereich Wasser engagierten ägyptischen Ministerien verbessern soll, andererseits eine effiziente Einbindung der Landbesitzer und Bauern garantiert. Die Einführung eines solchen Systems verlangt jedoch detaillierte Studien auf der Grundlage der Erfahrungen aus vielen vorausgegangenen Projekten, die sich mit der Verbesserung zwischen Zielen, Plänen und Aktivitäten der verschiedenen Umweltinstitutionen in Ägypten befasst haben.

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ANNEX 2-1

BRIEF DESCRIPTION OF THE EL-SALAM CANAL PROJECT

BRIEF DESCRIPTION OF EL-SALAM CANAL PROJECT

In the early sixties some agriculture expansion projects that depend on Nile water were discussed. El-Salam Canal was one of those projects aimed at increasing agricultural production through agricultural and stock development, improving income distribution, and generating employment through the settlement of smallholders and graduates from the rural population of the over-populated areas of Egypt.

The construction of the canal started in the 1980's. The objective was to irrigate about 620,000 feddan of new lands. The canal length is 86 km from its intake at Farasqour Barrage on the Damietta Branch of the River Nile in the East Delta along the south end of Lake Manzala to the Suez Canal.

The canal crosses the Suez Canal through a 1.3 km long siphon, 27.7 km south of Port Said city. The siphon consists of 4 tunnels (each 750 m long and 5.1 m diameter.). The discharge capacity is 40-160 m^3 per second. From this point, the canal course continues for 155 km eastward in Sinai peninsula to irrigate about 400,000 feddan as following ([1]):

- ***Phase 1***, the Tina Plain (60,000 feddan) as a special character because of its heavy saline clay soils.
- ***Phases 2-4,*** *the* South Qantara, Raba'a and Bir El-Abd (205,000 feddan) consist of mainly deep sandy soils.
- ***Block 5*** includes a potential extension area (El-Sir and Kawarir) of 135,000 feddan consisting of loamy soils situated between 50 and 150 m asl, which implies a high energy demand for lifting water.

At the onset of the El-Salam Canal project, the initial proposal assumed that the total drainage water available in Hadus and Lower Serw drains is around 3.45-milliard m^3/year (2.72 and 0.73 milliard m^3/year respectively). This policy employs a minimum of 10% from the available drainage water in the Lower Serw drain (0.07 milliard m^3/year) and a minimum of 20% in the Hadus drain (0.54 milliard m^3/year) to continue to flow towards Lake Manzala to protect its ecosystem. According to this proposal always 2.2-milliard m^3/year from drainage water are guaranteed for the project (DRI, 1985) ([2]).

However, the recent measurements showed that the yearly average water budget for Hadus drain reached to around 1.19-milliard m^3/year, which represent only 44% from the initial

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[1] World Bank Document, 1997: Arab Republic of Egypt, East Delta Agricultural Services Project, Staff appraisal report, Water and environment group middle east and north Africa region, Report Number: 16097, Tf No/Name: Tf034194-Egypt

[2] DRI, (Drainage research Institute),1985: Estimation of available water for the El-Salam Canal Project, Reuse of drainage water project, National water Research Center, Cairo

estimation 2.72 milliard m^3/year (^{3}). Therefore, it was decided to add some of drainage water from Farsqur drain to be used in the project especially after the completion of the new Farsqur pump station, which is located at 1.8 km left side of the El-Salam Canal. It is expected that this pump station will divert around 1.0 million m^3/day during the maximum needs period.

"*Climatic conditions are characteristic of the eastern Mediterranean, with hot summers and mild winters. Rainfall varies from 40 to 90 mm annually and occurs usually from October to March. All crops are grown under irrigation during two major growing seasons: winter (November to April), and summer (May to October)*".

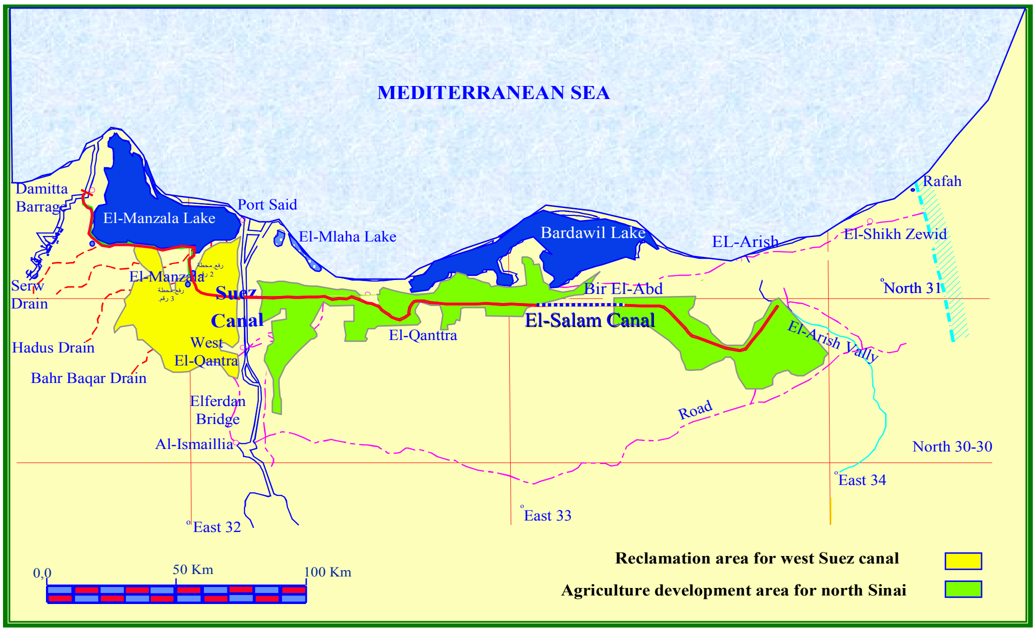

Figure 1: Map of El-Salam Canal Project (DRI internal data)

"*Soil textures vary from silt loams to heavy clays. Seashells and small amounts of gypsum are present in most profiles. The soils are highly saline but are well suited for irrigation once the soluble salts have been leached from the 0-50 cm depth. Under the soil surface layers, there is a clay cap at depths varying from 0.5 to 3.0 meters. The depth of this clay cap from the soil surface forms the most important criterion upon which the land reclaimability classification has been based. Groundwater below this clay cap is saline. The topography is very flat with land elevations generally ranging from 0.5 m below sea level to 3 m above mean sea level*" (^{4}).

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[3] Shaban M., Master thesis, 2003: Drainage water reuse strategy to extend Egypt's limited irrigation water resources: The El-Salam Canal Project, University of Applied Science, Lüneburg, Suderburg, Germany.

[4] World Bank Document, 1997: Arab Republic of Egypt, East Delta Agricultural Services Project, Staff appraisal report, Water and environment group middle east and north Africa region, Report No.: 16097, Tf No/Name: Tf034194-Egypt

HADUS DRAIN MONITORING SYSTEM

The Hadus drain starts a few kilometers before the Gemeeza Bridge (EH14), and ends at its outfall to Lake Manzala (EH17). It has a length of approximately 60 kilometers. Four kilometers after its starting point Hanut pumping station (EH02) extracts a considerable part of its discharge to the Hanut irrigation canal, that is approximately 17.7 million m^3/month. Next along the main drain, it receives a feed of water that is approximately 8.9 M m^3/month, through the Sadaqa pumping station (EH03). The Nizaam branch drain that receives 135 thousand m^3/day of El-Mansura city Wastewater Treatment Plant and in addition receives 26,000 m^3/day from other wastewater treatment plant, feeds into main Hadus drain before El-Dawar bridge (EH15). The Beni Abied (EH06), Additional Qassabi (EH07), and Main Qassabi (EH08) pumping stations discharge their water into the main Hadus drain respectively before receiving a discharge of a branch carry the outflow of the Erad pumping station (EH10) and the Geneena pumping station (EH09) which is used partly for irrigation purposes into the main Hadus. The Saft drain, i.e. a branch of Hadus, discharges into the main Hadus before its outfall (EH17), which is located just before the siphon of El-Salam canal. Water quality of Hadus is of special importance, as part of its water is diverted to the El-Salam Canal. The remainder is discharged into Lake Manzala.

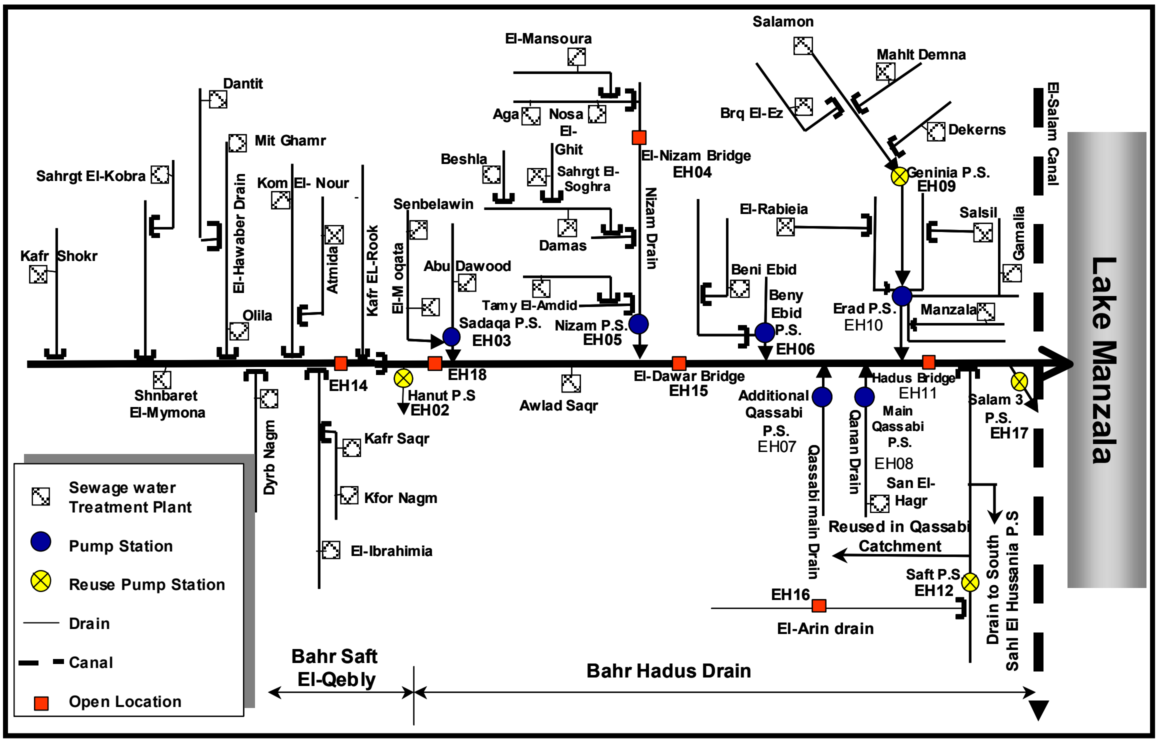

Figure 2: Layout of Hadus Drainage System

(Source: DRI internal data)

MAIN SOURCES OF WATER POLLUTION

With the growing population and intensified industrial and agricultural activities, water pollution is spreading in Egypt, especially in the Delta region. The medical records indicate that significant numbers of waterborne-disease cases (bilharzias, typhoid, paratyphoid, diarrhoea, hepatitis A and C) have been reported in many areas in Egypt. In most cases, the water pathogens reach the human being through four main ways (MOHP, 2000) ([5]):

- Drinking polluted water,
- Eating raw vegetables/fruits cultivated in farms irrigated with polluted water,
- Eating or drinking partially cooked meat or milk obtained from the dairy animals that grown in farms irrigated with polluted water and
- Eating partially cooked fish grown in polluted water body.

In fact, the El-Salam Canal works as a carrier for fresh Nile water augmented with relatively low quality water from Hadus and Serw drains that collect significant part of the drainage (polluted) water from the eastern part of the Nile Delta. These drains receive agricultural, municipal, rural, domestic and industrial wastes through intensive network of tributaries.

- **Agricultural Wastes:**

Agriculture is seen as a widespread non-point source of pollution. When chemicals of any kind are excessively used during the agriculture activities, they can migrate beyond the field and become an environmental problem such as salinity increase, deterioration of water quality due to agro-chemical use, and/or eutrophication of water bodies due to the increase of nutrient loads.

During the period from 1960 to 1988, the applications of nitrogen, phosphate and potassium fertilizers in the Egyptian agriculture increased nearly 4- fold. The use of pesticides has increased as well, but not at the same rate of fertilizers. In early 1991, the use of herbicides to control aquatic weeds in Egypt was stopped. ([6])

Unfortunately, these non-point pollution sources discharge into the agricultural drains to form point sources of pollution for the River Nile, lakes and irrigation canals in case of reusing water for irrigation.

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5 MOHP (Ministry of Health and Population), 2000: Practical instructions in the field of health emergencies-drinking water quality in Arabic, Cairo, available at: http://www.mohp.gov.eg/environment/statistics/dalel4.asp?x=3

6 Abu-Zeid, M. 1992, Egypt's efforts towards management of agricultural water demands, National Water Research Center, MPWWR, Egypt

- **Municipal and Rural Domestic Wastes**

During the last 3 decades, hundreds of wastewater treatments plants were established not only in the main cities but also covered significant number of small villages in Egypt. Nevertheless, there are still many cases whereby; many villages still discharge their municipal and rural domestic wastewater into waterways often without treatment.

In many villages and some small towns, the extension of drinking water networks do not accompany with the construction of new sewage systems or rehabilitation of the existing ones. Therefore, the annual wastewater discharges to the waterways are increasing leading to serious contamination and increasing public health hazards.

The constituents of domestic and urban discharge to water resources are mainly pathogens, nutrients, suspended solids, salts, and oxygen-demanding material.

- **Industrial Wastes**

Industrial pollution can be characterized as point sources of a wide variety of pollutants, of which heavy metals and toxic organic compounds generate the most concern.

Although the majority of the Egyptian industries adequately treat their wastewater before discharging to the waterways, still significant numbers of small industries and workshops do not have proper treating systems. In these cases, many organic and inorganic substances are added to the receiving water body and deteriorate its quality.

WATER QUALITY PARAMETERS (WQPs)

The WQPs can be divided into six major groups (oxygen budget related parameters, salts (macro ions), nutrients, physical parameters, bacteria, and heavy metals). A brief definition of some of these parameters (Chapman, 1992) ([7]) as well as the reason for their inclusion in relation to legislation and drainage water possible uses is given below.

1. Oxygen Budget

- **Dissolved Oxygen (DO):** The DO concentration gives information on the possibilities for flora and fauna living in the water system. The measurement of DO can be used to indicate the effects of pollution by organic matter. Determination of DO concentrations is a fundamental part of a water quality assessment since oxygen is involved in or influences nearly all chemical and biological processes in water bodies.

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[7] Chapman, D. (ed.), 1992: Water quality assessment. A guide to the use of Biota, sediments and water in environmental monitoring, Chapman & Hall, London

- **Biochemical Oxygen Demand (BOD)** The Biochemical Oxygen Demand (BOD) is defined as the amount of oxygen required by the microorganisms present in the sample to oxidise the organic matter. BOD is an indication for the potential of a polluted water or effluent to consume oxygen. The main sources of organic matter affecting the BOD concentration are raw sewage wastewater and industrial wastes.
- **Chemical Oxygen Demand (COD):** The Chemical Oxygen Demand is the amount of oxygen consumed by organic matter from boiling acid potassium dichromate solution. COD is widely used as a measure of the susceptibility to oxidation of the organic and inorganic materials present in water bodies and in the effluent from sewage and industrial plants.

2. Salts/Major Ions

The major ions (Na, Ca, Mg, K, CO_3, HCO_3, SO_4, and Cl) are variable in concentration in surface water due to local, geological, climatic, land use and geographical conditions.

- **Sodium and Sodium Adsorption Ratio (SAR):** Increased sodium levels in surface water may arise from sewage and industrial effluents as well as seawater intrusion in coastal areas. Elevated sodium in certain soil types can degrade soil structure thereby restricting water movement and affecting plant growth. The SAR estimates the degree to which sodium will be adsorbed and replaces the calcium and magnesium ions in the soil, potentially causing damage to the soil structure.
- **Potassium (K):** Potassium salts are widely used in industry and in fertilizers for agriculture and enter freshwater with industrial discharges and runoff and drainage water from agricultural land. Concentrations in natural water are usually less than 10 mg/1 (0.25 meq/l) whereas concentrations as high as 100 and 25,000 mg/l (2.55 and 640 meq/l) can occur in hot springs and brines respectively.
- **Calcium (Ca):** It is present in all water as Ca^{2+}. The salts of calcium together with those of magnesium are responsible for hardness of water. Ca is readily dissolved from rocks rich in calcium minerals particularly as carbonates and sulphates. Industrial, as well as water and wastewater treatment processes also contribute Ca to surface water.
- **Magnesium (Mg):** It is common in natural water as Mg^{2+} and along with calcium is a main contributor to water hardness. It occurs in many organometallic compounds and in organic matter since it is an essential element for living organisms. Magnesium arises principally from the weathering of rocks containing ferromagnesium minerals and from some carbonates rocks.

- **Carbonates and Bicarbonates:** The presence of carbonates (CO_3^{-2}) and bicarbonates (HCO_3^{-2}) influences the hardness and alkalinity of water. HCO_3^{-2} is a dominant anion in most surface waters while CO_3^{-2} is uncommon in natural surface water because they rarely exceed pH 9. Because groundwater can be more alkaline, it may have higher concentrations of carbonate.

- **Chloride (Cl):** High concentrations of chloride can make waters unpalatable and therefore unfit for use as drinking water. Higher concentrations can occur near sewage and other waste outlets, agricultural drains, and due to salt-water intrusion in coastal areas. Chloride is one of the usual toxic ions in irrigation water with sodium and boron. Each can cause damage to crops, individually or in combination.

- **Sulphate (SO_4):** Sulphate is naturally present in surface waters as SO_4. Industrial discharges and atmospheric precipitation can also add significant amounts of sulphate to surface waters. Sulphate can be used as an oxygen source by bacteria, which convert it to hydrogen sulphide (H_2S, HS^-), under anaerobic conditions. High levels of sulphate, >400 mg/1 (>8.3 meq/l), may make water unpleasant to drink.

3. Nutrients

Nutrient elements in water exist in ionic forms. The two most important nutrients are nitrogen and phosphorus and problems caused by these elements are mainly a result of human activities. The high crop yield varieties and intensive cultivation techniques have led to substantial increases in the rates of fertilizer application.

Various forms of nitrogen exist: ammonia, nitrite, nitrate, nitrogen gas and organic nitrogen. Phosphorus is present in both inorganic (orthophosphate) and organic forms. The selected parameters are:

- **Ammonia-nitrogen (N-NH_4):** At certain pH levels, high concentrations of ammonia are toxic to aquatic life and, therefore, harmful to the ecological balance of water bodies. High concentrations could be an indication of organic pollution such as from domestic sewage, industrial waste and fertilizer run-off.

- **Nitrate (NO_3-N):** High concentrations in natural waters may stimulate excessive plant growth (eutrophication). Nitrate is an indicator for the leaching of nutrients from agriculture and/or treatment plants. At high levels nitrate in the drinking water is toxic for children.

- **Orthophosphate (P-PO_4):** High concentrations in natural waters may stimulate excessive plant growth and are often the dominant factor in causing eutrophication. Natural sources of phosphorus are mainly the weathering of phosphorus bearing rocks and decomposition of organic matter. Domestic wastewater, particularly those containing detergents, industrial effluents and fertilizer run-off contribute to elevated levels in surface waters.

4. Physical Parameters

- **Suspended Solids, Transparency and Turbidity:** These parameters give information on the loads and transport of organic material, clay and silt. Micro-pollutants can be adsorbed to these solids, inducing high loads during floods. Turbidity may influence the growth of water plants. Some fish species need good transparency to hunt their prey. The concentration of total suspended solids (TSS) in streams generally increases as a function of flow. Particles are derived by erosion in the watershed and by the re-suspension of particles deposited in the streambed. The suspended matter may (i) coat the beds of streams, destroying the habitat of living organisms, (ii) choke the breathing surfaces of aquatic organisms and (iii) prevent penetration of solar energy, which is essential to plant growth. Also, it may play an important role in sorption and desorption of non-ferrous metals. Normal values of turbidity range from 1 to 1000 NTU and levels can be increased by the presence of organic matter pollution.

5. Microbiological parameters

- **Total Coliform (Coli):** The microbiological parameters are related to human health and are influenced through human and agricultural wastes. The main microbiological indicators are total and fecal coliform. The coliform bacterial count (bacteria originating from the gut) has been the most frequently used test. A number of physico-chemical processes can influence the biological nature of surface water systems, which are influenced, by substrate nature, light, temperature and oxygen. Crude sewage usually contains 10^6 to 10^7 count/100ml.

6. Metals

All of the non-ferrous metals have sulphides with very low solubility products and are precipitated by sulphide ion in anoxic circumstance and are therefore often incorporated in suspended matter and sediments.

- **Zinc (Zn):** Toxicity of zinc to aquatic plants is highly variable (effective concentration ranging from 0.01 to 100 mg/l). This extreme variability is due to (i) the effect of different physicochemical conditions on up-take and (ii) the ability of many species to adapt to high zinc levels. Zn^{+2} is moderately toxic to most species of fish, both marine and fresh water. There are several major sources of Zn^{+2} including the discharge of domestic wastewater, coal burning power plant, smelting and refining, pulp and paper manufacturing processes.

- **Lead (Pb):** Under many test conditions, lead is more toxic than chromium, manganese, zinc and iron but is less toxic than cadmium, mercury and copper. Primary sources of lead include manufacturing processes (particularly metals), atmospheric deposition, and domestic wastewater.
- **Copper (Cu):** It is highly toxic to most species of aquatic plants and is routinely used as an algaecide and herbicide. It is one of the most toxic heavy metals to fish where ionic copper Cu^{+2} and ionized hydroxides ($Cu_2OH_2^{+2}$) are the most toxic forms.
- **Iron (Fe):** In most surface waters, Fe^{+3} predominates. When combined with its salts, it becomes practically insoluble at least in aerobic waters. Iron is not toxic to plants in aerated soils but can contribute to soil acidification and loss of availability of essential phosphorus. Concentrations of over 50 mg/l and as low as 0.004 mg/l have been reported in surface waters. Iron is routinely detected in municipal effluents, particularly in cities where iron and steel are manufactured. Iron residues in surface waters are extremely variable, reflecting differences in underlying bedrock, erosion, industrial and municipal discharges.

FURTHER INFORMATION

The followings are some sources of information, which can be useful in relation with reusing drainage water in land reclamation projects in Egypt especially El-Salam Canal Project.

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- World Bank Document, 1997: Arab Republic of Egypt, East Delta Agricultural Services Project, Staff appraisal report, Water and environment group middle east and north Africa region, Report Number: 16097, Tf No/Name: Tf034194-Egypt

ANNEX 2-2

STAKEHOLDER OBJECTIVE MATRICES (SOM)

Annex 2-2A: The objective matrices filled by representatives from the Ministry of Water Resources and Irrigation (MWRI)

Annex 2-2B: The objective matrices filled by representatives from the Ministry of Agriculture and Land Reclamation (MALR)

Annex 2-2C: The objective matrices filled by representatives from the Ministry of Environment (MOE)

Annex 2-2D: The objectives matrices filled by representatives from Ministry of Health and Population (MOHP)

Annex 2-2E: The objectives matrices filled by representatives from Ministry of Housing, Utilities and New communities (MHUNC)

Annex 2-2F: The objectives matrices filled by representatives from Ministry of Industry (MOI)

Annex 2-2G: The objectives matrices filled by representatives from New Land Beneficiaries (NLB)

Annex 2-2A: The objective matrices filled by representatives from the Ministry of Water Resources and Irrigation (MWRI)

Objectives Matrix no. 1

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	3	3	3	3	3	3	2	3	2	2	0	3	0	3
facilitate impact assessment studies	3	3	1	3	2	3	3	3	2	3	1	2	0	2	0	2
facilitate baseline water quality information (Survey monitoring).	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
determine fate and transport of pollutants	3	3	3	3	2	3	1	3	2	2	-	-	0	2	0	1
measure effectiveness of conservation practices	3	3	3	3	3	3	-	2	-	-	-	-	0	0	0	0
make waste-load allocations	3	3	1	1	2	3	2	3	1	2	2	3	0	1	0	1
validate & calibrate models and establish a database for the planning and development of water resources	3	3	2	3	-	-	-	-	0	1	0	1	0	0	0	0
conduct research	3	3	2	2	1	3	3	3	0	2	0	1	0	1	0	1
define water quality problem	3	3	3	3	2	3	2	3	2	2	1	1	0	2	0	1
detect possible trends in water quality with respect to time and space;	3	3	3	3	3	3	2	3	2	2	2	3	0	1	0	1
assure a publicly credible basis for controversial (hot) decisions.	2	-	1	1	-	-	-	-	1	1	-	1	0	0	0	0

Annex 2-2A: The objective matrices filled by representatives from the Ministry of Water Resources and Irrigation (MWRI)

Objectives Matrix no. 2

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	2	3	2	3	-	2	-	1	-	1	0	2	0	1
facilitate impact assessment studies	3	3	1	2	-	2	-	1	1	1	-	1	0	1	0	1
facilitate baseline water quality information (Survey monitoring).	0	1	1	2	2	3	2	2	1	2	-	1	0	1	0	1
determine fate and transport of pollutants	2	2	1	2	2	2	1	2	1	2	-	-	0	2	0	1
measure effectiveness of conservation practices	1	1	1	1	1	1	-	-	-	-	-	-	-	-	-	-
make waste-load allocations	3	3	2	2	2	2	1	2	1	1	-	1	0	2	0	2
validate & calibrate models and establish a database for the planning and development of water resources	2	3	1	2	1	2	-	-	-	-	-	-	-	-	-	-
conduct research	3	3	2	3	2	2	1	2	0	1	0	1	0	2	0	2
define water quality problem	2	3	2	2	2	3	2	2	1	1	1	1	1	2	1	1
detect possible trends in water quality with respect to time and space;	3	3	2	3	2	3	1	2	1	1	-	1	1	3	1	2
assure a publicly credible basis for controversial (hot) decisions.	2	2	2	1	3	2	1	-	1	-	-	-	0	0	0	0

Annex 2-2A: The objective matrices filled by representatives from the Ministry of Water Resources and Irrigation (MWRI)

Objectives Matrix no. 3

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	2	3	2	3	1	2	1	2	-	1	1	1	1	1
facilitate impact assessment studies	2	2	2	2	2	3	-	-	1	1	-	1	0	0	0	0
facilitate baseline water quality information (Survey monitoring).	0	1	2	3	3	3	1	1	1	1	-	1	0	0	0	0
determine fate and transport of pollutants	3	2	1	1	2	3	1	1	1	2	-	-	0	1	0	1
measure effectiveness of conservation practices	2	2	1	1	2	2	-	-	-	1	-	-	-	-	-	-
make waste-load allocations	2	3	1	1	2	3	1	1	0	0	-	1	0	0	0	0
validate & calibrate models and establish a database for the planning and development of water resources	2	2	-	-	2	2	1	1	0	0	-	-	0	0	0	0
conduct research	3	3	2	2	2	3	1	1	-	-	0	1	0	2	0	1
define water quality problem	3	2	1	1	3	3	2	3	1	1	1	1	0	1	0	1
detect possible trends in water quality with respect to time and space;	3	3	3	3	2	3	2	2	1	1	-	1	0	1	0	1
assure a publicly credible basis for controversial (hot) decisions.	1	1	-	-	2	3	1	1	-	-	-	-	0	0	0	0

Annex 2-2A: The objective matrices filled by representatives from the Ministry of Water Resources and Irrigation (MWRI)

Objectives Matrix no. 4

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	3	3	3	3	2	3	1	1	1	1	1	2	1	1
facilitate impact assessment studies	3	3	2	3	3	3	1	2	1	2	0	0	0	0	0	0
facilitate baseline water quality information (Survey monitoring).	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	0
determine fate and transport of pollutants	3	3	1	1	2	2	1	2	1	1	0	0	0	0	0	0
measure effectiveness of conservation practices	1	1	1	2	3	3	1	1	-	1	0	0	0	0	0	0
make waste-load allocations	1	2	1	2	3	3	1	2	1	1	1	1	0	0	0	0
validate & calibrate models and establish a database for the planning and development of water resources	2	2	1	1	-	-	-	-	-	-	0	0	0	0	0	0
conduct research	3	3	3	3	3	3	-	1	-	-	-	1	0	1	0	1
define water quality problem	3	3	2	3	3	3	3	3	1	1	1	1	0	2	0	2
detect possible trends in water quality with respect to time and space;	3	3	2	3	3	3	3	3	-	1	1	1	0	2	0	0
assure a publicly credible basis for controversial (hot) decisions.	-	-	-	-	1	-	2	-	1	-	1	-	0	0	0	0

Annex 2-2A: The objective matrices filled by representatives from the Ministry of Water Resources and Irrigation (MWRI)

Objectives Matrix no. 5

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	2	3	3	3	1	2	-	-	-	-	0	1	0	1
facilitate impact assessment studies	2	3	2	2	1	2	1	1	-	1	-	-	0	1	0	0
facilitate baseline water quality information (Survey monitoring).	1	1	1	1	1	1	1	1	1	1	-	-	0	0	0	0
determine fate and transport of pollutants	1	2	1	1	1	1	-	-	-	1	-	-	0	1	0	1
measure effectiveness of conservation practices	2	2	2	2	2	1	1	2	-	1	-	1	0	1	0	1
make waste-load allocations	2	2	1	2	1	2	1	1	-	-	-	-	0	0	0	0
validate & calibrate models and establish a database for the planning and development of water resources	3	3	1	1	1	1	1	1	-	1	-	-	0	1	0	1
conduct research	2	3	3	3	2	3	1	1	1	1	1	1	0	1	0	1
define water quality problem	3	3	2	2	1	2	1	1	1	1	1	1	1	1	1	1
detect possible trends in water quality with respect to time and space;	3	3	2	2	1	2	1	1	1	1	-	-	0	1	0	1
assure a publicly credible basis for controversial (hot) decisions.	1	-	2	-	3	-	1	-	1	-	-	-	0	-	0	-

Annex 2-2A: The objective matrices filled by representatives from the Ministry of Water Resources and Irrigation (MWRI)

Summery results

Water Quality Monitoring Objectives	Objectives Matrix 1		Objectives Matrix 2		Objectives Matrix 3		Objectives Matrix 4		Objectives Matrix 5		Average	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	19	26	10	19	14	19	18	20	12	16	14.6	20.0
facilitate impact assessment studies	15	24	8	15	9	11	13	16	8	13	10.6	15.8
facilitate baseline water quality information (Survey monitoring).	0	0	6	14	7	11	6	8	6	6	5.0	7.8
determine fate and transport of pollutants	14	20	9	15	11	13	11	12	4	9	9.8	13.8
measure effectiveness of conservation practices	12	14	4	4	7	8	7	9	9	13	7.8	9.6
make waste-load allocations	14	20	12	18	8	12	9	13	7	9	10.0	14.4
validate & calibrate models and establish a database for the planning and development of water resources	8	11	6	10	7	7	5	5	9	12	7.0	9.0
conduct research	12	19	11	19	11	16	12	16	12	17	11.6	17.4
define water quality problem	16	21	14	18	14	15	16	21	14	15	14.8	18.0
detect possible trends in water quality with respect to time and space;	18	22	14	21	14	18	15	19	11	14	14.4	18.8
assure a publicly credible basis for controversial (hot) decisions.	6	3	11	7	5	6	5	0	9	0	7.2	3.2

Annex 2-2B: The objective matrices filled by representatives from the Ministry of Agriculture and Land Reclamation (MALR)

Objectives Matrix no. 1

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	3	3	2	3	2	3	1	2	1	2	1	3	1	2
facilitate impact assessment studies	3	2	2	3	2	2	2	3	-	-	-	-	0	3	0	2
facilitate baseline water quality information (Survey monitoring).	2	0	1	1	1	1	1	1	1	1	-	-	0	2	0	2
determine fate and transport of pollutants	3	3	1	2	2	3	1	2	-	-	-	-	0	2	0	1
measure effectiveness of conservation practices	3	3	2	3	3	3	1	3	-	-	2	3	0	1	0	1
make waste-load allocations	2	2	1	1	2	3	0	3	0	1	-	-	-	-	-	-
validate & calibrate models and establish a database for the planning and development of water resources	3	3	2	2	3	3	-	1	-	1	-	1	0	1	0	1
conduct research	3	3	2	3	3	3	-	1	-	1	0	1	0	1	0	1
define water quality problem	3	3	2	3	2	3	1	3	-	2						
detect possible trends in water quality with respect to time and space;	3	3	2	3	3	3	1	3	0	2	0	1	0	1	0	1
assure a publicly credible basis for controversial (hot) decisions.	1	2	1	2	1	3	0	2	0	1	0	1	0	1	0	1

Annex 2-2B: The objective matrices filled by representatives from the Ministry of Agriculture and Land Reclamation (MALR)

Objectives Matrix no. 2

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	3	3	2	2	3	3	1	1	-	-	0	1	0	1
facilitate impact assessment studies	2	0	1	2	1	2	1	2	1	1	-	-	0	0	0	0
facilitate baseline water quality information (Survey monitoring).	2	2	2	2	2	3	0	1	-	1	-	-	0	0	0	0
determine fate and transport of pollutants	3	3	2	2	2	3	1	1	-	-	-	-	0	0	0	0
measure effectiveness of conservation practices	2	1	1	1	2	2	2	3	1	1	-	-	0	0	0	0
make waste-load allocations	3	2	1	1	1	1	1	1	1	1	-	-	0	0	0	0
validate & calibrate models and establish a database for the planning and development of water resources	2	3	2	1	2	2	1	1	1	1	-	-	0	0	0	0
conduct research	3	0	2	3	3	3	2	2	1	1	-	-	0	1	0	1
define water quality problem	2	2	2	2	2	2	1	2	1	2	-	-	0	1	0	1
detect possible trends in water quality with respect to time and space;	2	2	2	3	2	3	2	2	1	1	-	-	0	2	0	1
assure a publicly credible basis for controversial (hot) decisions.	3	1	2	2	1	1	1	1	-	-	-	-	-	-	-	-

Annex 2-2B: The objective matrices filled by representatives from the Ministry of Agriculture and Land Reclamation (MALR)

Objectives Matrix no. 3

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	3	3	2	2	1	2	1	2	-	1	1	1	1	1
facilitate impact assessment studies	3	3	2	3	2	2	0	2	1	1	-	-	1	1	0	0
facilitate baseline water quality information (Survey monitoring).	2	2	3	3	1	1	-	-	1	1	-	-	0	0	0	0
determine fate and transport of pollutants	3	3	1	1	1	2	2	3	1	2	-	-	0	1	0	1
measure effectiveness of conservation practices	3	3	1	2	1	1	2	3	-	1	-	-	0	0	0	0
make waste-load allocations	3	3	1	1	1	1	-	-	0	0	-	-	0	0	0	0
validate & calibrate models and establish a database for the planning and development of water resources	3	3	3	3	2	3	-	-	0	0	-	-	0	0	0	0
conduct research	3	3	3	3	2	2	1	1	-	-	-	-	0	2	0	2
define water quality problem	3	3	3	1	2	3	1	1	1	1	-	-	-	1	-	1
detect possible trends in water quality with respect to time and space;	3	3	3	3	3	3	2	2	1	1	-	-	0	1	0	1
assure a publicly credible basis for controversial (hot) decisions.	2	2	-	-	1	1	-	-	-	-	-	-	0	0	0	0

Annex 2-2B: The objective matrices filled by representatives from the Ministry of Agriculture and Land Reclamation (MALR)

Objectives Matrix no. 4

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	2	3	3	3	3	1	2	-	-	-	-	1	2	1	1
facilitate impact assessment studies	3	3	2	3	1	2	1	1	-	-	-	-	1	1	1	1
facilitate baseline water quality information (Survey monitoring).	1	1	1	1	-	-	-	-	-	-	-	-	0	0	0	0
determine fate and transport of pollutants	2	2	1	1	3	3	1	-	-	-	-	-	0	0	0	0
measure effectiveness of conservation practices	3	3	1	2	3	3	1	1	-	-	-	-	0	0	0	0
make waste-load allocations	2	2	1	2	2	3	1	1	-	-	-	-	0	1	0	0
validate & calibrate models and establish a database for the planning and development of water resources	3	3	1	1	-	-	-	1	-	-	-	-	0	0	0	0
conduct research	2	3	1	3	2	2	1	1	-	-	-	-	0	1	0	1
define water quality problem	2	2	2	3	2	2	2	3	-	-	-	-	0	1	0	1
detect possible trends in water quality with respect to time and space;	3	3	2	3	3	3	2	2	-	-	-	-	0	1	0	1
assure a publicly credible basis for controversial (hot) decisions.	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0

Annex 2-2B: The objective matrices filled by representatives from the Ministry of Agriculture and Land Reclamation (MALR)

Objectives Matrix no. 5

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	2	2	3	3	3	3	2	3	2	3	1	1	0	2	0	2
facilitate impact assessment studies	1	2	2	3	2	2	1	2	-	1	-	-	0	1	0	1
facilitate baseline water quality information (Survey monitoring).	1	1	1	1	2	2	2	2	0	0	0	0	0	0	0	0
determine fate and transport of pollutants	1	1	2	1	1	2	1	1	-	1	-	-	0	0	0	0
measure effectiveness of conservation practices	1	1	2	2	3	2	1	1	-	-	-	-	0	0	0	0
make waste-load allocations	1	1	2	2	-	-	1	1	-	-	-	-	0	0	0	0
validate & calibrate models and establish a database for the planning and development of water resources	3	3	1	2	-	-	2	2	-	-	-	-	0	0	0	0
conduct research	2	2	3	3	1	1	2	2	1	1	1	1	0	0	0	1
define water quality problem	3	3	1	1	1	1	2	2	2	3	2	3	1	1	1	1
detect possible trends in water quality with respect to time and space;	3	3	2	3	2	2	2	2	1	1	1	1	0	0	0	0
assure a publicly credible basis for controversial (hot) decisions.	0	0	1	-	1	2	1	1	-	-	-	-	0	0	0	0

Annex 2-2B: The objective matrices filled by representatives from the Ministry of Agriculture and Land Reclamation (MALR)

Summery results

Water Quality Monitoring Objectives	Objectives Matrix 1		Objectives Matrix 2		Objectives Matrix 3		Objectives Matrix 4		Objectives Matrix 5		Average	
	Total											
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	17	24	15	17	15	18	15	16	16	22	15.6	19.4
facilitate impact assessment studies	11	18	7	9	11	15	11	14	8	15	9.6	14.2
facilitate baseline water quality information (Survey monitoring).	7	9	8	11	10	10	3	3	7	7	7.0	8.0
determine fate and transport of pollutants	8	15	10	11	9	14	8	7	7	7	8.4	10.8
measure effectiveness of conservation practices	13	20	9	9	8	12	9	11	9	8	9.6	12.0
make waste-load allocations	6	11	8	7	6	6	7	11	6	6	6.6	8.2
validate & calibrate models and establish a database for the planning and development of water resources	10	15	10	9	11	12	5	6	7	9	8.6	10.2
conduct research	10	17	13	14	12	16	7	14	13	14	11.0	15.0
define water quality problem	10	17	10	14	13	12	10	15	14	16	11.4	14.8
detect possible trends in water quality with respect to time and space;	11	20	11	17	15	17	12	16	13	15	12.4	17.0
assure a publicly credible basis for controversial (hot) decisions.	4	15	9	7	3	3	0	0	4	3	4.0	5.6

Annex 2-2C: The objective matrices filled by representatives from the Ministry of Environment (MOE)

Objectives Matrix no. 1

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	2	2	3	3	2	3	1	1	2	2	1	1	1	1
facilitate impact assessment studies	3	2	-	1	3	2	2	3	-	-	2	2	0	1	0	1
facilitate baseline water quality information (Survey monitoring).	1	1	-	1	2	1	1	1	2	2	1	2	0	0	0	1
determine fate and transport of pollutants	2	1	-	1	3	1	1	2	1	0	1	1	0	1	0	1
measure effectiveness of conservation practices	3	1	2	1	3	2	1	3	1	1	0	1	0	1	0	0
make waste-load allocations	3	0	-	-	2	1	0	3	1	1	-	-	0	0	0	0
validate & calibrate models and establish a database for the planning and development of water resources	1	-	-	0	3	2	-	1	1	1	1	1	0	0	0	0
conduct research	1	-	0	0	2	3	-	1	-	-	1	1	0	1	0	1
define water quality problem	3	1			3	2	1	3	1	1	1	1				
detect possible trends in water quality with respect to time and space;	3	1	0	0	3	3	1	3	1	2	1	1	0	0	0	0
assure a publicly credible basis for controversial (hot) decisions.	2	0	0	0	1	1	0	2	0	0	1	1	0	0	0	0

Annex 2-2C: The objective matrices filled by representatives from the Ministry of Environment (MOE)

Objectives Matrix no. 2

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	3	3	3	3	3	3	1	1	2	2	1	1	1	1
facilitate impact assessment studies	3	3	3	3	3	3	2	2	-	-	1	1	0	0	0	0
facilitate baseline water quality information (Survey monitoring).	3	3	1	1	1	1	-	-	-	-	1	1	0	0	0	0
determine fate and transport of pollutants	3	3	-	-	3	3	1	1	-	-	1	1	0	0	0	0
measure effectiveness of conservation practices	2	3	-	-	3	3	1	1	1	1	-	-	0	0	0	0
make waste-load allocations	3	3	-	-	2	2	-	-	-	-	2	2	0	0	0	0
validate & calibrate models and establish a database for the planning and development of water resources	3	3	-	-	2	2	-	-	-	-	1	1	0	0	0	0
conduct research	3	3	2	2	3	3	2	2	-	-	1	1	0	1	0	1
define water quality problem	3	3	3	3	3	3	2	2	1	1	1	1	0	2	0	2
detect possible trends in water quality with respect to time and space;	3	3	2	2	3	3	2	2	1	1	1	1	0	1	0	1
assure a publicly credible basis for controversial (hot) decisions.	-	-	-	-	1	1	-	-	1	1	1	1	0	0	0	0

Annex 2-2C: The objective matrices filled by representatives from the Ministry of Environment (MOE)

Objectives Matrix no. 3

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	2	3	3	3	3	2	2	2	2	3	3	2	2	1	1
facilitate impact assessment studies	3	2	2	2	3	3	2	3	0	0	2	2	0	1	0	0
facilitate baseline water quality information (Survey monitoring).	2	2	1	2	2	2	1	1	1	2	2	2	0	0	0	0
determine fate and transport of pollutants	2	2	-	-	2	2	1	2	1	1	1	2	0	0	0	0
measure effectiveness of conservation practices	2	2	1	1	2	3	2	2	1	1	1	1	0	0	0	0
make waste-load allocations	3	2	-	-	2	2	2	3	1	1	1	1	0	0	0	0
validate & calibrate models and establish a database for the planning and development of water resources	3	3	-	-	3	2	-	-	0	0	1	1	0	0	0	0
conduct research	3	3	2	2	3	3	2	2	0	0	-	-	0	1	0	0
define water quality problem	3	2	2	2	3	3	2	2	-	-	2	2	1	1	1	1
detect possible trends in water quality with respect to time and space;	3	3	2	2	3	3	2	2	2	2	2	2	1	1	1	1
assure a publicly credible basis for controversial (hot) decisions.	2	1	1	1	1	1	1	1	-	-	-	-	-	-	-	-

Annex 2-2C: The objective matrices filled by representatives from the Ministry of Environment (MOE)

Objectives Matrix no. 4

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	3	3	3	3	2	3	2	2	2	2	2	2	1	1
facilitate impact assessment studies	3	3	3	3	3	3	2	3	0	0	2	2	0	1	0	1
facilitate baseline water quality information (Survey monitoring).	3	3	1	2	2	2	1	1	2	2	2	2	0	0	0	1
determine fate and transport of pollutants	3	3	0	1	3	3	1	2	1	1	1	2	0	1	0	1
measure effectiveness of conservation practices	3	3	2	1	3	3	2	3	1	1	1	1	0	1	0	0
make waste-load allocations	3	3	0	0	2	2	2	3	1	1	2	2	0	0	0	0
validate & calibrate models and establish a database for the planning and development of water resources	3	3	0	0	3	2	0	1	1	1	1	1	0	0	0	0
conduct research	3	3	2	2	3	3	1	2	0	0	1	1	0	1	0	1
define water quality problem	3	3	3	3	3	3	1	3	1	1	2	2	1	2	1	1
detect possible trends in water quality with respect to time and space;	3	3	2	2	2	3	1	3	2	2	2	2	1	1	1	1
assure a publicly credible basis for controversial (hot) decisions.	-	-	1	1	1	1	1	2	1	1	1	1	0	0	0	0

Annex 2-2C: The objective matrices filled by representatives from the Ministry of Environment (MOE)

Objectives Matrix no. 5

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	2	2	2	2	3	3	2	3	2	2	2	3	1	1	1	1
facilitate impact assessment studies	3	3	2	3	2	2	1	2	1	1	2	2	0	0	0	0
facilitate baseline water quality information (Survey monitoring).	2	2	2	2	2	2	1	2	2	2	1	1	0	0	0	0
determine fate and transport of pollutants	2	3	2	1	2	2	2	2	1	1	2	2	0	0	0	0
measure effectiveness of conservation practices	2	2	1	2	2	3	1	1	-	-	2	2	0	0	0	0
make waste-load allocations	2	1	1	1	2	2	1	1	-	-	1	1	0	0	0	0
validate & calibrate models and establish a database for the planning and development of water resources	3	2	2	2	3	3	1	2	-	-	-	-	0	0	0	0
conduct research	2	3	1	1	3	3	1	2	-	-	1	1	0	1	0	0
define water quality problem	2	3	2	3	3	3	1	2	2	2	2	3	1	1	1	1
detect possible trends in water quality with respect to time and space;	2	3	3	3	3	3	2	2	-	-	1	2	0	0	0	0
assure a publicly credible basis for controversial (hot) decisions.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Annex 2-2C: The objective matrices filled by representatives from the Ministry of Environment (MOE)

Summery results

Water Quality Monitoring Objectives	Objectives Matrix 1		Objectives Matrix 2		Objectives Matrix 3		Objectives Matrix 4		Objectives Matrix 5		Average	
	Total											
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	18	19	20	20	22	21	21	22	18	20	19.8	20.4
facilitate impact assessment studies	13	14	15	15	15	16	16	19	13	15	14.4	15.8
facilitate baseline water quality information (Survey monitoring).	9	10	7	7	11	13	13	15	12	13	10.4	11.6
determine fate and transport of pollutants	11	9	11	11	9	11	12	17	13	13	11.2	12.2
measure effectiveness of conservation practices	13	12	10	11	11	13	15	16	10	13	11.8	13.0
make waste-load allocations	8	6	9	9	11	11	12	13	9	8	9.8	9.4
validate & calibrate models and establish a database for the planning and development of water resources	9	7	8	8	10	8	11	10	12	12	10.0	9.0
conduct research	6	10	14	16	13	14	13	16	11	14	11.4	14.0
define water quality problem	12	10	16	20	17	16	18	21	17	21	16.0	17.6
detect possible trends in water quality with respect to time and space;	12	13	15	17	19	19	16	20	14	16	15.2	17.0
assure a publicly credible basis for controversial (hot) decisions.	5	5	4	4	6	5	6	7	0	0	4.2	4.2

Annex 2-2D: The objectives matrices filled by representatives from Ministry of Health and Population (MOHP)

Objectives Matrix no. 1

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	2	3	2	2	3	3	2	2	2	2	0	1	0	1
facilitate impact assessment studies	3	3	2	3	2	2	2	2	-	-	1	1	0	1	0	1
facilitate baseline water quality information (Survey monitoring).	2	2	2	2	1	2	1	2	-	-	1	1	0	1	0	1
determine fate and transport of pollutants	2	2	1	2	2	2	2	2	1	1	2	2	0	1	0	1
measure effectiveness of conservation practices	3	3	2	3	3	3	3	3	-	-	1	1	0	-	0	-
make waste-load allocations	3	3	2	2	2	2	2	2	-	-	-	-	0	-	0	-
validate & calibrate models and establish a database for the planning and development of water resources	3	3	2	2	2	2	2	2	-	-	-	-	0	-	0	-
conduct research	3	3	2	2	2	2	2	2	-	-	-	-	0	1	0	1
define water quality problem	3	3	2	2	2	2	2	2	1	1	1	2	0	1	0	1
detect possible trends in water quality with respect to time and space;	3	3	2	2	3	3	1	2	1	1	-	-	0	-	0	-
assure a publicly credible basis for controversial (hot) decisions.	-	-	-	-	-	-	-	-	-	-	-	-	0	-	0	-

Annex 2-2D: The objectives matrices filled by representatives from Ministry of Health and Population (MOHP)

Objectives Matrix no. 2

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	3	3	3	3	2	3	-	-	-	-	-	-	-	-
facilitate impact assessment studies	3	3	2	2	2	2	2	1	-	-	-	-	-	-	-	-
facilitate baseline water quality information (Survey monitoring).	1	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-
determine fate and transport of pollutants	2	1	1	2	3	3	1	-	-	-	-	-	-	-	-	-
measure effectiveness of conservation practices	3	3	1	2	2	3	1	1	-	-	-	-	-	-	-	-
make waste-load allocations	2	2	2	2	2	3	1	2	-	-	-	-	-	-	-	-
validate & calibrate models and establish a database for the planning and development of water resources	3	3	1	1	-	-	-	1	-	-	-	-	-	-	-	-
conduct research	3	3	3	3	2	2	1	3	-	-	-	-	-	-	-	-
define water quality problem	3	3	2	3	2	2	2	3	-	-	-	-	-	-	-	-
detect possible trends in water quality with respect to time and space;	2	3	2	3	2	3	2	2	-	-	-	-	-	-	-	-
assure a publicly credible basis for controversial (hot) decisions.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Annex 2-2D: The objectives matrices filled by representatives from Ministry of Health and Population (MOHP)

Objectives Matrix no. 3

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	2	3	3	3	2	2	-	1	-	1	0	1	0	1
facilitate impact assessment studies	3	3	-	2	2	2	1	1	1	1	-	1	0	1	0	1
facilitate baseline water quality information (Survey monitoring).	2	3	2	3	1	2	2	2	1	2	-	1	0	1	0	1
determine fate and transport of pollutants	2	2	2	2	3	3	1	2	1	2	-	-	0	1	0	1
measure effectiveness of conservation practices	1	1	1	1	2	3	-	-	-	-	-	-	-	-	-	-
make waste-load allocations	3	3	2	2	2	3	1	2	1	1	-	1	0	1	0	1
validate & calibrate models and establish a database for the planning and development of water resources	2	3	1	2	2	2	1	2	1	1	1	1	-	-	-	-
conduct research	3	3	2	2	2	2	2	3	1	1	1	1	0	1	0	1
define water quality problem	2	3	2	3	2	2	2	2	1	1	1	1	1	1	1	1
detect possible trends in water quality with respect to time and space;	3	3	2	3	2	3	1	2	1	1	-	1	1	1	1	1
assure a publicly credible basis for controversial (hot) decisions.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Annex 2-2D: The objectives matrices filled by representatives from Ministry of Health and Population (MOHP)

Summery results

Water Quality Monitoring Objectives	Objectives Matrix 1		Objectives Matrix 2		Objectives Matrix 3		Average	
	Total							
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	17	20	13	15	12	17	8.4	10.4
facilitate impact assessment studies	12	15	11	9	8	13	6.2	7.4
facilitate baseline water quality information (Survey monitoring).	8	13	2	2	10	17	4.0	6.4
determine fate and transport of pollutants	12	15	8	6	10	15	6.0	7.2
measure effectiveness of conservation practices	15	16	8	10	4	5	5.4	6.2
make waste-load allocations	11	11	8	11	10	16	5.8	7.6
validate & calibrate models and establish a database for the planning and development of water resources	11	11	4	6	9	13	4.8	6.0
conduct research	11	13	10	14	13	17	6.8	8.8
define water quality problem	13	16	11	14	14	16	7.6	9.2
detect possible trends in water quality with respect to time and space;	11	13	10	13	12	17	6.6	8.6
assure a publicly credible basis for controversial (hot) decisions.	0	0	0	0	0	0	0.0	0.0

Annex 2-2E: The objectives matrices filled by representatives from Ministry of Housing, Utilities and New communities (MHUNC)

Objectives Matrix no. 1

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	2	2	2	3	1	2	2	3	1	1	-	-	-	-
facilitate impact assessment studies	2	2	1	2	2	2	1	2	1	1	1	1	-	-	-	-
facilitate baseline water quality information (Survey monitoring).	2	2	1	2	2	2	1	2	1	1	1	1	-	-	-	-
determine fate and transport of pollutants	2	2	-	-	2	2	1	2	2	2	1	1	-	-	-	-
measure effectiveness of conservation practices	2	2	2	2	2	2	1	2	2	2	1	1	-	-	-	-
make waste-load allocations	1	2	1	2	2	2	1	1	1	1	1	1	-	-	-	-
validate & calibrate models and establish a database for the planning and development of water resources	3	3	2	2	1	3	1	2	1	2	1	1	-	-	-	-
conduct research	3	3	1	1	3	3	1	1	1	2	1	1	-	-	-	-
define water quality problem	2	3	1	1	3	3	1	1	2	2	1	2	-	-	-	-
detect possible trends in water quality with respect to time and space;	3	3	3	3	3	3	2	2	2	3	1	1	-	-	-	-
assure a publicly credible basis for controversial (hot) decisions.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Annex 2-2F: The objectives matrices filled by representatives from Ministry of Industry (MOI)

Objectives Matrix no. 1

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	3	3	3	3	3	3	-	-	1	3	-	-	0	1
facilitate impact assessment studies	2	3	2	2	1	2	1	2	-	-	1	1	-	-	0	0
facilitate baseline water quality information (Survey monitoring).	2	2	2	2	2	3	0	1	-	-	1	1	-	-	0	0
determine fate and transport of pollutants	2	2	2	2	2	3	1	1	-	-	1	1	-	-	0	0
measure effectiveness of conservation practices	2	2	1	1	2	2	2	3	-	-	1	2	-	-	0	0
make waste-load allocations	2	2	1	1	1	1	1	1	-	-	1	1	-	-	0	0
validate & calibrate models and establish a database for the planning and development of water resources	3	3	1	1	2	2	1	1	-	-	1	1	-	-	0	0
conduct research	3	3	2	3	2	3	1	2	-	-	1	1	-	-	0	1
define water quality problem	3	3	2	2	2	2	1	2	-	-	1	2	-	-	0	1
detect possible trends in water quality with respect to time and space;	3	3	3	3	3	3	2	2	-	-	2	3	-	-	0	1
assure a publicly credible basis for controversial (hot) decisions.	1	1	1	1	1	1	1	1	-	-	1	1	-	-	-	-

Annex 2-2G: The objectives matrices filled by representatives from New Land Beneficiaries (NLB)

Objectives Matrix no. 1

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	3	3	3	3	3	3	-	3	-	-	2	3	2	3
facilitate impact assessment studies	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
facilitate baseline water quality information (Survey monitoring).	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
determine fate and transport of pollutants	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
measure effectiveness of conservation practices	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
make waste-load allocations	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
validate & calibrate models and establish a database for the planning and development of water resources	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
conduct research	3	3	2	2	3	3	3	3	-	-	-	-	0	2	0	2
define water quality problem	3	3	2	2	3	3	3	3	3	3	-	-	1	2	2	2
detect possible trends in water quality with respect to time and space;	3	3	-	-	3	3	3	3	-	-	-	-	0	2	2	2
assure a publicly credible basis for controversial (hot) decisions.	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0

Annex 2-2G: The objectives matrices filled by representatives from New Land Beneficiaries (NLB)

Objectives Matrix no. 2

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	3	3	-	-	-	-	-	-	-	-	1	3	1	3
facilitate impact assessment studies	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
facilitate baseline water quality information (Survey monitoring).	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
determine fate and transport of pollutants	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
measure effectiveness of conservation practices	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
make waste-load allocations	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
validate & calibrate models and establish a database for the planning and development of water resources	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
conduct research	3	3	3	3	-	-	-	-	-	-	-	-	0	2	1	3
define water quality problem	3	3	3	3	-	-	-	-	-	-	-	-	0	2	2	3
detect possible trends in water quality with respect to time and space;	3	3	-	-	-	-	-	-	-	-	-	-	0	2	1	1
assure a publicly credible basis for controversial (hot) decisions.	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0

Annex 2-2G: The objectives matrices filled by representatives from New Land Beneficiaries (NLB)

Objectives Matrix no. 3

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	3	3	3	3	3	3	0	3	0	0	0	3	0	3
facilitate impact assessment studies	-	-	-	-	-	-	-	-	-	-	-	-	0	1	0	1
facilitate baseline water quality information (Survey monitoring).	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
determine fate and transport of pollutants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
measure effectiveness of conservation practices	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
make waste-load allocations	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
validate & calibrate models and establish a database for the planning and development of water resources	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
conduct research	3	3	2	2	3	3	3	3	0	0	0	0	0	1	0	1
define water quality problem	3	3	2	2	3	3	3	3	3	3	0	0	0	1	0	1
detect possible trends in water quality with respect to time and space;	3	3	0	0	3	3	3	3	0	0	0	0	0	2	0	2
assure a publicly credible basis for controversial (hot) decisions.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Annex 2-2G: The objectives matrices filled by representatives from New Land Beneficiaries (NLB)

Summery results

Water Quality Monitoring Objectives	Objectives Matrix 1		Objectives Matrix 2		Objectives Matrix 3		Average	
	Total							
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	18	24	9	15	12	24	7.8	12.6
facilitate impact assessment studies	0	0	0	0	0	3	0.0	0.6
facilitate baseline water quality information (Survey monitoring).	0	0	0	0	0	0	0.0	0.0
determine fate and transport of pollutants	0	0	0	0	0	0	0.0	0.0
measure effectiveness of conservation practices	0	0	0	0	0	0	0.0	0.0
make waste-load allocations	0	0	0	0	0	0	0.0	0.0
validate & calibrate models and establish a database for the planning and development of water resources	0	0	0	0	0	0	0.0	0.0
conduct research	11	17	7	13	11	14	5.8	8.8
define water quality problem	18	20	8	13	14	17	8.0	10.0
detect possible trends in water quality with respect to time and space;	11	15	4	8	9	15	4.8	7.6
assure a publicly credible basis for controversial (hot) decisions.	0	0	0	0	0	0	0.0	0.0

Annex 2-2G: The objectives matrices filled by representatives from Old Land Beneficiaries (OLB)

Objectives Matrix no. 1

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	3	3	2	2	2	2	2	2	2	2	0	2	1	2
facilitate impact assessment studies	-	-	-	-	3	3	3	3	-	-	-	-	0	3	1	3
facilitate baseline water quality information (Survey monitoring).	-	-	-	-	-	-	-	-	-	-	-	-	0	1	0	1
determine fate and transport of pollutants	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
measure effectiveness of conservation practices	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
make waste-load allocations	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
validate & calibrate models and establish a database for the planning and development of water resources	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
conduct research	3	3	2	2	-	-	-	-	-	-	-	-	0	2	0	2
define water quality problem	3	3	2	2	3	3	-	-	-	-	-	-	0	2	1	2
detect possible trends in water quality with respect to time and space;	3	3	-	-	3	3	3	3	-	-	-	-	0	2	0	2
assure a publicly credible basis for controversial (hot) decisions.	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0

Annex 2-2G: The objectives matrices filled by representatives from Old Land Beneficiaries (OLB)

Objectives Matrix no. 2

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	3	3	-	-	2	2	-	-	-	-	1	3	1	3
facilitate impact assessment studies	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
facilitate baseline water quality information (Survey monitoring).	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
determine fate and transport of pollutants	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
measure effectiveness of conservation practices	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
make waste-load allocations	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
validate & calibrate models and establish a database for the planning and development of water resources	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
conduct research	3	3	3	3	-	-	2	2	-	-	-	-	0	2	1	3
define water quality problem	3	3	3	3	-	-		-	-	-	-	-	0	2	1	3
detect possible trends in water quality with respect to time and space;	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	2
assure a publicly credible basis for controversial (hot) decisions.	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0

Annex 2-2G: The objectives matrices filled by representatives from Old Land Beneficiaries (OLB)

Objectives Matrix no. 3

Water Quality Monitoring Objectives	Stakeholders Groups															
	MWRI		MALR		MOE		MOHP		MOHUNC		MOI		NLB		OLB	
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	3	3	3	3	3	3	3	3	3	3	-	3	1	2	1	3
facilitate impact assessment studies	-	-	-	-	-	-	-	-	-	-	-	-	0	1	0	1
facilitate baseline water quality information (Survey monitoring).	1	1	1	1	1	1	1	1	1	1	-	-	-	-	-	-
determine fate and transport of pollutants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
measure effectiveness of conservation practices	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
make waste-load allocations	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
validate & calibrate models and establish a database for the planning and development of water resources	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
conduct research	2	2	2	2	2	2	2	2	0	0	0	0	0	0	0	0
define water quality problem	3	3	2	3	3	2	3	3	2	2	1	1	0	0	0	0
detect possible trends in water quality with respect to time and space;	3	3	0	0	3	3	3	3	0	0	0	0	0	3	0	3
assure a publicly credible basis for controversial (hot) decisions.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Annex 2-2G: The objectives matrices filled by representatives from Old Land Beneficiaries (OLB)

Summery results

Water Quality Monitoring Objectives	Objectives Matrix 1		Objectives Matrix 2		Objectives Matrix 3		Average	
	Total							
	to use	to be informed	to use	to be informed	to use	to be informed	to use	to be informed
Assess compliance with standards	15	20	11	17	18	25	8.8	12.4
facilitate impact assessment studies	7	15	0	0	0	3	1.4	3.6
facilitate baseline water quality information (Survey monitoring).	0	3	0	0	5	5	1.0	1.6
determine fate and transport of pollutants	0	0	0	0	0	0	0.0	0.0
measure effectiveness of conservation practices	0	0	0	0	0	0	0.0	0.0
make waste-load allocations	0	0	0	0	0	0	0.0	0.0
validate & calibrate models and establish a database for the planning and development of water resources	0	0	0	0	0	0	0.0	0.0
conduct research	5	11	9	15	8	8	4.4	6.8
define water quality problem	9	14	7	13	14	14	6.0	8.2
detect possible trends in water quality with respect to time and space;	9	15	0	2	9	18	3.6	7.0
assure a publicly credible basis for controversial (hot) decisions.	0	0	0	0	0	0	0.0	0.0

The list of participants from all stakeholders

Name	Title	Institution
Ashraf Abd El-Megid Hadad	Senior Engineer	Ministry of Water Resources and Irrigation
Ahmed Mostafa	Assistance Researcher	
Adel Taha Shoaaib	Senior Engineer	
Bahaa Khalil	Research Assistant	
Gamal Abdel Nasser	Deputy Director	
Mohamed Amin Abu-Sinna	Professor	Ministry of Agriculture and Land Reclamation
Iman Mohamoud	Junior Engineer	
Ahmed Abdel Halim	Professor	
Ismael abdel Rahman	Junior Engineer	
Talaat El-Beshbeshy	Department Head	
Osama abdel Wahab	Chemist	Ministry of Environment
Radwa Abdel Salam	Environmentalist	
Ahmed Mohamed	Chemist	
Rabab Hassan	Chemist	
Nabil Abdel Wahab	Environmentalist	
Lobna Alsherbiny	Doctor	Ministry of Health and Population
Sara Abaas	Doctor	
Kamel Hassan	Doctor	
Mohamed Alsayed	Housing Sector	Ministry of Housing, Utilities and New Communities
Ismael Huessien	Engineer	Ministry of Industry
Abdel Salam Mohamed	Farmer	New Land Beneficiaries
Reda Abdel-Latif	Farmer	
Abdel Baset Omar	Farmer	
Mohamoud Ahmed	Teacher/Farmer	Old Land Beneficiaries
Ali Abdel-Rehiem	Agriculture Engineer	
Shawaqi Kalifa	Farmer	

ANNEX 4-1

WATER QUANTITY AND QUALITY MONITORING LOCATIONS FOR HADUS DRAIN AND ITS MAIN TRIBUTARIES

Annex 4-1: Water quantity and quality monitoring locations for Hadus drain and its main tributaries

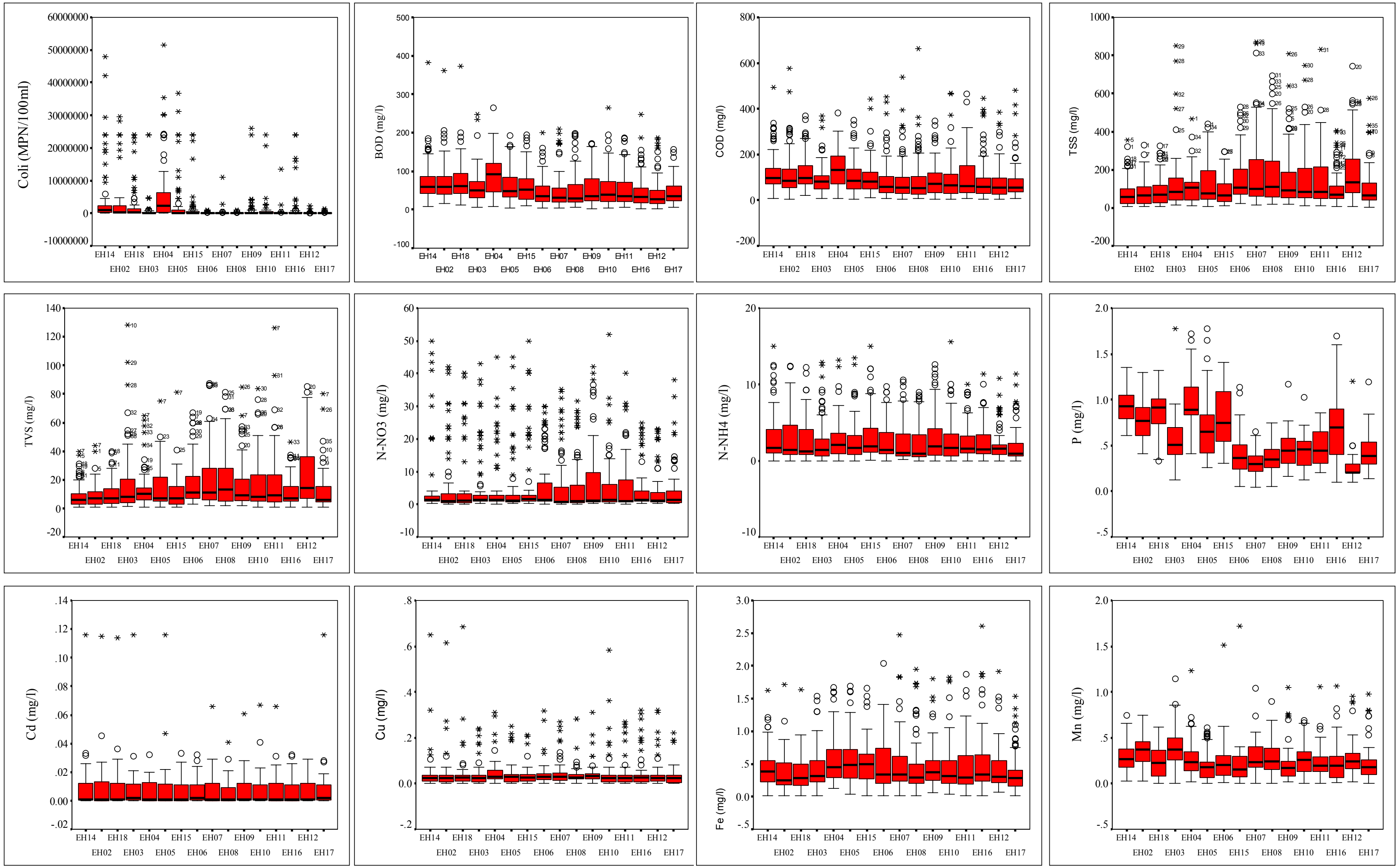
LOCATION NAME	LOCATION CODE	Area Served (10^3) feddan	Quality Data		Quantity Data		Coordinates		LOCATION TYPE
			From	To	From	To	latitude (North)	longitude (East)	
Gemeeza Bridge	EH14	-	Aug-97	Jan-05	Aug-84	Jul-99	31.5398	30.7967	Open Location
Hanut P.S.	EH02	74	Aug-97	Jan-05	Aug-84	Jul-04	30.8449	31.5958	Reuse
Additional Point between Hanut and Sadaqa Pump stations	EH18	-	Aug-97	Jan-05	Dec-97	Jul-99	31.6183	30.8747	Open Location
Sadaqa P.S.	EH03	43	Aug-97	Jan-05	Aug-84	Dec-99	31.6343	30.9130	P.S.
Nizam Bridge	EH04	-	Aug-97	Jan-05	Aug-84	Dec-99	31.5470	30.9778	Open Location
Nizam P.S.	EH05	45	Aug-97	Jan-05	Aug-84	Dec-99	31.5768	30.9768	P.S.
El-Dawar Bridge	EH15	-	Aug-97	Jan-05	Aug-84	Dec-99	31.7173	30.4953	Open Location
Beni Ebid P.S	EH06	53	Aug-97	Jan-05	Aug-84	Dec-99	31.7420	31.0363	Reuse
Additional Qassabi P.S.	EH07	60	Aug-97	Jan-05	Aug-84	Jul-99	31.8188	31.0633	P.S.
Main Qassabi P.S.	EH08	28	Aug-97	Jan-05	Aug-84	Dec-99	31.8958	31.0710	P.S.
Genina P.S.	EH09	38	Aug-97	Jan-05	Aug-84	Jul-04	31.1084	31.6884	Reuse
Erad P.S.	EH10	57	Aug-97	Jan-05	Aug-84	Dec-99	31.8707	31.1127	P.S.
Bahr Hadus Bridge	EH11	-	Aug-97	Jan-05	Aug-84	Dec-99	31.9007	31.0747	Open Location
Saft P.S.	EH12	175	Aug-97	Jan-05	Aug-84	Jul-04	30.9677	31.8785	30 % Reuse
El-Rian drain	EH16		Aug-97	Jan-05	May-98	Jul-99	31.7507	30.7438	Open Location
New Bahr Hadus Outfall to Salam Canal (El-Salam 3 P.S.)	EH17	-	Aug-97	Jan-05	Aug-94	Jul-04	32.0067	31.1053	Irrigation P.S.

P.S. = Pump Station

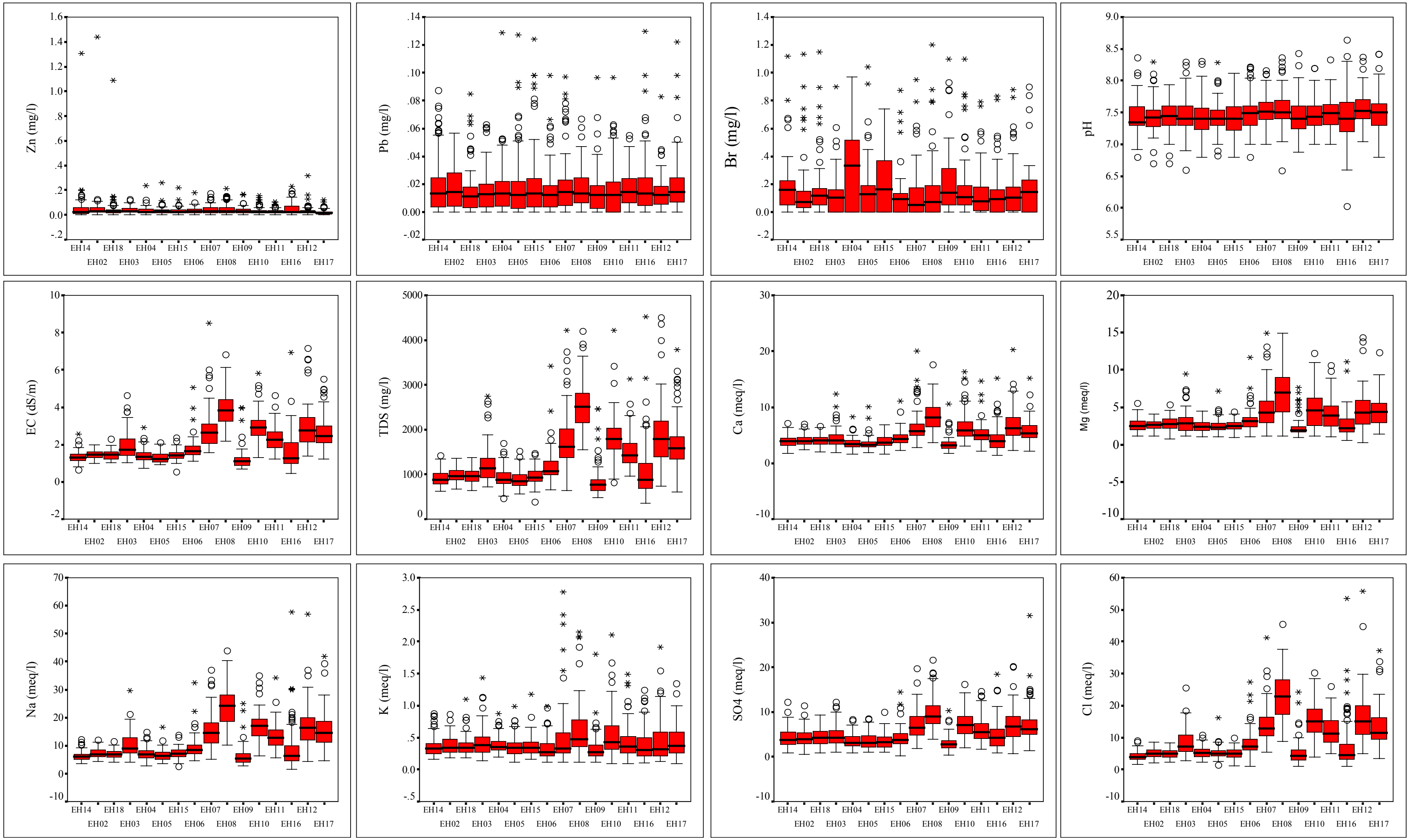
ANNEX 4-2

BOX AND WHISKER PLOTS FOR SOME WQPs MEASURED IN HADUS DRAIN

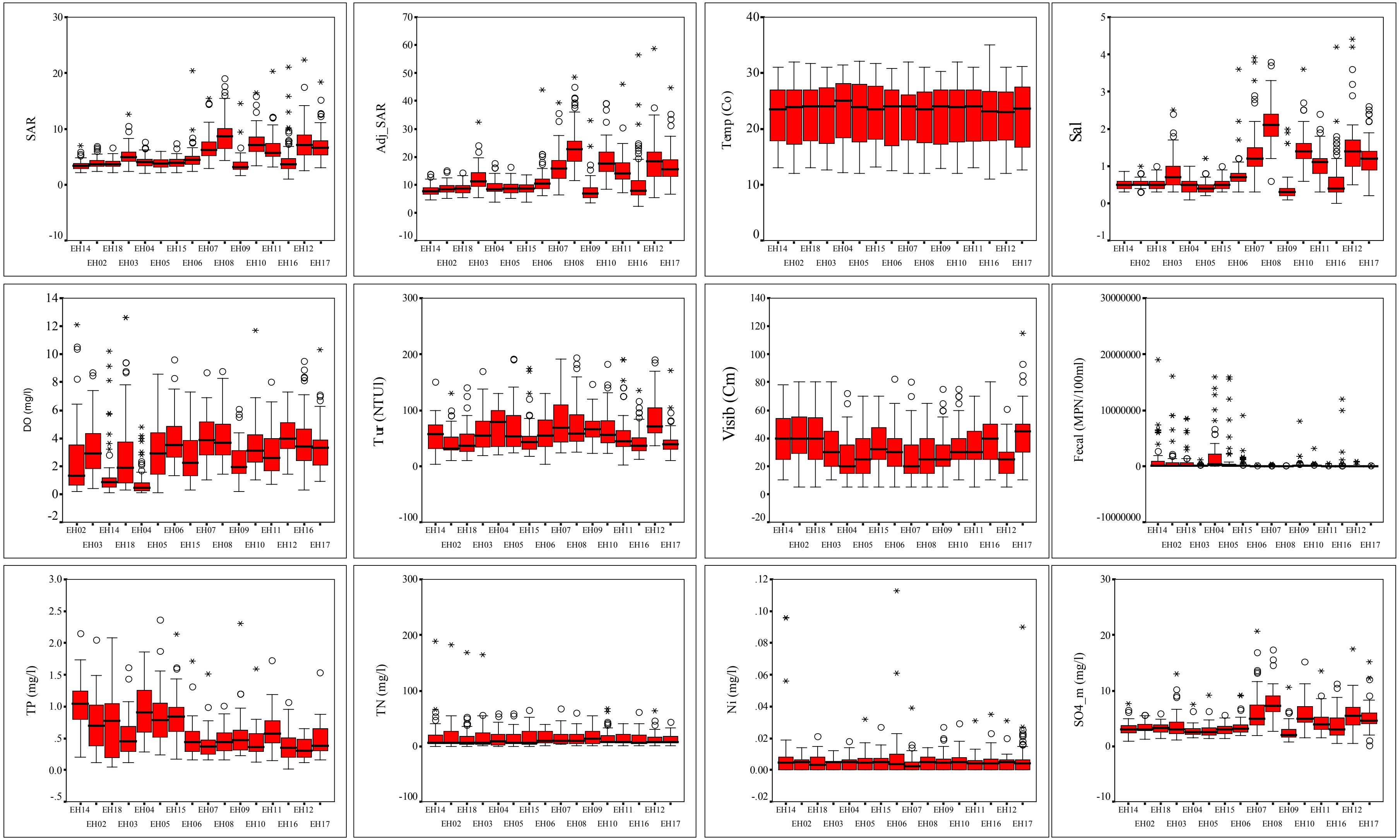
Annex 4-2: Box and Whisker plots for some WQPs measured in Hadus drain



Annex 4-2 Cont.: Box and Whisker plots for some WQPs measured in Hadus drain



Annex 4-2 Cont.: Box and Whisker plots for some WQPs measured in Hadus drain



ANNEX 4-3

UNIVARIATE SUMMARY STATISTICS FOR MONTHLY MEASUREMENTS OF WQPs IN HADUS DRAIN DURING THE PERIOD FROM AUGUST 1997 TILL JANUARY 2005

Annex 4-3: Univariate summary statistics for monthly measurements of WQPs in Hadus drain during the period from August 1997 till January 2005

Paramters	N	Range	Minimum	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
					Statistic	Std. Error		Statistic	Std. Error	Statistic	Std. Error
Coli (MPN/100ml)											
EH14	89	47996000.00	4000.00	48000000.00	4318587.64	949599.86	8958507.15	3.01	0.26	9.65	0.51
EH02	89	29497000.00	3000.00	29500000.00	3141471.35	748725.82	7063465.25	2.70	0.26	5.97	0.51
EH18	89	23999100.00	900.00	24000000.00	2497547.19	578866.74	5461017.94	2.95	0.26	8.27	0.51
EH03	90	23998500.00	1500.00	24000000.00	860338.89	377496.93	3581250.32	6.22	0.25	38.83	0.50
EH04	90	51595700.00	4300.00	51600000.00	6623327.78	1068709.29	10138666.55	2.19	0.25	4.87	0.50
EH05	90	36798500.00	1500.00	36800000.00	2791390.56	742316.01	7042228.05	3.25	0.25	10.35	0.50
EH15	90	23997700.00	2300.00	24000000.00	1711665.56	540528.51	5127903.65	3.83	0.25	13.72	0.50
EH06	90	927900.00	2100.00	930000.00	119131.11	20015.33	189882.07	3.37	0.25	11.62	0.50
EH07	89	10997900.00	2100.00	11000000.00	230498.99	126544.35	1193817.02	8.65	0.26	77.73	0.51
EH08	90	929240.00	760.00	930000.00	107078.11	18715.29	177548.78	3.56	0.25	13.89	0.50
EH09	90	25997900.00	2100.00	26000000.00	1028426.67	394358.22	3741210.55	6.09	0.25	37.86	0.50
EH10	90	23999300.00	700.00	24000000.00	812080.56	351499.34	3334615.51	6.31	0.25	40.23	0.50
EH11	90	13499100.00	900.00	13500000.00	285885.67	151320.02	1435547.73	9.00	0.25	83.25	0.50
EH16	90	23997700.00	2300.00	24000000.00	1622605.33	533615.15	5062317.79	3.70	0.25	12.86	0.50
EH12	90	2398000.00	2000.00	2400000.00	114261.11	33836.33	320999.58	5.45	0.25	32.85	0.50
EH17	90	1497700.00	2300.00	1500000.00	124570.00	25096.60	238087.28	3.68	0.25	15.30	0.50
BOD (mg/l)											
EH14	87	374.10	8.00	382.10	77.80	6.02	56.11	2.47	0.26	9.47	0.51
EH02	87	346.30	16.00	362.30	75.22	6.16	57.48	2.34	0.26	7.41	0.51
EH18	86	360.00	12.00	372.00	75.95	5.85	54.27	2.44	0.26	9.62	0.51
EH03	90	242.40	6.00	248.40	58.51	4.52	42.93	2.16	0.25	6.68	0.50
EH04	90	256.60	8.00	264.60	93.58	5.88	55.74	0.70	0.25	0.25	0.50
EH05	90	191.00	4.00	195.00	63.97	4.67	44.29	1.07	0.25	0.64	0.50
EH15	89	276.40	10.00	286.40	66.14	5.54	52.29	2.00	0.26	4.88	0.51
EH06	90	333.90	5.00	338.90	53.45	5.52	52.33	2.91	0.25	11.29	0.50
EH07	87	371.20	4.00	375.20	56.90	6.51	60.71	2.50	0.26	8.46	0.51
EH08	90	478.10	6.00	484.10	57.92	7.29	69.15	3.30	0.25	15.74	0.50
EH09	90	273.20	3.00	276.20	56.92	5.12	48.58	1.76	0.25	4.00	0.50
EH10	90	380.10	5.00	385.10	61.62	6.53	61.99	2.48	0.25	8.56	0.50
EH11	90	318.70	7.00	325.70	57.13	5.60	53.09	2.19	0.25	6.83	0.50
EH16	90	283.10	3.00	286.10	51.44	5.63	53.37	2.23	0.25	5.53	0.50
EH12	90	184.10	2.00	186.10	48.45	5.94	56.31	2.82	0.25	11.28	0.50
EH17	90	150.00	6.00	156.00	50.16	5.12	48.59	3.66	0.25	20.51	0.50
COD (mg/l)											
EH14	89	485.00	9.00	494.00	123.55	9.53	89.87	1.57	0.26	2.75	0.51
EH02	89	571.00	5.00	576.00	117.24	10.74	101.32	2.16	0.26	5.66	0.51
EH18	89	349.90	20.00	369.90	121.28	8.42	79.47	1.16	0.26	0.88	0.51
EH03	90	362.90	7.00	369.90	91.73	7.26	68.89	1.96	0.25	5.01	0.50
EH04	90	374.00	9.00	383.00	133.07	8.38	79.49	0.53	0.25	-0.08	0.50
EH05	90	345.00	5.00	350.00	100.30	7.66	72.67	1.34	0.25	1.98	0.50
EH15	89	430.00	12.00	442.00	100.40	8.59	81.03	1.99	0.26	4.98	0.51
EH06	90	444.00	9.00	453.00	88.67	9.39	89.04	2.19	0.25	5.31	0.50
EH07	87	533.00	5.00	538.00	86.37	10.36	96.63	2.34	0.26	6.26	0.51
EH08	90	654.00	9.00	663.00	90.19	10.84	102.88	2.68	0.25	10.37	0.50
EH09	90	341.00	4.00	345.00	87.72	7.84	74.37	1.51	0.25	2.17	0.50
EH10	90	462.00	6.00	468.00	90.20	9.67	91.78	2.18	0.25	5.69	0.50
EH11	90	458.00	8.00	466.00	101.92	10.40	98.65	1.59	0.25	2.39	0.50
EH16	90	440.00	4.00	444.00	88.28	10.49	99.49	2.07	0.25	3.72	0.50
EH12	90	382.70	3.00	385.70	79.22	8.55	81.14	1.80	0.25	3.30	0.50
EH17	90	475.00	7.00	482.00	81.87	8.98	85.15	2.64	0.25	8.29	0.50

Annex 4-3: Univariate summary statistics for monthly measurements of WQPs in Hadus drain during the period from August 1997 till January 2005

Paramters	N	Range	Minimum	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
					Statistic	Std. Error		Statistic	Std. Error	Statistic	Std. Error
TSS (mg/l)											
EH14	87	349.00	7.00	356.00	76.07	7.86	73.31	1.72	0.26	2.96	0.51
EH02	87	320.00	8.00	328.00	75.73	7.06	65.87	1.41	0.26	2.30	0.51
EH18	87	318.00	7.00	325.00	89.73	8.38	78.18	1.29	0.26	0.97	0.51
EH03	90	983.60	13.20	996.80	140.30	18.17	172.39	3.10	0.25	10.87	0.50
EH04	90	457.00	11.00	468.00	111.25	9.02	85.53	1.57	0.25	3.35	0.50
EH05	90	635.20	8.80	644.00	132.86	12.94	122.80	1.58	0.25	2.60	0.50
EH15	90	604.80	9.00	613.80	98.08	10.00	94.85	2.31	0.25	8.68	0.50
EH06	90	647.80	22.20	670.00	157.49	14.15	134.28	1.73	0.25	2.59	0.50
EH07	89	855.00	16.00	871.00	175.91	19.12	180.33	2.03	0.26	4.31	0.51
EH08	90	673.30	20.00	693.30	182.30	17.40	165.08	1.41	0.25	1.28	0.50
EH09	90	791.40	15.00	806.40	146.53	15.26	144.76	2.19	0.25	5.59	0.50
EH10	90	738.90	9.10	748.00	148.34	15.27	144.90	1.94	0.25	4.20	0.50
EH11	90	819.40	10.00	829.40	140.84	14.91	141.48	2.09	0.25	5.76	0.50
EH16	90	398.00	6.00	404.00	100.04	9.18	87.12	1.86	0.25	3.00	0.50
EH12	90	736.50	6.00	742.50	192.99	17.03	161.58	1.21	0.25	0.66	0.50
EH17	90	573.00	3.00	576.00	105.99	11.32	107.36	2.10	0.25	4.85	0.50
TVS (mg/l)											
EH14	88	39.00	1.00	40.00	8.34	0.90	8.44	1.83	0.26	3.14	0.51
EH02	88	43.00	1.00	44.00	8.44	0.87	8.12	2.08	0.26	5.54	0.51
EH18	88	39.00	1.00	40.00	9.56	0.96	9.04	1.54	0.26	1.90	0.51
EH03	90	126.50	1.50	128.00	16.91	2.44	23.12	2.88	0.25	9.01	0.50
EH04	90	64.00	1.00	65.00	13.19	1.38	13.06	2.36	0.25	5.89	0.50
EH05	90	74.10	0.90	75.00	14.78	1.61	15.26	1.59	0.25	2.30	0.50
EH15	90	80.00	1.00	81.00	10.95	1.35	12.79	3.03	0.25	12.38	0.50
EH06	90	64.00	3.00	67.00	17.40	1.71	16.22	1.68	0.25	1.88	0.50
EH07	89	85.10	2.00	87.10	17.36	1.91	18.01	2.03	0.26	4.42	0.51
EH08	90	79.20	2.00	81.20	19.75	2.04	19.33	1.48	0.25	1.53	0.50
EH09	90	83.80	1.00	84.80	14.87	1.66	15.73	2.23	0.25	5.28	0.50
EH10	90	82.90	1.10	84.00	16.38	1.84	17.43	1.89	0.25	3.60	0.50
EH11	90	125.00	1.00	126.00	17.25	2.23	21.18	2.55	0.25	8.44	0.50
EH16	90	45.80	0.80	46.60	10.76	0.99	9.35	1.70	0.25	2.71	0.50
EH12	90	84.20	1.00	85.20	21.40	2.11	20.06	1.34	0.25	1.08	0.50
EH17	89	79.00	1.00	80.00	11.73	1.41	13.34	2.93	0.26	10.74	0.51
N-NO3 (mg/l)											
EH14	88	49.89	0.11	50.00	5.80	1.22	11.45	2.60	0.26	5.72	0.51
EH02	87	41.87	0.13	42.00	5.92	1.13	10.64	2.15	0.26	3.51	0.51
EH18	88	39.96	0.04	40.00	5.47	1.12	10.47	2.32	0.26	4.12	0.51
EH03	90	42.60	0.40	43.00	6.10	1.10	10.43	2.18	0.25	3.81	0.50
EH04	87	44.94	0.06	45.00	5.25	0.96	9.04	2.36	0.26	5.10	0.51
EH05	90	44.80	0.20	45.00	5.89	1.08	10.22	2.28	0.25	4.39	0.50
EH15	89	49.80	0.20	50.00	6.36	1.18	11.24	2.18	0.25	3.91	0.50
EH06	89	29.86	0.14	30.00	6.83	0.99	9.38	1.25	0.26	-0.06	0.51
EH07	89	35.08	0.12	35.20	6.07	0.99	9.34	1.73	0.26	1.90	0.51
EH08	90	31.45	0.05	31.50	6.05	0.95	8.98	1.54	0.25	1.04	0.50
EH09	89	41.74	0.26	42.00	7.85	1.21	11.45	1.56	0.26	1.30	0.51
EH10	90	51.70	0.30	52.00	5.65	0.94	8.90	2.65	0.25	8.66	0.50
EH11	90	39.87	0.13	40.00	6.26	0.98	9.30	1.75	0.25	2.19	0.50
EH16	89	45.92	0.28	46.20	5.25	0.87	8.19	2.57	0.26	7.47	0.51
EH12	90	48.61	0.39	49.00	4.96	0.87	8.26	2.92	0.25	10.21	0.50
EH17	90	37.81	0.19	38.00	4.82	0.80	7.62	2.38	0.25	5.65	0.50

Annex 4-3: Univariate summary statistics for monthly measurements of WQPs in Hadus drain during the period from August 1997 till January 2005

Paramters	N	Range	Minimum	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
					Statistic	Std. Error		Statistic	Std. Error	Statistic	Std. Error
N-NH4 (mg/l)											
EH14	86	14.99	0.01	15.00	3.12	0.36	3.37	1.64	0.26	2.11	0.51
EH02	85	12.39	0.01	12.40	3.02	0.34	3.19	1.27	0.26	0.59	0.51
EH18	86	12.19	0.01	12.20	2.79	0.32	2.94	1.33	0.26	0.90	0.51
EH03	88	12.89	0.01	12.90	2.58	0.32	2.98	1.71	0.26	2.38	0.51
EH04	88	131.99	0.01	132.00	4.36	1.46	13.87	8.95	0.25	83.01	0.50
EH05	90	149.99	0.01	150.00	4.32	1.66	15.76	9.08	0.25	84.66	0.50
EH15	89	137.94	0.06	138.00	4.52	1.53	14.55	8.87	0.25	82.03	0.50
EH06	90	84.99	0.01	85.00	2.78	0.27	2.54	1.13	0.26	0.07	0.51
EH07	89	50.84	0.16	51.00	2.48	0.29	2.69	1.45	0.26	1.09	0.51
EH08	90	45.99	0.01	46.00	2.40	0.27	2.57	1.32	0.26	0.51	0.51
EH09	88	12.59	0.01	12.60	3.10	0.33	3.11	1.44	0.26	1.35	0.51
EH10	89	15.59	0.01	15.60	2.59	0.31	2.88	2.38	0.26	6.77	0.51
EH11	90	9.99	0.01	10.00	3.24	0.56	5.28	6.59	0.25	53.57	0.50
EH16	90	22.99	0.01	23.00	3.09	0.38	3.62	2.75	0.25	10.45	0.50
EH12	90	42.99	0.01	43.00	2.80	0.52	4.97	6.33	0.25	48.79	0.50
EH17	90	51.29	0.01	51.30	2.73	0.60	5.72	7.12	0.25	59.59	0.50
P (mg/l)											
EH14	36	1.17	0.61	1.78	0.95	0.04	0.23	1.33	0.39	3.56	0.77
EH02	36	1.29	0.41	1.70	0.83	0.05	0.27	0.96	0.39	1.58	0.77
EH18	36	1.34	0.33	1.67	0.89	0.04	0.26	0.23	0.39	1.42	0.77
EH03	36	1.66	0.12	1.78	0.63	0.06	0.36	1.77	0.39	4.55	0.77
EH04	36	1.31	0.41	1.72	1.02	0.05	0.32	0.61	0.39	0.02	0.77
EH05	36	1.52	0.26	1.78	0.75	0.07	0.42	1.15	0.39	0.34	0.77
EH15	36	1.10	0.31	1.41	0.82	0.05	0.31	0.28	0.39	-0.96	0.77
EH06	35	1.57	0.05	1.62	0.46	0.05	0.32	1.89	0.40	4.43	0.78
EH07	35	0.61	0.04	0.65	0.34	0.02	0.15	0.26	0.40	-0.47	0.78
EH08	35	0.70	0.05	0.75	0.37	0.03	0.16	0.38	0.40	0.04	0.78
EH09	35	1.01	0.16	1.17	0.46	0.03	0.20	1.32	0.40	3.39	0.78
EH10	35	0.91	0.12	1.03	0.44	0.03	0.19	0.64	0.40	1.31	0.78
EH11	36	0.66	0.20	0.86	0.48	0.03	0.20	0.34	0.39	-1.12	0.77
EH16	35	4.20	0.10	4.30	0.87	0.12	0.73	3.31	0.40	15.32	0.78
EH12	34	1.10	0.10	1.20	0.27	0.03	0.20	3.35	0.40	14.88	0.79
EH17	36	1.05	0.14	1.19	0.45	0.04	0.24	1.26	0.39	1.54	0.77
Cd (mg/l)											
EH14	88	0.12	0.00	0.12	0.01	0.00	0.02	4.99	0.26	28.03	0.51
EH02	89	0.12	0.00	0.12	0.01	0.00	0.02	4.79	0.26	26.17	0.51
EH18	89	0.12	0.00	0.12	0.01	0.00	0.02	4.94	0.26	27.65	0.51
EH03	90	0.12	0.00	0.12	0.01	0.00	0.02	5.31	0.25	31.03	0.50
EH04	90	0.12	0.00	0.12	0.01	0.00	0.01	5.92	0.25	45.84	0.50
EH05	90	0.13	0.00	0.13	0.01	0.00	0.02	5.19	0.25	29.92	0.50
EH15	90	0.12	0.00	0.12	0.01	0.00	0.01	6.01	0.25	46.57	0.50
EH06	90	0.09	0.00	0.09	0.01	0.00	0.01	4.74	0.25	32.16	0.50
EH07	88	0.13	0.00	0.13	0.01	0.00	0.01	3.41	0.26	18.26	0.51
EH08	90	0.11	0.00	0.11	0.01	0.00	0.01	5.56	0.25	40.70	0.50
EH09	89	0.06	0.00	0.06	0.01	0.00	0.01	3.00	0.26	14.79	0.51
EH10	89	0.07	0.00	0.07	0.01	0.00	0.01	3.59	0.26	18.90	0.51
EH11	89	0.07	0.00	0.07	0.01	0.00	0.01	4.86	0.26	30.38	0.51
EH16	90	0.12	0.00	0.12	0.01	0.00	0.01	5.77	0.25	43.67	0.50
EH12	90	0.12	0.00	0.12	0.01	0.00	0.01	5.99	0.25	46.39	0.50
EH17	90	0.12	0.00	0.12	0.01	0.00	0.01	5.71	0.25	42.42	0.50

Annex 4-3: Univariate summary statistics for monthly measurements of WQPs in Hadus drain during the period from August 1997 till January 2005

Paramters	N	Range	Minimum	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
					Statistic	Std. Error		Statistic	Std. Error	Statistic	Std. Error
Cu (mg/l)											
EH14	87	0.65	0.00	0.65	0.04	0.01	0.08	6.39	0.26	46.87	0.51
EH02	87	0.62	0.00	0.62	0.04	0.01	0.08	5.89	0.26	41.11	0.51
EH18	87	0.69	0.00	0.69	0.04	0.01	0.08	6.43	0.26	48.48	0.51
EH03	90	0.58	0.00	0.58	0.04	0.01	0.07	4.98	0.25	31.19	0.50
EH04	88	0.31	0.00	0.31	0.05	0.01	0.06	2.79	0.26	9.26	0.51
EH05	88	0.25	0.00	0.25	0.04	0.01	0.05	2.79	0.26	7.80	0.51
EH15	88	0.21	0.00	0.21	0.03	0.00	0.04	2.97	0.26	10.13	0.51
EH06	90	0.32	0.00	0.32	0.04	0.01	0.06	3.34	0.25	11.97	0.50
EH07	89	0.27	0.00	0.27	0.04	0.01	0.05	2.43	0.26	6.10	0.51
EH08	90	0.28	0.00	0.28	0.05	0.01	0.08	5.54	0.25	37.08	0.50
EH09	90	0.31	0.00	0.31	0.04	0.00	0.05	3.29	0.25	14.28	0.50
EH10	90	0.58	0.00	0.58	0.04	0.01	0.08	4.55	0.25	25.46	0.50
EH11	90	0.27	0.00	0.27	0.04	0.01	0.06	2.34	0.25	4.65	0.50
EH16	90	0.34	0.00	0.34	0.05	0.01	0.08	2.55	0.25	5.84	0.50
EH12	90	0.32	0.00	0.32	0.04	0.01	0.06	2.83	0.25	8.02	0.50
EH17	90	0.22	0.00	0.22	0.03	0.00	0.04	2.77	0.25	8.40	0.50
Fe (mg/l)											
EH14	88	1.62	0.01	1.63	0.46	0.03	0.31	1.26	0.26	1.51	0.51
EH02	88	1.71	0.00	1.71	0.37	0.03	0.29	1.55	0.26	4.19	0.51
EH18	88	1.63	0.01	1.64	0.36	0.03	0.27	1.55	0.26	4.24	0.51
EH03	86	1.52	0.01	1.53	0.46	0.04	0.34	1.30	0.25	1.22	0.50
EH04	90	1.70	0.12	1.82	0.58	0.04	0.38	1.46	0.25	1.78	0.50
EH05	90	2.25	0.03	2.28	0.58	0.04	0.42	1.56	0.25	2.82	0.50
EH15	89	1.99	0.01	2.00	0.54	0.04	0.36	1.55	0.26	3.11	0.51
EH06	90	2.07	0.01	2.08	0.52	0.05	0.45	1.44	0.25	2.08	0.50
EH07	89	2.60	0.01	2.61	0.56	0.05	0.51	2.30	0.26	5.40	0.51
EH08	90	2.90	0.01	2.91	0.47	0.05	0.50	2.40	0.25	6.97	0.50
EH09	90	1.74	0.06	1.80	0.50	0.04	0.36	1.73	0.25	2.99	0.50
EH10	90	1.79	0.04	1.83	0.47	0.04	0.42	1.96	0.25	3.53	0.50
EH11	90	1.86	0.01	1.87	0.43	0.04	0.38	1.56	0.25	2.58	0.50
EH16	90	2.60	0.01	2.61	0.52	0.05	0.46	2.17	0.25	5.43	0.50
EH12	90	1.85	0.07	1.92	0.46	0.04	0.35	1.76	0.25	3.56	0.50
EH17	90	1.65	0.01	1.66	0.41	0.04	0.37	1.63	0.25	2.13	0.50
Mn (mg/l)											
EH14	51	0.78	0.03	0.81	0.30	0.02	0.18	1.02	0.33	0.96	0.66
EH02	51	0.92	0.03	0.95	0.37	0.03	0.20	0.39	0.33	0.52	0.66
EH18	51	0.61	0.00	0.62	0.24	0.02	0.17	0.60	0.33	-0.64	0.66
EH03	53	1.14	0.00	1.14	0.36	0.03	0.23	0.79	0.32	1.45	0.64
EH04	54	1.94	0.02	1.96	0.35	0.05	0.34	2.67	0.32	9.62	0.64
EH05	54	0.84	0.00	0.84	0.21	0.03	0.19	1.22	0.32	0.94	0.64
EH15	54	1.72	0.00	1.72	0.24	0.04	0.28	3.27	0.32	14.75	0.64
EH06	54	1.74	0.01	1.75	0.29	0.05	0.35	2.77	0.32	8.30	0.64
EH07	53	1.47	0.00	1.47	0.31	0.04	0.26	2.58	0.33	8.26	0.64
EH08	53	1.26	0.00	1.26	0.31	0.03	0.25	1.56	0.32	3.27	0.64
EH09	54	1.49	0.02	1.51	0.44	0.18	1.35	6.86	0.32	49.27	0.63
EH10	54	1.34	0.00	1.34	0.46	0.18	1.33	7.06	0.32	51.33	0.63
EH11	54	1.36	0.00	1.36	0.26	0.03	0.25	2.56	0.32	7.94	0.64
EH16	54	1.05	0.01	1.06	0.26	0.03	0.25	1.45	0.32	1.80	0.64
EH12	54	0.94	0.02	0.95	0.30	0.03	0.24	1.50	0.32	1.85	0.64
EH17	54	0.98	0.00	0.98	0.28	0.04	0.26	1.42	0.32	0.87	0.64

Annex 4-3: Univariate summary statistics for monthly measurements of WQPs in Hadus drain during the period from August 1997 till January 2005

Paramters	N	Range	Minimum	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
					Statistic	Std. Error		Statistic	Std. Error	Statistic	Std. Error
Zn (mg/l)											
EH14	89	1.30	0.00	1.30	0.06	0.01	0.14	8.10	0.26	71.83	0.51
EH02	89	1.44	0.00	1.44	0.05	0.02	0.15	8.93	0.26	82.51	0.51
EH18	89	1.09	0.00	1.09	0.05	0.01	0.12	8.36	0.26	75.15	0.51
EH03	90	0.13	0.00	0.13	0.04	0.00	0.03	0.92	0.25	0.40	0.50
EH04	88	0.24	0.00	0.24	0.04	0.00	0.03	3.14	0.26	16.44	0.51
EH05	88	0.26	0.00	0.26	0.03	0.00	0.03	3.85	0.26	23.31	0.51
EH15	88	0.22	0.00	0.22	0.03	0.00	0.03	3.12	0.26	16.08	0.51
EH06	90	0.18	0.00	0.18	0.03	0.00	0.03	2.08	0.25	7.62	0.50
EH07	89	0.17	0.00	0.17	0.04	0.00	0.04	1.41	0.26	1.85	0.52
EH08	90	0.21	0.00	0.21	0.04	0.00	0.05	1.49	0.25	1.43	0.50
EH09	88	0.17	0.00	0.17	0.04	0.00	0.03	2.02	0.26	5.55	0.51
EH10	88	0.16	0.00	0.16	0.03	0.00	0.03	1.93	0.26	4.04	0.51
EH11	90	0.11	0.00	0.11	0.03	0.00	0.02	1.67	0.25	3.55	0.50
EH16	90	1.22	0.00	1.22	0.06	0.01	0.13	7.70	0.25	66.81	0.50
EH12	89	0.32	0.00	0.32	0.03	0.00	0.04	4.81	0.26	30.01	0.51
EH17	90	0.18	0.00	0.18	0.02	0.00	0.03	3.44	0.25	16.06	0.50
Pb (mg/l)											
EH14	89	0.09	0.00	0.09	0.02	0.00	0.02	1.41	0.26	1.12	0.51
EH02	89	0.06	0.00	0.06	0.02	0.00	0.02	0.80	0.26	-0.39	0.51
EH18	89	0.09	0.00	0.09	0.01	0.00	0.02	2.02	0.26	4.53	0.51
EH03	90	0.06	0.00	0.06	0.01	0.00	0.02	1.76	0.25	3.16	0.50
EH04	90	0.13	0.00	0.13	0.02	0.00	0.02	3.12	0.25	16.42	0.50
EH05	90	0.13	0.00	0.13	0.02	0.00	0.02	2.34	0.25	6.45	0.50
EH15	90	0.12	0.00	0.12	0.02	0.00	0.03	1.98	0.25	3.41	0.50
EH06	90	0.10	0.00	0.10	0.02	0.00	0.02	2.08	0.25	5.40	0.50
EH07	89	0.10	0.00	0.10	0.02	0.00	0.02	1.69	0.26	2.17	0.51
EH08	90	0.07	0.00	0.07	0.02	0.00	0.01	1.17	0.25	1.15	0.50
EH09	90	0.10	0.00	0.10	0.01	0.00	0.02	2.19	0.25	6.94	0.50
EH10	90	0.10	0.00	0.10	0.02	0.00	0.02	1.47	0.25	1.93	0.50
EH11	90	0.06	0.00	0.06	0.02	0.00	0.01	0.89	0.25	0.51	0.50
EH16	90	0.13	0.00	0.13	0.02	0.00	0.02	2.33	0.25	7.13	0.50
EH12	89	0.08	0.00	0.08	0.01	0.00	0.01	2.12	0.26	8.13	0.51
EH17	90	0.12	0.00	0.12	0.02	0.00	0.02	2.51	0.25	8.45	0.50
Br (mg/l)											
EH14	52	1.12	0.00	1.12	0.20	0.03	0.24	2.09	0.33	4.41	0.65
EH02	52	1.14	0.00	1.14	0.17	0.03	0.25	2.26	0.33	4.93	0.65
EH18	52	1.15	0.00	1.15	0.19	0.03	0.25	2.16	0.33	4.70	0.65
EH03	54	1.91	0.00	1.91	0.16	0.04	0.30	4.29	0.32	22.62	0.64
EH04	54	1.90	0.00	1.90	0.32	0.05	0.35	1.88	0.32	6.51	0.64
EH05	54	1.80	0.00	1.80	0.20	0.04	0.31	3.38	0.32	13.95	0.64
EH15	54	1.13	0.00	1.13	0.21	0.03	0.23	1.59	0.32	3.46	0.64
EH06	54	1.43	0.00	1.43	0.15	0.03	0.25	3.26	0.32	12.41	0.64
EH07	53	1.20	0.00	1.20	0.20	0.04	0.30	2.11	0.33	3.86	0.64
EH08	54	1.20	0.00	1.20	0.19	0.04	0.29	2.22	0.32	4.62	0.64
EH09	55	1.70	0.00	1.70	0.42	0.18	1.36	6.80	0.32	48.51	0.63
EH10	55	1.28	0.00	1.28	0.39	0.18	1.35	6.91	0.32	49.77	0.63
EH11	54	0.79	0.00	0.79	0.18	0.04	0.32	3.91	0.32	19.68	0.64
EH16	54	1.60	0.00	1.60	0.18	0.04	0.29	2.97	0.32	11.08	0.64
EH12	53	1.10	0.00	1.10	0.17	0.03	0.25	2.22	0.33	4.70	0.64
EH17	54	1.20	0.00	1.20	0.19	0.03	0.25	2.36	0.32	6.16	0.64

Annex 4-3: Univariate summary statistics for monthly measurements of WQPs in Hadus drain during the period from August 1997 till January 2005

Paramters	N	Range	Minimum	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
					Statistic	Std. Error		Statistic	Std. Error	Statistic	Std. Error
pH											
EH14	89	1.66	6.70	8.36	7.40	0.03	0.30	0.55	0.26	0.70	0.51
EH02	89	1.60	6.70	8.30	7.42	0.03	0.27	0.41	0.26	1.48	0.51
EH18	89	1.24	6.70	7.94	7.44	0.03	0.26	-0.22	0.26	-0.07	0.51
EH03	90	2.12	6.18	8.30	7.45	0.04	0.33	-0.26	0.25	2.07	0.50
EH04	90	1.51	6.80	8.31	7.42	0.03	0.29	0.82	0.25	0.99	0.50
EH05	89	1.46	6.82	8.28	7.43	0.03	0.25	0.55	0.26	1.09	0.51
EH15	90	1.32	6.80	8.12	7.41	0.03	0.28	0.38	0.25	0.27	0.50
EH06	90	1.42	6.80	8.22	7.47	0.03	0.29	0.53	0.25	0.46	0.50
EH07	89	1.16	7.00	8.16	7.50	0.02	0.23	0.53	0.26	0.33	0.51
EH08	90	1.78	6.58	8.36	7.54	0.03	0.29	0.28	0.25	1.37	0.50
EH09	84	1.55	6.88	8.43	7.44	0.03	0.31	0.68	0.26	0.50	0.52
EH10	90	1.20	7.00	8.20	7.47	0.03	0.25	0.62	0.25	0.32	0.50
EH11	90	1.33	7.00	8.33	7.49	0.03	0.26	0.61	0.25	0.49	0.50
EH16	88	2.61	6.03	8.64	7.42	0.04	0.41	0.05	0.26	1.46	0.51
EH12	90	1.33	7.04	8.37	7.54	0.03	0.26	0.82	0.25	0.95	0.50
EH17	90	1.62	6.80	8.42	7.50	0.03	0.29	0.82	0.25	1.31	0.50
EC (dS/m)											
EH14	85	1.92	0.65	2.57	1.32	0.03	0.28	1.33	0.26	4.61	0.52
EH02	87	1.01	0.99	2.00	1.43	0.02	0.22	0.46	0.26	-0.25	0.51
EH18	85	1.27	1.01	2.28	1.41	0.03	0.24	0.71	0.26	0.99	0.52
EH03	88	3.62	1.01	4.63	1.85	0.07	0.69	1.76	0.26	3.44	0.51
EH04	87	2.17	0.73	2.90	1.36	0.04	0.34	1.62	0.26	4.63	0.51
EH05	84	1.21	0.90	2.11	1.30	0.03	0.29	1.87	0.26	6.16	0.52
EH15	90	1.84	0.52	2.36	1.40	0.03	0.27	0.62	0.25	2.05	0.50
EH06	85	3.96	1.10	5.06	1.76	0.06	0.57	3.22	0.26	14.55	0.52
EH07	87	7.28	1.22	8.50	2.78	0.12	1.13	2.36	0.26	7.82	0.51
EH08	90	4.66	2.16	6.82	3.98	0.09	0.86	0.66	0.25	0.70	0.50
EH09	83	3.28	0.69	3.97	1.22	0.07	0.64	3.09	0.26	10.12	0.52
EH10	89	4.55	1.28	5.83	2.92	0.08	0.73	1.31	0.26	3.31	0.51
EH11	88	3.44	1.21	4.65	2.30	0.07	0.61	1.11	0.26	1.92	0.51
EH16	85	6.46	0.47	6.93	1.57	0.11	0.99	2.54	0.26	9.59	0.52
EH12	88	5.94	1.23	7.17	2.94	0.12	1.11	1.75	0.26	4.06	0.51
EH17	88	4.29	1.23	5.52	2.61	0.09	0.82	1.48	0.26	2.37	0.51
TDS (mg/l)											
EH14	89	790.00	630.00	1420.00	912.70	17.90	168.86	0.86	0.26	0.44	0.51
EH02	89	691.08	667.92	1359.00	965.41	17.01	160.46	0.29	0.26	-0.50	0.51
EH18	89	732.00	642.00	1374.00	959.10	18.62	175.68	0.52	0.26	-0.17	0.51
EH03	90	2029.00	715.00	2744.00	1230.76	45.89	435.38	1.68	0.25	2.85	0.50
EH04	90	1233.00	456.00	1689.00	910.65	22.17	210.33	1.02	0.25	2.02	0.50
EH05	89	955.79	554.21	1510.00	878.56	20.05	189.10	0.97	0.26	1.04	0.51
EH15	90	1083.20	380.57	1463.77	956.01	19.47	184.73	0.22	0.25	0.79	0.50
EH06	90	2770.48	649.52	3420.00	1154.15	37.76	358.23	3.52	0.25	18.63	0.50
EH07	89	3577.00	645.00	4222.00	1762.24	65.40	617.01	1.70	0.26	3.59	0.51
EH08	90	2663.00	1542.00	4205.00	2546.60	56.30	534.09	0.76	0.25	0.45	0.50
EH09	85	1983.77	472.00	2455.77	831.55	39.87	367.58	2.78	0.26	9.03	0.52
EH10	90	3399.42	810.58	4210.00	1847.76	50.45	478.65	1.85	0.25	6.86	0.50
EH11	90	2323.68	801.33	3125.00	1490.98	40.41	383.34	1.35	0.25	3.21	0.50
EH16	90	4176.00	352.00	4528.00	1060.79	68.31	648.06	2.51	0.25	9.15	0.50
EH12	90	3768.00	742.00	4510.00	1875.38	71.51	678.39	1.69	0.25	4.14	0.50
EH17	90	3183.79	610.00	3793.79	1674.90	58.80	557.84	1.54	0.25	3.06	0.50

Annex 4-3: Univariate summary statistics for monthly measurements of WQPs in Hadus drain during the period from August 1997 till January 2005

Paramters	N	Range	Minimum	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
					Statistic	Std. Error		Statistic	Std. Error	Statistic	Std. Error
Ca (meq/l)											
EH14	89	5.34	1.74	7.08	3.94	0.11	1.00	0.80	0.26	0.81	0.51
EH02	89	4.57	2.39	6.96	4.05	0.09	0.86	0.78	0.26	1.03	0.51
EH18	89	4.55	2.05	6.60	4.05	0.10	0.97	0.64	0.26	0.07	0.51
EH03	90	10.44	1.90	12.34	4.47	0.17	1.60	2.15	0.25	7.24	0.50
EH04	90	6.68	1.62	8.30	3.55	0.10	0.96	1.69	0.25	6.11	0.50
EH05	89	8.26	1.86	10.12	3.51	0.12	1.15	2.99	0.26	13.96	0.51
EH15	90	5.25	1.57	6.82	3.88	0.11	1.02	0.59	0.25	0.16	0.50
EH06	90	8.81	2.26	11.07	4.49	0.14	1.30	2.05	0.25	7.68	0.50
EH07	89	17.19	2.82	20.01	6.51	0.29	2.75	2.39	0.26	7.22	0.51
EH08	90	14.01	3.62	17.63	8.28	0.25	2.38	0.83	0.25	1.60	0.50
EH09	85	8.91	1.71	10.62	3.44	0.15	1.35	2.54	0.26	9.71	0.52
EH10	90	13.39	2.99	16.38	6.43	0.26	2.42	2.02	0.25	5.11	0.50
EH11	90	12.58	2.13	14.71	5.30	0.20	1.88	2.34	0.25	8.50	0.50
EH16	90	13.80	1.40	15.20	4.32	0.24	2.24	1.96	0.25	5.81	0.50
EH12	90	18.04	2.29	20.33	6.67	0.28	2.66	1.92	0.25	7.34	0.50
EH17	90	13.03	2.18	15.21	5.77	0.20	1.93	1.93	0.25	6.60	0.50
Mg (meq/l)											
EH14	89	4.39	1.11	5.50	2.57	0.08	0.79	0.71	0.26	1.30	0.51
EH02	89	3.00	1.12	4.12	2.61	0.07	0.70	0.00	0.26	-0.22	0.51
EH18	89	4.57	0.76	5.33	2.74	0.09	0.89	0.18	0.26	-0.13	0.51
EH03	90	8.30	1.15	9.45	3.09	0.16	1.49	1.73	0.25	4.06	0.50
EH04	90	3.54	0.95	4.49	2.41	0.08	0.74	0.44	0.25	0.08	0.50
EH05	89	6.13	0.99	7.12	2.42	0.09	0.86	2.20	0.26	9.48	0.51
EH15	90	3.42	0.97	4.39	2.50	0.07	0.69	0.28	0.25	0.12	0.50
EH06	90	10.67	1.02	11.69	3.21	0.15	1.46	2.66	0.25	12.68	0.50
EH07	89	13.87	1.08	14.94	4.71	0.28	2.60	1.64	0.26	3.53	0.51
EH08	90	13.78	1.12	14.90	6.80	0.35	3.29	0.28	0.25	-0.46	0.50
EH09	85	6.74	0.94	7.68	2.26	0.14	1.25	2.56	0.26	6.89	0.52
EH10	90	11.13	1.09	12.22	4.73	0.25	2.42	0.82	0.25	0.50	0.50
EH11	90	9.62	1.03	10.65	3.99	0.21	2.00	0.94	0.25	0.96	0.50
EH16	90	10.60	0.52	11.12	2.64	0.18	1.69	2.47	0.25	9.04	0.50
EH12	90	14.10	0.29	14.39	4.52	0.26	2.49	1.57	0.25	4.25	0.50
EH17	90	10.90	1.40	12.30	4.46	0.21	2.04	1.00	0.25	1.64	0.50
Na (meq/l)											
EH14	89	8.77	3.55	12.32	6.18	0.18	1.68	1.27	0.26	1.89	0.51
EH02	89	7.81	4.19	12.00	7.06	0.18	1.70	0.79	0.26	0.10	0.51
EH18	89	7.55	4.02	11.57	6.83	0.16	1.54	0.53	0.26	-0.06	0.51
EH03	90	25.58	4.12	29.70	10.08	0.44	4.16	1.70	0.25	4.75	0.50
EH04	90	12.11	2.69	14.80	6.98	0.22	2.08	1.00	0.25	2.17	0.50
EH05	89	13.10	3.45	16.55	6.54	0.20	1.90	1.93	0.26	7.86	0.51
EH15	90	11.39	2.40	13.79	7.23	0.20	1.86	0.59	0.25	1.55	0.50
EH06	90	27.70	4.61	32.31	9.29	0.41	3.88	3.04	0.25	14.18	0.50
EH07	89	32.03	4.97	37.00	15.47	0.62	5.88	1.37	0.26	2.44	0.51
EH08	90	33.81	10.17	43.98	24.05	0.70	6.67	0.48	0.25	0.22	0.50
EH09	85	22.33	2.67	25.00	6.17	0.39	3.64	3.12	0.26	12.39	0.52
EH10	90	28.67	6.40	35.07	17.10	0.52	4.96	0.97	0.25	2.19	0.50
EH11	90	28.44	5.67	34.11	13.25	0.48	4.54	1.34	0.25	4.09	0.50
EH16	90	56.28	1.39	57.67	8.88	0.86	8.16	3.20	0.25	14.33	0.50
EH12	90	52.76	4.21	56.97	17.46	0.81	7.70	1.89	0.25	6.85	0.50
EH17	90	37.32	4.48	41.80	15.32	0.68	6.47	1.81	0.25	4.85	0.50

Annex 4-3: Univariate summary statistics for monthly measurements of WQPs in Hadus drain during the period from August 1997 till January 2005

Paramters	N	Range	Minimum	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
					Statistic	Std. Error		Statistic	Std. Error	Statistic	Std. Error
K (meq/l)											
EH14	89	0.71	0.16	0.87	0.36	0.02	0.15	1.49	0.26	2.19	0.51
EH02	89	0.68	0.18	0.86	0.37	0.01	0.14	1.15	0.26	1.20	0.51
EH18	89	0.92	0.18	1.10	0.37	0.02	0.15	2.05	0.26	6.05	0.51
EH03	90	1.29	0.14	1.43	0.43	0.02	0.24	1.84	0.25	4.18	0.50
EH04	90	0.68	0.19	0.87	0.38	0.01	0.14	1.42	0.25	1.85	0.50
EH05	89	0.87	0.12	0.99	0.35	0.02	0.16	1.43	0.26	2.80	0.51
EH15	90	1.02	0.16	1.18	0.36	0.02	0.15	2.23	0.25	8.41	0.50
EH06	90	0.87	0.12	0.99	0.33	0.02	0.18	1.59	0.25	2.62	0.50
EH07	89	2.67	0.11	2.78	0.52	0.05	0.50	2.70	0.26	7.67	0.51
EH08	90	2.04	0.11	2.15	0.60	0.04	0.42	2.06	0.25	4.47	0.50
EH09	85	1.69	0.11	1.80	0.34	0.02	0.23	3.60	0.26	20.26	0.52
EH10	90	2.01	0.09	2.10	0.52	0.04	0.36	2.00	0.25	4.75	0.50
EH11	90	1.40	0.09	1.49	0.43	0.03	0.27	1.90	0.25	3.96	0.50
EH16	90	1.14	0.10	1.24	0.38	0.03	0.25	1.65	0.25	2.34	0.50
EH12	90	1.80	0.12	1.92	0.43	0.03	0.32	2.11	0.25	5.44	0.50
EH17	90	1.25	0.09	1.34	0.43	0.02	0.23	1.54	0.25	2.88	0.50
SO4 (meq/l)											
EH14	88	11.42	0.80	12.22	4.18	0.22	2.05	1.03	0.26	1.95	0.51
EH02	88	10.79	0.59	11.38	4.18	0.20	1.91	0.94	0.26	1.61	0.51
EH18	88	8.47	0.87	9.34	4.29	0.20	1.83	0.52	0.26	-0.22	0.51
EH03	90	11.19	1.00	12.19	4.52	0.24	2.27	1.06	0.25	1.55	0.50
EH04	90	7.54	0.82	8.36	3.46	0.16	1.54	0.85	0.25	0.83	0.50
EH05	89	7.46	1.00	8.46	3.48	0.19	1.77	0.92	0.26	0.32	0.51
EH15	90	9.01	1.00	10.01	3.53	0.17	1.63	1.02	0.25	1.79	0.50
EH06	90	14.20	0.25	14.45	4.18	0.23	2.21	1.99	0.25	6.19	0.50
EH07	89	17.88	1.89	19.77	7.01	0.35	3.27	1.19	0.26	2.14	0.51
EH08	90	17.76	3.91	21.67	9.67	0.38	3.59	0.98	0.25	1.03	0.50
EH09	85	9.98	0.32	10.30	2.98	0.19	1.79	1.50	0.26	3.23	0.52
EH10	90	14.21	2.00	16.21	7.09	0.31	2.90	0.72	0.25	0.40	0.50
EH11	90	12.91	1.65	14.56	5.81	0.28	2.67	1.19	0.25	1.51	0.50
EH16	90	17.68	0.75	18.43	4.76	0.33	3.15	1.74	0.25	4.49	0.50
EH12	90	19.38	0.75	20.13	7.18	0.39	3.70	1.02	0.25	1.98	0.50
EH17	90	30.20	1.37	31.57	7.01	0.45	4.22	2.74	0.25	12.26	0.50
Cl (meq/l)											
EH14	89	7.53	1.58	9.11	4.17	0.15	1.40	1.09	0.26	1.55	0.51
EH02	89	6.38	2.08	8.46	5.02	0.15	1.44	0.35	0.26	-0.27	0.51
EH18	89	5.92	2.38	8.30	4.87	0.14	1.35	0.15	0.26	-0.62	0.51
EH03	90	22.94	2.66	25.60	8.57	0.41	3.94	1.52	0.25	3.17	0.50
EH04	90	8.57	2.26	10.83	5.22	0.18	1.72	0.65	0.25	0.70	0.50
EH05	89	14.87	1.33	16.20	5.19	0.20	1.87	2.40	0.26	12.93	0.51
EH15	90	8.73	1.14	9.87	5.05	0.16	1.55	0.34	0.25	0.39	0.50
EH06	90	26.37	0.99	27.36	8.38	0.43	4.05	2.19	0.25	7.07	0.50
EH07	89	35.70	5.46	41.16	14.31	0.61	5.75	1.77	0.26	4.94	0.51
EH08	90	36.72	8.85	45.57	23.45	0.75	7.15	0.37	0.25	-0.07	0.50
EH09	85	23.22	1.04	24.26	5.13	0.40	3.67	3.03	0.26	11.97	0.52
EH10	90	26.31	3.90	30.21	15.64	0.51	4.85	0.45	0.25	0.67	0.50
EH11	90	21.11	4.94	26.05	12.01	0.46	4.33	0.82	0.25	0.27	0.50
EH16	90	52.58	1.02	53.60	7.24	0.83	7.85	3.18	0.25	13.81	0.50
EH12	90	50.81	5.05	55.86	16.28	0.80	7.60	2.27	0.25	8.83	0.50
EH17	90	33.71	3.53	37.24	13.51	0.63	5.96	1.70	0.25	4.03	0.50

Annex 4-3: Univariate summary statistics for monthly measurements of WQPs in Hadus drain during the period from August 1997 till January 2005

Paramters	N	Range	Minimum	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
					Statistic	Std. Error		Statistic	Std. Error	Statistic	Std. Error
SAR											
EH14	89	5.08	1.91	7.00	3.46	0.09	0.83	1.31	0.26	3.22	0.51
EH02	89	4.48	2.37	6.85	3.86	0.09	0.87	1.32	0.26	2.12	0.51
EH18	89	4.48	2.11	6.59	3.72	0.08	0.75	0.82	0.26	1.60	0.51
EH03	90	10.18	2.42	12.61	5.18	0.17	1.66	1.72	0.25	4.69	0.50
EH04	90	5.61	1.97	7.58	4.10	0.11	1.04	0.77	0.25	1.09	0.50
EH05	89	3.84	2.13	5.97	3.81	0.09	0.83	0.18	0.26	-0.49	0.51
EH15	90	5.30	2.13	7.43	3.91	0.10	0.91	0.85	0.25	1.84	0.50
EH06	90	18.01	2.37	20.38	4.79	0.22	2.07	5.12	0.25	36.38	0.50
EH07	89	12.57	2.92	15.48	6.66	0.24	2.28	1.72	0.26	4.04	0.51
EH08	90	14.70	4.36	19.06	9.10	0.32	3.02	1.02	0.25	1.29	0.50
EH09	85	12.83	1.66	14.49	3.61	0.18	1.68	3.85	0.26	21.57	0.52
EH10	90	13.06	3.45	16.51	7.51	0.26	2.46	1.21	0.25	2.47	0.50
EH11	90	17.07	3.18	20.25	6.33	0.26	2.43	2.56	0.25	11.42	0.50
EH16	90	20.08	1.02	21.10	4.50	0.32	3.08	2.84	0.25	10.67	0.50
EH12	90	19.81	2.57	22.38	7.57	0.33	3.12	1.79	0.25	5.46	0.50
EH17	90	15.25	3.08	18.33	6.83	0.27	2.53	1.81	0.25	5.12	0.50
Adj_SAR											
EH14	89	9.32	4.56	13.88	7.85	0.21	1.95	0.98	0.26	1.00	0.51
EH02	89	9.84	5.17	15.01	8.66	0.20	1.87	0.91	0.26	1.15	0.51
EH18	89	9.00	5.22	14.22	8.51	0.20	1.86	0.72	0.26	0.24	0.51
EH03	90	27.05	5.38	32.42	12.22	0.46	4.38	1.63	0.25	4.39	0.50
EH04	90	13.91	3.68	17.59	9.05	0.27	2.56	0.87	0.25	1.26	0.50
EH05	89	11.38	5.02	16.40	8.74	0.22	2.12	0.79	0.26	0.89	0.51
EH15	90	9.73	3.75	13.48	8.72	0.20	1.92	0.10	0.25	-0.02	0.50
EH06	90	37.93	5.99	43.92	11.22	0.49	4.67	4.21	0.25	26.78	0.50
EH07	89	32.96	6.25	39.21	16.60	0.61	5.77	1.51	0.26	3.06	0.51
EH08	90	37.07	11.46	48.53	23.48	0.75	7.09	1.29	0.25	2.14	0.50
EH09	85	29.44	3.51	32.95	8.01	0.46	4.20	3.33	0.26	15.97	0.52
EH10	90	30.67	8.51	39.18	18.66	0.61	5.83	1.34	0.25	2.90	0.50
EH11	90	38.84	7.08	45.92	15.15	0.58	5.47	2.33	0.25	10.48	0.50
EH16	90	54.23	2.15	56.38	10.38	0.85	8.11	2.98	0.25	12.28	0.50
EH12	90	53.37	5.37	58.74	18.69	0.81	7.67	2.01	0.25	7.54	0.50
EH17	90	38.17	6.56	44.73	16.75	0.65	6.17	1.70	0.25	4.78	0.50
Temp (C^{o})											
EH14	88	18.00	13.00	31.00	22.64	0.56	5.25	-0.28	0.26	-1.24	0.51
EH02	88	20.00	12.00	32.00	22.65	0.58	5.42	-0.23	0.26	-1.25	0.51
EH18	88	18.70	13.00	31.70	22.88	0.57	5.35	-0.26	0.26	-1.19	0.51
EH03	89	18.30	12.70	31.00	22.69	0.57	5.38	-0.25	0.26	-1.29	0.51
EH04	89	19.40	12.10	31.50	23.23	0.57	5.35	-0.31	0.26	-1.25	0.51
EH05	89	20.10	12.00	32.10	22.76	0.59	5.57	-0.25	0.26	-1.25	0.51
EH15	89	18.60	13.10	31.70	22.98	0.57	5.35	-0.20	0.26	-1.30	0.51
EH06	90	18.30	12.50	30.80	22.36	0.55	5.19	-0.30	0.25	-1.26	0.50
EH07	89	20.00	12.00	32.00	22.42	0.54	5.12	-0.30	0.26	-1.07	0.51
EH08	90	19.00	12.00	31.00	22.12	0.55	5.19	-0.19	0.25	-1.22	0.50
EH09	90	17.40	12.90	30.30	22.49	0.54	5.16	-0.28	0.25	-1.26	0.50
EH10	90	20.00	12.00	32.00	22.52	0.56	5.35	-0.19	0.25	-1.28	0.50
EH11	90	18.00	13.00	31.00	22.64	0.56	5.27	-0.24	0.25	-1.24	0.50
EH16	90	24.00	11.00	35.00	22.46	0.57	5.45	-0.06	0.25	-0.89	0.50
EH12	90	19.00	12.00	31.00	22.30	0.54	5.08	-0.22	0.25	-1.17	0.50
EH17	90	18.60	12.60	31.20	22.51	0.59	5.63	-0.25	0.25	-1.30	0.50

Annex 4-3: Univariate summary statistics for monthly measurements of WQPs in Hadus drain during the period from August 1997 till January 2005

Paramters	N	Range	Minimum	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
					Statistic	Std. Error		Statistic	Std. Error	Statistic	Std. Error
Sal											
EH14	89	0.65	0.20	0.85	0.48	0.01	0.13	0.54	0.26	0.19	0.51
EH02	89	0.70	0.30	1.00	0.54	0.01	0.13	0.62	0.26	1.17	0.51
EH18	89	0.70	0.30	1.00	0.53	0.02	0.15	0.50	0.26	0.48	0.51
EH03	90	2.20	0.30	2.50	0.82	0.05	0.43	1.74	0.25	3.63	0.50
EH04	90	0.90	0.10	1.00	0.49	0.02	0.18	0.75	0.25	0.51	0.50
EH05	90	1.00	0.20	1.20	0.46	0.02	0.18	1.89	0.25	5.56	0.50
EH15	90	0.70	0.30	1.00	0.54	0.02	0.15	0.71	0.25	0.37	0.50
EH06	90	3.30	0.30	3.60	0.74	0.04	0.40	4.85	0.25	30.68	0.50
EH07	88	3.60	0.30	3.90	1.34	0.07	0.66	1.90	0.26	4.57	0.51
EH08	90	3.20	0.60	3.80	2.11	0.06	0.56	0.57	0.25	0.83	0.50
EH09	90	1.90	0.10	2.00	0.38	0.04	0.34	3.34	0.25	12.40	0.50
EH10	90	3.00	0.60	3.60	1.44	0.05	0.44	1.79	0.25	6.07	0.50
EH11	90	2.10	0.30	2.40	1.06	0.04	0.36	0.95	0.25	1.65	0.50
EH16	86	4.10	0.10	4.20	0.59	0.06	0.60	3.06	0.25	14.26	0.50
EH12	90	3.90	0.50	4.40	1.43	0.07	0.69	2.08	0.25	6.15	0.50
EH17	90	2.40	0.20	2.60	1.22	0.05	0.47	1.12	0.25	1.48	0.50
DO (mg/l)											
EH14	87	11.90	0.20	12.10	1.45	0.21	1.99	2.92	0.26	8.31	0.51
EH02	90	8.50	0.20	8.70	2.36	0.26	2.45	1.96	0.26	4.26	0.51
EH18	88	10.09	0.11	10.20	2.76	0.30	2.78	1.80	0.26	3.13	0.51
EH03	86	12.30	0.30	12.60	3.19	0.20	1.88	0.76	0.25	0.27	0.50
EH04	89	6.30	0.10	6.40	0.87	0.12	1.15	2.72	0.25	7.82	0.50
EH05	89	8.50	0.10	8.60	3.03	0.21	2.03	0.61	0.25	-0.32	0.50
EH15	90	17.06	1.34	18.40	2.64	0.17	1.66	0.61	0.25	-0.37	0.50
EH06	90	7.00	0.30	7.30	3.96	0.24	2.24	3.34	0.25	18.81	0.50
EH07	89	7.90	1.00	8.90	4.01	0.17	1.60	0.57	0.26	0.22	0.51
EH08	90	7.46	1.40	8.86	3.96	0.18	1.67	0.92	0.25	0.80	0.50
EH09	89	16.91	0.19	17.10	2.41	0.20	1.94	5.10	0.25	36.70	0.50
EH10	90	10.80	0.90	11.70	3.47	0.18	1.74	1.78	0.25	5.63	0.50
EH11	90	7.31	0.70	8.01	2.95	0.16	1.56	0.85	0.25	0.12	0.50
EH16	90	5.90	1.40	7.30	3.70	0.27	2.53	1.89	0.25	7.36	0.50
EH12	90	16.60	0.30	16.90	4.21	0.14	1.29	0.33	0.25	-0.29	0.50
EH17	90	9.40	0.90	10.30	3.28	0.18	1.75	1.68	0.25	4.22	0.50
Turb (NTU)											
EH14	67	181.70	3.30	185.00	56.14	3.75	30.69	1.53	0.29	4.38	0.58
EH02	66	162.00	10.00	172.00	45.82	3.67	29.85	2.05	0.29	5.09	0.58
EH18	67	168.50	10.00	178.50	47.63	3.73	30.57	2.02	0.29	5.14	0.58
EH03	67	151.00	19.00	170.00	64.27	4.25	34.81	1.00	0.29	0.64	0.58
EH04	67	149.00	20.00	169.00	70.75	4.23	34.59	0.28	0.29	-0.57	0.58
EH05	66	167.00	24.00	191.00	69.02	4.91	39.85	1.23	0.29	1.23	0.58
EH15	67	160.00	15.00	175.00	49.48	3.84	31.42	2.28	0.29	6.18	0.58
EH06	66	195.10	2.90	198.00	68.53	4.97	40.36	1.23	0.29	1.47	0.58
EH07	65	168.00	24.00	192.00	82.89	5.51	44.45	0.78	0.30	-0.30	0.59
EH08	67	184.00	10.00	194.00	80.97	5.60	45.86	0.74	0.29	-0.51	0.58
EH09	65	124.00	23.00	147.00	68.72	3.27	26.33	0.76	0.30	1.05	0.59
EH10	67	159.00	23.00	182.00	70.28	4.27	34.93	1.05	0.29	0.84	0.58
EH11	66	187.20	2.80	190.00	62.00	4.93	40.07	1.54	0.29	2.00	0.58
EH16	66	157.00	10.00	167.00	49.32	4.00	32.51	1.44	0.29	2.01	0.58
EH12	64	156.00	37.00	193.00	90.48	5.30	42.37	1.10	0.30	0.26	0.59
EH17	67	162.00	9.00	171.00	46.30	3.34	27.32	1.91	0.29	5.79	0.58

Annex 4-3: Univariate summary statistics for monthly measurements of WQPs in Hadus drain during the period from August 1997 till January 2005

Paramters	N	Range	Minimum	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
					Statistic	Std. Error		Statistic	Std. Error	Statistic	Std. Error
Visib (Cm)											
EH14	88	68.00	10.00	78.00	40.31	1.77	16.58	0.30	0.26	-0.93	0.51
EH02	89	75.00	5.00	80.00	40.53	1.69	15.92	0.21	0.26	-0.72	0.51
EH18	89	75.00	5.00	80.00	39.38	1.69	15.99	0.35	0.26	-0.71	0.51
EH03	90	70.00	10.00	80.00	33.24	1.84	17.41	0.87	0.25	-0.02	0.50
EH04	90	67.00	5.00	72.00	25.63	1.51	14.34	0.94	0.25	0.51	0.50
EH05	90	65.00	5.00	70.00	27.96	1.72	16.34	0.86	0.25	-0.18	0.50
EH15	89	65.00	5.00	70.00	35.42	1.64	15.50	0.40	0.26	-0.24	0.51
EH06	90	77.00	5.00	82.00	30.89	1.70	16.14	0.79	0.25	0.09	0.50
EH07	89	75.00	5.00	80.00	26.32	1.66	15.66	1.09	0.26	0.87	0.51
EH08	88	60.00	5.00	65.00	27.31	1.75	16.41	0.66	0.26	-0.61	0.51
EH09	90	70.00	5.00	75.00	29.33	1.48	14.03	1.02	0.25	1.08	0.50
EH10	90	70.00	5.00	75.00	31.91	1.58	15.02	0.79	0.25	0.28	0.50
EH11	90	65.00	5.00	70.00	33.99	1.66	15.70	0.54	0.25	-0.24	0.50
EH16	90	70.00	10.00	80.00	40.74	1.88	17.79	0.14	0.25	-0.98	0.50
EH12	89	56.00	5.00	61.00	23.57	1.24	11.70	0.69	0.26	0.12	0.51
EH17	89	105.00	10.00	115.00	43.20	1.80	16.97	1.23	0.26	3.27	0.51
Fecal (MPN/100ml)											
EH14	53	18972000.00	28000.00	19000000.00	1381137.74	428811.91	3121797.82	4.00	0.33	19.55	0.64
EH02	53	16113000.00	7000.00	16120000.00	1136281.13	396400.85	2885841.76	3.73	0.33	15.19	0.64
EH18	53	8493000.00	7000.00	8500000.00	947332.08	276967.27	2016352.16	2.78	0.33	7.22	0.64
EH03	54	1099000.00	1000.00	1100000.00	109962.04	24288.84	178485.82	3.74	0.32	17.71	0.64
EH04	54	15975000.00	5000.00	15980000.00	2349092.22	561465.56	4125912.41	2.21	0.32	4.07	0.64
EH05	54	15998790.00	1210.00	16000000.00	1370197.96	484693.56	3561755.73	3.26	0.32	10.25	0.64
EH15	54	9099000.00	1000.00	9100000.00	455567.22	181229.77	1331761.40	5.50	0.32	34.60	0.64
EH06	54	164000.00	1000.00	165000.00	30413.89	4171.68	30655.44	2.06	0.32	5.99	0.64
EH07	53	299600.00	400.00	300000.00	28630.75	7043.99	51281.05	3.74	0.33	16.06	0.64
EH08	54	83850.00	150.00	84000.00	18792.41	2661.74	19559.74	1.51	0.32	2.36	0.64
EH09	54	7999610.00	390.00	8000000.00	327840.74	151866.08	1115983.23	6.43	0.32	44.12	0.64
EH10	54	3099750.00	250.00	3100000.00	125167.04	57677.39	423840.52	6.79	0.32	48.13	0.64
EH11	54	499760.00	240.00	500000.00	31811.67	9448.62	69432.90	6.07	0.32	40.64	0.64
EH16	54	11999400.00	600.00	12000000.00	525428.70	288275.45	2118383.27	4.87	0.32	23.49	0.64
EH12	54	799600.00	400.00	800000.00	46615.37	20782.86	152722.22	4.49	0.32	19.73	0.64
EH17	54	119000.00	1000.00	120000.00	19632.22	3246.48	23856.67	2.65	0.32	7.26	0.64
TP (mg/l)											
EH14	53	1.94	0.21	2.15	1.07	0.05	0.39	0.25	0.33	0.43	0.64
EH02	53	1.93	0.12	2.05	0.77	0.06	0.42	0.45	0.33	0.13	0.64
EH18	53	2.03	0.05	2.08	0.72	0.06	0.47	0.23	0.33	-0.42	0.64
EH03	54	1.50	0.11	1.61	0.55	0.04	0.31	1.27	0.32	1.94	0.64
EH04	54	1.58	0.28	1.86	0.97	0.05	0.40	0.28	0.32	-0.92	0.64
EH05	54	2.12	0.24	2.36	0.85	0.06	0.43	1.27	0.32	2.26	0.64
EH15	54	1.97	0.17	2.14	0.88	0.05	0.38	0.87	0.32	1.44	0.64
EH06	54	1.55	0.16	1.71	0.49	0.04	0.27	2.28	0.32	8.03	0.64
EH07	53	1.35	0.16	1.51	0.45	0.03	0.24	2.28	0.33	7.11	0.64
EH08	54	0.85	0.16	1.01	0.46	0.03	0.19	0.77	0.32	0.41	0.64
EH09	54	2.08	0.23	2.31	0.57	0.05	0.34	2.87	0.32	12.21	0.64
EH10	53	1.46	0.13	1.59	0.45	0.03	0.24	2.25	0.33	8.63	0.64
EH11	54	1.58	0.15	1.73	0.63	0.04	0.27	1.36	0.32	3.81	0.64
EH16	54	1.06	0.01	1.07	0.38	0.03	0.23	1.04	0.32	1.07	0.64
EH12	53	0.54	0.12	0.66	0.33	0.02	0.15	0.55	0.33	-0.88	0.64
EH17	54	1.38	0.16	1.54	0.50	0.04	0.26	1.38	0.32	2.99	0.64

Annex 4-3: Univariate summary statistics for monthly measurements of WQPs in Hadus drain during the period from August 1997 till January 2005

Paramters	N	Range	Minimum	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
					Statistic	Std. Error		Statistic	Std. Error	Statistic	Std. Error
TN (mg/l)											
EH14	53	188.69	0.31	189.00	16.54	3.98	28.98	4.41	0.33	24.33	0.64
EH02	53	181.95	0.05	182.00	17.16	3.78	27.52	4.38	0.33	24.82	0.64
EH18	53	168.69	0.31	169.00	15.08	3.52	25.61	4.48	0.33	25.24	0.64
EH03	54	164.41	0.59	165.00	13.25	2.02	14.69	1.49	0.33	1.29	0.64
EH04	53	58.65	0.05	58.70	13.80	1.99	14.45	1.39	0.33	1.30	0.64
EH05	53	58.23	0.31	58.54	12.69	1.86	13.51	1.70	0.33	2.71	0.64
EH15	53	65.07	0.05	65.12	14.37	2.26	16.47	1.42	0.33	1.06	0.64
EH06	53	38.83	0.39	39.22	15.62	1.62	11.83	0.56	0.33	-1.18	0.64
EH07	53	63.72	3.28	67.00	14.54	1.75	12.59	1.15	0.33	0.06	0.65
EH08	54	59.22	0.78	60.00	14.38	1.64	11.91	0.92	0.33	-0.56	0.64
EH09	53	54.26	0.39	54.65	17.75	2.05	14.90	0.97	0.33	-0.07	0.64
EH10	53	66.83	0.81	67.64	14.98	1.94	14.11	2.16	0.33	4.80	0.64
EH11	53	38.96	1.04	40.00	13.99	1.50	10.91	1.05	0.33	-0.20	0.64
EH16	52	59.68	1.47	61.15	12.71	1.65	11.90	1.88	0.33	4.27	0.65
EH12	53	62.57	1.08	63.65	13.11	1.68	12.26	2.08	0.33	5.01	0.64
EH17	53	42.42	0.53	42.95	12.34	1.32	9.58	1.15	0.33	0.67	0.64
Ni (mg/l)											
EH14	53	0.10	0.00	0.10	0.011	0.00	0.02	3.27	0.33	9.97	0.64
EH02	53	0.01	0.00	0.01	0.004	0.00	0.00	0.30	0.33	-0.84	0.64
EH18	53	0.02	0.00	0.02	0.005	0.00	0.01	1.11	0.33	0.78	0.64
EH03	54	0.01	0.00	0.01	0.004	0.00	0.00	0.69	0.32	-0.58	0.64
EH04	54	0.02	0.00	0.02	0.005	0.00	0.00	0.89	0.32	0.25	0.64
EH05	53	0.03	0.00	0.03	0.005	0.00	0.01	2.19	0.33	7.57	0.64
EH15	53	0.03	0.00	0.03	0.005	0.00	0.01	1.74	0.33	4.89	0.64
EH06	54	0.11	0.00	0.11	0.008	0.00	0.02	4.85	0.32	26.83	0.64
EH07	53	0.04	0.00	0.04	0.004	0.00	0.01	3.71	0.33	18.26	0.64
EH08	54	0.01	0.00	0.01	0.004	0.00	0.00	0.64	0.32	-0.65	0.64
EH09	54	0.03	0.00	0.03	0.005	0.00	0.01	1.68	0.32	3.44	0.64
EH10	54	0.03	0.00	0.03	0.005	0.00	0.01	1.69	0.32	4.82	0.64
EH11	54	0.03	0.00	0.03	0.005	0.00	0.01	2.75	0.32	9.61	0.64
EH16	54	0.04	0.00	0.04	0.005	0.00	0.01	2.28	0.32	6.92	0.64
EH12	54	0.03	0.00	0.03	0.005	0.00	0.01	2.52	0.32	10.02	0.64
EH17	54	0.09	0.00	0.09	0.007	0.00	0.01	4.50	0.32	25.62	0.64
SO4_m (meq/l)											
EH14	48	6.72	0.88	7.59	3.19	0.19	1.29	1.28	0.34	2.52	0.67
EH02	48	4.35	1.25	5.60	3.28	0.15	1.04	0.46	0.34	0.10	0.67
EH18	48	4.46	1.42	5.88	3.21	0.14	0.96	0.32	0.34	0.02	0.67
EH03	49	11.97	1.08	13.05	3.77	0.34	2.37	2.07	0.34	4.94	0.67
EH04	49	6.04	1.45	7.49	2.80	0.16	1.14	2.06	0.34	5.98	0.67
EH05	49	7.80	1.38	9.18	2.83	0.19	1.30	2.83	0.34	11.48	0.67
EH15	49	4.21	1.39	5.60	2.91	0.13	0.91	0.71	0.34	0.60	0.67
EH06	49	7.38	1.77	9.15	3.47	0.22	1.57	2.13	0.34	5.42	0.67
EH07	48	18.69	1.95	20.64	6.18	0.56	3.87	1.98	0.34	4.09	0.67
EH08	49	14.69	2.70	17.39	7.66	0.43	2.98	1.11	0.34	2.06	0.67
EH09	49	9.78	0.77	10.55	2.64	0.29	2.04	2.45	0.34	6.63	0.66
EH10	49	13.71	1.46	15.17	5.93	0.37	2.65	1.21	0.34	1.85	0.66
EH11	49	12.01	1.52	13.53	4.39	0.30	2.13	1.99	0.34	6.13	0.67
EH16	49	10.66	0.54	11.20	3.64	0.36	2.49	1.18	0.34	1.21	0.67
EH12	49	16.97	0.51	17.48	5.56	0.41	2.90	1.42	0.34	4.72	0.67
EH17	49	15.15	0.05	15.20	5.16	0.38	2.68	1.66	0.34	4.42	0.67

ANNEX 4-4

ASSESSMENT OF NORMALITY FOR THE TOTAL MEANS, YEARLY AVERAGES AND MONTHLY MEASUREMENTS OF WQPs IN HADUS DRAIN

ANNEX 4-4A: TOTAL MEANS

Annex 4-4A1: Normal probability and Box plots for means of some WQPs in Hadus Drain

Annex 4-4A2: Kolmogorov-Samirnov and Shapiro-Wilk tests results to check the normality for the means of WQ data in Hadus drain

ANNEX 4-4B: YEARLY AVERAGES

Annex 4-4B1: Kolmogorov-Samirnov and Shapiro-Wilk tests results to check the normality of the yearly averages (with respect to the monitoring sites) of WQ measurements in site group 1

Annex 4-4B2: Kolmogorov-Samirnov and Shapiro-Wilk tests results to check the normality of the yearly averages (with respect to the monitoring sites) of WQ measurements in site group 2

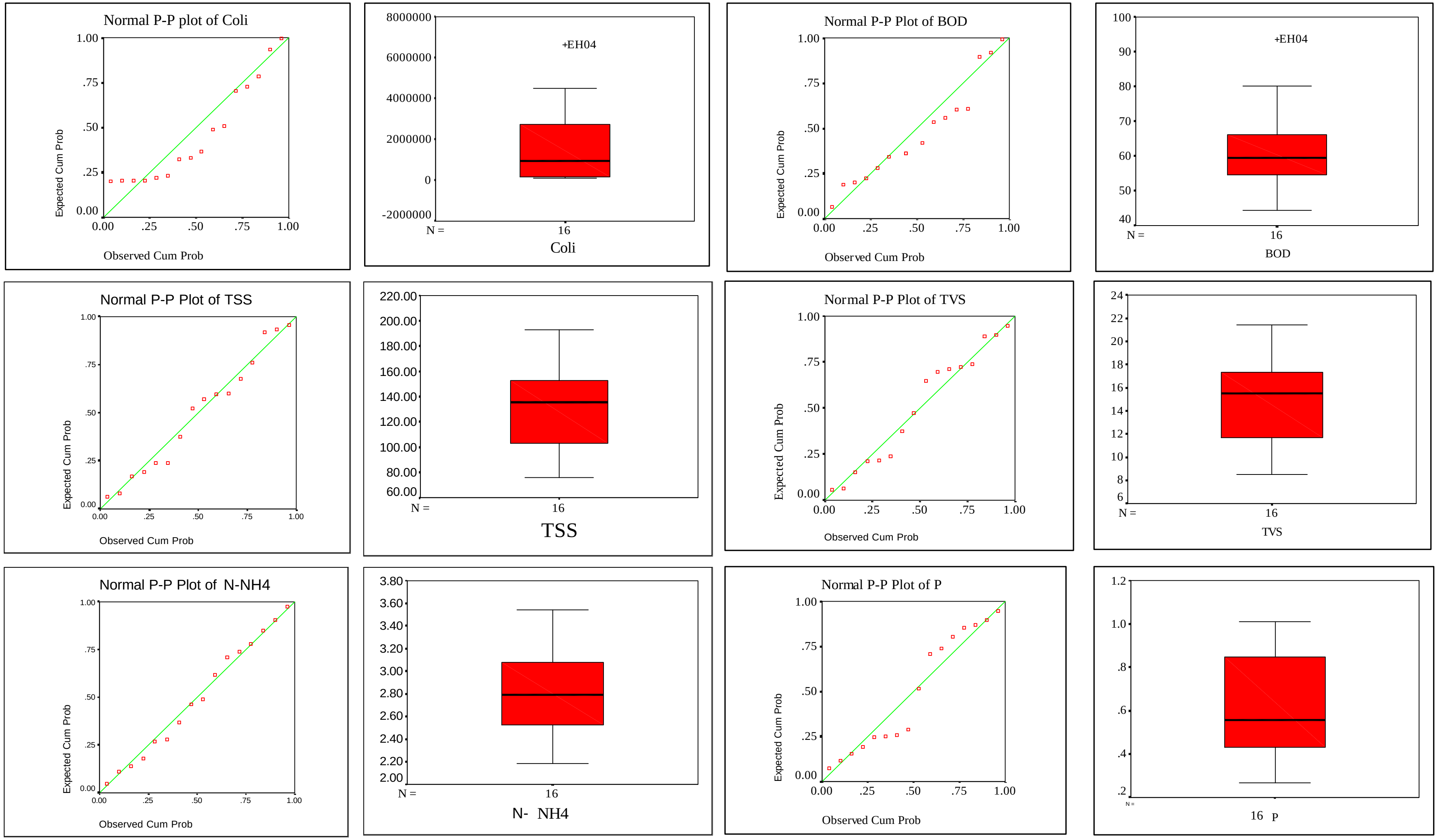
Annex 4-4B3: Kolmogorov-Samirnov and Shapiro-Wilk tests results to check the normality of the yearly averages (with respect to the monitoring sites) of WQ measurements in site group 3

Annex 4-4B4: Kolmogorov-Samirnov and Shapiro-Wilk tests results to check the normality of the yearly averages (with respect to the monitoring sites) of WQ measurements in site group 4

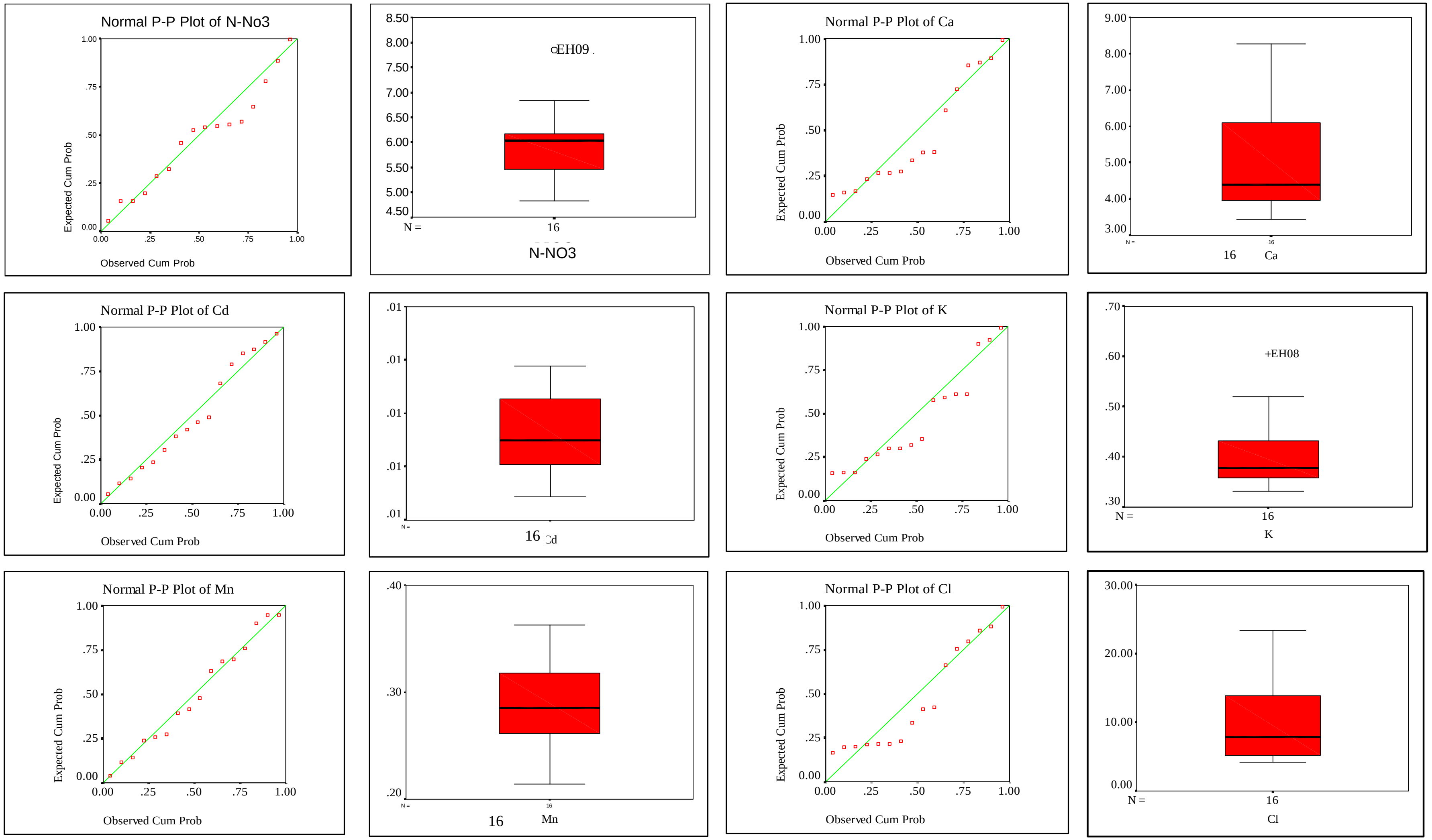
ANNEX 4-4C: MONTHLY DATA

Annex 4-4C: Kolmogorov-Samirnov test's significant results to check the normality for the monthly measurements of some WQPs in Hadus drain

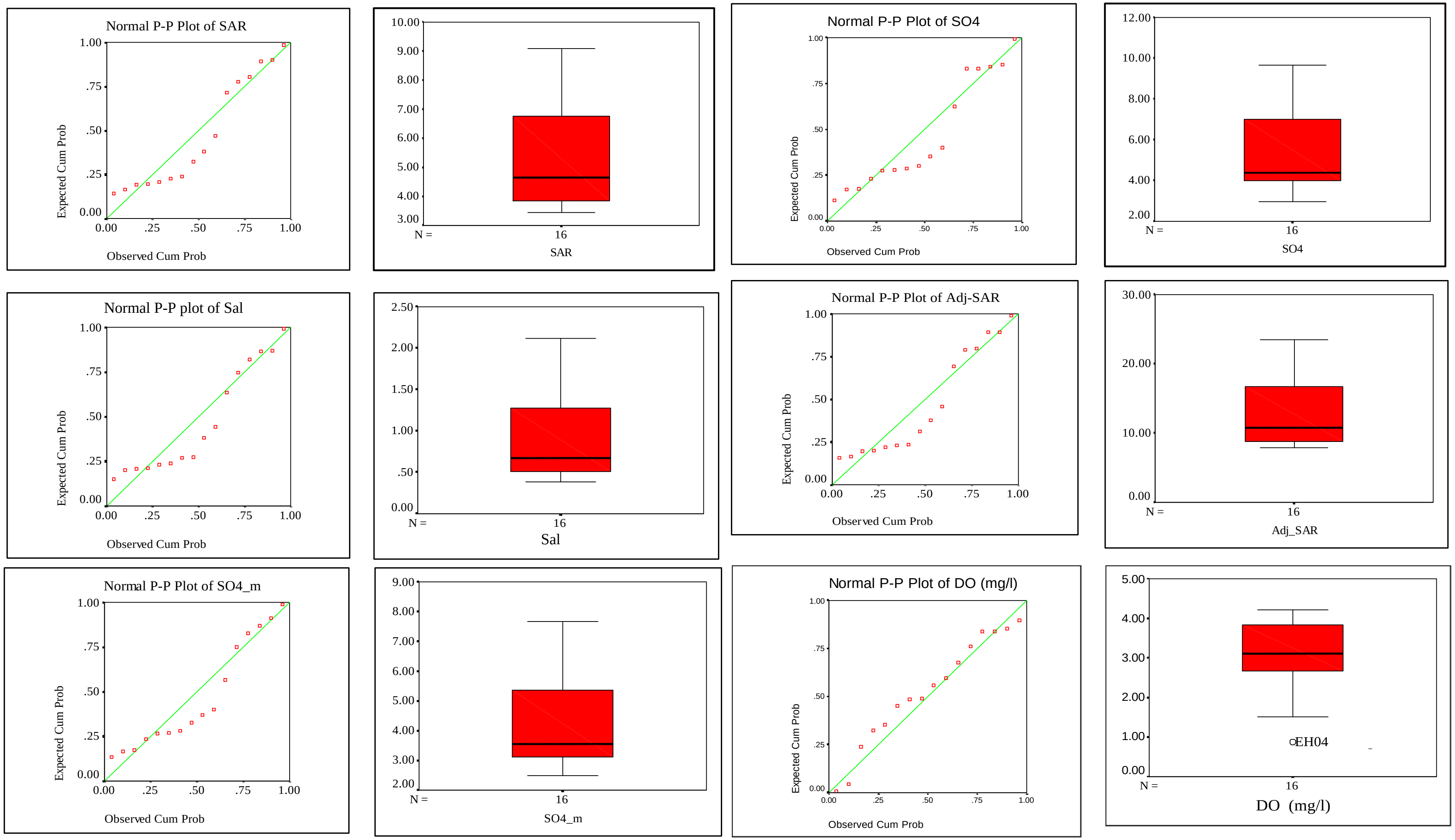
Annex 4-4A1: Normal probability and Box plots for means of some WQPs in Hadus Drain



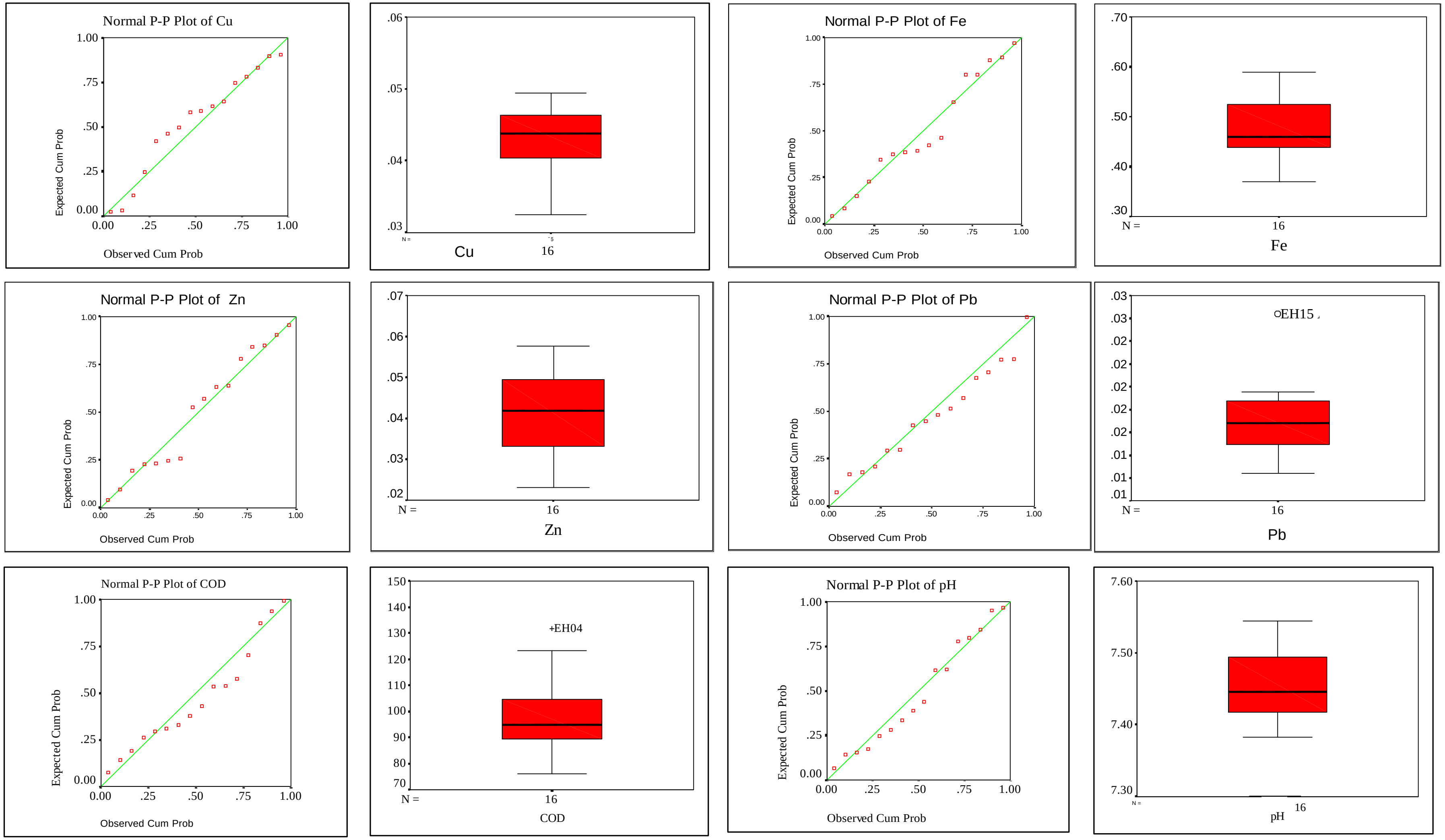
Annex 4-4A1: Normal probability and Box plots for means of some WQPs in Hadus Drain



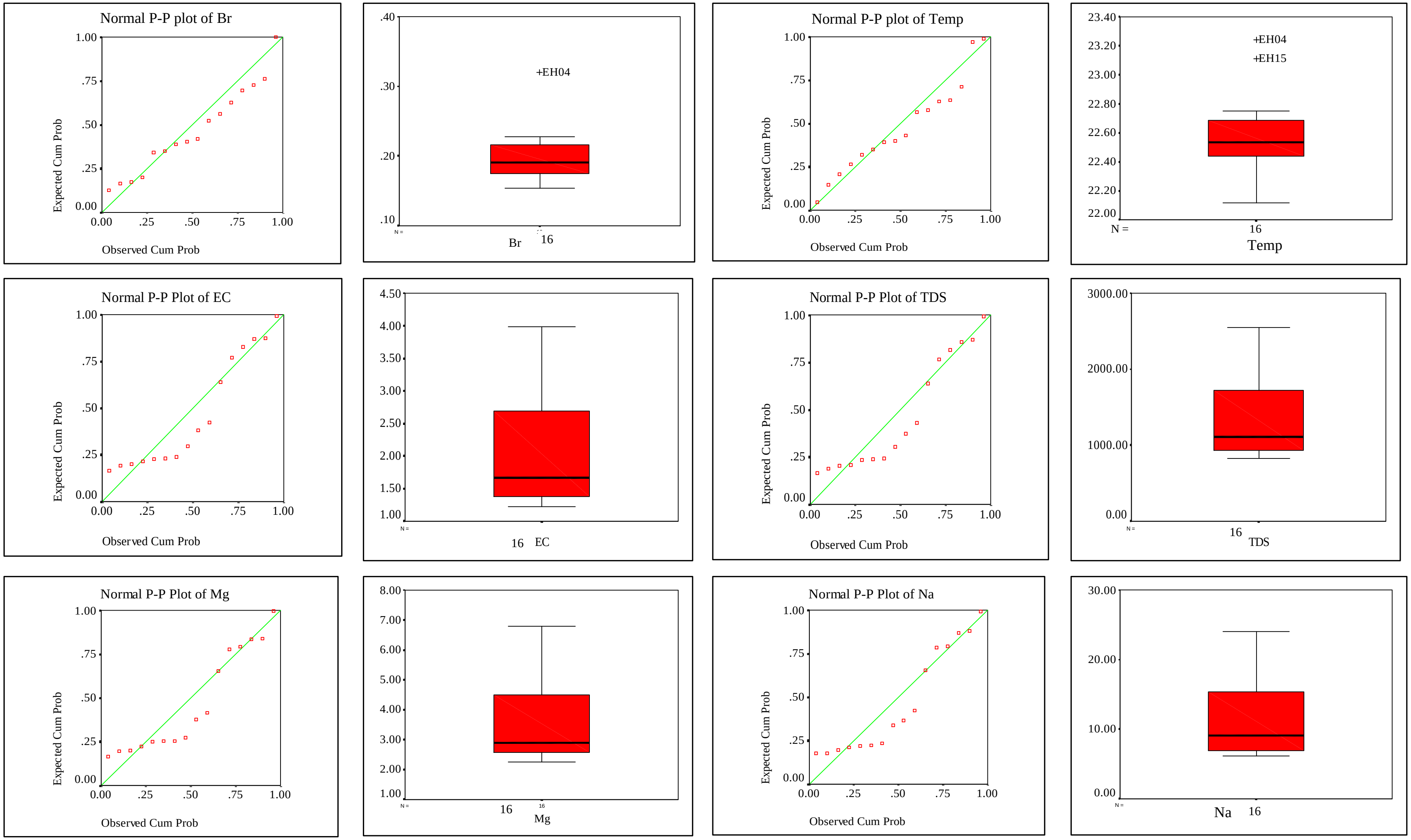
Annex 4-4A1: Normal probability and Box plots for means of some WQPs in Hadus Drain



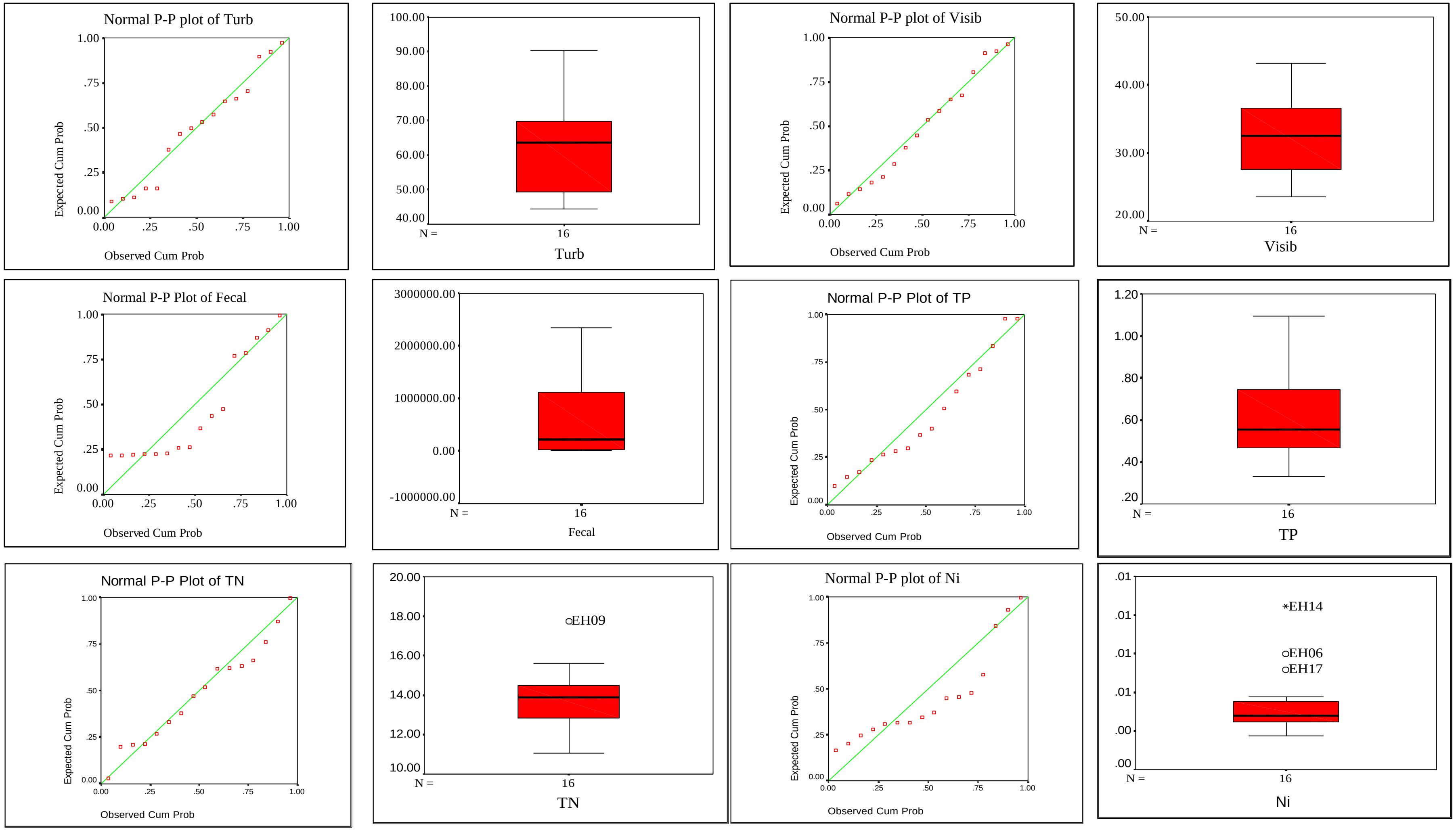
Annex 4-4A1: Normal probability and Box plots for means of some WQPs in Hadus Drain



Annex 4-4A1: Normal probability and Box plots for means of some WQPs in Hadus Drain



Annex 4-4A1: Normal probability and Box plots for means of some WQPs in Hadus Drain



Annex 4-4A2: Kolmogorov-Samirnov and Shapiro-Wilk tests results to check the normality for the means of WQ data in Hadus drain

Parameters	Kolmogorov-Smirnov [a]			Shapiro-Wilk		
	Statistic	df	Significance	Statistic	df	Significance
Coli (MPN/100ml)	0.201	16	**0.082**	0.822	16	0.010
BOD (mg/l)	0.205	16	**0.072**	0.914	16	**0.168**
COD (mg/l)	0.175	16	**0.200**	0.926	16	**0.276**
TSS (mg/l)	0.134	16	**0.200**	0.956	16	**0.560**
TVS (mg/l)	0.148	16	**0.200**	0.952	16	**0.508**
N-NO$_3$ (mg/l)	0.180	16	**0.174**	0.927	16	**0.956**
N-NH$_4$ (mg/l)	0.096	16	**0.200**	0.985	16	**0.927**
P (mg/l)	0.213	16	**0.051**	0.919	16	**0.217**
Cd (mg/l)	0.138	16	**0.200**	0.966	16	**0.735**
Cu (mg/l)	0.170	16	**0.200**	0.919	16	**0.215**
Fe (mg/l)	0.160	16	**0.200**	0.970	16	**0.798**
Mn (mg/l)	0.101	16	**0.200**	0.969	16	**0.783**
Zn (mg/l)	0.180	16	**0.178**	0.963	16	**0.683**
Pb (mg/l)	0.163	16	**0.200**	0.890	16	**0.059**
Br (mg/l)	0.175	16	**0.200**	0.823	16	0.010
pH	0.126	16	**0.200**	0.956	16	**0.572**
EC (dS/m)	0.205	16	**0.070**	0.847	16	0.012
TDS (mg/l)	0.197	16	**0.097**	0.849	16	0.013
Ca (meq/l)	0.245	16	0.011	0.874	16	0.034
Mg (meq/l)	0.227	16	0.027	0.832	16	0.010
Na (meq/l)	0.204	16	**0.075**	0.848	16	0.012
K (meq/l)	0.208	16	**0.062**	0.859	16	0.018
SO$_4$ (meq/l)	0.223	16	0.033	0.878	16	0.039
Cl (meq/l)	0.208	16	**0.062**	0.853	16	0.015
SAR	0.199	16	**0.089**	0.878	16	0.039
Adj_SAR	0.204	16	**0.073**	0.867	16	0.025
Temp (C)	0.176	16	**0.199**	0.924	16	**0.255**
Sal	0.228	16	0.025	0.855	16	0.016
DO (mg/l)	0.138	16	**0.200**	0.915	16	**0.176**
Turb (NTU)	0.150	16	**0.200**	0.944	16	**0.430**
Visib (Cm)	0.101	16	**0.200**	0.965	16	**0.723**
Fecal (MPN/100ml)	0.237	16	0.017	0.798	16	0.010
TP (mg/l)	0.162	16	**0.200**	0.906	16	**0.104**
TN (mg/l)	0.151	16	**0.200**	0.944	16	**0.431**
Ni (mg/l)	0.273	16	0.002	0.773	16	0.010
SO$_{4\_m}$ (meq/l)	0.225	16	0.030	0.883	16	0.044

[a] Lilliefors Significance Correction

Test Significance: The data follows normal distribution if the significance is greater than or equal 0.05.

Annex 4-4B1: Kolmogorov-Samirnov and Shapiro-Wilk tests results to check the normality of the yearly averages (with respect to the monitoring sites) of WQ measurements site group 1

Parameters	Locations	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Coli (MPN/100ml)	EH14	0.182	8	0.200	0.933	8	0.511
	EH02	0.187	8	0.200	0.881	8	0.248
	EH18	0.226	8	0.200	0.904	8	0.360
	EH03	0.335	8	0.009	0.737	8	0.010
BOD (mg/l)	EH14	0.242	8	0.189	0.888	8	0.282
	EH02	0.254	8	0.138	0.869	8	0.191
	EH18	0.230	8	0.200	0.907	8	0.379
	EH03	0.176	8	0.200	0.945	8	0.631
COD (mg/l)	EH14	0.222	8	0.200	0.886	8	0.274
	EH02	0.201	8	0.200	0.864	8	0.163
	EH18	0.236	8	0.200	0.862	8	0.155
	EH03	0.219	8	0.200	0.874	8	0.215
TSS (mg/l)	EH14	0.242	8	0.187	0.823	8	0.058
	EH02	0.204	8	0.200	0.885	8	0.267
	EH18	0.258	8	0.125	0.835	8	0.076
	EH03	0.274	8	0.078	0.825	8	0.060
TVS (mg/l)	EH14	0.214	8	0.200	0.827	8	0.064
	EH02	0.210	8	0.200	0.864	8	0.165
	EH18	0.252	8	0.144	0.825	8	0.060
	EH03	0.246	8	0.168	0.842	8	0.086
N-NO_3 (mg/l)	EH14	0.314	8	0.020	0.618	8	0.010
	EH02	0.287	8	0.051	0.728	8	0.010
	EH18	0.318	8	0.017	0.750	8	0.010
	EH03	0.329	8	0.011	0.741	8	0.010
N-NH_4 (mg/l)	EH14	0.244	8	0.178	0.844	8	0.090
	EH02	0.187	8	0.200	0.905	8	0.368
	EH18	0.133	8	0.200	0.956	8	0.743
	EH03	0.236	8	0.200	0.874	8	0.212
P (mg/l)	-						
Cd (mg/l)	EH14	0.319	8	0.016	0.780	8	0.022
	EH02	0.265	8	0.104	0.803	8	0.039
	EH18	0.286	8	0.053	0.786	8	0.026
	EH03	0.334	8	0.009	0.759	8	0.013
Cu (mg/l)	EH14	0.284	8	0.057	0.766	8	0.016
	EH02	0.258	8	0.124	0.872	8	0.202
	EH18	0.258	8	0.124	0.842	8	0.086
	EH03	0.274	8	0.078	0.839	8	0.082
Fe (mg/l)	EH14	0.193	8	0.200	0.919	8	0.435
	EH02	0.357	8	0.003	0.678	8	0.010
	EH18	0.260	8	0.118	0.861	8	0.148
	EH03	0.344	8	0.006	0.749	8	0.010
Mn (mg/l)	EH14	0.211	5	0.200	0.961	5	0.758
	EH02	0.200	5	0.200	0.888	5	0.373
	EH18	0.324	5	0.093	0.771	5	0.060
	EH03	0.241	5	0.200	0.842	5	0.220
Zn (mg/l)	EH14	0.288	8	0.050	0.742	8	0.010
	EH02	0.334	8	0.009	0.603	8	0.010
	EH18	0.234	8	0.200	0.860	8	0.145
	EH03	0.240	8	0.194	0.808	8	0.042

There are no valid cases for P. (some statistics cannot be computed).

Test Significance: The data follows normal distribution if the significance is greater than or equal 0.05.

Annex 4-4B1: Kolmogorov-Samirnov and Shapiro-Wilk tests results to check the normality of the yearly averages (with respect to the monitoring sites) of WQ measurements site group 1

Parameters	Locations	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Pb (mg/l)	EH14	0.328	8	0.011	0.765	8	0.016
	EH02	0.321	8	0.015	0.838	8	0.081
	EH18	0.233	8	0.200	0.853	8	0.112
	EH03	0.215	8	0.200	0.922	8	0.452
Br (mg/l)	EH14	0.223	5	0.200	0.960	5	0.754
	EH02	0.245	5	0.200	0.899	5	0.409
	EH18	0.260	5	0.200	0.883	5	0.353
	EH03	0.163	5	0.200	0.952	5	0.696
pH	EH14	0.254	8	0.139	0.925	8	0.464
	EH02	0.202	8	0.200	0.944	8	0.618
	EH18	0.234	8	0.200	0.884	8	0.263
	EH03	0.170	8	0.200	0.959	8	0.774
EC (dS/m)	EH14	0.264	8	0.107	0.937	8	0.551
	EH02	0.145	8	0.200	0.968	8	0.859
	EH18	0.171	8	0.200	0.948	8	0.662
	EH03	0.226	8	0.200	0.836	8	0.078
TDS (mg/l)	EH14	0.222	8	0.200	0.872	8	0.202
	EH02	0.162	8	0.200	0.965	8	0.830
	EH18	0.120	8	0.200	0.977	8	0.939
	EH03	0.205	8	0.200	0.904	8	0.360
Ca (meq/l)	EH14	0.173	8	0.200	0.962	8	0.805
	EH02	0.126	8	0.200	0.963	8	0.806
	EH18	0.163	8	0.200	0.914	8	0.409
	EH03	0.200	8	0.200	0.967	8	0.846
Mg (meq/l)	EH14	0.167	8	0.200	0.983	8	0.976
	EH02	0.185	8	0.200	0.962	8	0.797
	EH18	0.164	8	0.200	0.905	8	0.367
	EH03	0.190	8	0.200	0.913	8	0.404
Na (meq/l)	EH14	0.207	8	0.200	0.896	8	0.324
	EH02	0.154	8	0.200	0.923	8	0.455
	EH18	0.182	8	0.200	0.911	8	0.398
	EH03	0.183	8	0.200	0.964	8	0.819
K (meq/l)	EH14	0.211	8	0.200	0.881	8	0.247
	EH02	0.141	8	0.200	0.968	8	0.860
	EH18	0.190	8	0.200	0.960	8	0.778
	EH03	0.230	8	0.200	0.904	8	0.363
SO_4 (meq/l)	EH14	0.208	8	0.200	0.922	8	0.448
	EH02	0.234	8	0.200	0.873	8	0.210
	EH18	0.124	8	0.200	0.952	8	0.702
	EH03	0.160	8	0.200	0.953	8	0.709
Cl (meq/l)	EH14	0.242	8	0.186	0.914	8	0.414
	EH02	0.146	8	0.200	0.971	8	0.885
	EH18	0.220	8	0.200	0.956	8	0.739
	EH03	0.167	8	0.200	0.930	8	0.492
SAR	EH14	0.239	8	0.200	0.896	8	0.323
	EH02	0.208	8	0.200	0.878	8	0.235
	EH18	0.170	8	0.200	0.897	8	0.326
	EH03	0.152	8	0.200	0.958	8	0.765

Test Significance: The data follows normal distribution if the significance is greater than or equal 0.05.

Annex 4-4B1: Kolmogorov-Samirnov and Shapiro-Wilk tests results to check the normality of the yearly averages (with respect to the monitoring sites) of WQ measurements site group 1

Parameters	Locations	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Adj_SAR	EH14	0.236	8	0.200	0.905	8	0.368
	EH02	0.185	8	0.200	0.894	8	0.314
	EH18	0.232	8	0.200	0.897	8	0.326
	EH03	0.173	8	0.200	0.945	8	0.630
Temp (C^{o})	EH14	0.168	8	0.200	0.900	8	0.344
	EH02	0.154	8	0.200	0.926	8	0.470
	EH18	0.169	8	0.200	0.943	8	0.614
	EH03	0.177	8	0.200	0.859	8	0.140
Sal	EH14	0.231	8	0.200	0.885	8	0.268
	EH02	0.156	8	0.200	0.965	8	0.829
	EH18	0.205	8	0.200	0.886	8	0.273
	EH03	0.200	8	0.200	0.885	8	0.266
DO (mg/l)	EH14	0.256	8	0.131	0.798	8	0.035
	EH02	0.249	8	0.154	0.830	8	0.068
	EH18	0.308	8	0.024	0.833	8	0.072
	EH03	0.181	8	0.200	0.917	8	0.425
Turb (NTU)	EH14	0.183	7	0.200	0.914	7	0.436
	EH02	0.200	7	0.200	0.915	7	0.443
	EH18	0.221	7	0.200	0.864	7	0.216
	EH03	0.208	7	0.200	0.908	7	0.412
Visib (Cm)	EH14	0.163	8	0.200	0.905	8	0.368
	EH02	0.282	8	0.061	0.829	8	0.067
	EH18	0.376	8	0.001	0.760	8	0.014
	EH03	0.178	8	0.200	0.931	8	0.495
Fecal (MPN/100ml)	EH14	0.250	5	0.200	0.849	5	0.244
	EH02	0.223	5	0.200	0.852	5	0.253
	EH18	0.272	5	0.200	0.891	5	0.379
	EH03	0.207	5	0.200	0.833	5	0.190
TP (mg/l)	EH14	0.202	5	0.200	0.863	5	0.288
	EH02	0.183	5	0.200	0.903	5	0.421
	EH18	0.254	5	0.200	0.860	5	0.279
	EH03	0.306	5	0.142	0.845	5	0.228
TN (mg/l)	EH14	0.404	5	0.008	0.694	5	0.013
	EH02	0.293	5	0.186	0.817	5	0.135
	EH18	0.308	5	0.136	0.813	5	0.123
	EH03	0.280	5	0.200	0.812	5	0.120
Ni (mg/l)	EH14	0.355	5	0.039	0.735	5	0.033
	EH02	0.192	5	0.200	0.876	5	0.332
	EH18	0.182	5	0.200	0.916	5	0.464
	EH03	0.189	5	0.200	0.886	5	0.365
SO$_{4\_m}$ (meq/l)	EH14	0.300	5	0.162	0.749	5	0.042
	EH02	0.288	5	0.200	0.888	5	0.370
	EH18	0.175	5	0.200	0.939	5	0.591
	EH03	0.357	5	0.036	0.839	5	0.208

Test Significance: The data follows normal distribution if the significance is greater than or equal 0.05.

Annex 4-4B2: Kolmogorov-Samirnov and Shapiro-Wilk tests results to check the normality of the yearly averages (with respect to the monitoring sites) of WQ measurements in site group 2

Parameters	Locations	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Coli (MPN/100ml)	EH04	0.198	8	0.200	0.889	8	0.287
	EH05	0.289	8	0.049	0.694	8	0.010
	EH15	0.181	8	0.200	0.904	8	0.359
	EH06	0.181	8	0.200	0.931	8	0.494
BOD (mg/l)	EH04	0.239	8	0.200	0.871	8	0.198
	EH05	0.173	8	0.200	0.934	8	0.524
	EH15	0.271	8	0.087	0.886	8	0.272
	EH06	0.295	8	0.039	0.830	8	0.069
COD (mg/l)	EH04	0.258	8	0.125	0.908	8	0.380
	EH05	0.258	8	0.126	0.872	8	0.204
	EH15	0.247	8	0.163	0.857	8	0.130
	EH06	0.271	8	0.086	0.805	8	0.040
TSS (mg/l)	EH04	0.243	8	0.180	0.919	8	0.436
	EH05	0.329	8	0.011	0.778	8	0.020
	EH15	0.243	8	0.183	0.821	8	0.054
	EH06	0.341	8	0.007	0.817	8	0.049
TVS (mg/l)	EH04	0.244	8	0.176	0.879	8	0.238
	EH05	0.316	8	0.018	0.798	8	0.035
	EH15	0.256	8	0.132	0.839	8	0.082
	EH06	0.316	8	0.018	0.827	8	0.063
N-NO$_3$ (mg/l)	EH04	0.364	8	0.002	0.600	8	0.010
	EH05	0.333	8	0.009	0.722	8	0.010
	EH15	0.305	8	0.027	0.648	8	0.010
	EH06	0.367	8	0.002	0.752	8	0.011
N-NH$_4$ (mg/l)	EH04	0.365	8	0.002	0.562	8	0.010
	EH05	0.427	8	0.000	0.535	8	0.010
	EH15	0.450	8	0.000	0.511	8	0.010
	EH06	0.280	8	0.065	0.757	8	0.013
P (mg/l)							
Cd (mg/l)	EH04	0.235	8	0.200	0.853	8	0.112
	EH05	0.343	8	0.006	0.744	8	0.010
	EH15	0.362	8	0.003	0.761	8	0.014
	EH06	0.261	8	0.116	0.832	8	0.071
Cu (mg/l)	EH04	0.193	8	0.200	0.941	8	0.585
	EH05	0.173	8	0.200	0.935	8	0.530
	EH15	0.159	8	0.200	0.925	8	0.466
	EH06	0.250	8	0.151	0.888	8	0.285
Fe (mg/l)	EH04	0.236	8	0.200	0.844	8	0.090
	EH05	0.189	8	0.200	0.881	8	0.248
	EH15	0.183	8	0.200	0.930	8	0.491
	EH06	0.195	8	0.200	0.918	8	0.430
Mn (mg/l)	EH04	0.288	5	0.200	0.843	5	0.222
	EH05	0.326	5	0.088	0.915	5	0.460
	EH15	0.331	5	0.078	0.832	5	0.186
	EH06	0.356	5	0.037	0.855	5	0.261
Zn (mg/l)	EH04	0.211	8	0.200	0.850	8	0.098
	EH05	0.208	8	0.200	0.927	8	0.477
	EH15	0.296	8	0.038	0.798	8	0.035
	EH06	0.289	8	0.048	0.817	8	0.049

There are no valid cases for P. (some statistics cannot be computed).

Test Significance: The data follows normal distribution if the significance is greater than or equal 0.05.

Annex 4-4B2: Kolmogorov-Samirnov and Shapiro-Wilk tests results to check the normality of the yearly averages (with respect to the monitoring sites) of WQ measurements in site group 2

Parameters	Locations	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Pb (mg/l)	EH04	0.274	8	0.079	0.867	8	0.179
	EH05	0.328	8	0.011	0.800	8	0.036
	EH15	0.371	8	0.002	0.715	8	0.010
	EH06	0.243	8	0.181	0.880	8	0.245
Br (mg/l)	EH04	0.260	5	0.200	0.852	5	0.251
	EH05	0.189	5	0.200	0.974	5	0.858
	EH15	0.313	5	0.124	0.734	5	0.032
	EH06	0.170	5	0.200	0.979	5	0.902
pH	EH04	0.189	8	0.200	0.926	8	0.472
	EH05	0.161	8	0.200	0.983	8	0.976
	EH15	0.199	8	0.200	0.955	8	0.727
	EH06	0.192	8	0.200	0.953	8	0.706
EC (dS/m)	EH04	0.321	8	0.015	0.833	8	0.073
	EH05	0.185	8	0.200	0.965	8	0.828
	EH15	0.144	8	0.200	0.982	8	0.970
	EH06	0.179	8	0.200	0.929	8	0.485
TDS (mg/l)	EH04	0.199	8	0.200	0.928	8	0.479
	EH05	0.210	8	0.200	0.918	8	0.430
	EH15	0.213	8	0.200	0.867	8	0.179
	EH06	0.216	8	0.200	0.896	8	0.321
Ca (meq/l)	EH04	0.137	8	0.200	0.967	8	0.848
	EH05	0.146	8	0.200	0.933	8	0.514
	EH15	0.224	8	0.200	0.884	8	0.263
	EH06	0.165	8	0.200	0.919	8	0.437
Mg (meq/l)	EH04	0.180	8	0.200	0.911	8	0.398
	EH05	0.119	8	0.200	0.981	8	0.963
	EH15	0.220	8	0.200	0.875	8	0.220
	EH06	0.222	8	0.200	0.883	8	0.259
Na (meq/l)	EH04	0.246	8	0.169	0.913	8	0.405
	EH05	0.305	8	0.027	0.754	8	0.012
	EH15	0.213	8	0.200	0.934	8	0.524
	EH06	0.298	8	0.036	0.847	8	0.094
K (meq/l)	EH04	0.205	8	0.200	0.962	8	0.799
	EH05	0.194	8	0.200	0.966	8	0.840
	EH15	0.159	8	0.200	0.921	8	0.446
	EH06	0.206	8	0.200	0.927	8	0.473
SO_4 (meq/l)	EH04	0.151	8	0.200	0.971	8	0.895
	EH05	0.184	8	0.200	0.917	8	0.424
	EH15	0.190	8	0.200	0.943	8	0.609
	EH06	0.241	8	0.192	0.885	8	0.268
Cl (meq/l)	EH04	0.276	8	0.073	0.837	8	0.079
	EH05	0.214	8	0.200	0.915	8	0.416
	EH15	0.261	8	0.117	0.869	8	0.188
	EH06	0.249	8	0.156	0.894	8	0.311
SAR	EH04	0.114	8	0.200	0.979	8	0.955
	EH05	0.231	8	0.200	0.849	8	0.097
	EH15	0.148	8	0.200	0.980	8	0.960
	EH06	0.297	8	0.037	0.851	8	0.100

Test Significance: The data follows normal distribution if the significance is greater than or equal 0.05.

Annex 4-4B2: Kolmogorov-Samirnov and Shapiro-Wilk tests results to check the normality of the yearly averages (with respect to the monitoring sites) of WQ measurements in site group 2

Parameters	Locations	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Adj_SAR	EH04	0.191	8	0.200	0.972	8	0.898
	EH05	0.257	8	0.129	0.869	8	0.190
	EH15	0.160	8	0.200	0.961	8	0.793
	EH06	0.322	8	0.014	0.817	8	0.049
Temp (C^o)	EH04	0.228	8	0.200	0.941	8	0.587
	EH05	0.312	8	0.021	0.801	8	0.037
	EH15	0.239	8	0.200	0.930	8	0.488
	EH06	0.221	8	0.200	0.923	8	0.454
Sal	EH04	0.160	8	0.200	0.968	8	0.863
	EH05	0.281	8	0.063	0.744	8	0.010
	EH15	0.301	8	0.031	0.735	8	0.010
	EH06	0.229	8	0.200	0.868	8	0.184
DO (mg/l)	EH04	0.204	8	0.200	0.917	8	0.424
	EH05	0.201	8	0.200	0.921	8	0.448
	EH15	0.215	8	0.200	0.881	8	0.246
	EH06	0.229	8	0.200	0.860	8	0.145
Turb (NTU)	EH04	0.127	7	0.200	0.982	7	0.964
	EH05	0.151	7	0.200	0.972	7	0.901
	EH15	0.284	7	0.091	0.777	7	0.032
	EH06	0.185	7	0.200	0.915	7	0.442
Visib (Cm)	EH04	0.251	8	0.148	0.931	8	0.496
	EH05	0.230	8	0.200	0.908	8	0.381
	EH15	0.262	8	0.112	0.872	8	0.204
	EH06	0.241	8	0.190	0.889	8	0.289
Fecal (MPN/100ml)	EH04	0.296	5	0.174	0.805	5	0.099
	EH05	0.384	5	0.015	0.686	5	0.010
	EH15	0.218	5	0.200	0.870	5	0.310
	EH06	0.312	5	0.127	0.929	5	0.518
TP (mg/l)	EH04	0.163	5	0.200	0.952	5	0.690
	EH05	0.196	5	0.200	0.888	5	0.372
	EH15	0.259	5	0.200	0.898	5	0.404
	EH06	0.193	5	0.200	0.995	5	0.990
TN (mg/l)	EH04	0.314	5	0.121	0.733	5	0.032
	EH05	0.243	5	0.200	0.920	5	0.475
	EH15	0.343	5	0.055	0.742	5	0.037
	EH06	0.208	5	0.200	0.880	5	0.344
Ni (mg/l)	EH04	0.271	5	0.200	0.887	5	0.367
	EH05	0.270	5	0.200	0.809	5	0.108
	EH15	0.248	5	0.200	0.874	5	0.323
	EH06	0.292	5	0.188	0.781	5	0.072
SO_{4_m} (meq/l)	EH04	0.216	5	0.200	0.952	5	0.693
	EH05	0.270	5	0.200	0.851	5	0.248
	EH15	0.379	5	0.018	0.807	5	0.103
	EH06	0.316	5	0.114	0.803	5	0.096

Test Significance: The data follows normal distribution if the significance is greater than or equal 0.05.

Annex 4-4B3: Kolmogorov-Samirnov and Shapiro-Wilk tests results to check the normality of the yearly averages (with respect to the monitoring sites) of WQ measurements in site group 3

Parameters	Locations	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Coli (MPN/100ml)	EH07	0.382	8	0.001	0.581	8	0.010
	EH08	0.260	8	0.119	0.909	8	0.387
	EH09	0.351	8	0.004	0.722	8	0.010
	EH10	0.382	8	0.001	0.700	8	0.010
BOD (mg/l)	EH07	0.269	8	0.091	0.797	8	0.034
	EH08	0.258	8	0.124	0.811	8	0.045
	EH09	0.284	8	0.056	0.816	8	0.049
	EH10	0.216	8	0.200	0.879	8	0.240
COD (mg/l)	EH07	0.251	8	0.146	0.819	8	0.052
	EH08	0.259	8	0.121	0.833	8	0.072
	EH09	0.238	8	0.200	0.867	8	0.180
	EH10	0.222	8	0.200	0.875	8	0.217
TSS (mg/l)	EH07	0.324	8	0.013	0.810	8	0.044
	EH08	0.302	8	0.031	0.821	8	0.054
	EH09	0.297	8	0.037	0.824	8	0.059
	EH10	0.325	8	0.013	0.798	8	0.035
TVS (mg/l)	EH07	0.308	8	0.025	0.812	8	0.046
	EH08	0.285	8	0.055	0.845	8	0.091
	EH09	0.355	8	0.004	0.772	8	0.018
	EH10	0.341	8	0.007	0.796	8	0.033
N-NO_3 (mg/l)	EH07	0.348	8	0.005	0.751	8	0.011
	EH08	0.352	8	0.004	0.763	8	0.015
	EH09	0.370	8	0.002	0.728	8	0.010
	EH10	0.352	8	0.004	0.740	8	0.010
N-NH_4 (mg/l)	EH07	0.253	8	0.142	0.816	8	0.049
	EH08	0.258	8	0.124	0.843	8	0.089
	EH09	0.263	8	0.111	0.849	8	0.096
	EH10	0.248	8	0.159	0.834	8	0.075
P (mg/l)							
Cd (mg/l)	EH07	0.344	8	0.006	0.733	8	0.010
	EH08	0.349	8	0.005	0.772	8	0.018
	EH09	0.339	8	0.007	0.762	8	0.015
	EH10	0.322	8	0.015	0.776	8	0.019
Cu (mg/l)	EH07	0.172	8	0.200	0.943	8	0.606
	EH08	0.170	8	0.200	0.968	8	0.858
	EH09	0.233	8	0.200	0.926	8	0.468
	EH10	0.204	8	0.200	0.906	8	0.371
Fe (mg/l)	EH07	0.226	8	0.200	0.837	8	0.080
	EH08	0.263	8	0.110	0.856	8	0.126
	EH09	0.241	8	0.190	0.839	8	0.082
	EH10	0.249	8	0.156	0.837	8	0.079
Mn (mg/l)	EH07	0.260	5	0.200	0.845	5	0.230
	EH08	0.215	5	0.200	0.838	5	0.207
	EH09	0.258	5	0.200	0.882	5	0.351
	EH10	0.225	5	0.200	0.826	5	0.165
Zn (mg/l)	EH07	0.292	8	0.044	0.776	8	0.019
	EH08	0.344	8	0.006	0.694	8	0.010
	EH09	0.310	8	0.023	0.811	8	0.044
	EH10	0.349	8	0.005	0.770	8	0.017

There are no valid cases for P. (some statistics cannot be computed).

Test Significance: The data follows normal distribution if the significance is greater than or equal 0.05.

Annex 4-4B3: Kolmogorov-Samirnov and Shapiro-Wilk tests results to check the normality of the yearly averages (with respect to the monitoring sites) of WQ measurements in site group 3

Parameters	Locations	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Pb (mg/l)	EH07	0.303	8	0.030	0.824	8	0.060
	EH08	0.293	8	0.042	0.872	8	0.204
	EH09	0.170	8	0.200	0.928	8	0.482
	EH10	0.266	8	0.102	0.852	8	0.103
Br (mg/l)	EH07	0.244	5	0.200	0.822	5	0.152
	EH08	0.228	5	0.200	0.838	5	0.207
	EH09	0.164	5	0.200	0.927	5	0.500
	EH10	0.223	5	0.200	0.877	5	0.333
pH	EH07	0.192	8	0.200	0.926	8	0.473
	EH08	0.175	8	0.200	0.935	8	0.534
	EH09	0.161	8	0.200	0.940	8	0.580
	EH10	0.152	8	0.200	0.975	8	0.923
EC (dS/m)	EH07	0.225	8	0.200	0.911	8	0.397
	EH08	0.196	8	0.200	0.960	8	0.777
	EH09	0.152	8	0.200	0.967	8	0.846
	EH10	0.140	8	0.200	0.975	8	0.925
TDS (mg/l)	EH07	0.236	8	0.200	0.886	8	0.271
	EH08	0.219	8	0.200	0.906	8	0.369
	EH09	0.214	8	0.200	0.956	8	0.743
	EH10	0.193	8	0.200	0.941	8	0.586
Ca (meq/l)	EH07	0.292	8	0.043	0.675	8	0.010
	EH08	0.216	8	0.200	0.898	8	0.330
	EH09	0.184	8	0.200	0.955	8	0.730
	EH10	0.263	8	0.110	0.786	8	0.026
Mg (meq/l)	EH07	0.216	8	0.200	0.907	8	0.376
	EH08	0.218	8	0.200	0.901	8	0.349
	EH09	0.134	8	0.200	0.982	8	0.969
	EH10	0.239	8	0.199	0.814	8	0.047
Na (meq/l)	EH07	0.202	8	0.200	0.918	8	0.433
	EH08	0.185	8	0.200	0.933	8	0.511
	EH09	0.169	8	0.200	0.964	8	0.818
	EH10	0.207	8	0.200	0.927	8	0.475
K (meq/l)	EH07	0.304	8	0.028	0.697	8	0.010
	EH08	0.252	8	0.144	0.775	8	0.019
	EH09	0.134	8	0.200	0.956	8	0.744
	EH10	0.211	8	0.200	0.847	8	0.093
SO_4 (meq/l)	EH07	0.176	8	0.200	0.913	8	0.404
	EH08	0.107	8	0.200	0.989	8	0.990
	EH09	0.166	8	0.200	0.925	8	0.465
	EH10	0.236	8	0.200	0.909	8	0.387
Cl (meq/l)	EH07	0.193	8	0.200	0.922	8	0.451
	EH08	0.194	8	0.200	0.968	8	0.855
	EH09	0.186	8	0.200	0.951	8	0.694
	EH10	0.141	8	0.200	0.962	8	0.795
SAR	EH07	0.229	8	0.200	0.862	8	0.152
	EH08	0.219	8	0.200	0.932	8	0.498
	EH09	0.263	8	0.109	0.804	8	0.040
	EH10	0.175	8	0.200	0.930	8	0.488

Test Significance: The data follows normal distribution if the significance is greater than or equal 0.05.

Annex 4-4B3: Kolmogorov-Samirnov and Shapiro-Wilk tests results to check the normality of the yearly averages (with respect to the monitoring sites) of WQ measurements in site group 3

Parameters	Locations	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Adj_SAR	EH07	0.288	8	0.049	0.816	8	0.048
	EH08	0.233	8	0.200	0.915	8	0.416
	EH09	0.346	8	0.005	0.730	8	0.010
	EH10	0.163	8	0.200	0.906	8	0.372
Temp (C^o)	EH07	0.219	8	0.200	0.920	8	0.440
	EH08	0.201	8	0.200	0.907	8	0.378
	EH09	0.262	8	0.114	0.911	8	0.397
	EH10	0.276	8	0.072	0.885	8	0.267
Sal	EH07	0.216	8	0.200	0.925	8	0.465
	EH08	0.143	8	0.200	0.980	8	0.962
	EH09	0.193	8	0.200	0.938	8	0.559
	EH10	0.194	8	0.200	0.924	8	0.458
DO (mg/l)	EH07	0.162	8	0.200	0.951	8	0.686
	EH08	0.201	8	0.200	0.897	8	0.327
	EH09	0.242	8	0.185	0.832	8	0.071
	EH10	0.193	8	0.200	0.936	8	0.544
Turb (NTU)	EH07	0.235	7	0.200	0.873	7	0.255
	EH08	0.166	7	0.200	0.943	7	0.637
	EH09	0.279	7	0.105	0.925	7	0.487
	EH10	0.218	7	0.200	0.902	7	0.386
Visib (Cm)	EH07	0.262	8	0.114	0.894	8	0.315
	EH08	0.242	8	0.188	0.836	8	0.077
	EH09	0.273	8	0.081	0.899	8	0.335
	EH10	0.319	8	0.016	0.763	8	0.015
Fecal (MPN/100ml)	EH07	0.226	5	0.200	0.891	5	0.381
	EH08	0.229	5	0.200	0.788	5	0.080
	EH09	0.406	5	0.007	0.672	5	0.010
	EH10	0.379	5	0.018	0.760	5	0.049
TP (mg/l)	EH07	0.192	5	0.200	0.948	5	0.660
	EH08	0.255	5	0.200	0.916	5	0.463
	EH09	0.231	5	0.200	0.852	5	0.253
	EH10	0.196	5	0.200	0.998	5	0.990
TN (mg/l)	EH07	0.185	5	0.200	0.896	5	0.397
	EH08	0.183	5	0.200	0.913	5	0.454
	EH09	0.254	5	0.200	0.847	5	0.237
	EH10	0.229	5	0.200	0.842	5	0.219
Ni (mg/l)	EH07	0.366	5	0.027	0.849	5	0.241
	EH08	0.324	5	0.094	0.814	5	0.128
	EH09	0.242	5	0.200	0.903	5	0.420
	EH10	0.272	5	0.200	0.844	5	0.226
SO_{4_m} (meq/l)	EH07	0.401	5	0.009	0.715	5	0.020
	EH08	0.281	5	0.200	0.788	5	0.079
	EH09	0.277	5	0.200	0.888	5	0.371
	EH10	0.332	5	0.075	0.744	5	0.039

Test Significance: The data follows normal distribution if the significance is greater than or equal 0.05.

Annex 4-4B4: Kolmogorov-Samirnov and Shapiro-Wilk tests results to check the normality of the yearly averages (with respect to the monitoring sites) of WQ measurements in site group 4

Parameters	Locations	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Coli (MPN/100ml)	EH11	0.428	8	0.000	0.515	8	0.010
	EH16	0.235	8	0.200	0.837	8	0.079
	EH12	0.330	8	0.011	0.748	8	0.010
	EH17	0.322	8	0.015	0.830	8	0.069
BOD (mg/l)	EH11	0.268	8	0.093	0.848	8	0.096
	EH16	0.246	8	0.168	0.821	8	0.055
	EH12	0.275	8	0.075	0.890	8	0.292
	EH17	0.240	8	0.198	0.808	8	0.042
COD (mg/l)	EH11	0.248	8	0.159	0.850	8	0.099
	EH16	0.270	8	0.088	0.771	8	0.017
	EH12	0.265	8	0.102	0.872	8	0.204
	EH17	0.197	8	0.200	0.835	8	0.076
TSS (mg/l)	EH11	0.307	8	0.026	0.799	8	0.036
	EH16	0.370	8	0.002	0.688	8	0.010
	EH12	0.301	8	0.031	0.844	8	0.089
	EH17	0.329	8	0.011	0.775	8	0.019
TVS (mg/l)	EH11	0.332	8	0.010	0.773	8	0.018
	EH16	0.289	8	0.047	0.781	8	0.023
	EH12	0.308	8	0.024	0.849	8	0.097
	EH17	0.330	8	0.011	0.767	8	0.016
N-NO$_3$ (mg/l)	EH11	0.360	8	0.003	0.751	8	0.011
	EH16	0.341	8	0.007	0.764	8	0.015
	EH12	0.332	8	0.010	0.695	8	0.010
	EH17	0.329	8	0.011	0.756	8	0.012
N-NH$_4$ (mg/l)	EH11	0.255	8	0.135	0.864	8	0.163
	EH16	0.189	8	0.200	0.868	8	0.183
	EH12	0.383	8	0.001	0.719	8	0.010
	EH17	0.281	8	0.062	0.802	8	0.038
P (mg/l)							
Cd (mg/l)	EH11	0.359	8	0.003	0.763	8	0.015
	EH16	0.333	8	0.009	0.796	8	0.034
	EH12	0.358	8	0.003	0.767	8	0.016
	EH17	0.286	8	0.052	0.810	8	0.044
Cu (mg/l)	EH11	0.225	8	0.200	0.901	8	0.346
	EH16	0.219	8	0.200	0.874	8	0.215
	EH12	0.160	8	0.200	0.964	8	0.821
	EH17	0.152	8	0.200	0.933	8	0.515
Fe (mg/l)	EH11	0.291	8	0.045	0.865	8	0.170
	EH16	0.190	8	0.200	0.928	8	0.478
	EH12	0.260	8	0.120	0.807	8	0.042
	EH17	0.332	8	0.010	0.799	8	0.036
Mn (mg/l)	EH11	0.255	5	0.200	0.931	5	0.535
	EH16	0.208	5	0.200	0.845	5	0.230
	EH12	0.174	5	0.200	0.988	5	0.963
	EH17	0.183	5	0.200	0.982	5	0.922
Zn (mg/l)	EH11	0.198	8	0.200	0.939	8	0.570
	EH16	0.276	8	0.073	0.850	8	0.098
	EH12	0.250	8	0.150	0.909	8	0.387
	EH17	0.192	8	0.200	0.881	8	0.249

There are no valid cases for P. (some statistics cannot be computed).

Test Significance: The data follows normal distribution if the significance is greater than or equal 0.05.

Annex 4-4B4: Kolmogorov-Samirnov and Shapiro-Wilk tests results to check the normality of the yearly averages (with respect to the monitoring sites) of WQ measurements in site group 4

Parameters	Locations	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Pb (mg/l)	EH11	0.213	8	0.200	0.941	8	0.593
	EH16	0.319	8	0.016	0.852	8	0.104
	EH12	0.182	8	0.200	0.954	8	0.720
	EH17	0.293	8	0.042	0.848	8	0.096
Br (mg/l)	EH11	0.198	5	0.200	0.906	5	0.432
	EH16	0.232	5	0.200	0.866	5	0.297
	EH12	0.205	5	0.200	0.900	5	0.409
	EH17	0.228	5	0.200	0.841	5	0.215
pH	EH11	0.185	8	0.200	0.927	8	0.477
	EH16	0.154	8	0.200	0.971	8	0.887
	EH12	0.181	8	0.200	0.951	8	0.691
	EH17	0.231	8	0.200	0.872	8	0.201
EC (dS/m)	EH11	0.287	8	0.051	0.885	8	0.266
	EH16	0.200	8	0.200	0.938	8	0.565
	EH12	0.113	8	0.200	0.983	8	0.975
	EH17	0.236	8	0.200	0.866	8	0.175
TDS (mg/l)	EH11	0.275	8	0.075	0.866	8	0.174
	EH16	0.175	8	0.200	0.953	8	0.707
	EH12	0.200	8	0.200	0.924	8	0.460
	EH17	0.265	8	0.103	0.825	8	0.061
Ca (meq/l)	EH11	0.265	8	0.104	0.795	8	0.033
	EH16	0.213	8	0.200	0.896	8	0.325
	EH12	0.220	8	0.200	0.918	8	0.432
	EH17	0.223	8	0.200	0.863	8	0.157
Mg (meq/l)	EH11	0.229	8	0.200	0.919	8	0.437
	EH16	0.307	8	0.026	0.829	8	0.067
	EH12	0.210	8	0.200	0.884	8	0.264
	EH17	0.220	8	0.200	0.884	8	0.263
Na (meq/l)	EH11	0.140	8	0.200	0.951	8	0.688
	EH16	0.186	8	0.200	0.903	8	0.358
	EH12	0.211	8	0.200	0.911	8	0.398
	EH17	0.192	8	0.200	0.920	8	0.442
K (meq/l)	EH11	0.283	8	0.059	0.780	8	0.022
	EH16	0.221	8	0.200	0.894	8	0.314
	EH12	0.220	8	0.200	0.844	8	0.089
	EH17	0.279	8	0.066	0.807	8	0.042
SO_4 (meq/l)	EH11	0.157	8	0.200	0.908	8	0.383
	EH16	0.150	8	0.200	0.962	8	0.798
	EH12	0.126	8	0.200	0.975	8	0.921
	EH17	0.260	8	0.119	0.878	8	0.232
Cl (meq/l)	EH11	0.216	8	0.200	0.916	8	0.419
	EH16	0.187	8	0.200	0.908	8	0.381
	EH12	0.226	8	0.200	0.889	8	0.288
	EH17	0.236	8	0.200	0.918	8	0.432
SAR	EH11	0.135	8	0.200	0.961	8	0.794
	EH16	0.262	8	0.113	0.838	8	0.080
	EH12	0.183	8	0.200	0.953	8	0.711
	EH17	0.158	8	0.200	0.958	8	0.755

Test Significance: The data follows normal distribution if the significance is greater than or equal 0.05.

Annex 4-4B4: Kolmogorov-Samirnov and Shapiro-Wilk tests results to check the normality of the yearly averages (with respect to the monitoring sites) of WQ measurements in site group 4

Parameters	Locations	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Adj_SAR	EH11	0.122	8	0.200	0.944	8	0.620
	EH16	0.216	8	0.200	0.837	8	0.079
	EH12	0.197	8	0.200	0.907	8	0.378
	EH17	0.197	8	0.200	0.933	8	0.509
Temp (C^o)	EH11	0.255	8	0.134	0.881	8	0.249
	EH16	0.211	8	0.200	0.959	8	0.773
	EH12	0.204	8	0.200	0.903	8	0.358
	EH17	0.223	8	0.200	0.902	8	0.351
Sal	EH11	0.199	8	0.200	0.876	8	0.221
	EH16	0.186	8	0.200	0.901	8	0.345
	EH12	0.152	8	0.200	0.977	8	0.939
	EH17	0.227	8	0.200	0.907	8	0.375
DO (mg/l)	EH11	0.140	8	0.200	0.931	8	0.493
	EH16	0.228	8	0.200	0.933	8	0.512
	EH12	0.128	8	0.200	0.983	8	0.975
	EH17	0.323	8	0.014	0.610	8	0.010
Turb (NTU)	EH11	0.263	7	0.154	0.861	7	0.204
	EH16	0.213	7	0.200	0.895	7	0.355
	EH12	0.259	7	0.169	0.885	7	0.307
	EH17	0.206	7	0.200	0.906	7	0.402
Visib (Cm)	EH11	0.182	8	0.200	0.896	8	0.323
	EH16	0.170	8	0.200	0.931	8	0.497
	EH12	0.182	8	0.200	0.953	8	0.709
	EH17	0.192	8	0.200	0.930	8	0.492
Fecal (MPN/100ml)	EH11	0.366	5	0.027	0.720	5	0.023
	EH16	0.428	5	0.003	0.643	5	0.010
	EH12	0.416	5	0.005	0.676	5	0.010
	EH17	0.287	5	0.200	0.721	5	0.024
TP (mg/l)	EH11	0.401	5	0.009	0.708	5	0.018
	EH16	0.321	5	0.101	0.776	5	0.066
	EH12	0.283	5	0.200	0.774	5	0.063
	EH17	0.295	5	0.177	0.876	5	0.332
TN (mg/l)	EH11	0.223	5	0.200	0.874	5	0.325
	EH16	0.237	5	0.200	0.905	5	0.427
	EH12	0.279	5	0.200	0.805	5	0.099
	EH17	0.275	5	0.200	0.842	5	0.219
Ni (mg/l)	EH11	0.176	5	0.200	0.925	5	0.494
	EH16	0.364	5	0.029	0.846	5	0.232
	EH12	0.196	5	0.200	0.962	5	0.767
	EH17	0.321	5	0.102	0.807	5	0.102
SO_{4_m} (meq/l)	EH11	0.306	5	0.141	0.881	5	0.347
	EH16	0.182	5	0.200	0.963	5	0.779
	EH12	0.246	5	0.200	0.960	5	0.754
	EH17	0.440	5	0.002	0.689	5	0.011

Test Significance: The data follows normal distribution if the significance is greater than or equal 0.05.

Annex 4-4C: Kolmogorov-Samirnov test's significant results to check the normality for the monthly measurements of some WQPs in Hadus drain.

Location	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
Coli (MPN/100ml)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BOD (mg/l)	0.000	0.000	0.000	0.000	**0.082**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
COD (mg/l)	0.000	0.000	0.001	0.000	**0.200**	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TSS (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TVS (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N-NO$_3$ (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N-NH$_4$ (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
P (mg/l)	**0.200**	**0.200**	**0.200**	**0.200**	**0.104**	0.001	**0.200**	0.023	**0.200**	**0.200**	**0.200**	**0.200**	**0.200**	0.001	0.004	0.002
Cd (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cu (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe (mg/l)	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn (mg/l)	**0.065**	**0.200**	0.005	**0.200**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
Zn (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pb (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000
Br (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
pH	0.006	0.004	**0.200**	0.007	0.009	**0.087**	**0.200**	0.000	0.015	**0.059**	0.009	0.039	**0.056**	**0.092**	**0.136**	0.004
EC (dS/m)	0.005	**0.200**	**0.200**	0.000	0.000	0.013	**0.064**	0.000	0.000	**0.200**	0.000	0.034	**0.060**	0.000	0.001	0.000
TDS (mg/l)	0.009	**0.157**	**0.200**	0.000	0.002	**0.086**	**0.200**	0.000	0.000	0.047	0.000	0.001	0.006	0.000	0.003	0.000
Ca (meq/l)	**0.051**	0.004	0.011	0.000	0.012	0.000	0.000	0.013	0.000	**0.081**	0.000	0.000	0.000	0.000	0.015	0.001
Mg (meq/l)	**0.200**	**0.200**	**0.200**	0.000	**0.200**	0.000	**0.200**	0.000	0.000	**0.200**	0.000	**0.174**	0.039	0.000	0.003	**0.186**
Na (meq/l)	0.000	0.001	**0.085**	0.000	**0.050**	**0.136**	**0.200**	0.000	0.001	**0.200**	0.000	0.007	**0.153**	0.000	0.001	0.000
K (meq/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SO$_4$ (meq/l)	0.003	0.027	0.036	**0.200**	0.006	0.006	0.025	0.000	0.028	0.036	0.000	**0.200**	0.000	0.001	**0.200**	0.000
Cl (meq/l)	0.006	**0.068**	**0.200**	0.000	**0.200**	0.000	**0.200**	0.000	0.000	**0.200**	0.000	**0.200**	0.001	0.000	0.009	0.004
SAR	0.035	0.000	0.038	0.011	0.029	**0.200**	**0.200**	0.000	0.000	0.000	0.000	0.004	0.001	0.000	0.004	0.000
Adj_SAR	0.031	0.005	**0.170**	0.003	0.008	**0.078**	**0.200**	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.001	0.000
Temp (Co)	0.002	0.002	0.007	0.005	0.000	0.000	0.001	0.000	0.001	0.007	0.003	0.003	0.000	0.047	0.000	0.003
Sal	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000
DO (mg/l)	0.000	0.000	0.000	0.008	0.000	0.035	0.004	0.001	**0.200**	**0.099**	0.000	0.013	0.001	0.000	0.042	0.000
Turb (NTU)	0.031	0.000	0.000	0.044	0.039	0.000	0.000	0.008	0.008	0.001	**0.200**	0.022	0.000	0.000	0.000	0.000
Visib (Cm)	0.001	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.009	0.000	0.001
Fecal (MPN/100ml)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
TP (mg/l)	**0.182**	**0.200**	0.008	0.047	**0.165**	**0.200**	0.015	**0.082**	0.000	**0.085**	0.000	0.000	**0.085**	**0.200**	0.004	0.002
TN (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ni (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SO$_{4\_m}$ (meq/l)	**0.061**	**0.082**	**0.200**	0.000	0.002	0.003	**0.067**	0.000	0.000	**0.200**	0.000	0.004	0.000	0.009	**0.200**	0.003

Test Significance: The data follows normal distribution if the significance is greater than or equal 0.05.

ANNEX 4-5

ASSESSMENT OF DEPENDENCY FOR THE TOTAL MEANS, YEARLY AVERAGES AND MONTHLY MEASUREMENTS OF WQPs IN HADUS DRAIN

ANNEX 4-5A: TOTAL MEANS

Annex 4-5A1: Correlation matrix (Kendall 's tau nonparametric test) for the WQ means in Hadus drain monitoring sites

ANNEX 4-5B: YEARLY AVERAGES

Annex 4-5B1: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (Site Group 1 - Yearly averages)

Annex 4-5B2: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (Site Group 2 - Yearly averages)

Annex 4-5B3: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (Site Group 3 - Yearly averages)

Annex 4-5B4: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (Site Group 4 - Yearly averages)

ANNEX 4-5C: MONTHLY DATA

Annex 4-5C1: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (Site Group 1 - Monthly measurements)

Annex 4-5C2: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (Site Group 2 - Monthly measurements)

Annex 4-5C3: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (Site Group 3 - Monthly measurements)

Annex 4-5C4: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (site Group 4 - Monthly measurements)

Annex 4-5A: Correlation matrix **(**Kendall 's tau nonparametric test) for the WQ means in Hadus drain monitoring sites

	Coli	BOD	COD	TSS	TVS	N-NO_3	N-NH4	P	Cd	Cu	Fe	Mn	Zn	Pb	Br	pH	EC
Coli (MPN/100ml)	1.00	0.66 **	0.68 **	-0.63 **	-0.58 **	-0.13	0.50 **	0.72 **	0.37 *	0.07	0.02	-0.08	0.30	0.18	0.43 *	-0.78 **	-0.62 **
BOD (mg/l)	0.66 **	1.00	0.95 **	-0.53 **	-0.48 *	-0.04	0.49 **	0.69 **	0.28	0.04	-0.23	-0.01	0.19	0.09	0.49 **	-0.61 **	-0.44 *
COD (mg/l)	0.68 **	0.95 **	1.00	-0.52 **	-0.47 *	-0.05	0.52 **	0.67 **	0.32	0.08	-0.20	0.00	0.22	0.10	0.45 *	-0.60 **	-0.43 *
TSS (mg/l)	-0.63 **	-0.53 **	-0.52 **	1.00	0.92 **	0.20	-0.57 **	-0.68 **	-0.27	0.10	0.28	0.15	-0.33	-0.25	-0.33	0.62 **	0.45 *
TVS (mg/l)	-0.58 **	-0.48 *	-0.47 *	0.92 **	1.00	0.15	-0.55 **	-0.60 **	-0.18	0.12	0.30	0.13	-0.35	-0.27	-0.35	0.60 **	0.37 *
N-NO_3 (mg/l)	-0.13	-0.04	-0.05	0.20	0.15	1.00	0.10	-0.15	-0.20	-0.23	0.02	0.05	0.13	-0.18	-0.07	0.02	-0.05
N-NH_4 (mg/l)	0.50 **	0.49 **	0.52 **	-0.57 **	-0.55 **	0.10	1.00	0.58 **	0.07	0.13	-0.05	-0.18	0.47 *	0.08	0.23	-0.55 **	-0.48 **
P (mg/l)	0.72 **	0.69 **	0.67 **	-0.68 **	-0.60 **	-0.15	0.58 **	1.00	0.25	0.08	-0.03	-0.17	0.32	0.17	0.38 *	-0.73 **	-0.60 **
Cd (mg/l)	0.37 *	0.28	0.32	-0.27	-0.18	-0.20	0.07	0.25	1.00	0.27	-0.05	0.25	0.13	0.25	-0.03	-0.22	-0.12
Cu (mg/l)	0.07	0.04	0.08	0.10	0.12	-0.23	0.13	0.08	0.27	1.00	0.38 *	-0.05	0.00	0.15	-0.03	0.02	0.05
Fe (mg/l)	0.02	-0.23	-0.20	0.28	0.30	0.02	-0.05	-0.03	-0.05	0.38 *	1.00	0.03	-0.05	0.03	-0.05	0.00	-0.10
Mn (mg/l)	-0.08	-0.01	0.00	0.15	0.13	0.05	-0.18	-0.17	0.25	-0.05	0.03	1.00	-0.08	-0.10	-0.08	0.07	0.20
Zn (mg/l)	0.30	0.19	0.22	-0.33	-0.35	0.13	0.47 *	0.32	0.13	0.00	-0.05	-0.08	1.00	0.18	0.03	-0.45 *	-0.22
Pb (mg/l)	0.18	0.09	0.10	-0.25	-0.27	-0.18	0.08	0.17	0.25	0.15	0.03	-0.10	0.18	1.00	0.12	-0.20	-0.07
Br (mg/l)	0.43 *	0.49 **	0.45 *	-0.33	-0.35	-0.07	0.23	0.38 *	-0.03	-0.03	-0.05	-0.08	0.03	0.12	1.00	-0.35	-0.38 *
pH	-0.78 **	-0.61 **	-0.60 **	0.62 **	0.60 **	0.02	-0.55 **	-0.73 **	-0.22	0.02	0.00	0.07	-0.45 *	-0.20	-0.35	1.00	0.60 **
EC (dS/m)	-0.62 **	-0.44 *	-0.43 *	0.45 *	0.37 *	-0.05	-0.48 **	-0.60 **	-0.12	0.05	-0.10	0.20	-0.22	-0.07	-0.38 *	0.60 **	1.00
TDS (mg/l)	-0.62 **	-0.44 *	-0.43 *	0.45 *	0.37 *	-0.05	-0.48 **	-0.60 **	-0.12	0.05	-0.10	0.20	-0.22	-0.07	-0.38 *	0.60 **	1.00 **
Ca (meq/l)	-0.65 **	-0.48 *	-0.47 *	0.45 *	0.37 *	-0.05	-0.42 *	-0.60 **	-0.12	0.12	-0.03	0.17	-0.25	-0.03	-0.38 *	0.70 **	0.90 **
Mg (meq/l)	-0.62 **	-0.44 *	-0.43 *	0.42 *	0.37 *	0.08	-0.45 *	-0.60 **	-0.05	0.05	-0.13	0.17	-0.22	-0.03	-0.38 *	0.63 **	0.87 **
Na (meq/l)	-0.67 **	-0.49 **	-0.48 **	0.53 **	0.45 *	-0.03	-0.57 **	-0.62 **	-0.20	0.03	-0.02	0.15	-0.27	-0.05	-0.37 *	0.62 **	0.92 **
K (meq/l)	-0.32	-0.11	-0.10	0.35	0.30	-0.08	-0.55 **	-0.40 *	0.05	0.05	-0.13	0.30	-0.32	-0.03	-0.08	0.43 *	0.67 **
SO_4 (meq/l)	-0.58 **	-0.44 *	-0.43 *	0.38 *	0.30	-0.08	-0.38 *	-0.53 **	-0.08	0.12	-0.07	0.10	-0.18	-0.03	-0.32	0.63 **	0.87 **
Cl (meq/l)	-0.68 **	-0.51 **	-0.50 **	0.55 **	0.47 *	-0.02	-0.58 **	-0.63 **	-0.25	0.02	0.00	0.17	-0.28	-0.10	-0.32	0.67 **	0.87 **
SAR	-0.63 **	-0.46 *	-0.48 **	0.57 **	0.48 **	-0.10	-0.63 **	-0.58 **	-0.23	0.07	0.02	0.12	-0.33	-0.08	-0.33	0.58 **	0.85 **
Adj_SAR	-0.67 **	-0.46 *	-0.48 **	0.53 **	0.45 *	-0.07	-0.60 **	-0.58 **	-0.23	0.03	-0.02	0.12	-0.30	-0.08	-0.33	0.62 **	0.88 **
Temp (C^o)	0.50 **	0.54 **	0.52 **	-0.40 *	-0.35	-0.07	0.17	0.48 **	0.17	-0.17	-0.28	0.02	0.03	0.08	0.27	-0.45 *	-0.35
Sal	-0.67 **	-0.49 **	-0.48 **	0.50 **	0.42 *	0.00	-0.53 **	-0.62 **	-0.13	0.03	-0.08	0.12	-0.20	-0.02	-0.37 *	0.62 **	0.92 **
DO (mg/l)	-0.63 **	-0.73 **	-0.72 **	0.57 **	0.48 **	0.00	-0.47 *	-0.65 **	-0.13	0.17	0.12	0.08	-0.13	-0.05	-0.57 **	0.58 **	0.62 **
Turb (NTU)	-0.33	-0.33	-0.32	0.70 **	0.68 **	0.07	-0.47 *	-0.42 *	-0.10	0.27	0.55 **	0.22	-0.37 *	-0.12	-0.13	0.38 *	0.22
Visib (Cm)	0.20	0.24	0.22	-0.57 **	-0.58 **	-0.13	0.37 *	0.32	0.10	-0.27	-0.55 **	-0.22	0.33	0.22	0.07	-0.28	-0.08
Fecal (MPN/100ml)	0.85 **	0.61 **	0.63 **	-0.55 **	-0.53 **	-0.15	0.52 **	0.67 **	0.28	0.08	0.03	-0.10	0.28	0.10	0.42 *	-0.70 **	-0.57 **
TP (mg/l)	0.65 **	0.78 **	0.73 **	-0.55 **	-0.47 *	-0.02	0.38 *	0.73 **	0.22	-0.15	-0.17	-0.07	0.15	0.10	0.48 **	-0.63 **	-0.53 **
TN (mg/l)	-0.13	-0.01	0.02	0.23	0.18	0.70 **	0.07	-0.15	-0.17	-0.07	0.08	0.05	0.07	-0.12	-0.03	-0.02	0.05
Ni (mg/l)	0.17	0.09	0.12	-0.23	-0.25	-0.17	0.13	0.15	-0.17	-0.07	0.08	-0.12	-0.10	0.12	0.33	-0.18	-0.28
SO_{4_m} (meq/l)	-0.58 **	-0.41 *	-0.40 *	0.38 *	0.30	-0.05	-0.42 *	-0.57 **	-0.02	0.12	-0.07	0.20	-0.15	0.00	-0.38 *	0.60 **	0.90 **

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

Annex 4-5A Cont.: Correlation matrix (Kendall 's tau nonparametric test) for the WQ means in Hadus drain monitoring sites

	TDS	Ca	Mg	Na	K	SO$_4$	Cl	SAR	Adj_SAR	Temp	Sal	DO	Turb	Visib	Fecal	TP	TN	Ni	SO$_{4\_m}$
Coli (MPN/100ml)	-0.62 **	-0.65 **	-0.62 **	-0.67 **	-0.32	-0.58 **	-0.68 **	-0.63 **	-0.67 **	0.50 **	-0.67 **	-0.63 **	-0.33	0.20	0.85 **	0.65 **	-0.13	0.17	-0.58 **
BOD (mg/l)	-0.44 *	-0.48 *	-0.44 *	-0.49 **	-0.11	-0.44 *	-0.51 **	-0.46 *	-0.46 *	0.54 **	-0.49 **	-0.73 **	-0.33	0.24	0.61 **	0.78 **	-0.01	0.09	-0.41 *
COD (mg/l)	-0.43 *	-0.47 *	-0.43 *	-0.48 **	-0.10	-0.43 *	-0.50 **	-0.48 **	-0.48 **	0.52 **	-0.48 **	-0.72 **	-0.32	0.22	0.63 **	0.73 **	0.02	0.12	-0.40 *
TSS (mg/l)	0.45 *	0.45 *	0.42 *	0.53 **	0.35	0.38 *	0.55 **	0.57 **	0.53 **	-0.40 *	0.50 **	0.57 **	0.70 **	-0.57 **	-0.55 **	-0.55 **	0.23	-0.23	0.38 *
TVS (mg/l)	0.37 *	0.37 *	0.37 *	0.45 *	0.30	0.30	0.47 *	0.48 **	0.45 *	-0.35	0.42 *	0.48 **	0.68 **	-0.58 **	-0.53 **	-0.47 *	0.18	-0.25	0.30
N-NO$_3$ (mg/l)	-0.05	-0.05	0.08	-0.03	-0.08	-0.08	-0.02	-0.10	-0.07	-0.07	0.00	0.00	0.07	-0.13	-0.15	-0.02	0.70 **	-0.17	-0.05
N-NH$_4$ (mg/l)	-0.48 **	-0.42 *	-0.45 *	-0.57 **	-0.55 **	-0.38 *	-0.58 **	-0.63 **	-0.60 **	0.17	-0.53 **	-0.47 *	-0.47 *	0.37 *	0.52 **	0.38 *	0.07	0.13	-0.42 *
P (mg/l)	-0.60 **	-0.60 **	-0.60 **	-0.62 **	-0.40 *	-0.53 **	-0.63 **	-0.58 **	-0.58 **	0.48 **	-0.62 **	-0.65 **	-0.42 *	0.32	0.67 **	0.73 **	-0.15	0.15	-0.57 **
Cd (mg/l)	-0.12	-0.12	-0.05	-0.20	0.05	-0.08	-0.25	-0.23	-0.23	0.17	-0.13	-0.13	-0.10	0.10	0.28	0.22	-0.17	-0.17	-0.02
Cu (mg/l)	0.05	0.12	0.05	0.03	0.05	0.12	0.02	0.07	0.03	-0.17	0.03	0.17	0.27	-0.27	0.08	-0.15	-0.07	-0.07	0.12
Fe (mg/l)	-0.10	-0.03	-0.13	-0.02	-0.13	-0.07	0.00	0.02	-0.02	-0.28	-0.08	0.12	0.55 **	-0.55 **	0.03	-0.17	0.08	0.08	-0.07
Mn (mg/l)	0.20	0.17	0.17	0.15	0.30	0.10	0.17	0.12	0.12	0.02	0.12	0.08	0.22	-0.22	-0.10	-0.07	0.05	-0.12	0.20
Zn (mg/l)	-0.22	-0.25	-0.22	-0.27	-0.32	-0.18	-0.28	-0.33	-0.30	0.03	-0.20	-0.13	-0.37 *	0.33	0.28	0.15	0.07	-0.10	-0.15
Pb (mg/l)	-0.07	-0.03	-0.03	-0.05	-0.03	-0.03	-0.10	-0.08	-0.08	0.08	-0.02	-0.05	-0.12	0.22	0.10	0.10	-0.12	0.12	0.00
Br (mg/l)	-0.38 *	-0.38 *	-0.38 *	-0.37 *	-0.08	-0.32	-0.32	-0.33	-0.33	0.27	-0.37 *	-0.57 **	-0.13	0.07	0.42 *	0.48 **	-0.03	0.33	-0.38 *
pH	0.60 **	0.70 **	0.63 **	0.62 **	0.43 *	0.63 **	0.67 **	0.58 **	0.62 **	-0.45 *	0.62 **	0.58 **	0.38 *	-0.28	-0.70 **	-0.63 **	-0.02	-0.18	0.60 **
EC (dS/m)	1.00 **	0.90 **	0.87 **	0.92 **	0.67 **	0.87 **	0.87 **	0.85 **	0.88 **	-0.35	0.92 **	0.62 **	0.22	-0.08	-0.57 **	-0.53 **	0.05	-0.28	0.90 **
TDS (mg/l)	1.00	0.90 **	0.87 **	0.92 **	0.67 **	0.87 **	0.87 **	0.85 **	0.88 **	-0.35	0.92 **	0.62 **	0.22	-0.08	-0.57 **	-0.53 **	0.05	-0.28	0.90 **
Ca (meq/l)	0.90 **	1.00	0.87 **	0.82 **	0.60 **	0.90 **	0.77 **	0.75 **	0.78 **	-0.45 *	0.82 **	0.65 **	0.28	-0.15	-0.60 **	-0.57 **	-0.02	-0.25	0.90 **
Mg (meq/l)	0.87 **	0.87 **	1.00	0.78 **	0.67 **	0.83 **	0.73 **	0.72 **	0.75 **	-0.35	0.85 **	0.62 **	0.15	-0.05	-0.60 **	-0.53 **	0.08	-0.32	0.87 **
Na (meq/l)	0.92 **	0.82 **	0.78 **	1.00	0.62 **	0.78 **	0.95 **	0.93 **	0.97 **	-0.30	0.93 **	0.60 **	0.30	-0.17	-0.62 **	-0.52 **	0.10	-0.30	0.82 **
K (meq/l)	0.67 **	0.60 **	0.67 **	0.62 **	1.00	0.60 **	0.60 **	0.62 **	0.62 **	-0.05	0.62 **	0.28	0.25	-0.15	-0.37 *	-0.20	0.02	-0.25	0.67 **
SO$_4$ (meq/l)	0.87 **	0.90 **	0.83 **	0.78 **	0.60 **	1.00	0.73 **	0.72 **	0.75 **	-0.42 *	0.82 **	0.62 **	0.18	-0.05	-0.53 **	-0.57 **	-0.08	-0.28	0.87 **
Cl (meq/l)	0.87 **	0.77 **	0.73 **	0.95 **	0.60 **	0.73 **	1.00	0.92 **	0.95 **	-0.32	0.88 **	0.55 **	0.32	-0.18	-0.63 **	-0.53 **	0.12	-0.25	0.77 **
SAR	0.85 **	0.75 **	0.72 **	0.93 **	0.62 **	0.72 **	0.92 **	1.00	0.97 **	-0.27	0.87 **	0.57 **	0.33	-0.20	-0.58 **	-0.48 **	0.03	-0.23	0.75 **
Adj_SAR	0.88 **	0.78 **	0.75 **	0.97 **	0.62 **	0.75 **	0.95 **	0.97 **	1.00	-0.27	0.90 **	0.57 **	0.30	-0.17	-0.62 **	-0.48 **	0.07	-0.27	0.78 **
Temp (C^o)	-0.35	-0.45 *	-0.35	-0.30	-0.05	-0.42 *	-0.32	-0.27	-0.27	1.00	-0.30	-0.57 **	-0.37 *	0.33	0.35	0.58 **	-0.10	0.00	-0.35
Sal	0.92 **	0.82 **	0.85 **	0.93 **	0.62 **	0.82 **	0.88 **	0.87 **	0.90 **	-0.30	1.00	0.60 **	0.23	-0.10	-0.62 **	-0.52 **	0.07	-0.30	0.85 **
DO (mg/l)	0.62 **	0.65 **	0.62 **	0.60 **	0.28	0.62 **	0.55 **	0.57 **	0.57 **	-0.57 **	0.60 **	1.00	0.37 *	-0.23	-0.52 **	-0.82 **	-0.07	-0.27	0.58 **
Turb (NTU)	0.22	0.28	0.15	0.30	0.25	0.18	0.32	0.33	0.30	-0.37 *	0.23	0.37 *	1.00	-0.87 **	-0.25	-0.35	0.13	-0.07	0.18
Visib (Cm)	-0.08	-0.15	-0.05	-0.17	-0.15	-0.05	-0.18	-0.20	-0.17	0.33	-0.10	-0.23	-0.87 **	1.00	0.12	0.22	-0.20	0.07	-0.05
Fecal (MPN/100ml)	-0.57 **	-0.60 **	-0.60 **	-0.62 **	-0.37 *	-0.53 **	-0.63 **	-0.58 **	-0.62 **	0.35	-0.62 **	-0.52 **	-0.25	0.12	1.00	0.53 **	-0.15	0.22	-0.57 **
TP (mg/l)	-0.53 **	-0.57 **	-0.53 **	-0.52 **	-0.20	-0.57 **	-0.53 **	-0.48 **	-0.48 **	0.58 **	-0.52 **	-0.82 **	-0.35	0.22	0.53 **	1.00	0.02	0.18	-0.53 **
TN (mg/l)	0.05	-0.02	0.08	0.10	0.02	-0.08	0.12	0.03	0.07	-0.10	0.07	-0.07	0.13	-0.20	-0.15	0.02	1.00	0.00	0.02
Ni (mg/l)	-0.28	-0.25	-0.32	-0.30	-0.25	-0.28	-0.25	-0.23	-0.27	0.00	-0.30	-0.27	-0.07	0.07	0.22	0.18	0.00	1.00	-0.28
SO$_{4\_m}$ (meq/l)	0.90 **	0.90 **	0.87 **	0.82 **	0.67 **	0.87 **	0.77 **	0.75 **	0.78 **	-0.35	0.85 **	0.58 **	0.18	-0.05	-0.57 **	-0.53 **	0.02	-0.28	1.00

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

Annex 4-5B1: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (**Site Group 1 - Yearly averages**)

Locations	EH14	EH02	EH18	EH03	EH14	EH02	EH18	EH03
Coli (MPN/100ml)					**Cu (mg/l)**			
EH14	1.00	0.57 *	0.57 *	0.29	1.00	0.57 *	0.86 **	0.71 *
EH02	0.57 *	1.00	0.57 *	0.57 *	0.57 *	1.00	0.71 *	0.43
EH18	0.57 *	0.57 *	1.00	0.57 *	0.86 **	0.71 *	1.00	0.71 *
EH03	0.29	0.57 *	0.57 *	1.00	0.71 *	0.43	0.71 *	1.00
BOD (mg/l)					**Fe (mg/l)**			
EH14	1.00	0.69 *	0.84 **	0.91 **	1.00	0.21	0.36	0.50
EH02	0.69 *	1.00	0.71 *	0.64 *	0.21	1.00	0.71 *	0.57 *
EH18	0.84 **	0.71 *	1.00	0.93 **	0.36	0.71 *	1.00	0.57 *
EH03	0.91 **	0.64 *	0.93 **	1.00	0.50	0.57 *	0.57 *	1.00
COD (mg/l)					**Mn (mg/l)**			
EH14	1.00	0.93 **	0.84 **	0.93 **	1.00	0.60	0.00	0.40
EH02	0.93 **	1.00	0.91 **	0.86 **	0.60	1.00	-0.40	0.40
EH18	0.84 **	0.91 **	1.00	0.76 **	0.00	-0.40	1.00	0.20
EH03	0.93 **	0.86 **	0.76 **	1.00	0.40	0.40	0.20	1.00
TSS (mg/l)					**Zn (mg/l)**			
EH14	1.00	0.50	0.71 *	0.64 *	1.00	0.29	0.64 *	0.43
EH02	0.50	1.00	0.64 *	0.71 *	0.29	1.00	0.64 *	0.57 *
EH18	0.71 *	0.64 *	1.00	0.64 *	0.64 *	0.64 *	1.00	0.64 *
EH03	0.64 *	0.71 *	0.64 *	1.00	0.43	0.57 *	0.64 *	1.00
TVS (mg/l)					**Pb (mg/l)**			
EH14	1.00	0.79 **	0.93 **	0.50	1.00	0.71 *	0.86 **	0.86 **
EH02	0.79 **	1.00	0.71 *	0.71 *	0.71 *	1.00	0.86 **	0.86 **
EH18	0.93 **	0.71 *	1.00	0.43	0.86 **	0.86 **	1.00	1.00 **
EH03	0.50	0.71 *	0.43	1.00	0.86 **	0.86 **	1.00 **	1.00
N-NO$_3$ (mg/l)					**Br (mg/l)**			
EH14	1.00	0.71 *	0.71 *	0.86 **	1.00	0.80	1.00	0.60
EH02	0.71 *	1.00	1.00 **	0.86 **	0.80	1.00	0.80	0.80
EH18	0.71 *	1.00 **	1.00	0.86 **	1.00	0.80	1.00	0.60
EH03	0.86 **	0.86 **	0.86 **	1.00	0.60	0.80	0.60	1.00
N-NH$_4$ (mg/l)					**pH**			
EH14	1.00	0.64 *	0.64 *	0.29	1.00	0.50	0.64 *	0.79 **
EH02	0.64 *	1.00	0.86 **	0.64 *	0.50	1.00	0.71 *	0.29
EH18	0.64 *	0.86 **	1.00	0.64 *	0.64 *	0.71 *	1.00	0.57 *
EH03	0.29	0.64 *	0.64 *	1.00	0.79 **	0.29	0.57 *	1.00
P (mg/l)					**EC (dS/m)**			
EH14	1.00	0.33	0.33	0.33	1.00	0.57 *	0.64 *	0.64 *
EH02	0.33	1.00	1.00	-0.33	0.57 *	1.00	0.64 *	0.21
EH18	0.33	1.00	1.00	-0.33	0.64 *	0.64 *	1.00	0.29
EH03	0.33	-0.33	-0.33	1.00	0.64 *	0.21	0.29	1.00
Cd (mg/l)					**TDS (mg/l)**			
EH14	1.00	0.57 *	0.64 *	0.50	1.00	0.50	0.57 *	0.00
EH02	0.57 *	1.00	0.93 **	0.93 **	0.50	1.00	0.64 *	-0.07
EH18	0.64 *	0.93 **	1.00	0.86 **	0.57 *	0.64 *	1.00	0.00
EH03	0.50	0.93 **	0.86 **	1.00	0.00	-0.07	0.00	1.00

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

Annex 4-5B1: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (**Site Group 1 - Yearly averages**)

Locations	EH14	EH02	EH18	EH03	EH14	EH02	EH18	EH03
Ca (meq/l)					**Sal**			
EH14	1.00	0.79 **	0.86 **	0.36	1.00	0.69 *	0.76 **	0.11
EH02	0.79 **	1.00	0.93 **	0.57 *	0.69 *	1.00	0.50	-0.07
EH18	0.86 **	0.93 **	1.00	0.50	0.76 **	0.50	1.00	0.29
EH03	0.36	0.57 *	0.50	1.00	0.11	-0.07	0.29	1.00
Mg (meq/l)					**DO (mg/l)**			
EH14	1.00	0.57 *	0.79 **	0.64 *	1.00	0.43	0.14	0.21
EH02	0.57 *	1.00	0.64 *	0.50	0.43	1.00	0.43	0.36
EH18	0.79 **	0.64 *	1.00	0.57 *	0.14	0.43	1.00	0.93 **
EH03	0.64 *	0.50	0.57 *	1.00	0.21	0.36	0.93 **	1.00
Na (meq/l)					**Turb (NTU)**			
EH14	1.00	0.00	0.50	0.29	1.00	0.71 *	0.52	0.52
EH02	0.00	1.00	0.50	0.43	0.71 *	1.00	0.81 *	0.62
EH18	0.50	0.50	1.00	0.36	0.52	0.81 *	1.00	0.81 *
EH03	0.29	0.43	0.36	1.00	0.52	0.62	0.81 *	1.00
K (meq/l)					**Visib (Cm)**			
EH14	1.00	0.71 *	0.86 **	0.57 *	1.00	0.50	0.57 *	0.18
EH02	0.71 *	1.00	0.86 **	0.86 **	0.50	1.00	0.79 **	0.55
EH18	0.86 **	0.86 **	1.00	0.71 *	0.57 *	0.79 **	1.00	0.62 *
EH03	0.57 *	0.86 **	0.71 *	1.00	0.18	0.55	0.62 *	1.00
SO_4 (meq/l)					**Fecal (MPN/100ml)**			
EH14	1.00	0.86 **	0.86 **	0.43	1.00	0.60	0.60	0.40
EH02	0.86 **	1.00	0.71 *	0.57 *	0.60	1.00	0.60	0.80
EH18	0.86 **	0.71 *	1.00	0.57 *	0.60	0.60	1.00	0.40
EH03	0.43	0.57 *	0.57 *	1.00	0.40	0.80	0.40	1.00
Cl (meq/l)					**TP (mg/l)**			
EH14	1.00	0.86 **	0.86 **	0.14	1.00	-0.20	-0.20	-0.40
EH02	0.86 **	1.00	0.71 *	0.14	-0.20	1.00	1.00	0.80
EH18	0.86 **	0.71 *	1.00	0.29	-0.20	1.00	1.00	0.80
EH03	0.14	0.14	0.29	1.00	-0.40	0.80	0.80	1.00
SAR					**TN (mg/l)**			
EH14	1.00	-0.21	0.00	-0.29	1.00	1.00	0.80	0.80
EH02	-0.21	1.00	0.50	0.64 *	1.00	1.00	0.80	0.80
EH18	0.00	0.50	1.00	0.43	0.80	0.80	1.00	1.00
EH03	-0.29	0.64 *	0.43	1.00	0.80	0.80	1.00	1.00
Adj_SAR					**Ni (mg/l)**			
EH14	1.00	0.43	0.64 *	0.36	1.00	0.80	0.40	0.40
EH02	0.43	1.00	0.79 **	0.79 **	0.80	1.00	0.60	0.60
EH18	0.64 *	0.79 **	1.00	0.57 *	0.40	0.60	1.00	0.60
EH03	0.36	0.79 **	0.57 *	1.00	0.40	0.60	0.60	1.00
Temp (C^o)					**SO_{4_m} (meq/l)**			
EH14	1.00	0.50	0.93 **	0.79 **	1.00	0.40	-0.20	0.60
EH02	0.50	1.00	0.43	0.57 *	0.40	1.00	0.40	0.80
EH18	0.93 **	0.43	1.00	0.71 *	-0.20	0.40	1.00	0.20
EH03	0.79 **	0.57 *	0.71 *	1.00	0.60	0.80	0.20	1.00

** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).

Annex 4-5B2: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (**Site Group 2 - Yearly averages**)

Locations	EH04	EH05	EH15	EH06	EH04	EH05	EH15	EH06
Coli (MPN/100ml)					**Cu (mg/l)**			
EH04	1.00	0.29	0.29	0.07	1.00	0.50	0.57 *	0.71 *
EH05	0.29	1.00	0.86 **	0.07	0.50	1.00	0.50	0.79 **
EH15	0.29	0.86 **	1.00	0.07	0.57 *	0.50	1.00	0.71 *
EH06	0.07	0.07	0.07	1.00	0.71 *	0.79 **	0.71 *	1.00
BOD (mg/l)					**Fe (mg/l)**			
EH04	1.00	0.50	0.71 *	0.86 **	1.00	0.79 **	0.79 **	0.93 **
EH05	0.50	1.00	0.64 *	0.36	0.79 **	1.00	0.71 *	0.71 *
EH15	0.71 *	0.64 *	1.00	0.71 *	0.79 **	0.71 *	1.00	0.86 **
EH06	0.86 **	0.36	0.71 *	1.00	0.93 **	0.71 *	0.86 **	1.00
COD (mg/l)					**Mn (mg/l)**			
EH04	1.00	0.71 *	0.79 **	0.93 **	1.00	1.00 **	0.60	0.40
EH05	0.71 *	1.00	0.79 **	0.64 *	1.00 **	1.00	0.60	0.40
EH15	0.79 **	0.79 **	1.00	0.71 *	0.60	0.60	1.00	0.80
EH06	0.93 **	0.64 *	0.71 *	1.00	0.40	0.40	0.80	1.00
TSS (mg/l)					**Zn (mg/l)**			
EH04	1.00	0.50	0.71 *	0.29	1.00	0.43	0.07	0.14
EH05	0.50	1.00	0.50	0.21	0.43	1.00	0.50	0.57 *
EH15	0.71 *	0.50	1.00	0.43	0.07	0.50	1.00	0.79 **
EH06	0.29	0.21	0.43	1.00	0.14	0.57 *	0.79 **	1.00
TVS (mg/l)					**Pb (mg/l)**			
EH04	1.00	0.71 *	0.86 **	0.43	1.00	0.93 **	0.86 **	0.86 **
EH05	0.71 *	1.00	0.57 *	0.29	0.93 **	1.00	0.93 **	0.93 **
EH15	0.86 **	0.57 *	1.00	0.43	0.86 **	0.93 **	1.00	1.00 **
EH06	0.43	0.29	0.43	1.00	0.86 **	0.93 **	1.00 **	1.00
N-NO$_3$ (mg/l)					**Br (mg/l)**			
EH04	1.00	0.86 **	0.71 *	0.79 **	1.00	-0.20	0.60	0.00
EH05	0.86 **	1.00	0.71 *	0.79 **	-0.20	1.00	0.20	0.80
EH15	0.71 *	0.71 *	1.00	0.64 *	0.60	0.20	1.00	0.40
EH06	0.79 **	0.79 **	0.64 *	1.00	0.00	0.80	0.40	1.00
N-NH$_4$ (mg/l)					**pH**			
EH04	1.00	0.29	0.21	0.07	1.00	0.29	0.50	0.57 *
EH05	0.29	1.00	0.64 *	0.64 *	0.29	1.00	0.36	0.29
EH15	0.21	0.64 *	1.00	0.43	0.50	0.36	1.00	0.93 **
EH06	0.07	0.64 *	0.43	1.00	0.57 *	0.29	0.93 **	1.00
P (mg/l)					**EC (dS/m)**			
EH04	Not Enough Data				1.00	0.14	0.71 *	-0.07
EH05					0.14	1.00	0.29	0.50
EH15					0.71 *	0.29	1.00	-0.07
EH06					-0.07	0.50	-0.07	1.00
Cd (mg/l)					**TDS (mg/l)**			
EH04	1.00	0.93 **	0.71 *	0.57 *	1.00	0.21	0.64 *	0.21
EH05	0.93 **	1.00	0.79 **	0.50	0.21	1.00	0.29	0.57 *
EH15	0.71 *	0.79 **	1.00	0.71 *	0.64 *	0.29	1.00	0.57 *
EH06	0.57 *	0.50	0.71 *	1.00	0.21	0.57 *	0.57 *	1.00

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

Annex 4-5B2: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (**Site Group 2 - Yearly averages**)

Locations	EH04	EH05	EH15	EH06	EH04	EH05	EH15	EH06
	Ca (meq/l)				**Sal**			
EH04	1.00	0.86 **	0.71 *	0.57 *	1.00	0.00	0.44	0.04
EH05	0.86 **	1.00	0.71 *	0.71 *	0.00	1.00	0.52	0.33
EH15	0.71 *	0.71 *	1.00	0.57 *	0.44	0.52	1.00	0.40
EH06	0.57 *	0.71 *	0.57 *	1.00	0.04	0.33	0.40	1.00
	Mg (meq/l)				**DO (mg/l)**			
EH04	1.00	0.99 **	0.71 *	0.71 *	1.00	-0.36	0.21	-0.14
EH05	0.99 **	1.00	0.71 *	0.71 *	-0.36	1.00	0.14	-0.07
EH15	0.71 *	0.71 *	1.00	0.71 *	0.21	0.14	1.00	0.50
EH06	0.71 *	0.71 *	0.71 *	1.00	-0.14	-0.07	0.50	1.00
	Na (meq/l)				**Turb (NTU)**			
EH04	1.00	0.14	0.57 *	0.57 *	1.00	-0.33	-0.14	-0.43
EH05	0.14	1.00	0.14	0.14	-0.33	1.00	0.43	0.52
EH15	0.57 *	0.14	1.00	0.57 *	-0.14	0.43	1.00	0.33
EH06	0.57 *	0.14	0.57 *	1.00	-0.43	0.52	0.33	1.00
	K (meq/l)				**Visib (Cm)**			
EH04	1.00	0.79 **	0.86 **	0.79 **	1.00	-0.14	-0.11	0.00
EH05	0.79 **	1.00	0.93 **	0.71 *	-0.14	1.00	0.69 *	0.57 *
EH15	0.86 **	0.93 **	1.00	0.79 **	-0.11	0.69 *	1.00	0.84 **
EH06	0.79 **	0.71 *	0.79 **	1.00	0.00	0.57 *	0.84 **	1.00
	SO_4 (meq/l)				**Fecal (MPN/100ml)**			
EH04	1.00	0.86 **	0.79 **	0.79 **	1.00	0.40	0.40	-0.80
EH05	0.86 **	1.00	0.64 *	0.79 **	0.40	1.00	1.00	-0.60
EH15	0.79 **	0.64 *	1.00	0.86 **	0.40	1.00	1.00	-0.60
EH06	0.79 **	0.79 **	0.86 **	1.00	-0.80	-0.60	-0.60	1.00
	Cl (meq/l)				**TP (mg/l)**			
EH04	1.00	0.71 *	0.71 *	-0.29	1.00	-0.20	-0.40	0.00
EH05	0.71 *	1.00	0.43	-0.43	-0.20	1.00	0.80	0.40
EH15	0.71 *	0.43	1.00	0.00	-0.40	0.80	1.00	0.60
EH06	-0.29	-0.43	0.00	1.00	0.00	0.40	0.60	1.00
	SAR				**TN (mg/l)**			
EH04	1.00	0.57 *	0.50	0.36	1.00	0.60	0.40	0.20
EH05	0.57 *	1.00	0.36	-0.07	0.60	1.00	0.80	0.60
EH15	0.50	0.36	1.00	0.57 *	0.40	0.80	1.00	0.80
EH06	0.36	-0.07	0.57 *	1.00	0.20	0.60	0.80	1.00
	Adj_SAR				**Ni (mg/l)**			
EH04	1.00	0.36	0.50	0.50	1.00	0.60	0.60	0.60
EH05	0.36	1.00	0.43	0.29	0.60	1.00	1.00	0.60
EH15	0.50	0.43	1.00	0.71 *	0.60	1.00	1.00	0.60
EH06	0.50	0.29	0.71 *	1.00	0.60	0.60	0.60	1.00
	Temp (C^o)				**SO_{4_m} (meq/l)**			
EH04	1.00	0.79 **	0.71 *	0.86 **	1.00	1.00 **	0.80	0.80
EH05	0.79 **	1.00	0.64 *	0.64 *	1.00 **	1.00	0.80	0.80
EH15	0.71 *	0.64 *	1.00	0.71 *	0.80	0.80	1.00	1.00 **
EH06	0.86 **	0.64 *	0.71 *	1.00	0.80	0.80	1.00 **	1.00

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

Annex 4-5B3: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (**Site Group 3 - Yearly averages**)

Locations	EH07	EH08	EH09	EH10	EH07	EH08	EH09	EH10
Coli (MPN/100ml)					**Cu (mg/l)**			
EH07	1.00	-0.29	0.36	0.43	1.00	0.71 *	0.71 *	0.64 *
EH08	-0.29	1.00	-0.07	0.14	0.71 *	1.00	0.71 *	0.36
EH09	0.36	-0.07	1.00	0.79 **	0.71 *	0.71 *	1.00	0.36
EH10	0.43	0.14	0.79 **	1.00	0.64 *	0.36	0.36	1.00
BOD (mg/l)					**Fe (mg/l)**			
EH07	1.00	0.79 **	0.86 **	0.93 **	1.00	0.71 *	0.50	0.86 **
EH08	0.79 **	1.00	0.79 **	0.86 **	0.71 *	1.00	0.50	0.86 **
EH09	0.86 **	0.79 **	1.00	0.93 **	0.50	0.50	1.00	0.50
EH10	0.93 **	0.86 **	0.93 **	1.00	0.86 **	0.86 **	0.50	1.00
COD (mg/l)					**Mn (mg/l)**			
EH07	1.00	0.79 **	0.93 **	0.93 **	1.00	0.80	1.00 **	0.60
EH08	0.79 **	1.00	0.86 **	0.86 **	0.80	1.00	0.80	0.40
EH09	0.93 **	0.86 **	1.00	1.00 **	1.00 **	0.80	1.00	0.60
EH10	0.93 **	0.86 **	1.00 **	1.00	0.60	0.40	0.60	1.00
TSS (mg/l)					**Zn (mg/l)**			
EH07	1.00	0.64 *	0.71 *	0.71 *	1.00	0.57 *	0.76 **	0.76 **
EH08	0.64 *	1.00	0.36	0.50	0.57 *	1.00	0.62 *	0.33
EH09	0.71 *	0.36	1.00	0.71 *	0.76 **	0.62 *	1.00	0.67 *
EH10	0.71 *	0.50	0.71 *	1.00	0.76 **	0.33	0.67 *	1.00
TVS (mg/l)					**Pb (mg/l)**			
EH07	1.00	0.64 *	0.86 **	0.93 **	1.00	0.79 **	0.86 **	0.79 **
EH08	0.64 *	1.00	0.50	0.71 *	0.79 **	1.00	0.79 **	0.71 *
EH09	0.86 **	0.50	1.00	0.79 **	0.86 **	0.79 **	1.00	0.79 **
EH10	0.93 **	0.71 *	0.79 **	1.00	0.79 **	0.71 *	0.79 **	1.00
N-NO$_3$ (mg/l)					**Br (mg/l)**			
EH07	1.00	1.00 **	0.79 **	0.71 *	1.00	0.80	1.00	0.80
EH08	1.00 **	1.00	0.79 **	0.71 *	0.80	1.00	0.80	1.00
EH09	0.79 **	0.79 **	1.00	0.79 **	1.00	0.80	1.00	0.80
EH10	0.71 *	0.71 *	0.79 **	1.00	0.80	1.00	0.80	1.00
N-NH$_4$ (mg/l)					**pH**			
EH07	1.00	0.79 **	0.86 **	1.00 **	1.00	0.71 *	0.50	0.71 *
EH08	0.79 **	1.00	0.64 *	0.79 **	0.71 *	1.00	0.50	0.71 *
EH09	0.86 **	0.64 *	1.00	0.86 **	0.50	0.50	1.00	0.64 *
EH10	1.00 **	0.79 **	0.86 **	1.00	0.71 *	0.71 *	0.64 *	1.00
P (mg/l)					**EC (dS/m)**			
EH07	Not Enough Data				1.00	0.36	0.43	0.29
EH08					0.36	1.00	0.07	0.21
EH09					0.43	0.07	1.00	0.57 *
EH10					0.29	0.21	0.57 *	1.00
Cd (mg/l)					**TDS (mg/l)**			
EH07	1.00	0.93 **	0.86 **	0.79 **	1.00	0.29	0.57 *	0.43
EH08	0.93 **	1.00	0.93 **	0.86 **	0.29	1.00	0.43	0.43
EH09	0.86 **	0.93 **	1.00	0.93 **	0.57 *	0.43	1.00	0.57 *
EH10	0.79 **	0.86 **	0.93 **	1.00	0.43	0.43	0.57 *	1.00

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

Annex 4-5B3: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (**Site Group 3 - Yearly averages**)

Locations	EH07	EH08	EH09	EH10
Ca (meq/l)				
EH07	1.00	0.71 *	0.64 *	0.43
EH08	0.71 *	1.00	0.36	0.71 *
EH09	0.64 *	0.36	1.00	0.21
EH10	0.43	0.71 *	0.21	1.00
Mg (meq/l)				
EH07	1.00	0.57 *	0.64 *	0.79 **
EH08	0.57 *	1.00	0.64 *	0.64 *
EH09	0.64 *	0.64 *	1.00	0.71 *
EH10	0.79 **	0.64 *	0.71 *	1.00
Na (meq/l)				
EH07	1.00	0.50	0.29	0.43
EH08	0.50	1.00	0.07	0.64 *
EH09	0.29	0.07	1.00	-0.14
EH10	0.43	0.64 *	-0.14	1.00
K (meq/l)				
EH07	1.00	0.86 **	0.93 **	0.93 **
EH08	0.86 **	1.00	0.79 **	0.93 **
EH09	0.93 **	0.79 **	1.00	0.86 **
EH10	0.93 **	0.93 **	0.86 **	1.00
SO$_4$ (meq/l)				
EH07	1.00	0.50	0.57 *	0.64 *
EH08	0.50	1.00	0.36	0.43
EH09	0.57 *	0.36	1.00	0.50
EH10	0.64 *	0.43	0.50	1.00
Cl (meq/l)				
EH07	1.00	0.36	0.43	0.29
EH08	0.36	1.00	0.07	0.50
EH09	0.43	0.07	1.00	-0.29
EH10	0.29	0.50	-0.29	1.00
SAR				
EH07	1.00	0.86 **	0.00	0.79 **
EH08	0.86 **	1.00	0.14	0.79 **
EH09	0.00	0.14	1.00	0.07
EH10	0.79 **	0.79 **	0.07	1.00
Adj_SAR				
EH07	1.00	0.71 *	-0.07	0.71 *
EH08	0.71 *	1.00	0.07	0.86 **
EH09	-0.07	0.07	1.00	0.07
EH10	0.71 *	0.86 **	0.07	1.00
Temp (C^o)				
EH07	1.00	0.71 *	0.36	0.64 *
EH08	0.71 *	1.00	0.07	0.79 **
EH09	0.36	0.07	1.00	0.14
EH10	0.64 *	0.79 **	0.14	1.00

Locations	EH07	EH08	EH09	EH10
Sal				
EH07	1.00	0.21	0.64 *	0.11
EH08	0.21	1.00	0.14	0.25
EH09	0.64 *	0.14	1.00	0.25
EH10	0.11	0.25	0.25	1.00
DO (mg/l)				
EH07	1.00	0.86 **	-0.64 *	0.36
EH08	0.86 **	1.00	-0.64 *	0.50
EH09	-0.64 *	-0.64 *	1.00	-0.14
EH10	0.36	0.50	-0.14	1.00
Turb (NTU)				
EH07	1.00	0.81 *	0.33	0.81 *
EH08	0.81 *	1.00	0.33	0.81 *
EH09	0.33	0.33	1.00	0.33
EH10	0.81 *	0.81 *	0.33	1.00
Visib (Cm)				
EH07	1.00	0.79 **	0.04	0.76 **
EH08	0.79 **	1.00	0.11	0.76 **
EH09	0.04	0.11	1.00	0.00
EH10	0.76 **	0.76 **	0.00	1.00
Fecal (MPN/100ml)				
EH07	1.00	-0.60	0.20	-0.20
EH08	-0.60	1.00	-0.60	-0.20
EH09	0.20	-0.60	1.00	0.60
EH10	-0.20	-0.20	0.60	1.00
TP (mg/l)				
EH07	1.00	0.20	0.00	1.00
EH08	0.20	1.00	-0.40	0.20
EH09	0.00	-0.40	1.00	0.00
EH10	1.00	0.20	0.00	1.00
TN (mg/l)				
EH07	1.00	1.00 **	1.00 **	1.00 **
EH08	1.00 **	1.00	1.00 **	1.00 **
EH09	1.00 **	1.00 **	1.00	1.00 **
EH10	1.00 **	1.00 **	1.00 **	1.00
Ni (mg/l)				
EH07	1.00	-0.20	0.00	-0.20
EH08	-0.20	1.00	0.40	0.60
EH09	0.00	0.40	1.00	0.80
EH10	-0.20	0.60	0.80	1.00
SO$_{4\_m}$ (meq/l)				
EH07	1.00	0.60	0.60	0.40
EH08	0.60	1.00	0.60	0.40
EH09	0.60	0.60	1.00	0.80
EH10	0.40	0.40	0.80	1.00

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

Annex 4-5B4: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (**Site Group 4 - Yearly averages**)

Locations	EH11	EH16	EH12	EH17	EH11	EH16	EH12	EH17
Coli (MPN/100ml)					**Cu (mg/l)**			
EH11	1.00	0.00	0.07	0.50	1.00	0.64 *	0.57 *	0.71 *
EH16	0.00	1.00	0.64 *	-0.07	0.64 *	1.00	0.79 **	0.93 **
EH12	0.07	0.64 *	1.00	0.14	0.57 *	0.79 **	1.00	0.71 *
EH17	0.50	-0.07	0.14	1.00	0.71 *	0.93 **	0.71 *	1.00
BOD (mg/l)					**Fe (mg/l)**			
EH11	1.00	0.71 *	0.86 **	0.93 **	1.00	0.64 *	0.50	0.57 *
EH16	0.71 *	1.00	0.71 *	0.79 **	0.64 *	1.00	0.71 *	0.50
EH12	0.86 **	0.71 *	1.00	0.93 **	0.50	0.71 *	1.00	0.36
EH17	0.93 **	0.79 **	0.93 **	1.00	0.57 *	0.50	0.36	1.00
COD (mg/l)					**Mn (mg/l)**			
EH11	1.00	0.86 **	0.93 **	0.93 **	1.00	0.40	0.60	0.60
EH16	0.86 **	1.00	0.93 **	0.93 **	0.40	1.00	0.80	0.40
EH12	0.93 **	0.93 **	1.00	1.00 **	0.60	0.80	1.00	0.60
EH17	0.93 **	0.93 **	1.00 **	1.00	0.60	0.40	0.60	1.00
TSS (mg/l)					**Zn (mg/l)**			
EH11	1.00	0.36	0.36	0.86 **	1.00	-0.21	0.25	0.50
EH16	0.36	1.00	0.29	0.36	-0.21	1.00	-0.25	0.29
EH12	0.36	0.29	1.00	0.21	0.25	-0.25	1.00	-0.25
EH17	0.86 **	0.36	0.21	1.00	0.50	0.29	-0.25	1.00
TVS (mg/l)					**Pb (mg/l)**			
EH11	1.00	0.64 *	0.50	0.86 **	1.00	0.91 **	0.86 **	0.71 *
EH16	0.64 *	1.00	0.71 *	0.64 *	0.91 **	1.00	0.76 **	0.69 *
EH12	0.50	0.71 *	1.00	0.36	0.86 **	0.76 **	1.00	0.57 *
EH17	0.86 **	0.64 *	0.36	1.00	0.71 *	0.69 *	0.57 *	1.00
N-NO_3 (mg/l)					**Br (mg/l)**			
EH11	1.00	0.79 **	0.64 *	0.71 *	1.00	0.80	0.80	0.60
EH16	0.79 **	1.00	0.71 *	0.93 **	0.80	1.00	0.60	0.80
EH12	0.64 *	0.71 *	1.00	0.64 *	0.80	0.60	1.00	0.80
EH17	0.71 *	0.93 **	0.64 *	1.00	0.60	0.80	0.80	1.00
N-NH_4 (mg/l)					**pH**			
EH11	1.00	0.64 *	0.64 *	0.86 **	1.00	0.21	0.43	0.43
EH16	0.64 *	1.00	0.43	0.79 **	0.21	1.00	0.50	0.36
EH12	0.64 *	0.43	1.00	0.50	0.43	0.50	1.00	0.86 **
EH17	0.86 **	0.79 **	0.50	1.00	0.43	0.36	0.86 **	1.00
P (mg/l)					**EC (dS/m)**			
EH11	Not Enough Data				1.00	-0.14	0.57 *	0.64 *
EH16					-0.14	1.00	0.00	-0.07
EH12					0.57 *	0.00	1.00	0.93 **
EH17					0.64 *	-0.07	0.93 **	1.00
Cd (mg/l)					**TDS (mg/l)**			
EH11	1.00	0.71 *	0.86 **	1.00 **	1.00	-0.07	0.43	0.86 **
EH16	0.71 *	1.00	0.71 *	0.71 *	-0.07	1.00	0.21	-0.07
EH12	0.86 **	0.71 *	1.00	0.86 **	0.43	0.21	1.00	0.57 *
EH17	1.00 **	0.71 *	0.86 **	1.00	0.86 **	-0.07	0.57 *	1.00

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

Annex 4-5B4: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (**Site Group 4 - Yearly averages**)

Locations	EH11	EH16	EH12	EH17	EH11	EH16	EH12	EH17
Ca (meq/l)					**Sal**			
EH11	1.00	0.21	0.93 **	0.57 *	1.00	-0.18	0.55	0.59 *
EH16	0.21	1.00	0.14	0.36	-0.18	1.00	0.07	0.04
EH12	0.93 **	0.14	1.00	0.64 *	0.55	0.07	1.00	0.69 *
EH17	0.57 *	0.36	0.64 *	1.00	0.59 *	0.04	0.69 *	1.00
Mg (meq/l)					**DO (mg/l)**			
EH11	1.00	0.57 *	0.71 *	0.93 **	1.00	0.14	0.07	0.50
EH16	0.57 *	1.00	0.43	0.50	0.14	1.00	-0.36	0.07
EH12	0.71 *	0.43	1.00	0.64 *	0.07	-0.36	1.00	0.00
EH17	0.93 **	0.50	0.64 *	1.00	0.50	0.07	0.00	1.00
Na (meq/l)					**Turb (NTU)**			
EH11	1.00	0.43	0.57 *	0.64 *	1.00	0.33	0.71 *	0.52
EH16	0.43	1.00	0.71 *	0.36	0.33	1.00	0.43	0.62
EH12	0.57 *	0.71 *	1.00	0.50	0.71 *	0.43	1.00	0.62
EH17	0.64 *	0.36	0.50	1.00	0.52	0.62	0.62	1.00
K (meq/l)					**Visib (Cm)**			
EH11	1.00	0.64 *	0.86 **	0.79 **	1.00	0.50	0.79 **	0.55
EH16	0.64 *	1.00	0.79 **	0.57 *	0.50	1.00	0.57 *	0.33
EH12	0.86 **	0.79 **	1.00	0.79 **	0.79 **	0.57 *	1.00	0.76 **
EH17	0.79 **	0.57 *	0.79 **	1.00	0.55	0.33	0.76 **	1.00
SO_4 (meq/l)					**Fecal (MPN/100ml)**			
EH11	1.00	0.36	0.86 **	0.79 **	1.00	-0.40	-0.20	0.80
EH16	0.36	1.00	0.36	0.43	-0.40	1.00	0.40	-0.60
EH12	0.86 **	0.36	1.00	0.93 **	-0.20	0.40	1.00	0.00
EH17	0.79 **	0.43	0.93 **	1.00	0.80	-0.60	0.00	1.00
Cl (meq/l)					**TP (mg/l)**			
EH11	1.00	0.07	0.57 *	0.64 *	1.00	-0.20	-0.40	1.00
EH16	0.07	1.00	0.36	0.14	-0.20	1.00	0.80	-0.20
EH12	0.57 *	0.36	1.00	0.64 *	-0.40	0.80	1.00	-0.40
EH17	0.64 *	0.14	0.64 *	1.00	1.00	-0.20	-0.40	1.00
SAR					**TN (mg/l)**			
EH11	1.00	0.50	0.93 **	0.79 **	1.00	0.80	0.80	0.80
EH16	0.50	1.00	0.43	0.57 *	0.80	1.00	1.00	1.00 **
EH12	0.93 **	0.43	1.00	0.71 *	0.80	1.00	1.00 **	1.00 **
EH17	0.79 **	0.57 *	0.71 *	1.00	0.80	1.00 **	1.00 **	1.00
Adj_SAR					**Ni (mg/l)**			
EH11	1.00	0.50	0.86 **	0.79 **	1.00	0.20	0.00	1.00 **
EH16	0.50	1.00	0.50	0.57 *	0.20	1.00	0.40	0.20
EH12	0.86 **	0.50	1.00	0.64 *	0.00	0.40	1.00	0.00
EH17	0.79 **	0.57 *	0.64 *	1.00	1.00 **	0.20	0.00	1.00
Temp (C^o)					**SO_{4_m} (meq/l)**			
EH11	1.00	0.29	0.57 *	0.79 **	1.00	0.20	0.80	0.40
EH16	0.29	1.00	0.71 *	0.21	0.20	1.00	0.00	0.40
EH12	0.57 *	0.71 *	1.00	0.36	0.80	0.00	1.00	0.20
EH17	0.79 **	0.21	0.36	1.00	0.40	0.40	0.20	1.00

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

Annex 4-5C1: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (**Site Group 1 - Monthly measurements)**

Locations	EH14	EH02	EH18	EH03	EH14	EH02	EH18	EH03
Coli (MPN/100ml)					**Cu (mg/l)**			
EH14	1.00	0.20 **	0.39 **	0.17 *	1.00	0.43 **	0.63 **	0.56 **
EH02	0.20 **	1.00	0.52 **	0.35 **	0.43 **	1.00	0.49 **	0.42 **
EH18	0.39 **	0.52 **	1.00	0.38 **	0.63 **	0.49 **	1.00	0.54 **
EH03	0.17 *	0.35 **	0.38 **	1.00	0.56 **	0.42 **	0.54 **	1.00
BOD (mg/l)					**Fe (mg/l)**			
EH14	1.00	0.46 **	0.50 **	0.45 **	1.00	0.34 **	0.40 **	0.36 **
EH02	0.46 **	1.00	0.49 **	0.43 **	0.34 **	1.00	0.49 **	0.35 **
EH18	0.50 **	0.49 **	1.00	0.50 **	0.40 **	0.49 **	1.00	0.37 **
EH03	0.45 **	0.43 **	0.50 **	1.00	0.36 **	0.35 **	0.37 **	1.00
COD (mg/l)					**Mn (mg/l)**			
EH14	1.00	0.51 **	0.55 **	0.51 **	1.00	0.11	0.34 **	0.29 **
EH02	0.51 **	1.00	0.54 **	0.51 **	0.11	1.00	-0.17	0.24 *
EH18	0.55 **	0.54 **	1.00	0.56 **	0.34 **	-0.17	1.00	0.09
EH03	0.51 **	0.51 **	0.56 **	1.00	0.29 **	0.24 *	0.09	1.00
TSS (mg/l)					**Zn (mg/l)**			
EH14	1.00	0.61 **	0.58 **	0.42 **	1.00	0.36 **	0.50 **	0.43 **
EH02	0.61 **	1.00	0.60 **	0.43 **	0.36 **	1.00	0.45 **	0.50 **
EH18	0.58 **	0.60 **	1.00	0.52 **	0.50 **	0.45 **	1.00	0.46 **
EH03	0.42 **	0.43 **	0.52 **	1.00	0.43 **	0.50 **	0.46 **	1.00
TVS (mg/l)					**Pb (mg/l)**			
EH14	1.00	0.62 **	0.63 **	0.44 **	1.00	0.69 **	0.67 **	0.65 **
EH02	0.62 **	1.00	0.65 **	0.47 **	0.69 **	1.00	0.67 **	0.69 **
EH18	0.63 **	0.65 **	1.00	0.52 **	0.67 **	0.67 **	1.00	0.63 **
EH03	0.44 **	0.47 **	0.52 **	1.00	0.65 **	0.69 **	0.63 **	1.00
N-NO$_3$ (mg/l)					**Br (mg/l)**			
EH14	1.00	0.33 **	0.45 **	0.42 **	1.00	0.40 **	0.80 **	0.51 **
EH02	0.33 **	1.00	0.56 **	0.43 **	0.40 **	1.00	0.34 **	0.34 **
EH18	0.45 **	0.56 **	1.00	0.45 **	0.80 **	0.34 **	1.00	0.58 **
EH03	0.42 **	0.43 **	0.45 **	1.00	0.51 **	0.34 **	0.58 **	1.00
N-NH$_4$ (mg/l)					**pH**			
EH14	1.00	0.48 **	0.64 **	0.47 **	1.00	0.50 **	0.48 **	0.43 **
EH02	0.48 **	1.00	0.47 **	0.41 **	0.50 **	1.00	0.47 **	0.43 **
EH18	0.64 **	0.47 **	1.00	0.55 **	0.48 **	0.47 **	1.00	0.55 **
EH03	0.47 **	0.41 **	0.55 **	1.00	0.43 **	0.43 **	0.55 **	1.00
P (mg/l)					**EC (dS/m)**			
EH14	1.00	0.33 **	0.22	0.43 **	1.00	0.39 **	0.70 **	0.25 **
EH02	0.33 **	1.00	0.54 **	0.17	0.39 **	1.00	0.46 **	0.11
EH18	0.22	0.54 **	1.00	0.28 *	0.70 **	0.46 **	1.00	0.30 **
EH03	0.43 **	0.17	0.28 *	1.00	0.25 **	0.11	0.30 **	1.00
Cd (mg/l)					**TDS (mg/l)**			
EH14	1.00	0.76 **	0.76 **	0.77 **	1.00	0.39 **	0.63 **	0.21 **
EH02	0.76 **	1.00	0.84 **	0.82 **	0.39 **	1.00	0.39 **	0.21 **
EH18	0.76 **	0.84 **	1.00	0.84 **	0.63 **	0.39 **	1.00	0.31 **
EH03	0.77 **	0.82 **	0.84 **	1.00	0.21 **	0.21 **	0.31 **	1.00

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

Annex 4-5C1: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (**Site Group 1 - Monthly measurements**)

Locations	EH14	EH02	EH18	EH03
Ca (meq/l)				
EH14	1.00	0.53 **	0.56 **	0.19 **
EH02	0.53 **	1.00	0.49 **	0.18 *
EH18	0.56 **	0.49 **	1.00	0.27 **
EH03	0.19 **	0.18 *	0.27 **	1.00
Mg (meq/l)				
EH14	1.00	0.40 **	0.50 **	0.27 **
EH02	0.40 **	1.00	0.46 **	0.34 **
EH18	0.50 **	0.46 **	1.00	0.40 **
EH03	0.27 **	0.34 **	0.40 **	1.00
Na (meq/l)				
EH14	1.00	0.31 **	0.54 **	0.22 **
EH02	0.31 **	1.00	0.32 **	0.17 *
EH18	0.54 **	0.32 **	1.00	0.22 **
EH03	0.22 **	0.17 *	0.22 **	1.00
K (meq/l)				
EH14	1.00	0.45 **	0.62 **	0.44 **
EH02	0.45 **	1.00	0.45 **	0.53 **
EH18	0.62 **	0.45 **	1.00	0.54 **
EH03	0.44 **	0.53 **	0.54 **	1.00
SO$_4$ (meq/l)				
EH14	1.00	0.45 **	0.63 **	0.33 **
EH02	0.45 **	1.00	0.50 **	0.35 **
EH18	0.63 **	0.50 **	1.00	0.42 **
EH03	0.33 **	0.35 **	0.42 **	1.00
Cl (meq/l)				
EH14	1.00	0.31 **	0.58 **	0.15 *
EH02	0.31 **	1.00	0.38 **	0.05
EH18	0.58 **	0.38 **	1.00	0.07
EH03	0.15 *	0.05	0.07	1.00
SAR				
EH14	1.00	0.29 **	0.43 **	0.16 *
EH02	0.29 **	1.00	0.33 **	0.21 **
EH18	0.43 **	0.33 **	1.00	0.22 **
EH03	0.16 *	0.21 **	0.22 **	1.00
Adj_SAR				
EH14	1.00	0.35 **	0.49 **	0.26 **
EH02	0.35 **	1.00	0.34 **	0.26 **
EH18	0.49 **	0.34 **	1.00	0.28 **
EH03	0.26 **	0.26 **	0.28 **	1.00
Temp (C^o)				
EH14	1.00	0.76 **	0.84 **	0.84 **
EH02	0.76 **	1.00	0.76 **	0.79 **
EH18	0.84 **	0.76 **	1.00	0.85 **
EH03	0.84 **	0.79 **	0.85 **	1.00

	EH14	EH02	EH18	EH03
Sal				
EH14	1.00	0.38 **	0.70 **	0.21 **
EH02	0.38 **	1.00	0.56 **	0.10
EH18	0.70 **	0.56 **	1.00	0.26 **
EH03	0.21 **	0.10	0.26 **	1.00
DO (mg/l)				
EH14	1.00	0.22 **	0.20 **	0.30 **
EH02	0.22 **	1.00	0.35 **	0.35 **
EH18	0.20 **	0.35 **	1.00	0.45 **
EH03	0.30 **	0.35 **	0.45 **	1.00
Turb (NTU)				
EH14	1.00	0.31 **	0.32 **	0.13
EH02	0.31 **	1.00	0.58 **	0.31 **
EH18	0.32 **	0.58 **	1.00	0.31 **
EH03	0.13	0.31 **	0.31 **	1.00
Visib (Cm)				
EH14	1.00	0.23 **	0.26 **	0.07
EH02	0.23 **	1.00	0.58 **	0.36 **
EH18	0.26 **	0.58 **	1.00	0.38 **
EH03	0.07	0.36 **	0.38 **	1.00
Fecal (MPN/100ml)				
EH14	1.00	0.35 **	0.56 **	0.29 **
EH02	0.35 **	1.00	0.41 **	0.40 **
EH18	0.56 **	0.41 **	1.00	0.36 **
EH03	0.29 **	0.40 **	0.36 **	1.00
TP (mg/l)				
EH14	1.00	0.05	0.14	0.01
EH02	0.05	1.00	0.62 **	0.31 **
EH18	0.14	0.62 **	1.00	0.50 **
EH03	0.01	0.31 **	0.50 **	1.00
TN (mg/l)				
EH14	1.00	0.30 **	0.70 **	0.52 **
EH02	0.30 **	1.00	0.41 **	0.37 **
EH18	0.70 **	0.41 **	1.00	0.58 **
EH03	0.52 **	0.37 **	0.58 **	1.00
Ni (mg/l)				
EH14	1.00	0.52 **	0.58 **	0.45 **
EH02	0.52 **	1.00	0.36 **	0.39 **
EH18	0.58 **	0.36 **	1.00	0.65 **
EH03	0.45 **	0.39 **	0.65 **	1.00
SO$_{4\_m}$ (meq/l)				
EH14	1.00	0.27 **	0.40 **	0.28 **
EH02	0.27 **	1.00	0.43 **	0.32 **
EH18	0.40 **	0.43 **	1.00	0.45 **
EH03	0.28 **	0.32 **	0.45 **	1.00

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

Annex 4-5C2: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (**Site Group 2 - Monthly measurements**)

Locations	EH04	EH05	EH15	EH06	EH04	EH05	EH15	EH06
Coli (MPN/100ml)					**Cu (mg/l)**			
EH04	1.00	0.07	0.23 **	0.04	1.00	0.57 **	0.34 **	0.52 **
EH05	0.07	1.00	0.43 **	0.14 *	0.57 **	1.00	0.47 **	0.60 **
EH15	0.23 **	0.43 **	1.00	0.18 *	0.34 **	0.47 **	1.00	0.54 **
EH06	0.04	0.14 *	0.18 *	1.00	0.52 **	0.60 **	0.54 **	1.00
BOD (mg/l)					**Fe (mg/l)**			
EH04	1.00	0.38 **	0.41 **	0.40 **	1.00	0.44 **	0.41 **	0.39 **
EH05	0.38 **	1.00	0.46 **	0.40 **	0.44 **	1.00	0.43 **	0.41 **
EH15	0.41 **	0.46 **	1.00	0.52 **	0.41 **	0.43 **	1.00	0.43 **
EH06	0.40 **	0.40 **	0.52 **	1.00	0.39 **	0.41 **	0.43 **	1.00
COD (mg/l)					**Mn (mg/l)**			
EH04	1.00	0.42 **	0.46 **	0.47 **	1.00	0.39 **	0.40 **	0.40 **
EH05	0.42 **	1.00	0.51 **	0.52 **	0.39 **	1.00	0.49 **	0.57 **
EH15	0.46 **	0.51 **	1.00	0.58 **	0.40 **	0.49 **	1.00	0.57 **
EH06	0.47 **	0.52 **	0.58 **	1.00	0.40 **	0.57 **	0.57 **	1.00
TSS (mg/l)					**Zn (mg/l)**			
EH04	1.00	0.32 **	0.46 **	0.32 **	54.00	0.46 **	0.36 **	0.46 **
EH05	0.32 **	1.00	0.54 **	0.42 **	0.46 **	1.00	0.55 **	0.49 **
EH15	0.46 **	0.54 **	1.00	0.37 **	0.36 **	0.55 **	1.00	0.45 **
EH06	0.32 **	0.42 **	0.37 **	1.00	0.46 **	0.49 **	0.45 **	1.00
TVS (mg/l)					**Pb (mg/l)**			
EH04	1.00	0.29 **	0.48 **	0.34 **	1.00	0.59 **	0.67 **	0.65 **
EH05	0.29 **	1.00	0.54 **	0.38 **	0.59 **	1.00	0.71 **	0.72 **
EH15	0.48 **	0.54 **	1.00	0.36 **	0.67 **	0.71 **	1.00	0.68 **
EH06	0.34 **	0.38 **	0.36 **	1.00	0.65 **	0.72 **	0.68 **	1.00
N-NO_3 (mg/l)					**Br (mg/l)**			
EH04	1.00	0.55 **	0.56 **	0.37 **	1.00	0.62 **	0.73 **	0.64 **
EH05	0.55 **	1.00	0.54 **	0.46 **	0.62 **	1.00	0.71 **	0.67 **
EH15	0.56 **	0.54 **	1.00	0.42 **	0.73 **	0.71 **	1.00	0.66 **
EH06	0.37 **	0.46 **	0.42 **	1.00	0.64 **	0.67 **	0.66 **	1.00
N-NH_4 (mg/l)					**pH**			
EH04	1.00	0.62 **	0.61 **	0.26 **	1.00	0.41 **	0.43 **	0.35 **
EH05	0.62 **	1.00	0.59 **	0.39 **	0.41 **	1.00	0.42 **	0.33 **
EH15	0.61 **	0.59 **	1.00	0.36 **	0.43 **	0.42 **	1.00	0.46 **
EH06	0.26 **	0.39 **	0.36 **	1.00	0.35 **	0.33 **	0.46 **	1.00
P (mg/l)					**EC (dS/m)**			
EH04	1.00	0.27 *	0.32 **	0.21	1.00	0.36 **	0.51 **	0.34 **
EH05	0.27 *	1.00	0.54 **	0.51 **	0.36 **	1.00	0.48 **	0.48 **
EH15	0.32 **	0.54 **	1.00	0.42 **	0.51 **	0.48 **	1.00	0.38 **
EH06	0.21	0.51 **	0.42 **	1.00	0.34 **	0.48 **	0.38 **	1.00
Cd (mg/l)					**TDS (mg/l)**			
EH04	1.00	0.93 **	0.84 **	0.82 **	1.00	0.37 **	0.53 **	0.34 **
EH05	0.93 **	1.00	0.86 **	0.86 **	0.37 **	1.00	0.46 **	0.45 **
EH15	0.84 **	0.86 **	1.00	0.86 **	0.53 **	0.46 **	1.00	0.41 **
EH06	0.82 **	0.86 **	0.86 **	1.00	0.34 **	0.45 **	0.41 **	1.00

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

Annex 4-5C2: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (**Site Group 2 - Monthly measurements**)

Locations	EH04	EH05	EH15	EH06	EH04	EH05	EH15	EH06
Ca (meq/l)					**Sal**			
EH04	1.00	0.52 **	0.48 **	0.33 **	1.00	0.37 **	0.60 **	0.41 **
EH05	0.52 **	1.00	0.62 **	0.49 **	0.37 **	1.00	0.57 **	0.50 **
EH15	0.48 **	0.62 **	1.00	0.45 **	0.60 **	0.57 **	1.00	0.49 **
EH06	0.33 **	0.49 **	0.45 **	1.00	0.41 **	0.50 **	0.49 **	1.00
Mg (meq/l)					**DO (mg/l)**			
EH04	1.00	0.47 **	0.48 **	0.46 **	1.00	-0.22	-0.13	-0.16 *
EH05	0.47 **	1.00	0.44 **	0.49 **	-0.22 **	1.00	0.19 **	0.26 **
EH15	0.48 **	0.44 **	1.00	0.51 **	0.13	0.19	1.00	0.29 **
EH06	0.46 **	0.49 **	0.51 **	1.00	-0.16 *	0.26 **	0.29 **	1.00
Na (meq/l)					**Turb (NTU)**			
EH04	1.00	0.31 **	0.39 **	0.25 **	1.00	-0.18 *	0.19 *	0.02
EH05	0.31 **	1.00	0.30 **	0.42 **	-0.18 *	1.00	0.14	0.18 *
EH15	0.39 **	0.30 **	1.00	0.31 **	0.19 *	0.14	1.00	0.19 *
EH06	0.25 **	0.42 **	0.31 **	1.00	0.02	0.18 *	0.19 *	1.00
K (meq/l)					**Visib (Cm)**			
EH04	1.00	0.54 **	0.52 **	0.50 **	1.00	-0.15 *	0.05	-0.03
EH05	0.54 **	1.00	0.64 **	0.64 **	-0.15 *	1.00	0.39 **	0.32 **
EH15	0.52 **	0.64 **	1.00	0.62 **	0.05	0.39 **	1.00	0.38 **
EH06	0.50 **	0.64 **	0.62 **	1.00	-0.03	0.32 **	0.38 **	1.00
SO_4 (meq/l)					**Fecal (MPN/100ml)**			
EH04	1.00	0.53 **	0.44 **	0.39 **	1.00	-0.01	0.15	-0.10
EH05	0.53 **	1.00	0.46 **	0.40 **	-0.01	1.00	0.36 **	0.02
EH15	0.44 **	0.46 **	1.00	0.35 **	0.15	0.36 **	1.00	0.16
EH06	0.39 **	0.40 **	0.35 **	1.00	-0.10	0.02	0.16	1.00
Cl (meq/l)					**TP (mg/l)**			
EH04	1.00	0.39 **	0.48 **	0.20 **	1.00	-0.09	0.22 *	0.14
EH05	0.39 **	1.00	0.43 **	0.23 **	-0.09	1.00	0.25 **	0.27 **
EH15	0.48 **	0.43 **	1.00	0.27 **	0.22 *	0.25 **	1.00	0.20 *
EH06	0.20 **	0.23 **	0.27 **	1.00	0.14	0.27 **	0.20 *	1.00
SAR					**TN (mg/l)**			
EH04	1.00	0.39 **	0.32 **	0.21 **	1.00	0.59 **	0.62 **	0.13
EH05	0.39 **	1.00	0.26 **	0.32 **	0.59 **	1.00	0.64 **	0.29 **
EH15	0.32 **	0.26 **	1.00	0.23 **	0.62 **	0.64 **	1.00	0.26 **
EH06	0.21 **	0.32 **	0.23 **	1.00	0.13	0.29 **	0.26 **	1.00
Adj_SAR					**Ni (mg/l)**			
EH04	1.00	0.35 **	0.36 **	0.19 **	1.00	0.70 **	0.66 **	0.63 **
EH05	0.35 **	1.00	0.28 **	0.37 **	0.70 **	1.00	0.54 **	0.48 **
EH15	0.36 **	0.28 **	1.00	0.26 **	0.66 **	0.54 **	1.00	0.57 **
EH06	0.19 **	0.37 **	0.26 **	1.00	0.63 **	0.48 **	0.57 **	1.00
Temp (C^o)					**SO_{4_m} (meq/l)**			
EH04	1.00	0.84 **	0.84 **	0.85 **	1.00	0.43 **	0.52 **	0.48 **
EH05	0.84 **	1.00	0.85 **	0.86 **	0.43 **	1.00	0.57 **	0.49 **
EH15	0.84 **	0.85 **	1.00	0.88 **	0.52 **	0.57 **	1.00	0.47 **
EH06	0.85 **	0.86 **	0.88 **	1.00	0.48 **	0.49 **	0.47 **	1.00

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

Annex 4-5C3: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (**Site Group 3 - Monthly measurements**)

Locations	EH07	EH08	EH09	EH10	EH07	EH08	EH09	EH10
Coli (MPN/100ml)					**Cu (mg/l)**			
EH07	1.00	0.26 **	0.28 **	0.23 **	1.00	0.69 **	0.51 **	0.48 **
EH08	0.26 **	1.00	0.14 *	0.19 **	0.69 **	1.00	0.50 **	0.49 **
EH09	0.28 **	0.14 *	1.00	0.43 **	0.51 **	0.50 **	1.00	0.39 **
EH10	0.23 **	0.19 **	0.43 **	1.00 **	0.48 **	0.49 **	0.39 **	1.00 **
BOD (mg/l)					**Fe (mg/l)**			
EH07	1.00	0.60 **	0.62 **	0.61 **	1.00	0.44 **	0.51 **	0.45 **
EH08	0.60 **	1.00	0.58 **	0.63 **	0.44 **	1.00	0.27 **	0.47 **
EH09	0.62 **	0.58 **	1.00	0.63 **	0.51 **	0.27 **	1.00	0.33 **
EH10	0.61 **	0.63 **	0.63 **	1.00 **	0.45 **	0.47 **	0.33 **	1.00 **
COD (mg/l)					**Mn (mg/l)**			
EH07	1.00	0.69 **	0.68 **	0.68 **	1.00	0.50 **	0.44 **	0.44 **
EH08	0.69 **	1.00	0.64 **	0.69 **	0.50 **	1.00	0.42 **	0.32 **
EH09	0.68 **	0.64 **	1.00	0.69 **	0.44 **	0.42 **	1.00	0.39 **
EH10	0.68 **	0.69 **	0.69 **	1.00 **	0.44 **	0.32 **	0.39 **	1.00
TSS (mg/l)					**Zn (mg/l)**			
EH07	1.00	0.55 **	0.39 **	0.52 **	1.00	0.61 **	0.49 **	0.36 **
EH08	0.55 **	1.00	0.42 **	0.55 **	0.61 **	1.00	0.50 **	0.37 **
EH09	0.39 **	0.42 **	1.00	0.44 **	0.49 **	0.50 **	1.00	0.40 **
EH10	0.52 **	0.55 **	0.44 **	1.00 **	0.36 **	0.37 **	0.40 **	1.00 **
TVS (mg/l)					**Pb (mg/l)**			
EH07	1.00	0.60 **	0.45 **	0.57 **	1.00	0.67 **	0.65 **	0.72 **
EH08	0.60 **	1.00	0.47 **	0.62 **	0.67 **	1.00	0.54 **	0.63 **
EH09	0.45 **	0.47 **	1.00	0.50 **	0.65 **	0.54 **	1.00	0.69 **
EH10	0.57 **	0.62 **	0.50 **	1.00 **	0.72 **	0.63 **	0.69 **	1.00 **
N-NO$_3$ (mg/l)					**Br (mg/l)**			
EH07	1.00	0.68 **	0.66 **	0.59 **	1.00	0.56 **	0.49 **	0.66 **
EH08	0.68 **	1.00	0.65 **	0.54 **	0.56 **	1.00	0.37 **	0.69 **
EH09	0.66 **	0.65 **	1.00	0.62 **	0.49 **	0.37 **	1.00	0.46 **
EH10	0.59 **	0.54 **	0.62 **	1.00 **	0.66 **	0.69 **	0.46 **	1.00 **
N-NH$_4$ (mg/l)					**pH**			
EH07	1.00	0.66 **	0.55 **	0.52 **	1.00	0.43 **	0.26 **	0.43 **
EH08	0.66 **	1.00	0.60 **	0.64 **	0.43 **	1.00	0.25 **	0.34 **
EH09	0.55 **	0.60 **	1.00	0.61 **	0.26 **	0.25 **	1.00	0.39 **
EH10	0.52 **	0.64 **	0.61 **	1.00 **	0.43 **	0.34 **	0.39 **	1.00 **
P (mg/l)					**EC (dS/m)**			
EH07	1.00	0.37 **	0.34 **	0.22	1.00	0.43 **	0.12	0.42 **
EH08	0.37 **	1.00	0.34 **	0.35 **	0.43 **	1.00	0.20 **	0.44 **
EH09	0.34 **	0.34 **	1.00	0.52 **	0.12	0.20 **	1.00	0.23 **
EH10	0.22 **	0.35 **	0.52 **	1.00 **	0.42 **	0.44 **	0.23 **	1.00 **
Cd (mg/l)					**TDS (mg/l)**			
EH07	1.00	0.91 **	0.82 **	0.83 **	1.00	0.46 **	0.12	0.31 **
EH08	0.91 **	1.00	0.86 **	0.85 **	0.46 **	1.00	0.15 *	0.42 **
EH09	0.82 **	0.86 **	1.00	0.84 **	0.12	0.15 *	1.00	0.18 *
EH10	0.83 **	0.85 **	0.84 **	1.00 **	0.31 **	0.42 **	0.18 **	1.00 **

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

Annex 4-5C3: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (**Site Group 3 - Monthly measurements**)

Locations	EH07	EH08	EH09	EH10
Ca (meq/l)				
EH07	1.00	0.46 **	0.24 **	0.45 **
EH08	0.46 **	1.00	0.11	0.55 **
EH09	0.24 **	0.11	1.00	0.20 **
EH10	0.45 **	0.55 **	0.20 **	1.00 **
Mg (meq/l)				
EH07	1.00	0.63 **	0.36 **	0.59 **
EH08	0.63 **	1.00	0.35 **	0.66 **
EH09	0.36 **	0.35 **	1.00	0.37 **
EH10	0.59 **	0.66 **	0.37 **	1.00 **
Na (meq/l)				
EH07	1.00	0.49 **	0.15	0.37 **
EH08	0.49 **	1.00	0.20 **	0.46 **
EH09	0.15	0.20 **	1.00	0.18 *
EH10	0.37 **	0.46 **	0.18 **	1.00 **
K (meq/l)				
EH07	1.00	0.70 **	0.56 **	0.72 **
EH08	0.70 **	1.00	0.46 **	0.79 **
EH09	0.56 **	0.46 **	1.00	0.52 **
EH10	0.72 **	0.79 **	0.52 **	1.00 **
SO$_4$ (meq/l)				
EH07	1.00	0.41 **	0.29 **	0.28 **
EH08	0.41 **	1.00	0.25 **	0.31 **
EH09	0.29 **	0.25 **	1.00	0.23 **
EH10	0.28 **	0.31 **	0.23 **	1.00 **
Cl (meq/l)				
EH07	1.00	0.47 **	0.13	0.39 **
EH08	0.47 **	1.00	0.13	0.50 **
EH09	0.13	0.13	1.00	0.22 **
EH10	0.39 **	0.50 **	0.22 **	1.00 **
SAR				
EH07	1.00	0.58 **	0.15 *	0.45 **
EH08	0.58 **	1.00	0.17 *	0.55 **
EH09	0.15 *	0.17 *	1.00	0.14
EH10	0.45 **	0.55 **	0.14 **	1.00 **
Adj_SAR				
EH07	1.00	0.52 **	0.15 *	0.42 **
EH08	0.52 **	1.00	0.18 *	0.50 **
EH09	0.15 *	0.18 *	1.00	0.17 *
EH10	0.42 **	0.50 **	0.17 **	1.00 **
Temp (C^o)				
EH07	1.00	0.91 **	0.86 **	0.89 **
EH08	0.91 **	1.00	0.86 **	0.93 **
EH09	0.86 **	0.86 **	1.00	0.87 **
EH10	0.89 **	0.93 **	0.87 **	1.00 **

Locations	EH07	EH08	EH09	EH10
Sal				
EH07	1.00	0.50 **	0.15	0.41 **
EH08	0.50 **	1.00	0.19 *	0.51 **
EH09	0.15	0.19 *	1.00	0.35 **
EH10	0.41 **	0.51 **	0.35 **	1.00 **
DO (mg/l)				
EH07	1.00	0.50 **	0.28 **	0.40 **
EH08	0.50 **	1.00	0.29 **	0.48 **
EH09	0.28 **	0.29 **	1.00	0.22 **
EH10	0.40 **	0.48 **	0.22 **	1.00 **
Turb (NTU)				
EH07	1.00	0.61 **	0.02	0.54 **
EH08	0.61 **	1.00	0.10	0.50 **
EH09	0.02	0.10	1.00	-0.01
EH10	0.54 **	0.50 **	-0.01 **	1.00 **
Visib (Cm)				
EH07	1.00	0.61 **	0.10	0.51 **
EH08	0.61 **	1.00	0.12	0.56 **
EH09	0.10	0.12	1.00	0.12
EH10	0.51 **	0.56 **	0.12 **	1.00 **
Fecal (MPN/100ml)				
EH07	1.00	0.45 **	0.15	0.15
EH08	0.45 **	1.00	0.01	0.08
EH09	0.15	0.01	1.00	0.43 **
EH10	0.15 **	0.08 **	0.43 **	1.00 **
TP (mg/l)				
EH07	1.00	0.43 **	0.39 **	0.34 **
EH08	0.43 **	1.00	0.27 **	0.37 **
EH09	0.39 **	0.27 **	1.00	0.29 **
EH10	0.34 **	0.37 **	0.29 **	1.00 **
TN (mg/l)				
EH07	1.00	0.72 **	0.61 **	0.44 **
EH08	0.72 **	1.00	0.60 **	0.61 **
EH09	0.61 **	0.60 **	1.00	0.51 **
EH10	0.44 **	0.61 **	0.51 **	1.00 **
Ni (mg/l)				
EH07	1.00	0.44 **	0.58 **	0.56 **
EH08	0.44 **	1.00	0.62 **	0.61 **
EH09	0.58 **	0.62 **	1.00	0.71 **
EH10	0.56 **	0.61 **	0.71 **	1.00 **
SO$_{4\_m}$ (meq/l)				
EH07	1.00	0.52 **	0.33 **	0.53 **
EH08	0.52 **	1.00	0.29 **	0.70 **
EH09	0.33 **	0.29 **	1.00	0.38 **
EH10	0.53 **	0.70 **	0.38 **	1.00 **

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

Annex 4-5C4: Correlation matrix (Kendall 's tau nonparametric test) for WQPs in Hadus drain (**Site Group 4 - Monthly measurements**)

Locations	EH11	EH12	EH16	EH17	EH11	EH12	EH16	EH17
Coli (MPN/100ml)					**Cu (mg/l)**			
EH11	1.00	0.10	0.17 *	0.07	1.00	0.60 **	0.49 **	0.66 **
EH12	0.10	1.00	0.15 *	-0.04	0.60 **	1.00	0.65 **	0.68 **
EH16	0.17 *	0.15 *	1.00	0.01	0.49 **	0.65 **	1.00	0.59 **
EH17	0.07 **	-0.04 **	0.01 **	1.00 **	0.66 **	0.68 **	0.59 **	1.00 **
BOD (mg/l)					**Fe (mg/l)**			
EH11	1.00	0.50 **	0.56 **	0.63 **	1.00	0.16 *	0.44 **	0.47 **
EH12	0.50 **	1.00	0.59 **	0.51 **	0.16 *	1.00	0.29 **	0.21 **
EH16	0.56 **	0.59 **	1.00	0.57 **	0.44 **	0.29 **	1.00	0.45 **
EH17	0.63 **	0.51 **	0.57 **	1.00 **	0.47 **	0.21 **	0.45 **	1.00 **
COD (mg/l)					**Mn (mg/l)**			
EH11	1.00	0.61 **	0.66 **	0.69 **	1.00	0.36 **	0.39 **	0.36 **
EH12	0.61 **	1.00	0.66 **	0.61 **	0.36 **	1.00	0.33 **	0.39 **
EH16	0.66 **	0.66 **	1.00	0.65 **	0.39 **	0.33 **	1.00	0.24 **
EH17	0.69 **	0.61 **	0.65 **	1.00 **	0.36 **	0.39 **	0.24 **	1.00
TSS (mg/l)					**Zn (mg/l)**			
EH11	1.00	0.38 **	0.46 **	0.45 **	1.00	0.30 **	0.29 **	0.31 **
EH12	0.38 **	1.00	0.25 **	0.29 **	0.30 **	1.00	0.32 **	0.10
EH16	0.46 **	0.25 **	1.00	0.36 **	0.29 **	0.32 **	1.00	0.22 **
EH17	0.45 **	0.29 **	0.36 **	1.00 **	0.31 **	0.10 **	0.22 **	1.00 **
TVS (mg/l)					**Pb (mg/l)**			
EH11	1.00	0.45 **	0.47 **	0.52 **	1.00	0.58 **	0.49 **	0.51 **
EH12	0.45 **	1.00	0.36 **	0.31 **	0.58 **	1.00	0.53 **	0.53 **
EH16	0.47 **	0.36 **	1.00	0.45 **	0.49 **	0.53 **	1.00	0.43 **
EH17	0.52 **	0.31 **	0.45 **	1.00 **	0.51 **	0.53 **	0.43 **	1.00 **
N-NO$_3$ (mg/l)					**Br (mg/l)**			
EH11	1.00	0.52 **	0.48 **	0.57 **	1.00	0.45 **	0.74 **	0.46 **
EH12	0.52 **	1.00	0.58 **	0.54 **	0.45 **	1.00	0.60 **	0.51 **
EH16	0.48 **	0.58 **	1.00	0.45 **	0.74 **	0.60 **	1.00	0.45 **
EH17	0.57 **	0.54 **	0.45 **	1.00 **	0.46 **	0.51 **	0.45 **	1.00 **
N-NH$_4$ (mg/l)					**pH**			
EH11	1.00	0.47 **	0.34 **	0.40 **	1.00	0.34 **	0.36 **	0.39 **
EH12	0.47 **	1.00	0.41 **	0.38 **	0.34 **	1.00	0.39 **	0.28 **
EH16	0.34 **	0.41 **	1.00	0.22 **	0.36 **	0.39 **	1.00	0.34 **
EH17	0.40 **	0.38 **	0.22 **	1.00 **	0.39 **	0.28 **	0.34 **	1.00 **
P (mg/l)					**EC (dS/m)**			
EH11	1.00	0.24 *	0.50 **	0.41 **	1.00	0.15 *	0.56 **	0.62 **
EH12	0.24 *	1.00	0.22	0.34 **	0.15 *	1.00	0.24 **	0.14
EH16	0.50 **	0.22	1.00	0.43 **	0.56 **	0.24 **	1.00	0.61 **
EH17	0.41 **	0.34 **	0.43 **	1.00 **	0.62 **	0.14 **	0.61 **	1.00 **
Cd (mg/l)					**TDS (mg/l)**			
EH11	1.00	0.85 **	0.85 **	0.84 **	1.00	0.17 *	0.57 **	0.60 **
EH12	0.85 **	1.00	0.87 **	0.82 **	0.17 *	1.00	0.27 **	0.18 *
EH16	0.85 **	0.87 **	1.00	0.86 **	0.57 **	0.27 **	1.00	0.61 **
EH17	0.84 **	0.82 **	0.86 **	1.00 **	0.60 **	0.18 **	0.61 **	1.00 **

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

Annex 4-5C4: Correlation matrix **(**Kendall 's tau nonparametric test) for WQPs in Hadus drain **(Site Group 4 - Monthly measurements)**

Locations	EH11	EH12	EH16	EH17	EH11	EH12	EH16	EH17
	Ca (meq/l)				**Sal**			
EH11	1.00	0.17 *	0.42 **	0.43 **	1.00	0.17 *	0.56 **	0.60 **
EH12	0.17 *	1.00	0.26 **	0.18 *	0.17 *	1.00	0.29 **	0.20 **
EH16	0.42 **	0.26 **	1.00	0.43 **	0.56 **	0.29 **	1.00	0.61 **
EH17	0.43 **	0.18 **	0.43 **	1.00 **	0.60 **	0.20 **	0.61 **	1.00 **
	Mg (meq/l)				**DO (mg/l)**			
EH11	1.00	0.30 **	0.61 **	0.64 **	1.00	0.27 **	0.15 *	0.30 **
EH12	0.30 **	1.00	0.34 **	0.28 **	0.27 **	1.00	0.13	0.06
EH16	0.61 **	0.34 **	1.00	0.57 **	0.15 *	0.13	1.00	0.21 **
EH17	0.64 **	0.28 **	0.57 **	1.00 **	0.30 **	0.06 **	0.21 **	1.00 **
	Na (meq/l)				**Turb (NTU)**			
EH11	1.00	0.16 *	0.58 **	0.58 **	1.00	0.23 **	0.47 **	0.23 **
EH12	0.16 *	1.00	0.25 **	0.19 **	0.23 **	1.00	0.25 **	0.24 **
EH16	0.58 **	0.25 **	1.00	0.60 **	0.47 **	0.25 **	1.00	0.21 *
EH17	0.58 **	0.19 **	0.60 **	1.00 **	0.23 **	0.24 **	0.21 **	1.00 **
	K (meq/l)				**Visib (Cm)**			
EH11	1.00	0.45 **	0.66 **	0.58 **	1.00	0.34 **	0.49 **	0.36 **
EH12	0.45 **	1.00	0.42 **	0.38 **	0.34 **	1.00	0.19 *	0.29 **
EH16	0.66 **	0.42 **	1.00	0.62 **	0.49 **	0.19 *	1.00	0.24 **
EH17	0.58 **	0.38 **	0.62 **	1.00 **	0.36 **	0.29 **	0.24 **	1.00 **
	SO_4 (meq/l)				**Fecal (MPN/100ml)**			
EH11	1.00	0.29 **	0.50 **	0.50 **	1.00	-0.08	0.18	0.12
EH12	0.29 **	1.00	0.26 **	0.23 **	-0.08	1.00	0.21 *	0.06
EH16	0.50 **	0.26 **	1.00	0.43 **	0.18	0.21 *	1.00	0.39 **
EH17	0.50 **	0.23 **	0.43 **	1.00 **	0.12 **	0.06	0.39 **	1.00 **
	Cl (meq/l)				**TP (mg/l)**			
EH11	1.00	0.09	0.56 **	0.56 **	1.00	0.00	0.22 *	0.40 **
EH12	0.09	1.00	0.17 *	0.06	0.00	1.00	0.40 **	-0.08
EH16	0.56 **	0.17 *	1.00	0.59 **	0.22 *	0.40 **	1.00	-0.02
EH17	0.56 **	0.06 **	0.59 **	1.00 **	0.40 **	-0.08	-0.02	1.00 **
	SAR				**TN (mg/l)**			
EH11	1.00	0.12	0.59 **	0.48 **	1.00	0.41 **	0.40 **	0.34 **
EH12	0.12	1.00	0.22 **	0.13	0.41 **	1.00	0.54 **	0.30 **
EH16	0.59 **	0.22 **	1.00	0.52 **	0.40 **	0.54 **	1.00	0.18
EH17	0.48 **	0.13 **	0.52 **	1.00 **	0.34 **	0.30 **	0.18	1.00 **
	Adj_SAR				**Ni (mg/l)**			
EH11	1.00	0.16 *	0.57 **	0.49 **	1.00	0.54 **	0.44 **	0.60 **
EH12	0.16 *	1.00	0.26 **	0.21 **	0.54 **	1.00	0.50 **	0.54 **
EH16	0.57 **	0.26 **	1.00	0.51 **	0.44 **	0.50 **	1.00	0.33 **
EH17	0.49 **	0.21 **	0.51 **	1.00 **	0.60 **	0.54 **	0.33 **	1.00 **
	Temp (C^o)				**SO_{4_m} (meq/l)**			
EH11	1.00	0.82 **	0.89 **	0.84 **	1.00	0.14	0.55 **	0.50 **
EH12	0.82 **	1.00	0.86 **	0.76 **	0.14	1.00	0.34 **	0.24 *
EH16	0.89 **	0.86 **	1.00	0.80 **	0.55 **	0.34 **	1.00	0.50 **
EH17	0.84 **	0.76 **	0.80 **	1.00 **	0.50 **	0.24 **	0.50 **	1.00 **

** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).

ANNEX 4-6

MULTIVARIATE ANALYSIS OF VARIANCE AND DISCRIMINANT ANALYSIS FOR THE YEARLY AVERAGES OF SOME WQPs IN HADUS DRAIN

ANNEX 4-6A: MULTIVARIATE TEST STATISTICS

Annex 4-6A1: SPSS output of the multivariate test statistics for the yearly averages of some WQPs measured in site group 1

Annex 4-6A2: SPSS output of the multivariate test statistics for the yearly averages of some WQPs measured in site group 2

Annex 4-6A3: SPSS output of the multivariate test statistics for the yearly averages of some WQPs measured in site group 3

Annex 4-6A4: SPSS output of the multivariate test statistics for the yearly averages of some WQPs measured in site group 4

ANNEX 4-6B: LEVENE'S TEST

Annex 4-6B1: SPSS output for Levene's Test of Equality of Error Variances for the yearly averages of some WQPs measured in site group 1

Annex 4-6B2: SPSS output for Levene's Test of Equality of Error Variances for the yearly averages of some WQPs measured in site group 2

Annex 4-6B3: SPSS output for Levene's Test of Equality of Error Variances for the yearly averages of some WQPs measured in site group 3

Annex 4-6B4: SPSS output for Levene's Test of Equality of Error Variances for the yearly averages of some WQPs measured in site group 4

ANNEX 4-6C: TESTS OF BETWEEN-SUBJECTS EFFECTS

Annex 4-6C1: SPSS output of the Tests of Between-Subjects Effects for the yearly averages of some WQPs measured in site group 1

Annex 4-6C2: SPSS output of the Tests of Between-Subjects Effects for the yearly averages of some WQPs measured in site group 2

Annex 4-6C3: SPSS output of the Tests of Between-Subjects Effects for the yearly averages of some WQPs measured in site group 3

Annex 4-6C4: SPSS output of the Tests of Between-Subjects Effects for the yearly averages of some WQPs measured in site group 4

ANNEX 4-6D: RANGE TESTS

Annex 4-6D1: Range test (post hoc) results in MANOVA SPSS output, which were carried out for some WQPs in site group 1

Annex 4-6D2: Range test (post hoc) results in MANOVA SPSS output, which were carried out for some WQPs in site group 2

Annex 4-6D3: Range test (post hoc) results in MANOVA SPSS output, which were carried out for some WQPs in site group 3

Annex 4-6D4: Range test (post hoc) results in MANOVA SPSS output, which were carried out for some WQPs in site group 4

ANNEX 4-6E: CANONICAL DISCRIMINANT FUNCTIONS ANALYSIS

Annex 4-6E1: Canonical discriminant function analysis in SPSS output for some WQPs in site group 1

Annex 4-6E2: Canonical discriminant function analysis in SPSS output for some WQPs in site group 2

Annex 4-6E3: Canonical discriminant function analysis in SPSS output for some WQPs in site group 3

Annex 4-6E4: Canonical discriminant function analysis in SPSS output for some WQPs in site group 4

ANNEX 4-6F: STRUCTURE MATRICES

Annex 4-6F1: Structure matrix in SPSS output for some WQPs in site group 1

Annex 4-6F2: Structure matrix in SPSS output for some WQPs in site group 2

Annex 4-6F3: Structure matrix in SPSS output for some WQPs in site group 3

Annex 4-6F4: Structure matrix in SPSS output for some WQPs in site group 4

ANNEX 4-6G: FUNCTION (VARIATE) CENTROIDS

Annex 4-6G1: The values of the function (variate) centroids in SPSS output for some WQPs in site group 1

Annex 4-6G2: The values of the function (variate) centroids in SPSS output for some WQPs in site group 2

Annex 4-6G3: The values of the function (variate) centroids in SPSS output for some WQPs in site group 3

Annex 4-6G4: The values of the function (variate) centroids in SPSS output for some WQPs in site group 4

ANNEX 4-6H: COMBINED GROUPS PLOT

Annex 4-6H 1: Combined groups plot in SPSS output for some WQPs in site group 1

Annex 4-6H 2: Combined groups plot in SPSS output for some WQPs in site group 2

Annex 4-6H 3: Combined groups plot in SPSS output for some WQPs in site group 3

Annex 4-6H 4: Combined groups plot in SPSS output for some WQPs in site group 4

ANNEX 4-6I: CLASSIFICATION RESULTS

Annex 4-6I1: The overall classification results in SPSS output for some WQPs in site group 1

Annex 4-6I2: The overall classification results in SPSS output for some WQPs in site group 2

Annex 4-6I3: The overall classification results in SPSS output for some WQPs in site group 3

Annex 4-6I4: The overall classification results in SPSS output for some WQPs in site group 4

Annex 4-6A1: SPSS output of the multivariate test statistics for the yearly averages of some WQPs measured in site group 1

Effect		Value	F	Hypothesis df	Error df	Sig.	Noncent. Parameter	Observed Power
Intercept	Pillai's Trace	1.00	24605.58	19	10	0.000	467505.95	1.00
	Wilks' Lambda	0.00	24605.58	19	10	0.000	467505.95	1.00
	Hotelling's Trace	46750.60	24605.58	19	10	0.000	467505.95	1.00
	Roy's Largest Root	46750.60	24605.58	19	10	0.000	467505.95	1.00
Location	Pillai's Trace	2.23	1.818	57	36	0.029	103.63	0.98
	Wilks' Lambda	0.00	2.934	57	31	0.001	164.99	1.00
	Hotelling's Trace	33.59	5.107	57	26	0.000	291.08	1.00
	Roy's Largest Root	29.21	18.448	19	12	0.000	350.51	1.00

Annex 4-6A2: SPSS output of the multivariate test statistics for the yearly averages of some WQPs measured in site group 2

Effect		Value	F	Hypothesis df	Error df	Sig.	Noncent. Parameter	Observed Power
Intercept	Pillai's Trace	1.00	31880.20	11	18	0.000	350682.20	1.00
	Wilks' Lambda	0.00	31880.20	11	18	0.000	350682.20	1.00
	Hotelling's Trace	19482.34	31880.20	11	18	0.000	350682.20	1.00
	Roy's Largest Root	19482.34	31880.20	11	18	0.000	350682.20	1.00
Location	Pillai's Trace	2.04	3.876	33	60	0.000	127.90	1.00
	Wilks' Lambda	0.02	4.393	33	54	0.000	140.37	1.00
	Hotelling's Trace	9.45	4.775	33	50	0.000	157.57	1.00
	Roy's Largest Root	5.90	10.732	11	20	0.000	118.05	1.00

Annex 4-6A3: SPSS output of the multivariate test statistics for the yearly averages of some WQPs measured in site group 3

Effect		Value	F	Hypothesis df	Error df	Sig.	Noncent. Parameter	Observed Power
Intercept	Pillai's Trace	1.00	23650.73	13	16	0.000	307459.52	1.00
	Wilks' Lambda	0.00	23650.73	13	16	0.000	307459.52	1.00
	Hotelling's Trace	19216.22	23650.73	13	16	0.000	307459.52	1.00
	Roy's Largest Root	19216.22	23650.73	13	16	0.000	307459.52	1.00
Location	Pillai's Trace	1.93	2.491	39	54	0.001	97.14	1.00
	Wilks' Lambda	0.01	4.718	39	48	0.000	179.31	1.00
	Hotelling's Trace	23.43	8.810	39	44	0.000	343.58	1.00
	Roy's Largest Root	20.36	28.193	13	18	0.000	366.51	1.00

Annex 4-6A4: SPSS output of the multivariate test statistics for the yearly averages of some WQPs measured in site group 4

Effect		Value	F	Hypothesis df	Error df	Sig.	Noncent. Parameter	Observed Power
Intercept	Pillai's Trace	1.00	11303.15	15	14	0.000	169547.26	1.00
	Wilks' Lambda	0.00	11303.15	15	14	0.000	169547.26	1.00
	Hotelling's Trace	12110.52	11303.15	15	14	0.000	169547.26	1.00
	Roy's Largest Root	12110.52	11303.15	15	14	0.000	169547.26	1.00
Location	Pillai's Trace	2.21	2.978	45	48	0.000	134.02	1.00
	Wilks' Lambda	0.01	4.202	45	42	0.000	185.27	1.00
	Hotelling's Trace	23.07	6.495	45	38	0.000	292.28	1.00
	Roy's Largest Root	19.44	20.741	15	16	0.000	311.11	1.00

Note: All calculations were computed using alpha = 0.05

Annex 4-6B1: SPSS output for Levene's Test of Equality of Error Variances for the yearly averages of some WQPs measured in site group 1

Parameters	F	df_1	df_2	Sig.
BOD	1.853	3	28	0.160
COD	0.919	3	28	0.444
TSS	2.188	3	28	0.112
TVS	2.803	3	28	0.058
$N\text{-}NH_4$	0.034	3	28	0.991
pH	1.127	3	28	0.355
EC	10.805	3	28	0.000
TDS	4.280	3	28	0.013
Ca	0.515	3	28	0.675
Mg	4.611	3	28	0.010
Na	5.010	3	28	0.007
K	1.316	3	28	0.289
SO_4	0.467	3	28	0.708
Cl	1.949	3	28	0.145
SAR	4.649	3	28	0.009
Adj_SAR	2.460	3	28	0.083
Temp	0.402	3	28	0.752
Sal	4.773	3	28	0.008
Turb	0.132	3	28	0.940

Annex 4-6B2: SPSS output for Levene's Test of Equality of Error Variances for the yearly averages of some WQPs measured in site group 2

Parameters	F	df_1	df_2	Sig.
Cu	0.281	3	28	0.839
Fe	0.876	3	28	0.465
pH	0.176	3	28	0.912
TDS	3.139	3	28	0.041
Ca	3.656	3	28	0.024
Mg	4.871	3	28	0.008
K	0.492	3	28	0.691
SO_4	0.596	3	28	0.623
Cl	1.583	3	28	0.216
DO	4.914	3	28	0.007
Visib	0.757	3	28	0.528

Annex 4-6B3: SPSS output for Levene's Test of Equality of Error Variances for the yearly averages of some WQPs measured in site group 3

Parameters	F	df1	df2	Sig.
COD	0.097	3	28	0.961
Cu	1.513	3	28	0.233
Fe	0.443	3	28	0.724
pH	0.014	3	28	0.998
EC	3.137	3	28	0.041
TDS	1.990	3	28	0.138
Na	5.017	3	28	0.007
SO_4	1.843	3	28	0.162
Cl	4.977	3	28	0.007
Temp	0.340	3	28	0.796
Sal	3.629	3	28	0.025
DO	0.279	3	28	0.840
Turb	2.936	3	28	0.051

Annex 4-6B4: SPSS output for Levene's Test of Equality of Error Variances for the yearly averages of some WQPs measured in site group 4

Parameters	F	df1	df2	Sig.
BOD	0.570	3	28	0.639
Cu	1.595	3	28	0.213
Zn	26.273	3	28	0.000
pH	1.431	3	28	0.255
EC	1.111	3	28	0.361
TDS	1.400	3	28	0.263
Na	1.314	3	28	0.290
SO_4	2.361	3	28	0.093
Cl	0.961	3	28	0.425
SAR	1.152	3	28	0.346
Adj_SAR	1.105	3	28	0.364
Temp	1.356	3	28	0.276
Sal	1.281	3	28	0.300
Turb	3.192	3	28	0.039
Visib	1.157	3	28	0.343

Note: Levene’s test of equality of variances indicates that the assumption of equal variances is met when sig. > 0.05.

Annex 4-6C1: SPSS output of the Tests of Between-Subjects Effects for the yearly averages of some WQPs measured in site group 1

Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power
BOD	2151.41	3	717.14	0.583	0.631	1.75	0.16
COD	3971.93	3	1323.98	0.339	0.797	1.02	0.11
TSS	20383.74	3	6794.58	0.933	0.438	2.80	0.23
TVS	378.51	3	126.17	1.231	0.317	3.69	0.29
N-NH$_4$	3.52	3	1.17	0.036	0.991	0.11	0.06
pH	0.03	3	0.01	0.754	0.530	2.26	0.19
EC	1.31	3	0.44	23.123	0.000	69.37	1.00
TDS	498161.99	3	166054.00	24.993	0.000	74.98	1.00
Ca	0.86	3	0.29	0.576	0.636	1.73	0.15
Mg	1.20	3	0.40	1.414	0.260	4.24	0.33
Na	75.21	3	25.07	30.391	0.000	91.17	1.00
K	0.02	3	0.01	0.644	0.593	1.93	0.17
SO$_4$	0.91	3	0.30	0.203	0.893	0.61	0.08
Cl	93.26	3	31.09	23.123	0.000	69.37	1.00
SAR	15.21	3	5.07	26.254	0.000	78.76	1.00
Adj_SAR	91.37	3	30.46	18.943	0.000	56.83	1.00
Temp	0.30	3	0.10	0.147	0.931	0.44	0.07
Sal	0.56	3	0.19	32.465	0.000	97.39	1.00
Turb	1262.97	3	420.99	1.409	0.261	4.23	0.33

Annex 4-6C3: SPSS output of the Tests of Between-Subjects Effects for the yearly averages of some WQPs measured in site group 3

Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power
COD	403.68	3	134.56	0.023	0.995	0.07	0.05
Cu	0.00	3	0.00	0.358	0.783	1.08	0.11
Fe	0.04	3	0.01	0.222	0.880	0.67	0.09
pH	0.03	3	0.01	0.602	0.619	1.81	0.16
EC	30.33	3	10.11	65.153	0.000	195.46	1.00
TDS	11750563.07	3	3916854.36	89.780	0.000	269.34	1.00
Na	1292.54	3	430.85	52.906	0.000	158.72	1.00
SO$_4$	177.72	3	59.24	28.580	0.000	85.74	1.00
Cl	1334.22	3	444.74	45.727	0.000	137.18	1.00
Temp	0.79	3	0.26	0.631	0.601	1.89	0.16
Sal	11.90	3	3.97	78.392	0.000	235.18	1.00
DO	10.66	3	3.55	7.185	0.001	21.55	0.97
Turb	4008.68	3	1336.23	1.726	0.184	5.18	0.40

Annex 4-6C2: SPSS output of the Tests of Between-Subjects Effects for the yearly averages of some WQPs measured in site group 2

Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power
Cu	0.00	3	0.00	0.995	0.409	2.99	0.24
Fe	0.09	3	0.03	0.343	0.794	1.03	0.11
pH	0.02	3	0.01	0.497	0.687	1.49	0.14
TDS	351264.92	3	117088.31	21.670	0.000	65.01	1.00
Ca	4.78	3	1.59	5.646	0.004	16.94	0.91
Mg	3.05	3	1.02	3.685	0.024	11.05	0.74
K	0.01	3	0.00	0.399	0.755	1.20	0.12
SO$_4$	2.61	3	0.87	1.052	0.385	3.16	0.25
Cl	60.27	3	20.09	19.852	0.000	59.56	1.00
DO	38.32	3	12.77	19.981	0.000	59.94	1.00
Visib	393.10	3	131.03	1.512	0.233	4.54	0.35

Annex 4-6C4: SPSS output of the Tests of Between-Subjects Effects for the yearly averages of some WQPs measured in site group 4

Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power
BOD	1562.13	3	520.71	0.276	0.842	0.83	0.10
Cu	0.00	3	0.00	0.400	0.754	1.20	0.12
Zn	0.01	3	0.00	3.448	0.030	10.34	0.71
pH	0.04	3	0.01	0.517	0.674	1.55	0.14
EC	7.77	3	2.59	19.990	0.000	59.97	1.00
TDS	2686149.35	3	895383.12	20.238	0.000	60.71	1.00
Na	311.67	3	103.89	11.619	0.000	34.86	1.00
SO$_4$	27.33	3	9.11	3.620	0.025	10.86	0.73
Cl	329.17	3	109.72	11.351	0.000	34.05	1.00
SAR	43.50	3	14.50	5.152	0.006	15.45	0.88
Adj_SAR	304.97	3	101.66	7.528	0.001	22.58	0.97
Temp	0.66	3	0.22	0.299	0.826	0.90	0.10
Sal	2.83	3	0.94	21.189	0.000	63.57	1.00
Turb	11562.22	3	3854.07	6.400	0.002	19.20	0.94
Visib	1776.38	3	592.13	6.536	0.002	19.61	0.95

Note: The parameters with sig. >0.05, do not have significant differences between their means at 95% level of confidence.

Annex 4-6D1: Range test (post hoc) results in MANOVA SPSS output which were carried out for some WQPs in site group 1

Dependent Variable	Range Test	(I) Locations	(J) Locations	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
EC	Tamhane	EH02	EH03	-0.41 *	0.07	0.007	-0.70	-0.12
			EH14	0.11	0.07	0.070	-0.01	0.24
			EH18	0.03	0.07	0.990	-0.11	0.17
		EH03	EH14	0.52 *	0.07	0.001	0.23	0.82
			EH18	0.44 *	0.07	0.004	0.15	0.73
		EH14	EH18	-0.08	0.07	0.347	-0.22	0.05
TDS	Tamhane	EH02	EH03	-260.05 *	40.76	0.002	-420.19	-99.92
			EH14	61.67	40.76	0.320	-31.80	155.13
			EH18	6.52	40.76	1.000	-93.05	106.09
		EH03	EH14	321.72 *	40.76	0.000	164.14	479.30
			EH18	266.57 *	40.76	0.002	107.60	425.54
		EH14	EH18	-55.15	40.76	0.380	-143.56	33.27
Na	Tamhane	EH02	EH03	-3.06 *	0.45	0.002	-4.97	-1.15
			EH14	0.94	0.45	0.088	-0.11	1.98
			EH18	0.24	0.45	0.981	-0.81	1.29
		EH03	EH14	3.99 *	0.45	0.000	2.12	5.87
			EH18	3.30 *	0.45	0.002	1.42	5.18
		EH14	EH18	-0.70	0.45	0.071	-1.44	0.04
CL	LSD	EH02	EH03	-3.35 *	0.58	0.000	-4.53	-2.16
			EH14	1.10	0.58	0.067	-0.08	2.29
			EH18	0.35	0.58	0.547	-0.83	1.54
		EH03	EH14	4.45 *	0.58	0.000	3.26	5.64
			EH18	3.70 *	0.58	0.000	2.51	4.89
		EH14	EH18	-0.75	0.58	0.206	-1.94	0.44
SAR	Tamhane	EH02	EH03	-1.33 *	0.22	0.006	-2.27	-0.38
			EH14	0.49	0.22	0.057	-0.01	1.00
			EH18	0.14	0.22	0.952	-0.36	0.64
		EH03	EH14	1.82 *	0.22	0.001	0.89	2.75
			EH18	1.46 *	0.22	0.004	0.53	2.39
		EH14	EH18	-0.36 *	0.22	0.021	-0.67	-0.04
ADJ_SAR	LSD	EH02	EH03	-3.26 *	0.63	0.000	-4.56	-1.96
			EH14	1.17	0.63	0.075	-0.13	2.47
			EH18	0.37	0.63	0.561	-0.93	1.67
		EH03	EH14	4.43 *	0.63	0.000	3.14	5.73
			EH18	3.64 *	0.63	0.000	2.34	4.93
		EH14	EH18	-0.80	0.63	0.218	-2.10	0.50
Sal	Tamhane	EH02	EH03	-0.27 *	0.04	0.000	-0.42	-0.13
			EH14	0.06	0.04	0.244	-0.03	0.16
			EH18	0.01	0.04	1.000	-0.09	0.12
		EH03	EH14	0.34 *	0.04	0.000	0.20	0.48
			EH18	0.29 *	0.04	0.000	0.14	0.43
		EH14	EH18	-0.05	0.04	0.421	-0.14	0.04

(*): The mean differences are significant at 95% level of confidence.

Annex 4-6D2: Range test (post hoc) results in MANOVA SPSS output which were carried out for some WQPs in site group 2

Dependent Variable	Range Test	(I) Locations	(J) Locations	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
TDS	Tamhane	EH04	EH05	42.60	36.75	0.713	-51.81	137.01
			EH06	-231.76 *	36.75	0.001	-372.06	-91.46
			EH15	-42.80	36.75	0.682	-134.71	49.12
		EH05	EH06	-274.36 *	36.75	0.000	-411.71	-137.02
			EH15	-85.40 *	36.75	0.040	-167.80	-3.00
		EH06	EH15	188.96 *	36.75	0.007	52.45	325.48
Ca	Tamhane	EH04	EH05	0.08	0.27	1.000	-0.77	0.93
			EH06	-0.90 *	0.27	0.014	-1.63	-0.17
			EH15	-0.34	0.27	0.869	-1.29	0.61
		EH05	EH06	-0.98 *	0.27	0.005	-1.67	-0.29
			EH15	-0.42	0.27	0.705	-1.35	0.51
		EH06	EH15	0.56	0.27	0.289	-0.29	1.40
Mg	Tamhane	EH04	EH05	0.01	0.26	1.000	-0.58	0.61
			EH06	-0.75	0.26	0.179	-1.74	0.24
			EH15	-0.21	0.26	0.884	-0.81	0.39
		EH05	EH06	-0.76	0.26	0.193	-1.78	0.25
			EH15	-0.22	0.26	0.917	-0.91	0.46
		EH06	EH15	0.54	0.26	0.526	-0.47	1.55
Cl	LSD	EH04	EH05	0.56	0.50	0.279	-0.47	1.59
			EH06	-2.98 *	0.50	0.000	-4.01	-1.95
			EH15	-0.17	0.50	0.742	-1.20	0.86
		EH05	EH06	-3.53 *	0.50	0.000	-4.57	-2.50
			EH15	-0.72	0.50	0.162	-1.75	0.31
		EH06	EH15	2.81 *	0.50	0.000	1.78	3.84
DO	Tamhane	EH04	EH05	-2.10 *	0.40	0.006	-3.58	-0.63
			EH06	-3.02 *	0.40	0.000	-4.10	-1.94
			EH15	-1.73 *	0.40	0.000	-2.52	-0.94
		EH05	EH06	-0.91	0.40	0.444	-2.48	0.65
			EH15	0.37	0.40	0.966	-1.11	1.85
		EH06	EH15	1.28 *	0.40	0.018	0.20	2.37
Visib	LSD	EH04	EH05	-1.55	4.66	0.741	-11.09	7.98
			EH06	-4.93	4.66	0.299	-14.46	4.61
			EH15	-9.13	4.66	0.060	-18.67	0.40
		EH05	EH06	-3.38	4.66	0.474	-12.91	6.16
			EH15	-7.58	4.66	0.115	-17.11	1.96
		EH06	EH15	-4.20	4.66	0.374	-13.74	5.33

(*): The mean differences are significant at 95% level of confidence.

Annex 4-6D3: Range test (post hoc) results in MANOVA SPSS output which were carried out for some WQPs in site group 3

Dependent Variable	Range Test	(I) Locations	(J) Locations	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
EC	Tamhane	EH07	EH08	-1.19 *	0.20	0.002	-1.98	-0.40
			EH09	1.53 *	0.20	0.000	0.86	2.20
			EH10	-0.16	0.20	0.971	-0.84	0.51
		EH08	EH09	2.73 *	0.20	0.000	2.08	3.37
			EH10	1.03 *	0.20	0.002	0.38	1.68
		EH09	EH10	-1.70 *	0.20	0.000	-2.03	-1.37
TDS	LSD	EH07	EH08	-772.49 *	104.44	0.000	-986.41	-558.56
			EH09	929.45 *	104.44	0.000	715.53	1143.38
			EH10	-95.62	104.44	0.368	-309.54	118.31
		EH08	EH09	1701.94 *	104.44	0.000	1488.01	1915.87
			EH10	676.87 *	104.44	0.000	462.94	890.80
		EH09	EH10	-1025.07*	104.44	0.000	-1239.00	-811.14
Na	Tamhane	EH07	EH08	-8.40 *	1.43	0.004	-14.14	-2.66
			EH09	9.39 *	1.43	0.000	5.83	12.95
			EH10	-1.72	1.43	0.738	-5.64	2.21
		EH08	EH09	17.79 *	1.43	0.000	12.28	23.30
			EH10	6.68 *	1.43	0.017	1.11	12.26
		EH09	EH10	-11.11 *	1.43	0.000	-13.97	-8.25
SO_4	LSD	EH07	EH08	-2.61 *	0.72	0.001	-4.08	-1.14
			EH09	3.98 *	0.72	0.000	2.50	5.45
			EH10	-0.06	0.72	0.932	-1.54	1.41
		EH08	EH09	6.59 *	0.72	0.000	5.11	8.06
			EH10	2.55 *	0.72	0.001	1.07	4.02
		EH09	EH10	-4.04 *	0.72	0.000	-5.52	-2.57
Cl	Tamhane	EH07	EH08	-8.91 *	1.56	0.010	-15.70	-2.12
			EH09	9.26 *	1.56	0.000	6.27	12.24
			EH10	-1.42	1.56	0.779	-4.81	1.98
		EH08	EH09	18.17 *	1.56	0.000	11.37	24.96
			EH10	7.49 *	1.56	0.029	0.73	14.26
		EH09	EH10	-10.67 *	1.56	0.000	-13.29	-8.05
Sal	Tamhane	EH07	EH08	-0.77 *	0.11	0.001	-1.21	-0.32
			EH09	0.94 *	0.11	0.000	0.58	1.30
			EH10	-0.12	0.11	0.913	-0.49	0.25
		EH08	EH09	1.71 *	0.11	0.000	1.33	2.09
			EH10	0.65 *	0.11	0.001	0.26	1.04
		EH09	EH10	-1.06 *	0.11	0.000	-1.28	-0.84
DO	LSD	EH07	EH08	0.04	0.35	0.903	-0.68	0.76
			EH09	1.43 *	0.35	0.000	0.71	2.16
			EH10	0.47	0.35	0.192	-0.25	1.19
		EH08	EH09	1.39 *	0.35	0.000	0.67	2.11
			EH10	0.43	0.35	0.235	-0.29	1.15
		EH09	EH10	-0.97 *	0.35	0.010	-1.69	-0.24

(*) The mean differences are significant at 95% level of confidence.

Annex 4-6D4: Range test (post hoc) results in MANOVA SPSS output which were carried out for some WQPs in site group 4

Dependent Variable	Range Test	(I) Locations	(J) Locations	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Zn	Tamhane	EH11	EH12	-0.01	0.01	0.694	-0.02	0.01
			EH16	-0.03	0.01	0.470	-0.08	0.03
			EH17	0.00	0.01	0.883	-0.01	0.02
		EH12	EH16	-0.02	0.01	0.663	-0.08	0.03
			EH17	0.01	0.01	0.193	0.00	0.02
		EH16	EH17	0.03	0.01	0.344	-0.02	0.09
EC	LSD	EH11	EH12	-0.64 *	0.18	0.001	-1.01	-0.27
			EH16	0.70 *	0.18	0.001	0.33	1.07
			EH17	-0.30	0.18	0.104	-0.67	0.07
		EH12	EH16	1.34 *	0.18	0.000	0.97	1.71
			EH17	0.34	0.18	0.071	-0.03	0.71
		EH16	EH17	-1.00 *	0.18	0.000	-1.37	-0.63
TDS	LSD	EH11	EH12	-383.80 *	105.17	0.001	-599.23	-168.37
			EH16	403.51 *	105.17	0.001	188.08	618.94
			EH17	-178.81	105.17	0.100	-394.24	36.62
		EH12	EH16	787.31 *	105.17	0.000	571.88	1002.74
			EH17	204.99	105.17	0.061	-10.44	420.42
		EH16	EH17	-582.32 *	105.17	0.000	-797.75	-366.89
Na	LSD	EH11	EH12	-4.29 *	1.50	0.008	-7.36	-1.23
			EH16	4.23 *	1.50	0.009	1.17	7.29
			EH17	-1.89	1.50	0.216	-4.95	1.17
		EH12	EH16	8.52 *	1.50	0.000	5.46	11.59
			EH17	2.40	1.50	0.119	-0.66	5.47
		EH16	EH17	-6.12 *	1.50	0.000	-9.18	-3.06
SO_4	LSD	EH11	EH12	-1.32	0.79	0.107	-2.95	0.30
			EH16	0.93	0.79	0.252	-0.70	2.55
			EH17	-1.20	0.79	0.141	-2.83	0.42
		EH12	EH16	2.25 *	0.79	0.008	0.62	3.87
			EH17	0.12	0.79	0.882	-1.51	1.74
		EH16	EH17	-2.13 *	0.79	0.012	-3.76	-0.51
Cl	LSD	EH11	EH12	-4.31 *	1.55	0.010	-7.49	-1.13
			EH16	4.58 *	1.55	0.006	1.40	7.77
			EH17	-1.37	1.55	0.384	-4.56	1.81
		EH12	EH16	8.89 *	1.55	0.000	5.71	12.08
			EH17	2.94	1.55	0.069	-0.25	6.12
		EH16	EH17	-5.95 *	1.55	0.001	-9.14	-2.77

(*): The mean differences are significant at 95% level of confidence.

Annex 4-6D4: Range test (post hoc) results in MANOVA SPSS output which were carried out for some WQPs in site group 4

Dependent Variable	Range Test	(I) Locations	(J) Locations	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
SAR	LSD	EH11	EH12	-1.33	0.84	0.123	-3.05	0.38
			EH16	1.88 *	0.84	0.033	0.16	3.60
			EH17	-0.35	0.84	0.678	-2.07	1.37
		EH12	EH16	3.22 *	0.84	0.001	1.50	4.93
			EH17	0.98	0.84	0.251	-0.74	2.70
		EH16	EH17	-2.23 *	0.84	0.013	-3.95	-0.52
Adj_SAR	LSD	EH11	EH12	-3.72	1.84	0.052	-7.49	0.04
			EH16	4.74 *	1.84	0.015	0.98	8.51
			EH17	-1.34	1.84	0.472	-5.10	2.43
		EH12	EH16	8.47 *	1.84	0.000	4.70	12.23
			EH17	2.38	1.84	0.205	-1.38	6.15
		EH16	EH17	-6.08 *	1.84	0.003	-9.85	-2.32
Sal	LSD	EH11	EH12	-0.37 *	0.11	0.001	-0.59	-0.16
			EH16	0.44 *	0.11	0.000	0.22	0.65
			EH17	-0.16	0.11	0.152	-0.37	0.06
		EH12	EH16	0.81 *	0.11	0.000	0.60	1.03
			EH17	0.22 *	0.11	0.048	0.00	0.43
		EH16	EH17	-0.59 *	0.11	0.000	-0.81	-0.38
Turb	Tamhane	EH11	EH12	-34.18	12.27	0.249	-82.07	13.71
			EH16	8.71	12.27	0.982	-30.42	47.84
			EH17	15.10	12.27	0.787	-23.48	53.68
		EH12	EH16	42.89 *	12.27	0.041	1.48	84.31
			EH17	49.28 *	12.27	0.017	8.30	90.26
		EH16	EH17	6.39	12.27	0.957	-16.70	29.47
Visib	LSD	EH11	EH12	10.01 *	4.76	0.044	0.27	19.76
			EH16	-6.49	4.76	0.184	-16.24	3.26
			EH17	-9.39	4.76	0.058	-19.14	0.35
		EH12	EH16	-16.50 *	4.76	0.002	-26.25	-6.76
			EH17	-19.41 *	4.76	0.000	-29.16	-9.66
		EH16	EH17	-2.91	4.76	0.546	-12.65	6.84

(*): The mean differences are significant at 95% level of confidence.

Annex 4-6E1: Canonical discriminant function analysis in SPSS output for some WQPs in site group 1

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	29.21	86.97	86.97	0.98
2	3.44	10.23	97.19	0.88
3	0.94	2.81	100.00	0.70

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 3	0.004	108.45	57.00	0.000
2 through 3	0.116	41.99	36.00	0.227
3	0.515	12.94	17.00	0.740

Annex 4-6E2: Canonical discriminant function analysis in SPSS output for some WQPs in site group 2

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	5.90	62.43	62.43	0.92
2	2.71	28.69	91.12	0.85
3	0.84	8.88	100.00	0.68

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 3	0.021	90.54	33.00	0.000
2 through 3	0.146	45.14	20.00	0.001
3	0.544	14.32	9.00	0.111

Annex 4-6E3: Canonical discriminant function analysis in SPSS output for some WQPs in site group 3

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	20.36	86.92	86.92	0.98
2	2.75	11.72	98.64	0.86
3	0.32	1.36	100.00	0.49

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 3	0.009	104.83	39.00	0.000
2 through 3	0.202	35.94	24.00	0.056
3	0.758	6.23	11.00	0.857

Annex 4-6E4: Canonical discriminant function analysis in SPSS output for some WQPs in site group 4

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	19.44	84.27	84.27	0.98
2	2.40	10.39	94.66	0.84
3	1.23	5.34	100.00	0.74

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 3	0.006	108.45	45.00	0.000
2 through 3	0.132	43.56	28.00	0.031
3	0.448	17.27	13.00	0.187

Annex 4-6F1: Structure matrix in SPSS output for some WQPs in site group 1

Variables	Function		
	1	2	3
BOD	0.34 *	-0.03	-0.01
COD	0.33 *	0.02	-0.01
TSS	0.31 *	0.05	-0.02
TVS	0.30 *	-0.02	-0.04
$N\text{-}NH_4$	0.29 *	0.00	0.00
pH	0.29 *	0.03	0.02
EC	0.26 *	0.04	0.01
TDS	0.07 *	0.00	-0.07
Ca	0.05 *	-0.03	0.02
Mg	0.04 *	-0.03	-0.02
Na	-0.01 *	0.01	-0.01
K	0.05	-0.16 *	0.10
SO_4	0.01	0.06 *	0.00
Cl	0.05	-0.02	-0.15 *
SAR	0.03	-0.10	-0.15 *
Adj_SAR	-0.04	0.00	0.13 *
Temp	0.06	-0.03	-0.10 *
Sal	-0.03	-0.01	0.07 *
Turb	0.03	-0.01	-0.05 *

Annex 4-6F2: Structure matrix in SPSS output for some WQPs in site group 2

Variables	Function		
	1	2	3
TDS	0.62 *	0.13	0.18
Cl	0.58 *	0.11	0.36
Ca	0.32 *	0.04	-0.05
Mg	0.26 *	0.01	0.05
SO_4	0.14 *	0.00	-0.05
DO	0.44	-0.60 *	-0.08
K	-0.07	0.08 *	-0.02
Visib	0.08	-0.02	-0.38 *
Cu	-0.05	-0.01	0.33 *
Fe	-0.03	0.01	0.20 *
pH	0.07	-0.06	0.14 *

Annex 4-6F3: Structure matrix in SPSS output for some WQPs in site group 3

Variables	Function		
	1	2	3
TDS	0.69 *	-0.11	-0.10
Sal	0.64 *	-0.10	0.01
EC	0.58 *	-0.07	0.03
Na	0.53 *	-0.13	0.02
Cl	0.49 *	-0.13	-0.15
SO_4	0.39 *	0.01	-0.01
DO	0.18	0.22 *	0.16
Turb	0.06	0.20 *	-0.18
Fe	0.00	0.09 *	-0.01
Temp	-0.04	0.01	0.31 *
pH	0.05	0.03	-0.19 *
Cu	0.03	0.06	0.08 *
COD	0.00	-0.02	0.03 *

Annex 4-6F4: Structure matrix in SPSS output for some WQPs in site group 4

Variables	Function		
	1	2	3
Sal	0.34 *	0.07	-0.13
TDS	0.33 *	0.07	-0.18
EC	0.33 *	0.08	-0.17
Na	0.25 *	0.04	-0.14
Cl	0.25 *	0.01	-0.09
Adj_SAR	0.20 *	0.04	-0.05
SAR	0.17 *	0.03	-0.01
pH	0.05 *	-0.02	-0.02
Turb	0.13	-0.39 *	0.06
Visib	-0.13	0.37 *	-0.21
Zn	-0.11	-0.24 *	-0.09
Temp	-0.01	0.11 *	0.03
Cu	-0.02	-0.10 *	0.09
SO_4	0.13	0.09	-0.19 *
BOD	-0.02	0.05	0.12 *

(*****): Largest absolute correlation between each variable and any discriminant function

Annex 4-6G1: The values of the function (variate) centroids in SPSS output for some WQPs in site group 1

Locations	Function		
	1	2	3
EH02	-1.67	2.62	0.71
EH03	8.57	-0.60	0.09
EH14	-4.51	-2.19	0.71
EH18	-2.38	0.16	-1.51

Annex 4-6G2: The values of the function (variate) centroids in SPSS output for some WQPs in site group 2

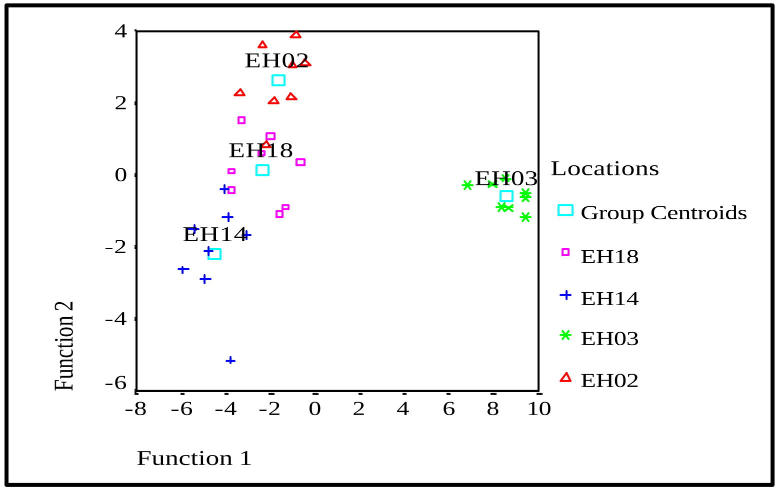
Locations	Function		
	1	2	3
EH04	-1.88	2.10	0.58
EH05	-1.86	-2.24	0.39
EH06	3.69	-0.06	0.51
EH15	0.05	0.20	-1.48

Annex 4-6G3: The values of the function (variate) centroids in SPSS output for some WQPs in site group 3

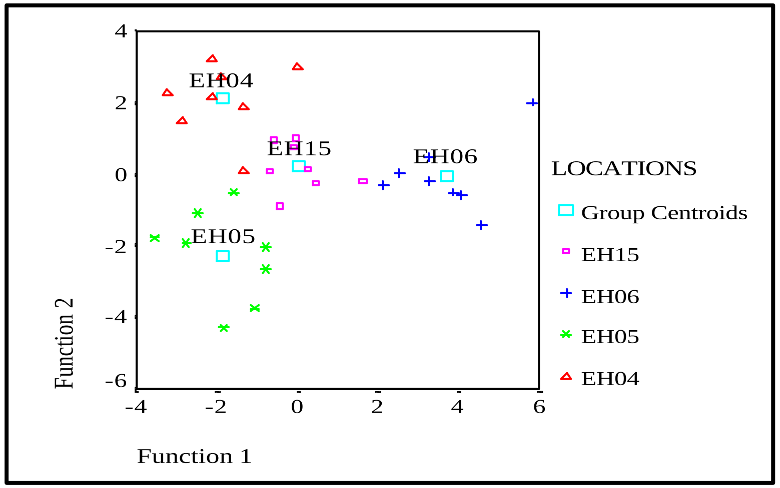
Locations	Function		
	1	2	3
EH07	0.53	2.67	0.06
EH08	5.27	-0.94	-0.55
EH09	-6.53	-0.66	-0.34
EH10	0.73	-1.07	0.83

Annex 4-6G4: The values of the function (variate) centroids in SPSS output for some WQPs in site group 4

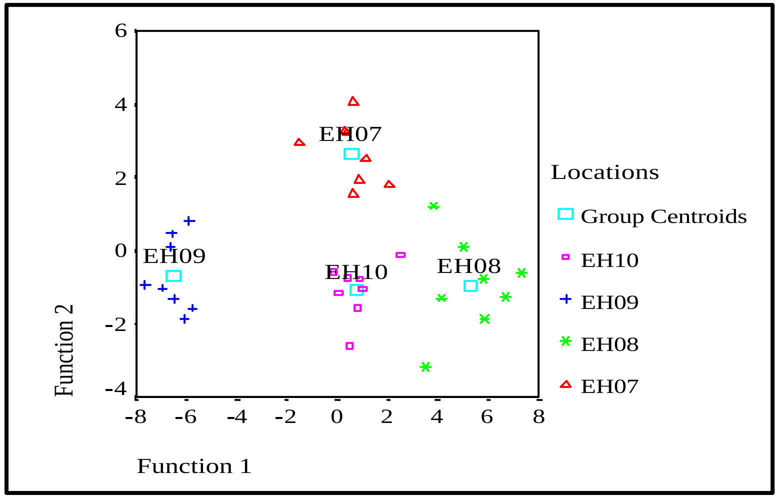
Locations	Function		
	1	2	3
EH11	0.23	0.63	1.74
EH12	5.13	-1.68	-0.35
EH16	-6.38	-1.00	-0.38
EH17	1.02	2.05	-1.01



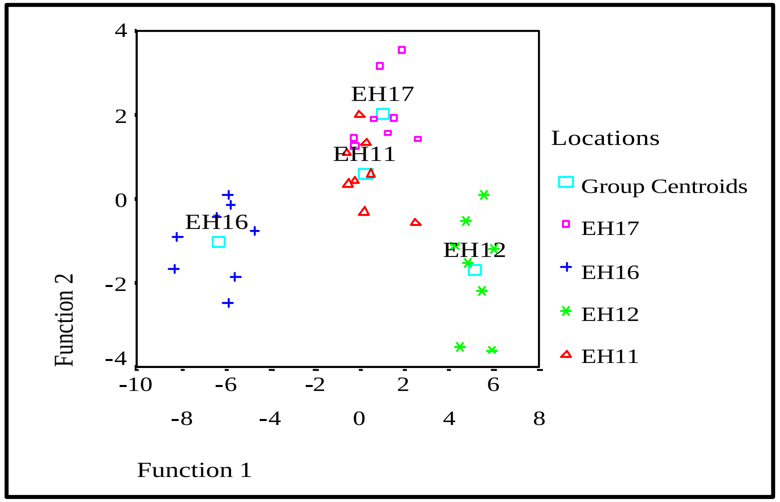
Annex 4-6H 1: Combined groups plot in SPSS output for some WQPs in site group 1



Annex 4-6H 2: Combined groups plot in SPSS output for some WQPs in site group 2



Annex 4-6H 3: Combined groups plot in SPSS output for some WQPs in site group 3



Annex 4-6H 4: Combined groups plot in SPSS output for some WQPs in site group 4

Annex 4-6I1: The overall classification results in SPSS output for some WQPs in site group 1

	Locations	Predicted Group Membership				Total
		EH02	EH03	EH14	EH18	
Count	EH02	8	0	0	0	8
	EH03	0	8	0	0	8
	EH14	0	0	8	0	8
	EH18	0	0	0	8	8
%	EH02	100%	0	0	0	100%
	EH03	0	100%	0	0	100%
	EH14	0	0	100%	0	100%
	EH18	0	0	0	100%	100%

100.0% of original grouped cases correctly classified.

Annex 4-6I2: The overall classification results in SPSS output for some WQPs in site group 2

	Locations	Predicted Group Membership				Total
		EH04	EH05	EH06	EH15	
Count	EH04	7	0	0	1	8
	EH05	0	8	0	0	8
	EH06	0	0	8	0	8
	EH15	0	0	0	8	8
%	EH04	87.5%	0	0	12.5	100%
	EH05	0	100%	0	0	100%
	EH06	0	0	100%	0	100%
	EH15	0	0	0	100%	100%

96.9% of original grouped cases correctly classified.

Annex 4-6I3: The overall classification results in SPSS output for some WQPs in site group 3

	Locations	Predicted Group Membership				Total
		EH07	EH08	EH09	EH10	
Count	EH07	8	0	0	0	8
	EH08	0	8	0	0	8
	EH09	0	0	8	0	8
	EH10	0	0	0	8	8
%	EH07	100%	0	0	0	100%
	EH08	0	100%	0	0	100%
	EH09	0	0	100%	0	100%
	EH10	0	0	0	100%	100%

100.0% of original grouped cases correctly classified.

Annex 4-6I4: The overall classification results in SPSS output for some WQPs in site group 4

	Locations	Predicted Group Membership				Total
		EH11	EH12	EH16	EH17	
Count	EH11	7	0	0	1	8
	EH12	0	8	0	0	8
	EH16	0	0	8	0	8
	EH17	1	0	0	7	8
%	EH11	88%	0	0	12.5	100%
	EH12	0	100%	0	0	100%
	EH16	0	0	100%	0	100%
	EH17	12.5	0	0	88%	100%

93.8% of original grouped cases correctly classified.

ANNEX 4-7

WILCOXON SIGNED RANK TEST SIGNIFICANT RESULTS FOR THE MONTHLY MEASUREMENTS OF 36 WQPs AT SOME ADJACENT MONITORING SITES IN HADUS DRAIN

Annex 4-7: Wilcoxon Signed Rank test significant results to compare the monthly measurements of 36 WQPs at some adjacent monitoring sites in Hadus drain

Parameters	**Site Group 1**			**Site Group 2**		
	EH02 - EH14	**EH18 - EH14**	**EH18 - EH02**	**EH05 - EH04**	**EH15 - EH04**	**EH15 - EH05**
Coli (MPN/100ml)	0.028	0.001	0.554	0.000	0.000	0.057
BOD (mg/l)	0.149	0.594	0.093	0.000	0.000	0.909
COD (mg/l)	0.069	0.762	0.129	0.000	0.000	0.677
TSS (mg/l)	0.750	0.007	0.102	0.394	0.006	0.000
TVS (mg/l)	0.756	0.024	0.204	0.532	0.010	0.001
N-NO$_3$ (mg/l)	0.216	0.258	0.144	0.176	0.803	0.185
N-NH$_4$ (mg/l)	0.165	0.092	0.514	0.054	0.489	0.367
P (mg/l)	0.000	0.101	0.029	0.000	0.000	0.062
Cd (mg/l)	0.346	0.731	0.713	0.380	0.245	0.202
Cu (mg/l)	0.183	0.149	0.008	0.000	0.000	0.321
Fe (mg/l)	0.003	0.001	0.380	0.800	0.205	0.287
Mn (mg/l)	0.017	0.076	0.004	0.000	0.001	0.775
Zn (mg/l)	0.586	0.266	0.948	0.516	0.128	0.179
Pb (mg/l)	0.575	0.122	0.058	0.840	0.654	0.066
Br (mg/l)	0.163	0.082	0.043	0.000	0.000	0.094
pH	0.015	0.068	0.198	0.078	0.863	0.499
EC (dS/m)	0.000	0.000	0.449	0.012	0.004	0.000
TDS (mg/l)	0.000	0.000	0.841	0.029	0.001	0.000
Ca (meq/l)	0.101	0.151	0.636	0.057	0.000	0.000
Mg (meq/l)	0.426	0.004	0.096	0.541	0.056	0.073
Na (meq/l)	0.000	0.000	0.788	0.006	0.142	0.000
K (meq/l)	0.221	0.663	0.337	0.001	0.061	0.070
SO$_4$ (meq/l)	0.708	0.092	0.498	0.978	0.208	0.058
Cl (meq/l)	0.000	0.000	0.393	0.500	0.814	0.789
SAR	0.000	0.000	0.455	0.002	0.015	0.391
Adj_SAR	0.000	0.000	0.790	0.078	0.147	0.374
Temp (C^o)	0.598	0.004	0.271	0.000	0.123	0.121
Sal	0.000	0.000	0.370	0.027	0.000	0.000
DO (mg/l)	0.000	0.000	0.324	0.000	0.000	0.060
Turb (NTU)	0.000	0.006	0.070	0.728	0.000	0.001
Visib (Cm)	0.313	0.506	0.056	0.525	0.000	0.000
Fecal (MPN/100ml)	0.139	0.012	0.527	0.003	0.000	0.146
TP (mg/l)	0.000	0.002	0.225	0.050	0.116	0.263
TN (mg/l)	0.726	0.802	0.503	0.062	0.261	0.327
Ni (mg/l)	0.117	0.136	0.902	0.925	0.829	0.799
SO$_{4\_m}$ (meq/l)	0.576	0.623	0.372	0.841	0.080	0.059

Test Significance: the location pair does not significantly differ if alpha is greater than or equal 0.05.

Annex 4-7 Cont.: Wilcoxon Signed Rank test significant results to compare the monthly measurements of 36 WQPs at some adjacent monitoring sites in Hadus drain

Parameters	Site Group 3				Site Group 4		
	EH08 - EH07	EH09 - EH07	EH10 - EH07	EH10 - EH09	EH17 - EH11	EH12 - EH16	EH17 - EH12
Coli (MPN/100ml)	0.598	0.000	0.000	0.489	0.191	0.001	0.167
BOD (mg/l)	0.172	0.173	0.068	0.901	0.057	0.076	0.084
COD (mg/l)	0.236	0.055	0.050	0.704	0.004	0.091	0.400
TSS (mg/l)	0.876	0.051	0.009	0.898	0.016	0.000	0.000
TVS (mg/l)	0.740	0.053	0.113	0.651	0.003	0.000	0.000
N-NO$_3$ (mg/l)	0.262	0.000	0.074	0.057	0.125	0.081	0.576
N-NH$_4$ (mg/l)	0.469	0.001	0.214	0.088	0.007	0.279	0.804
P (mg/l)	0.056	0.001	0.004	0.122	0.347	0.000	0.000
Cd (mg/l)	0.964	0.573	0.896	0.400	0.830	0.334	0.775
Cu (mg/l)	0.135	0.900	0.097	0.098	0.010	0.739	0.103
Fe (mg/l)	0.133	0.318	0.018	0.126	0.733	0.191	0.069
Mn (mg/l)	0.452	0.009	0.101	0.060	0.454	0.055	0.075
Zn (mg/l)	0.624	0.276	0.196	0.234	0.001	0.011	0.002
Pb (mg/l)	0.237	0.000	0.066	0.079	0.401	0.057	0.216
Br (mg/l)	0.137	0.126	0.049	0.232	0.338	0.883	0.246
pH	0.075	0.005	0.054	0.155	0.881	0.001	0.119
EC (dS/m)	0.000	0.000	0.002	0.000	0.000	0.000	0.000
TDS (mg/l)	0.000	0.000	0.015	0.000	0.000	0.000	0.000
Ca (meq/l)	0.000	0.000	0.465	0.000	0.001	0.000	0.000
Mg (meq/l)	0.000	0.000	0.544	0.000	0.000	0.000	0.598
Na (meq/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K (meq/l)	0.000	0.000	0.002	0.000	0.121	0.055	0.174
SO$_4$ (meq/l)	0.000	0.000	0.711	0.000	0.000	0.000	0.339
Cl (meq/l)	0.000	0.000	0.002	0.000	0.005	0.000	0.000
SAR	0.000	0.000	0.000	0.000	0.007	0.000	0.006
Adj_SAR	0.000	0.000	0.000	0.000	0.001	0.000	0.002
Temp (C^o)	0.003	0.169	0.084	0.946	0.735	0.601	0.056
Sal	0.000	0.000	0.002	0.000	0.000	0.000	0.000
DO (mg/l)	0.212	0.000	0.001	0.000	0.674	0.007	0.000
Turb (NTU)	0.292	0.048	0.000	0.766	0.002	0.000	0.000
Visib (Cm)	0.162	0.169	0.000	0.180	0.000	0.000	0.000
Fecal (MPN/100ml)	0.674	0.000	0.000	0.001	0.075	0.033	0.158
TP (mg/l)	0.004	0.000	0.285	0.000	0.000	0.131	0.000
TN (mg/l)	0.828	0.004	0.217	0.332	0.053	0.780	0.783
Ni (mg/l)	0.115	0.074	0.056	1.000	0.146	0.809	0.350
SO$_{4\_m}$ (meq/l)	0.000	0.000	0.808	0.000	0.004	0.000	0.109

Test Significance: the location pair does not significantly differ if alpha is greater than or equal 0.05.

ANNEX 4-8

LINEAR REGRESSION ANALYSIS FOR THE WQPs MEASURED AT SOME MONITORING LOCATIONS IN HADUS DRAIN

ANNEX 4-8A: SITE GROUP 1

Annex 4-8A1: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH02 and EH14

Annex 4-8A2: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH18 and EH14

Annex 4-8A3: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH02 and EH18

ANNEX 4-8B: SITE GROUP 2

Annex 4-8B1: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH04 and EH15

Annex 4-8B2: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH04 and EH05

Annex 4-8B3: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH15 and EH05

ANNEX 4-8C: SITE GROUP 3

Annex 4-8C1: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH08 and EH07

Annex 4-8C2: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH09 and EH07

Annex 4-8C3: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH10 and EH07

Annex 4-8C4: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH10 and EH09

Annex 4-8C5: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH11 and EH10

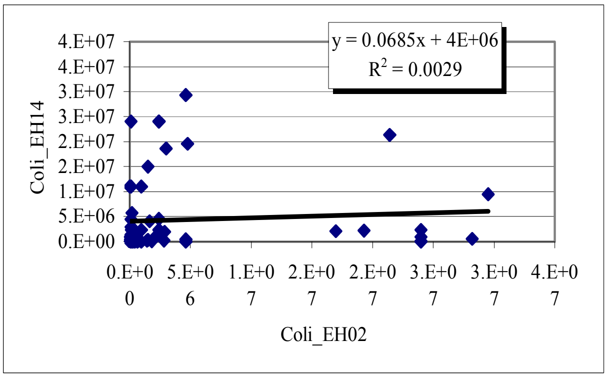
ANNEX 4-8D: SITE GROUP 4

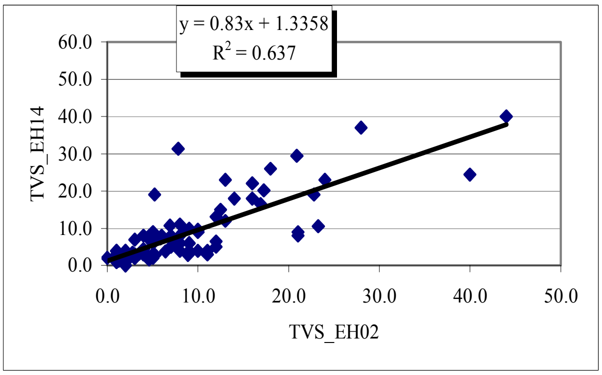
Annex 4-8D1: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH11 and EH17

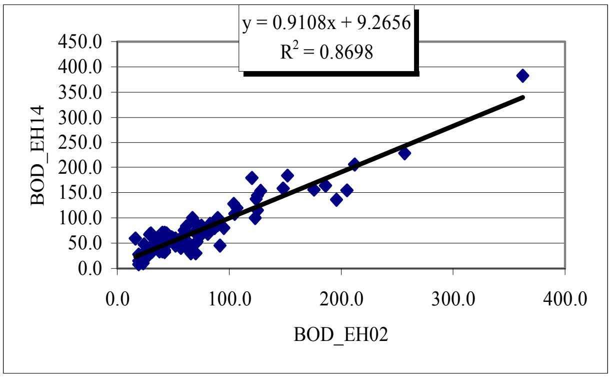
Annex 4-8D2: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH12 and EH16

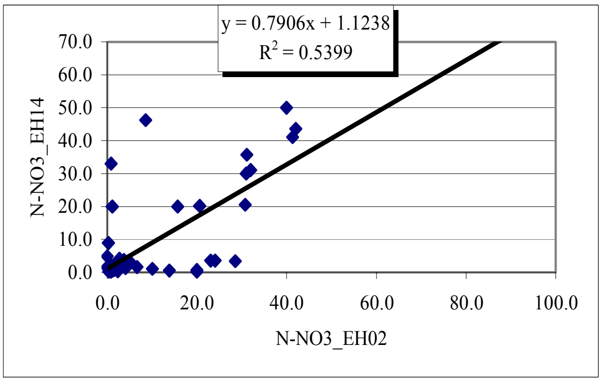
Annex 4-8D3: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH17 and EH12

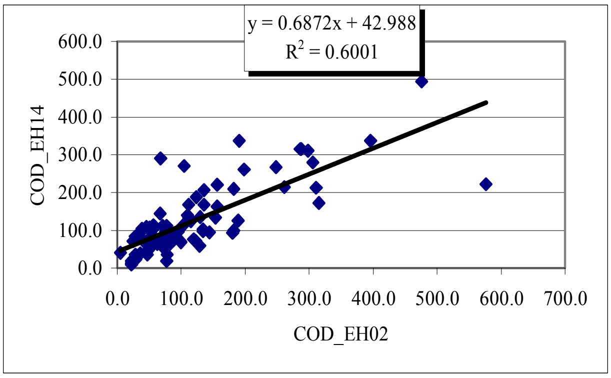
Annex 4-8A1: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH02 and EH14

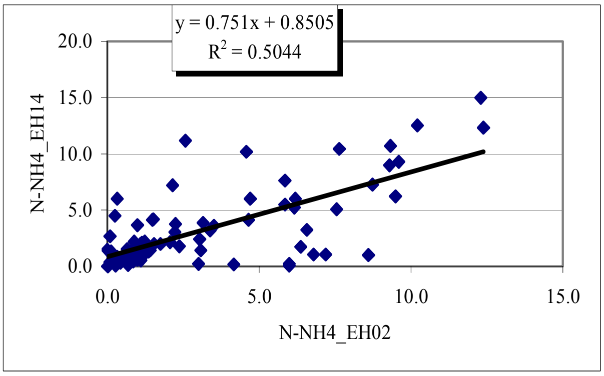


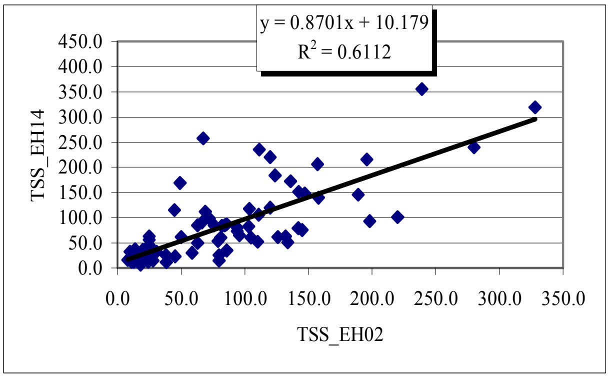


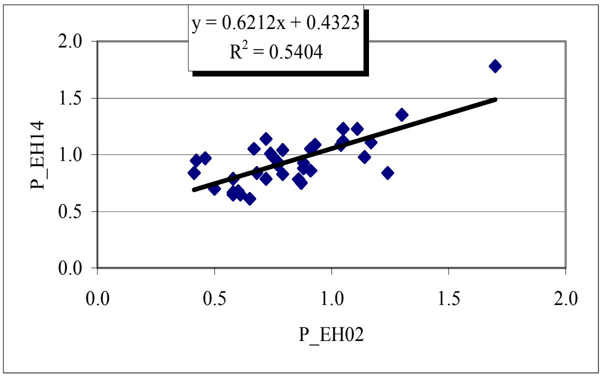




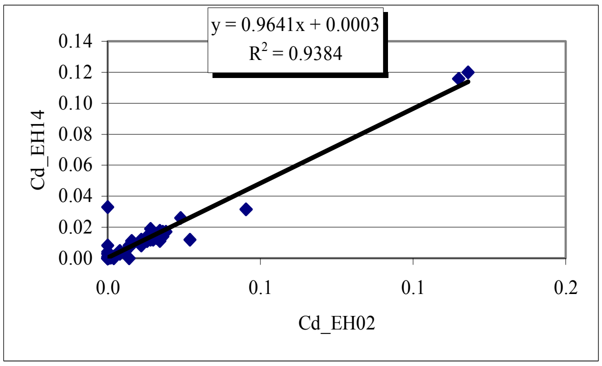


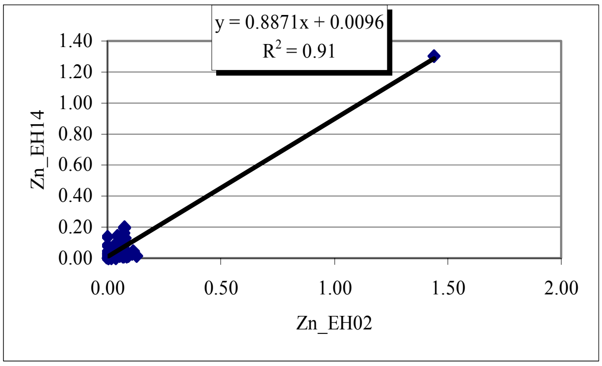


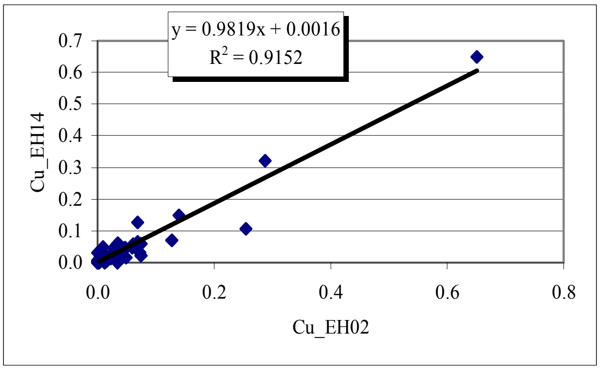


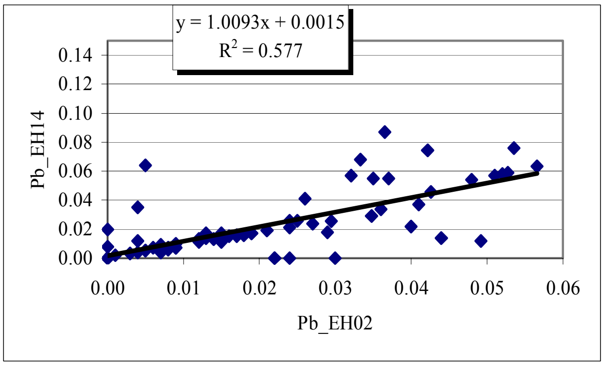


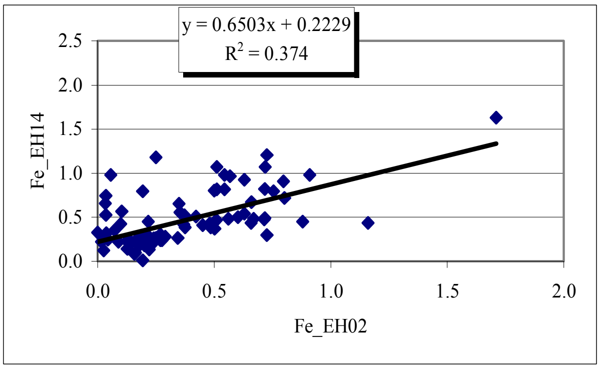
Annex 4-8A1 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH02 and EH14

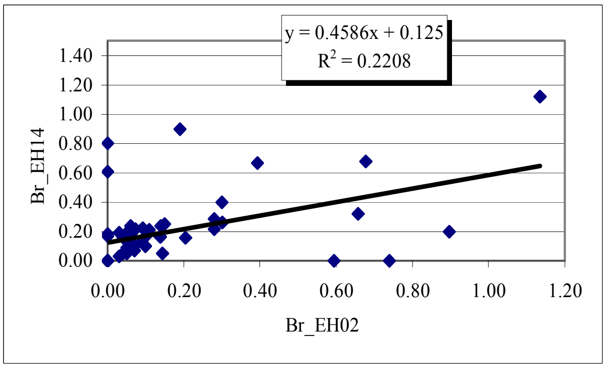


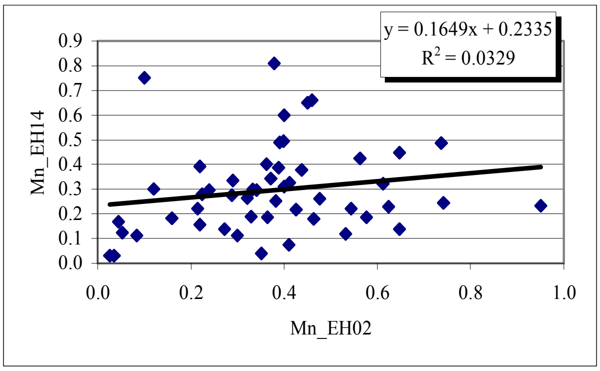


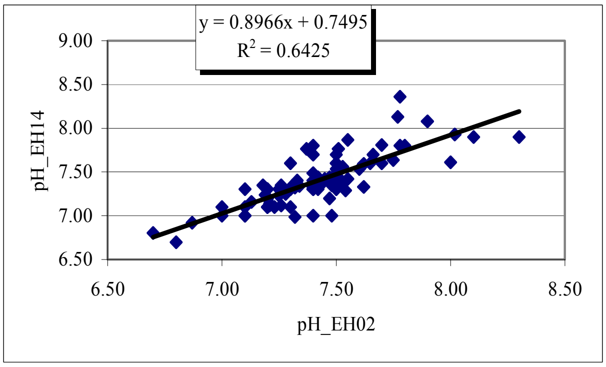




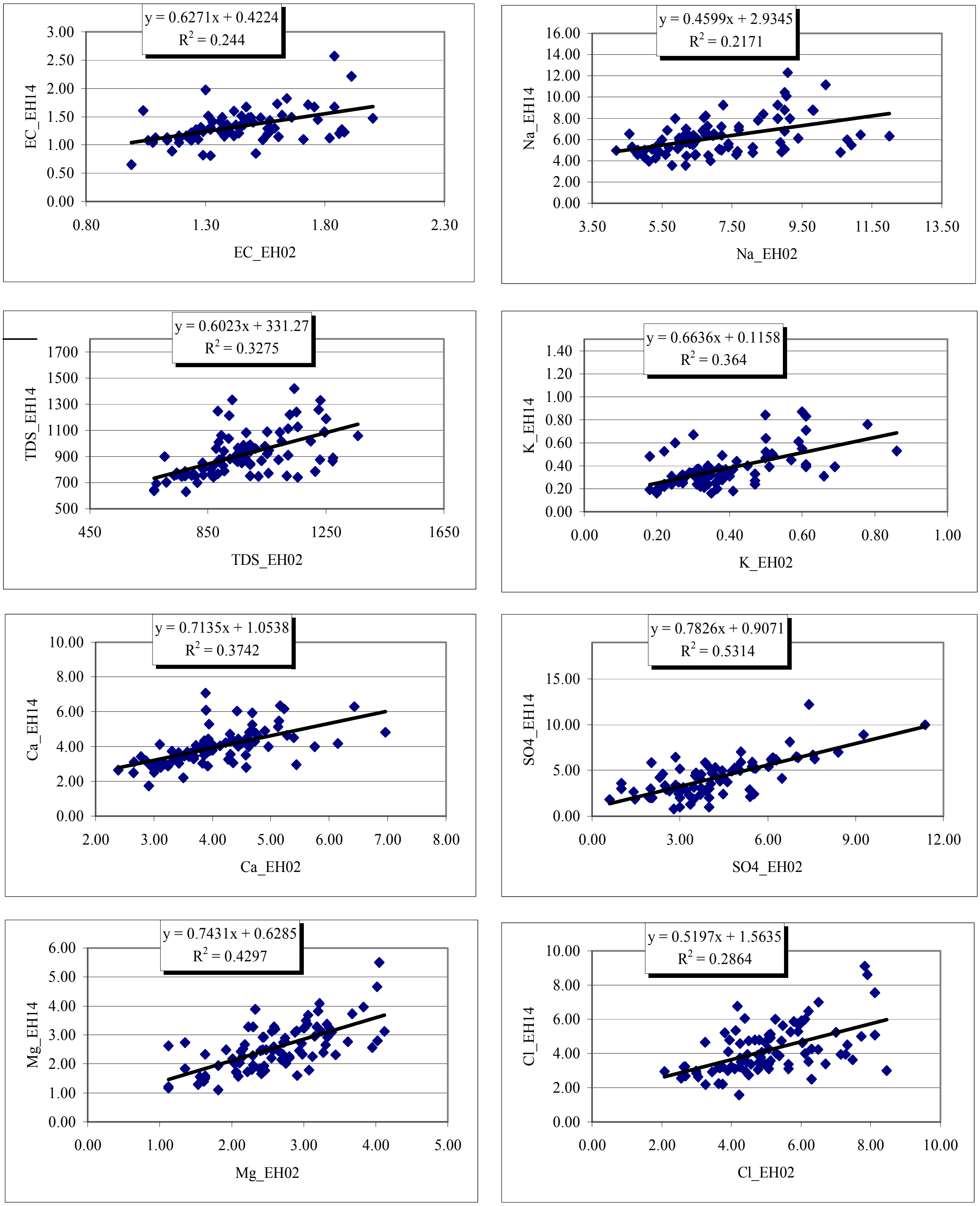




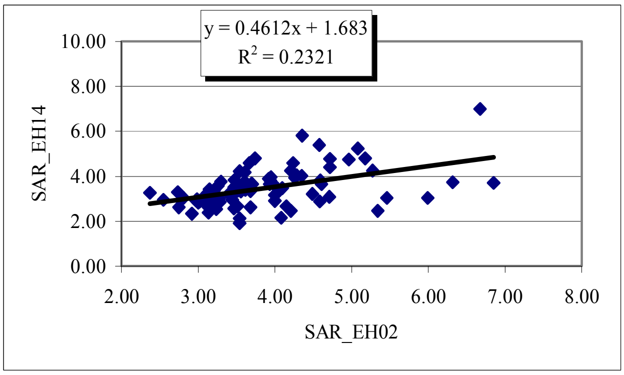


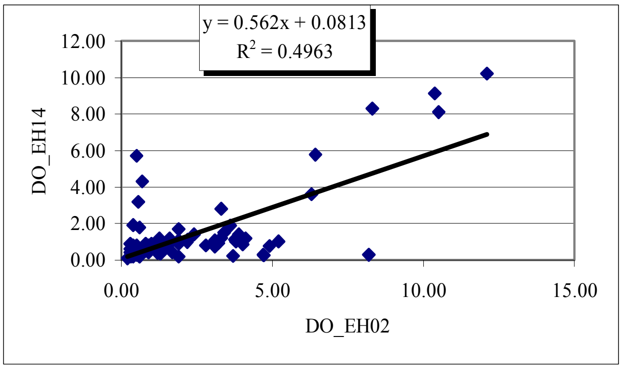


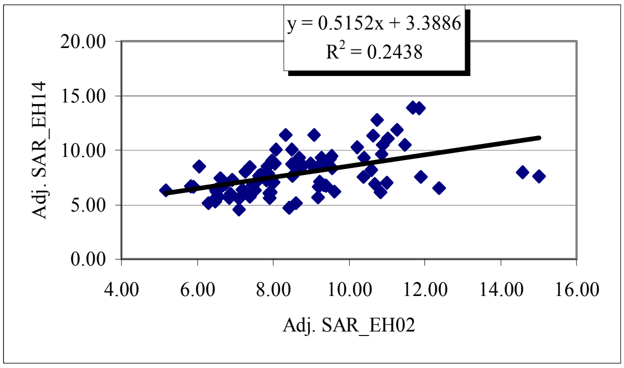
Annex 4-8A1 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH02 and EH14

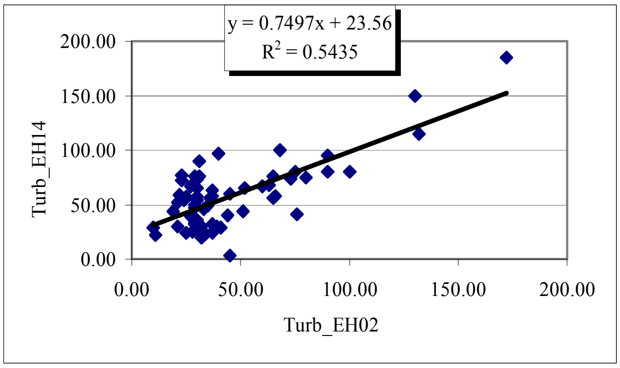


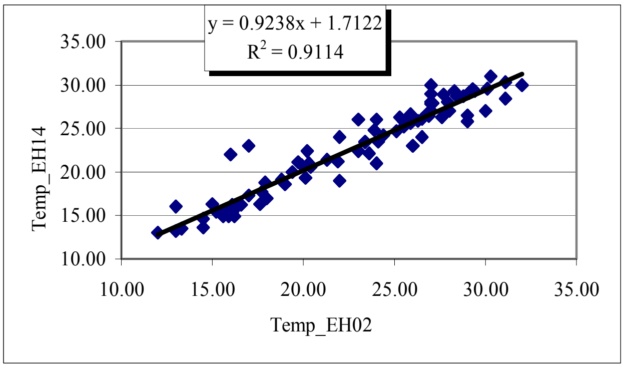
Annex 4-8A1 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH02 and EH14

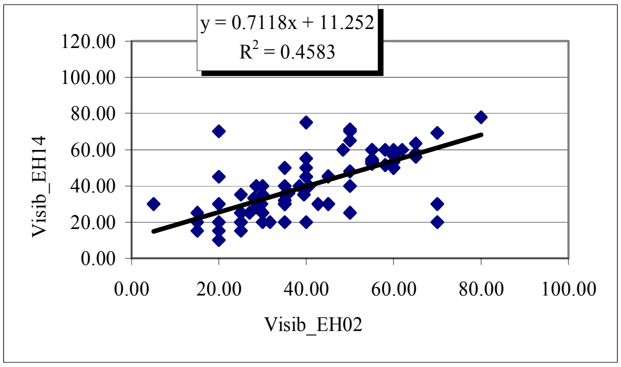


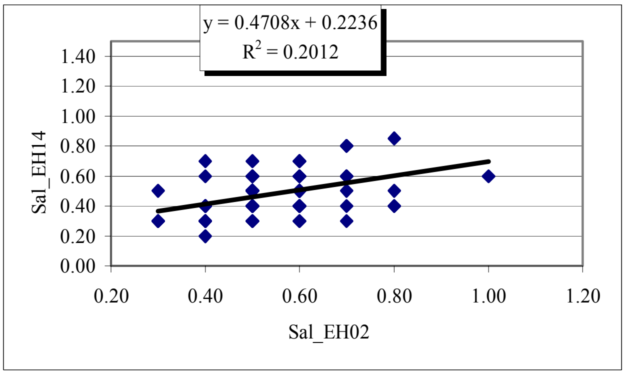


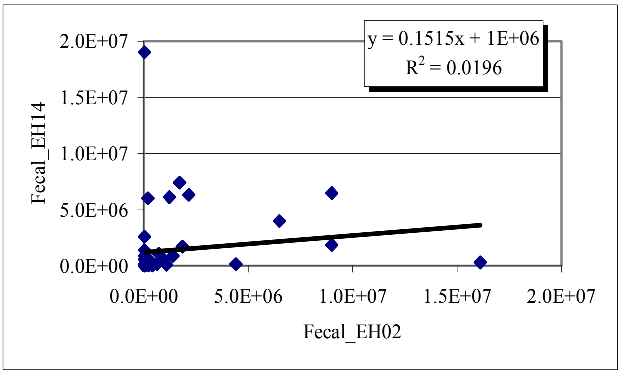




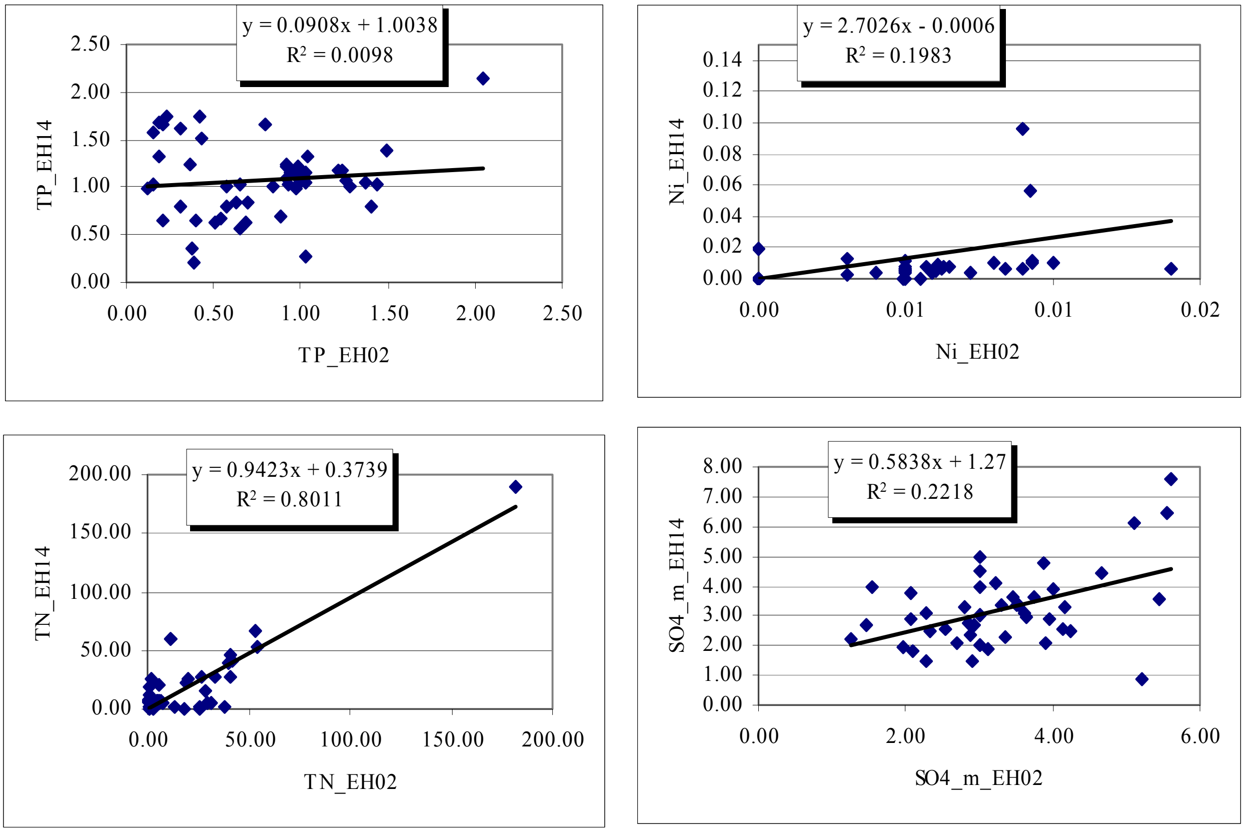




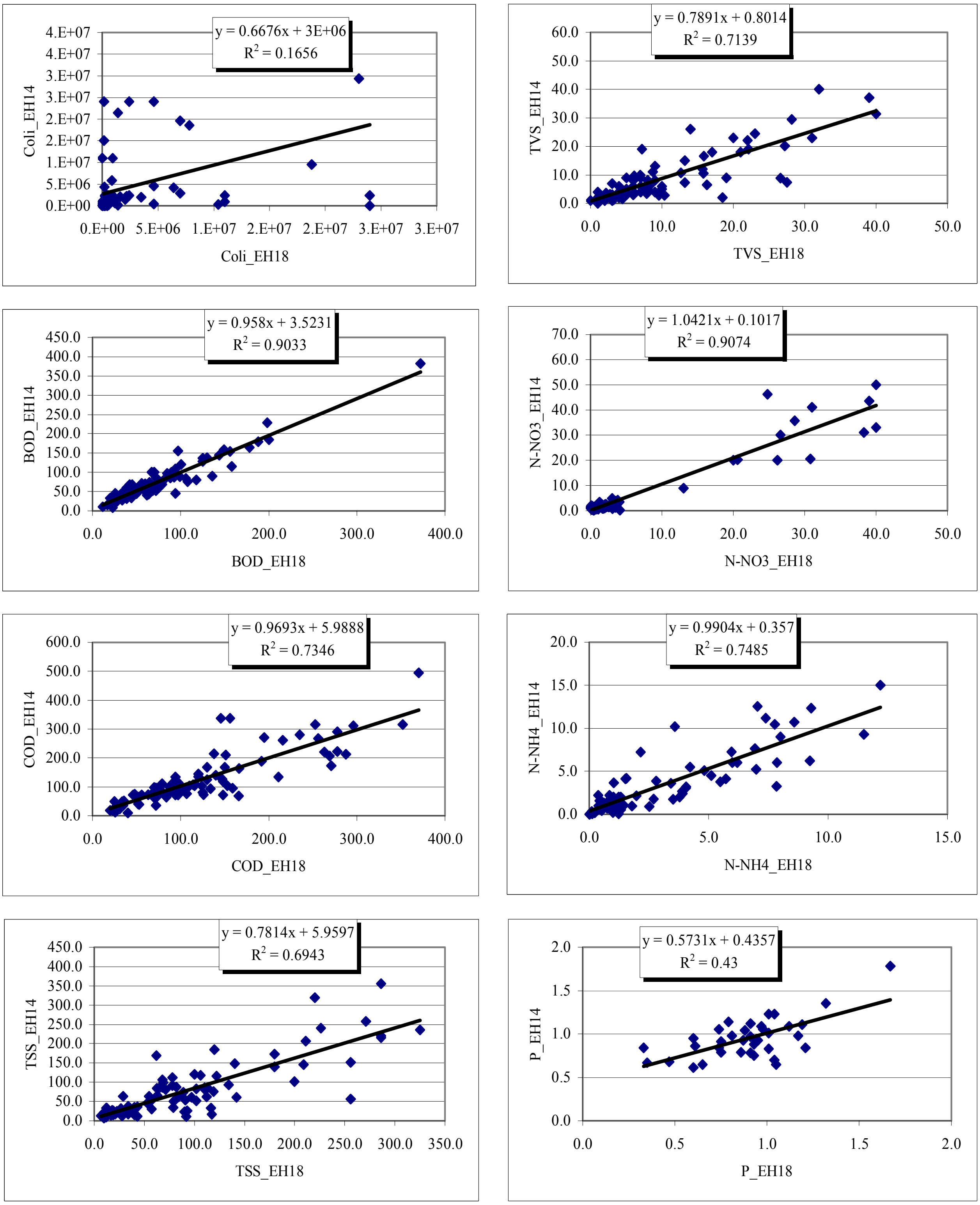




Annex 4-8A1 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH02 and EH14



Annex 4-8A2: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH14 and EH18



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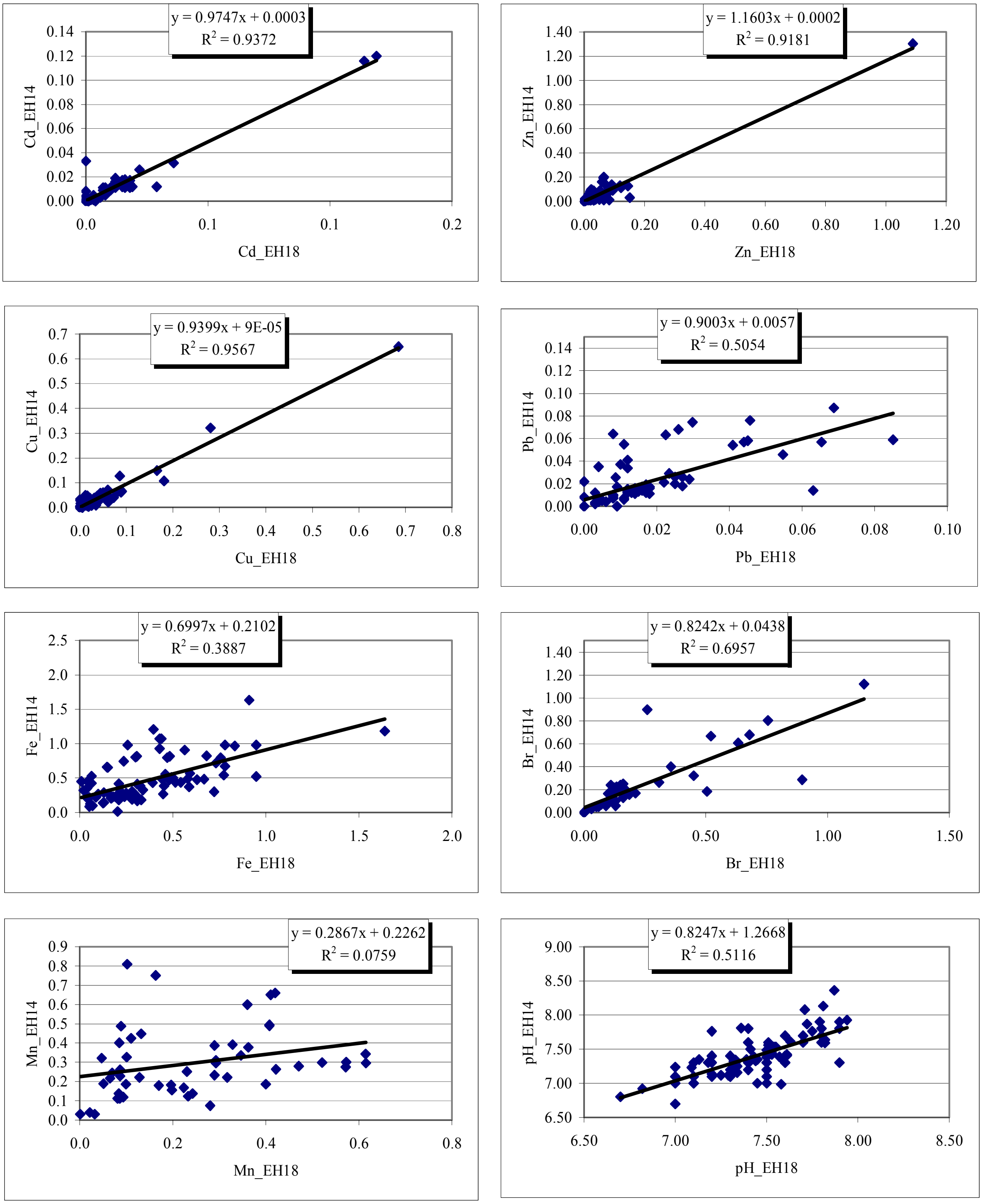

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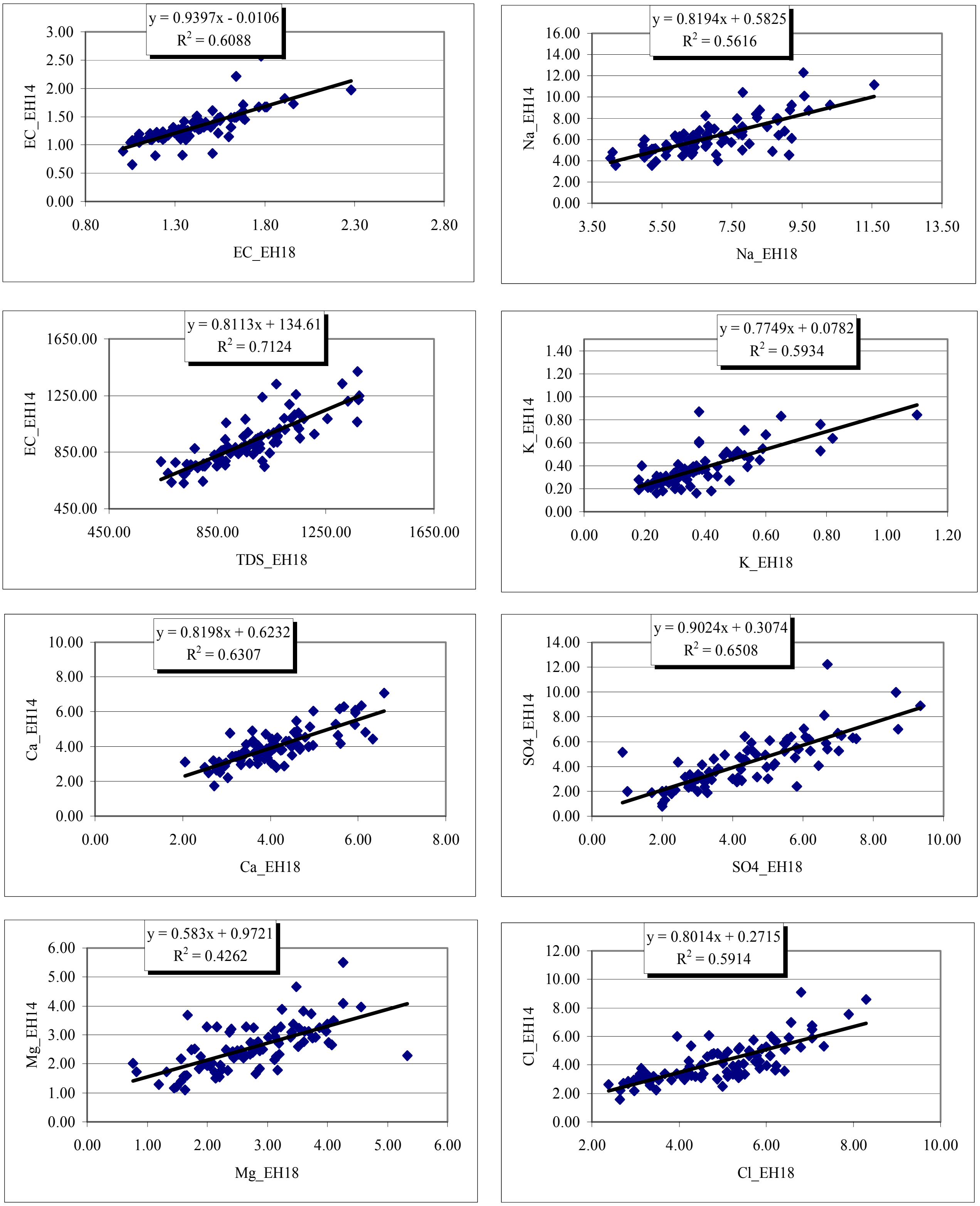

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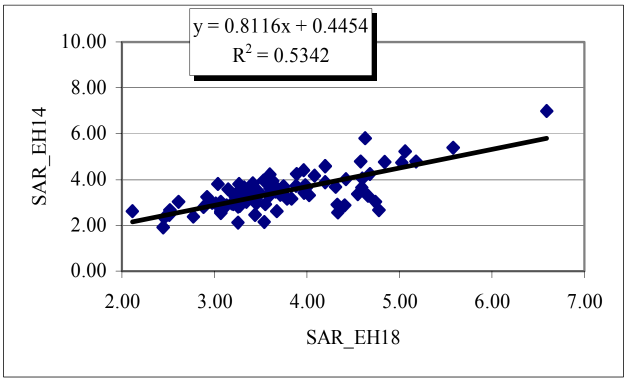
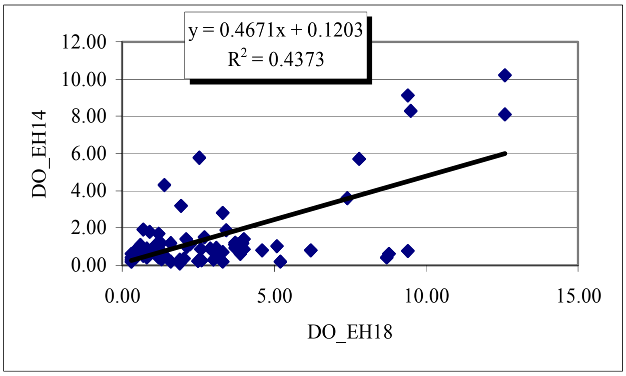
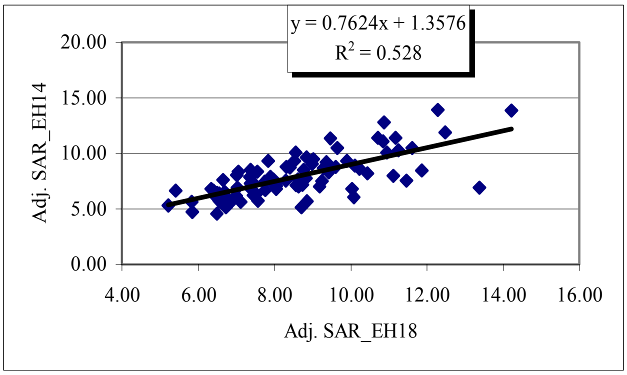
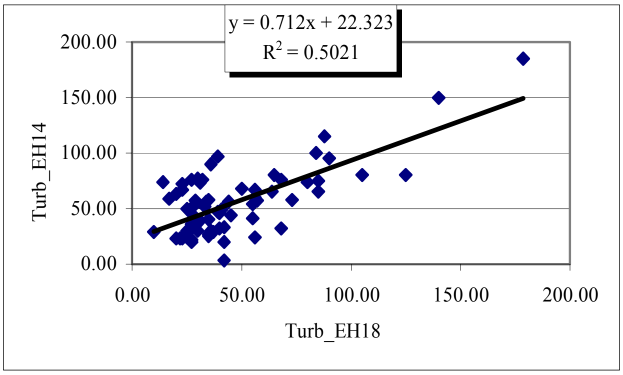
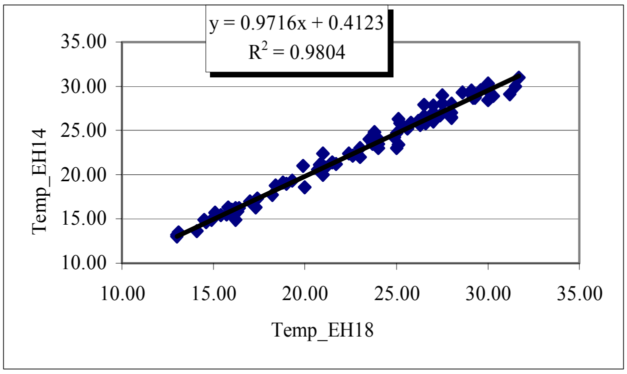
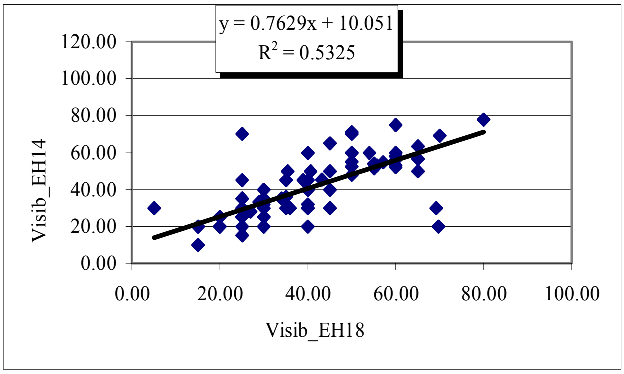


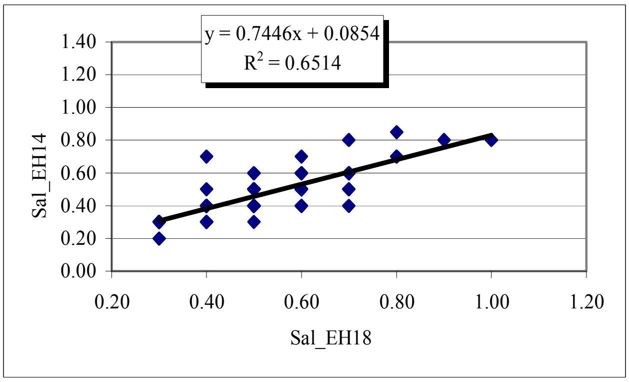


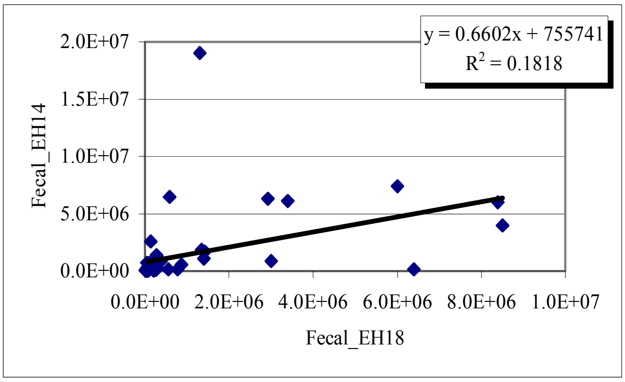




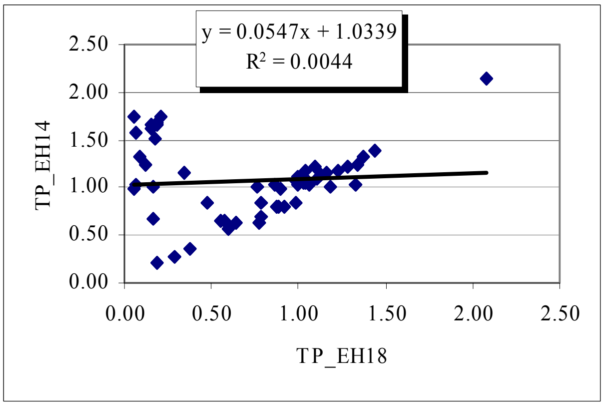


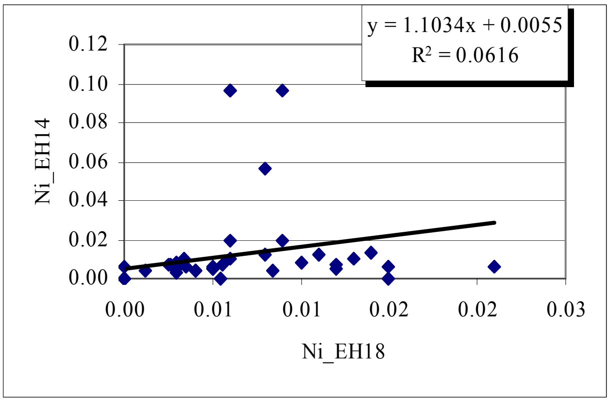


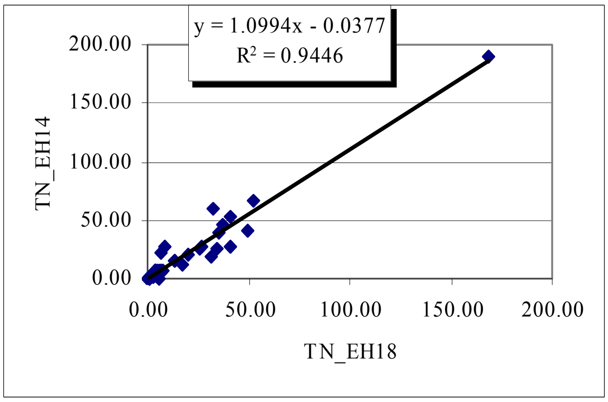


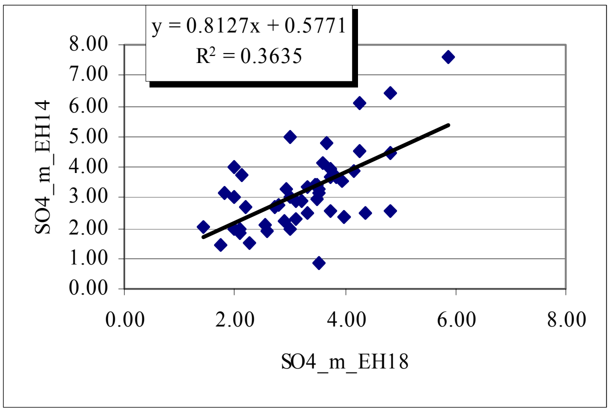


Annex 4-8A2 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH14 and EH18

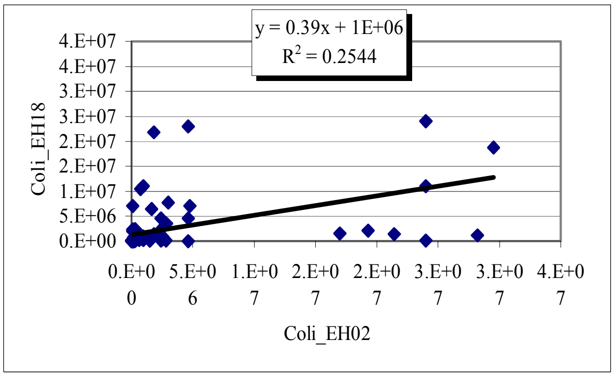


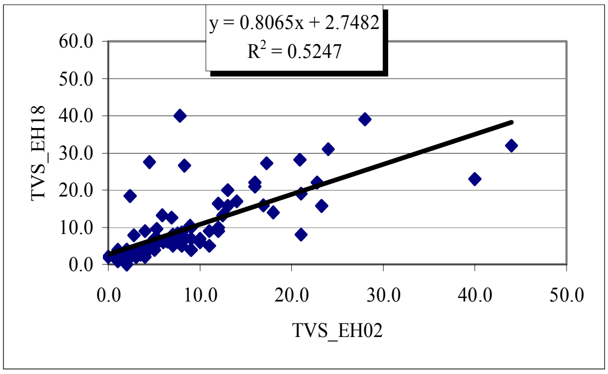


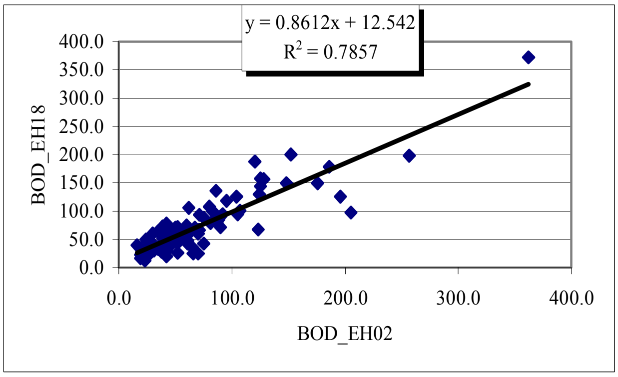


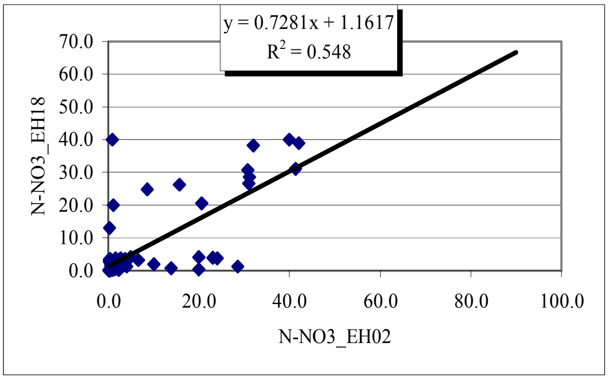


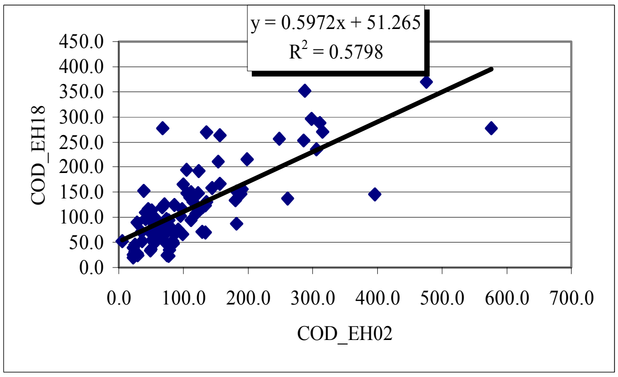
Annex 4-8A3: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH02 and EH18

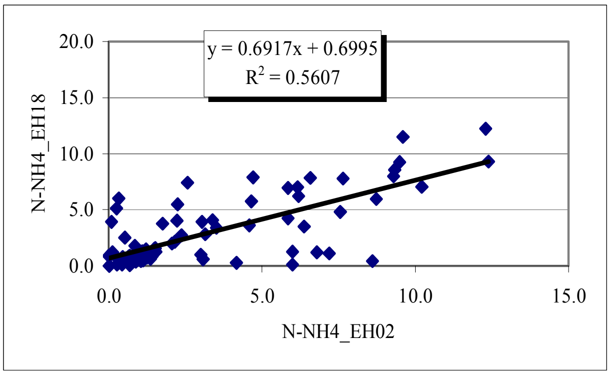


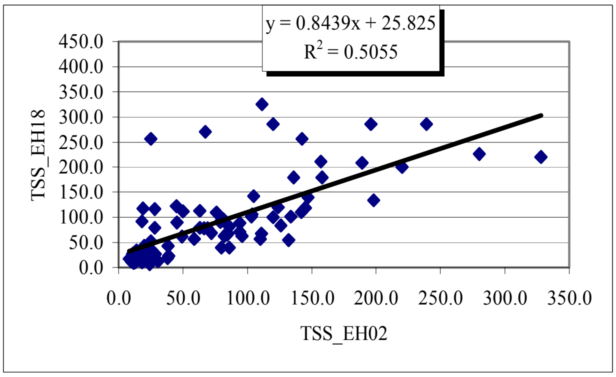


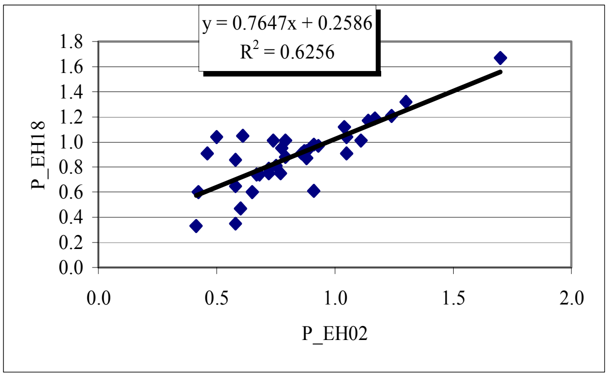




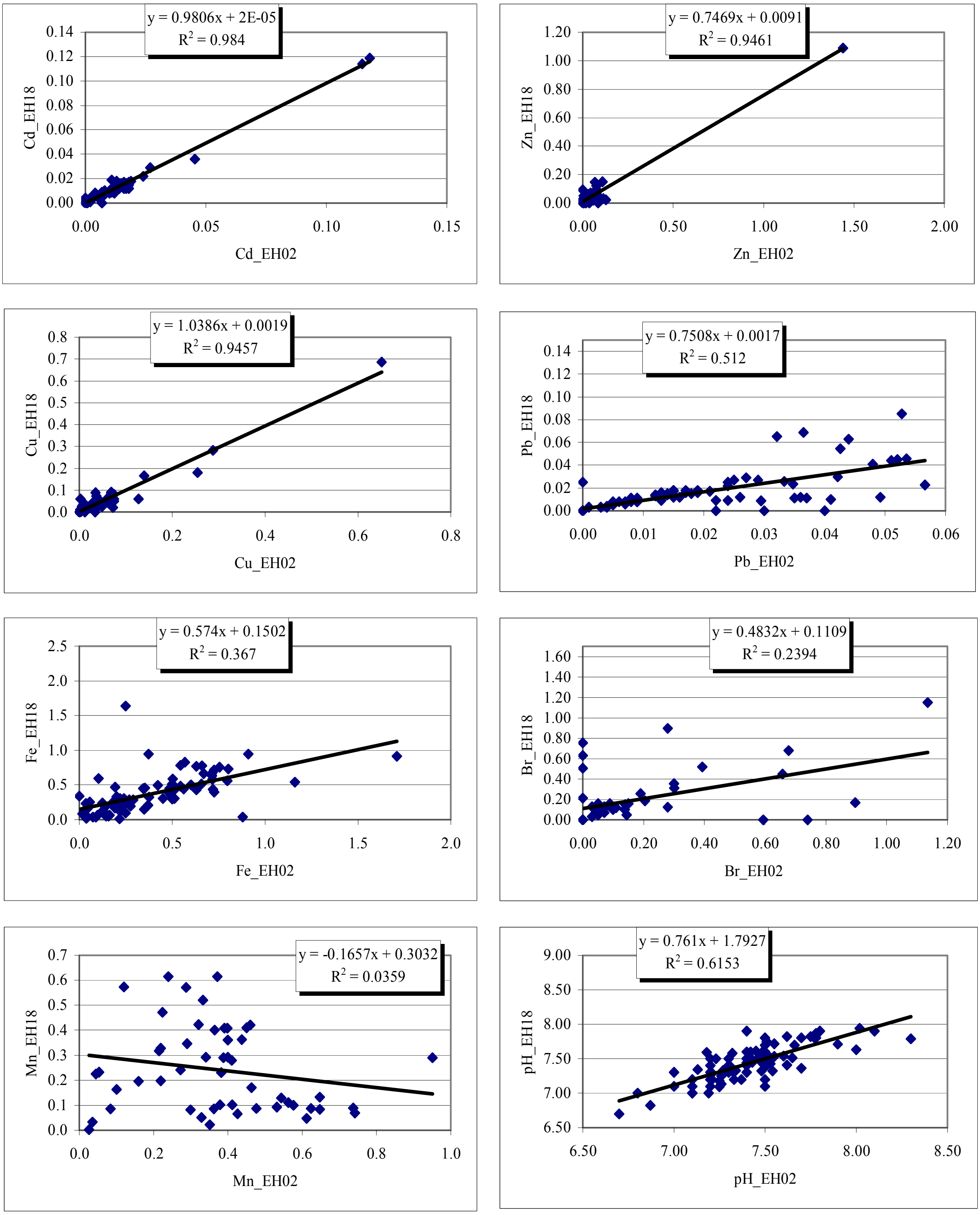




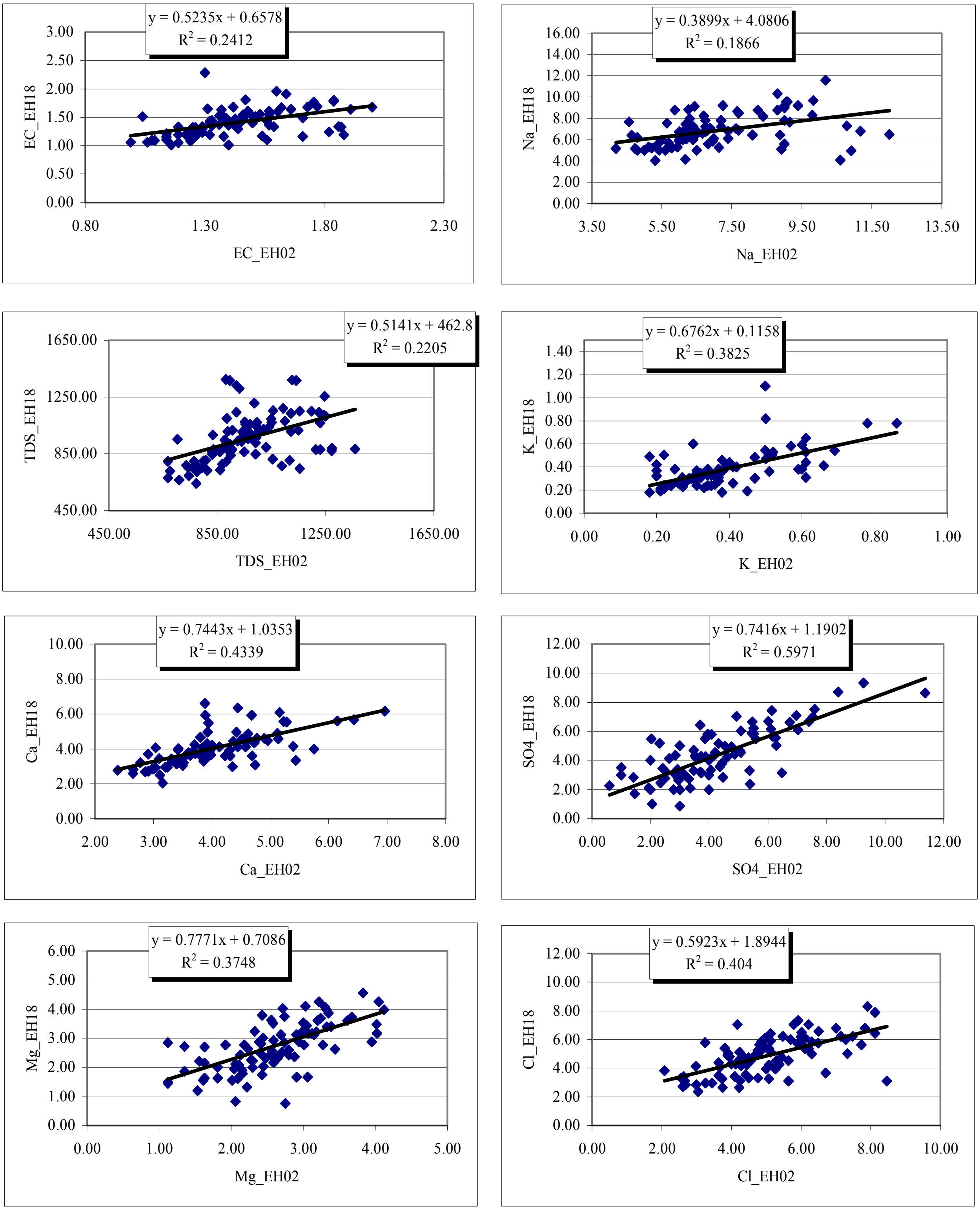




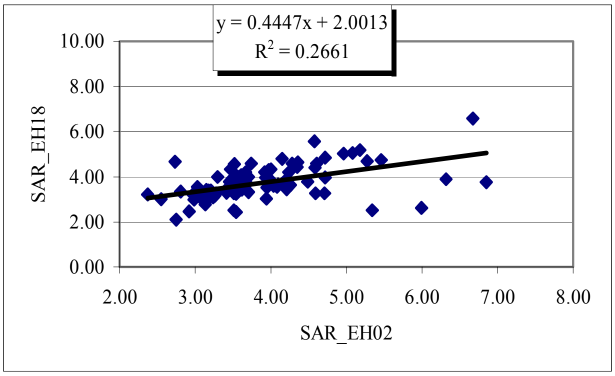
Annex 4-8A3: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH02 and EH18

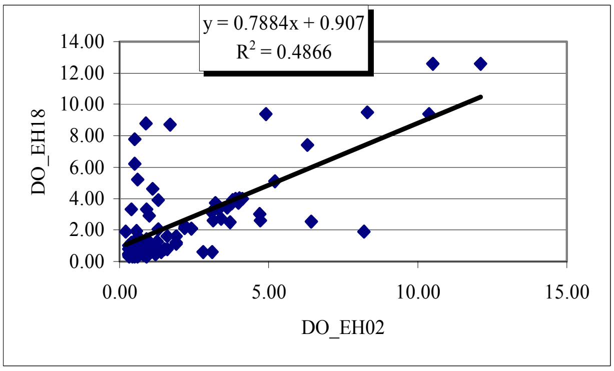


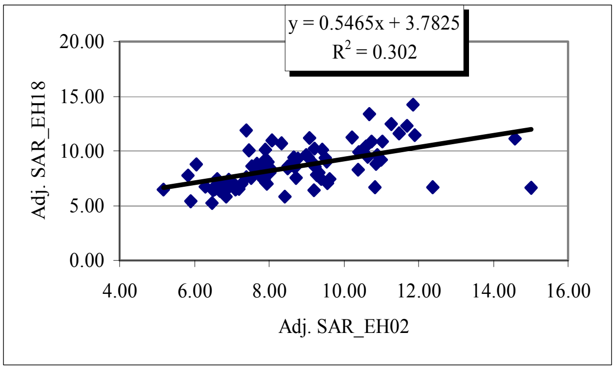
Annex 4-8A3: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH02 and EH18

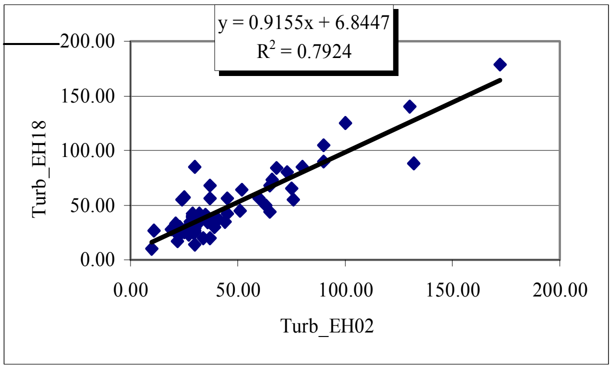


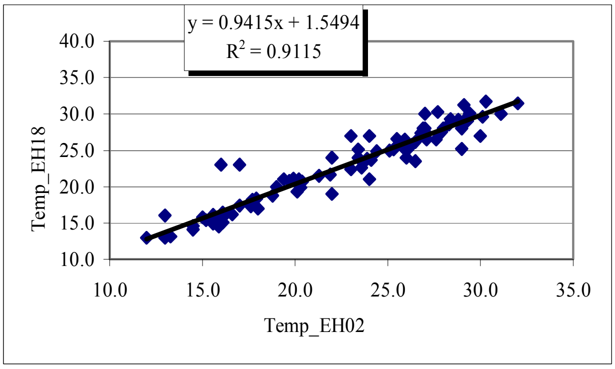
Annex 4-8A3: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH02 and EH18

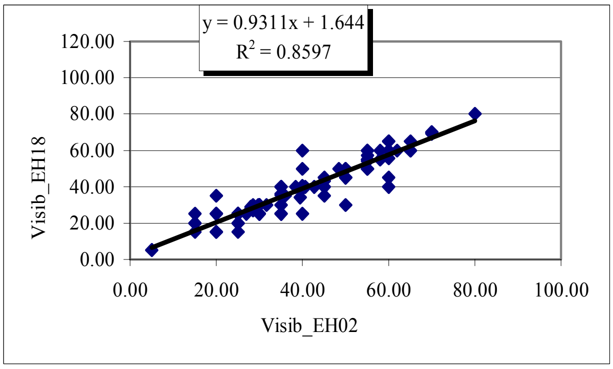


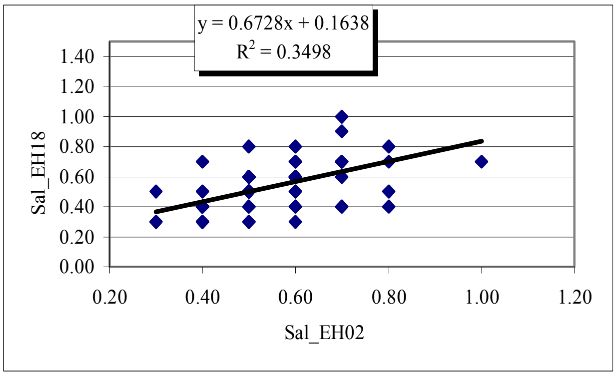


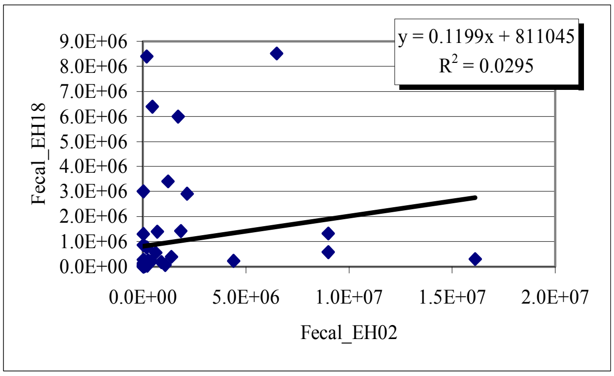




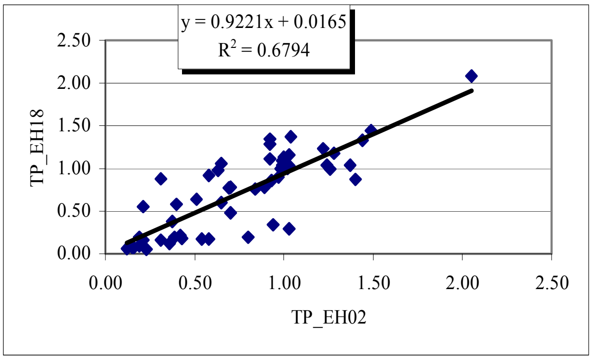


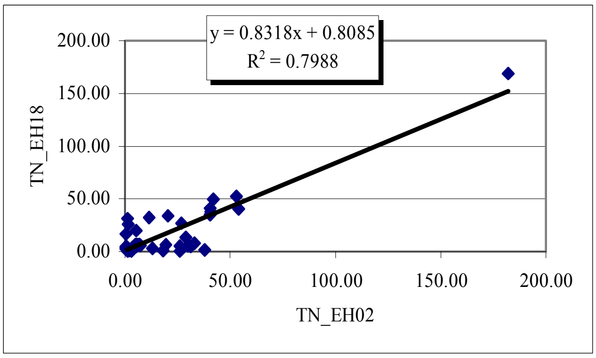


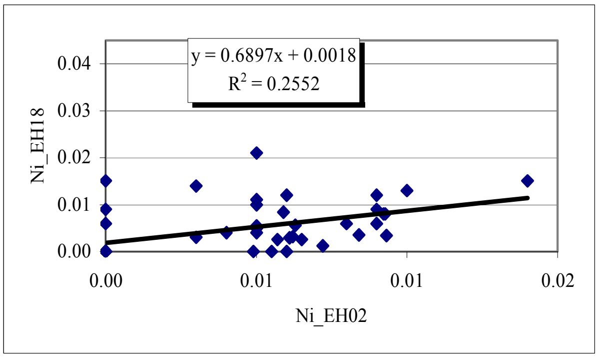


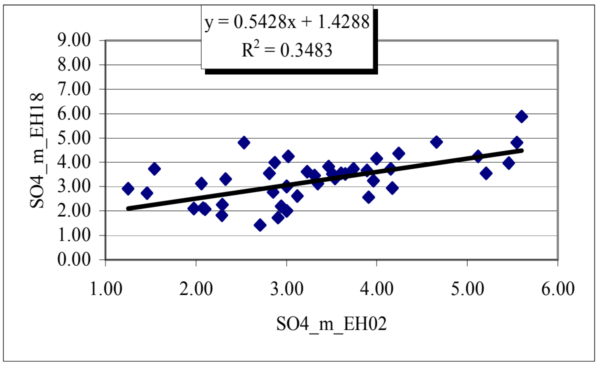


Annex 4-8A3: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH02 and EH18

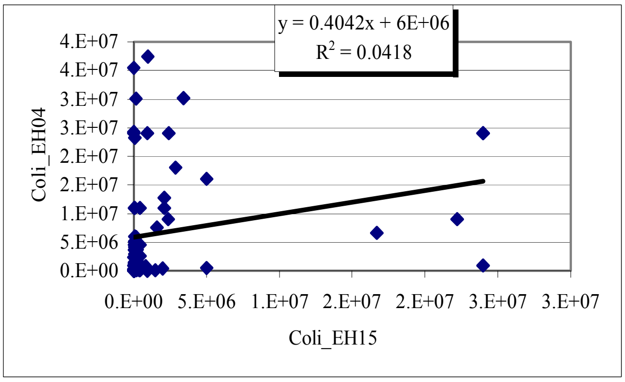


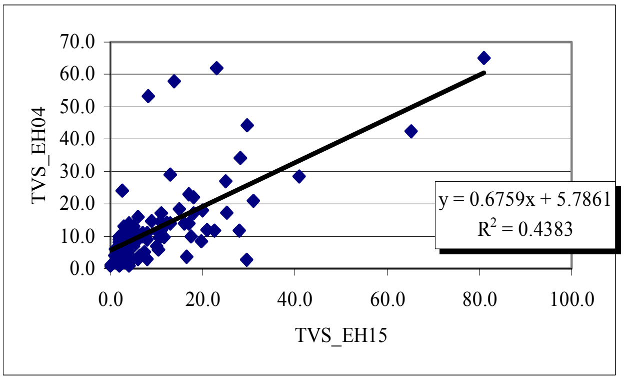


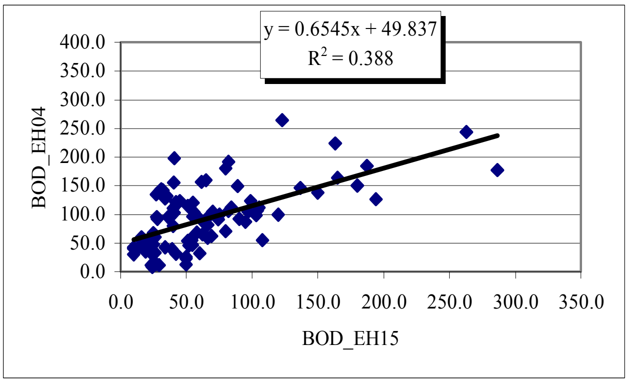


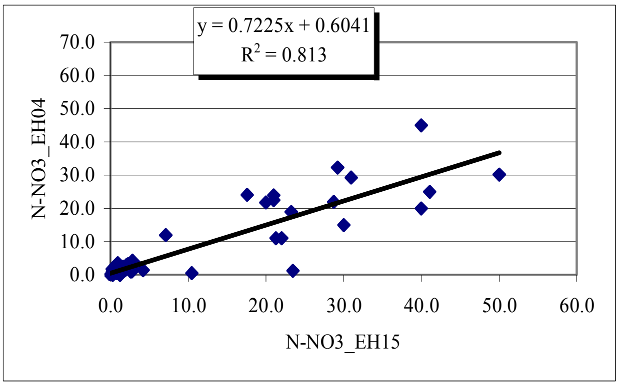


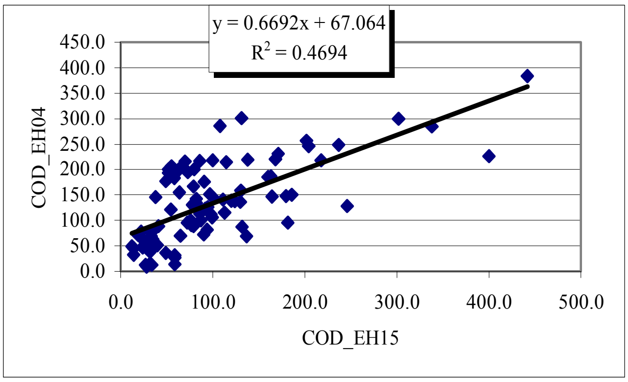
Annex 4-8B1: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH04 and EH15

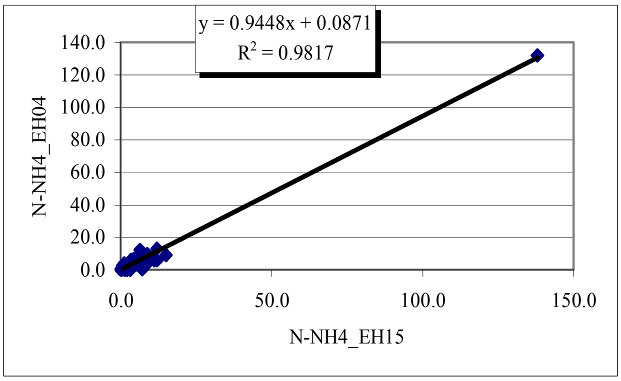


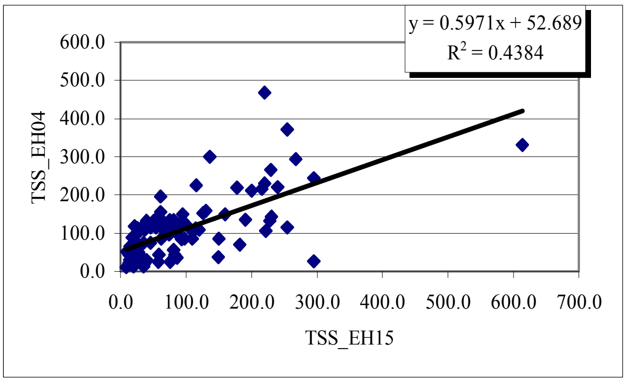


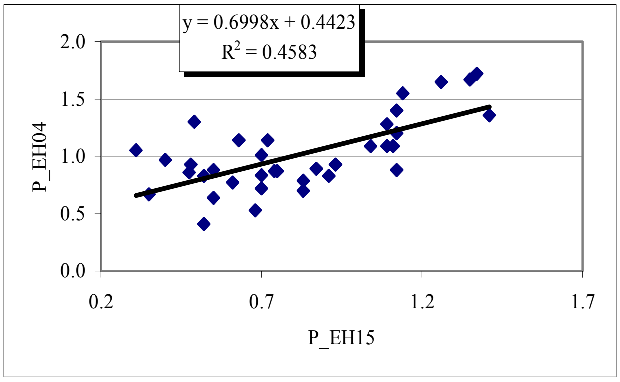




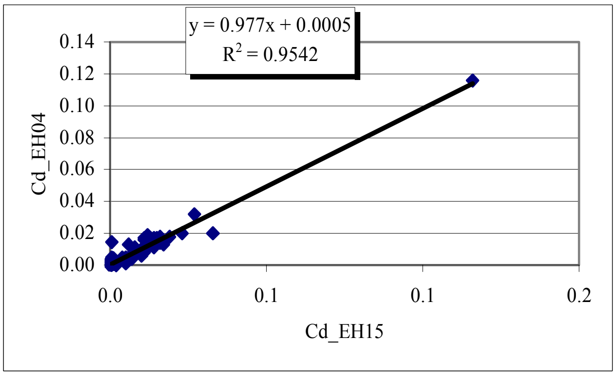


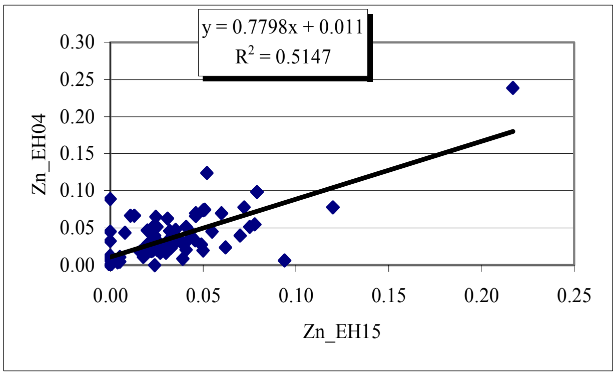


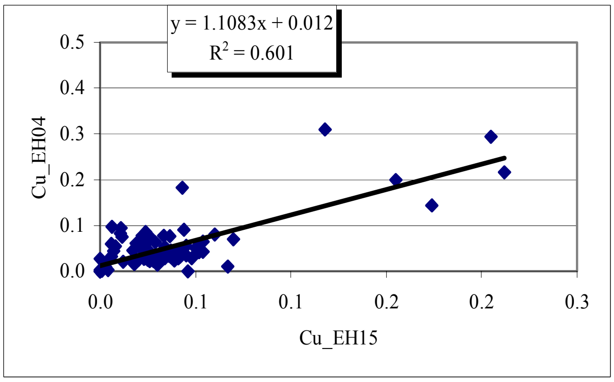


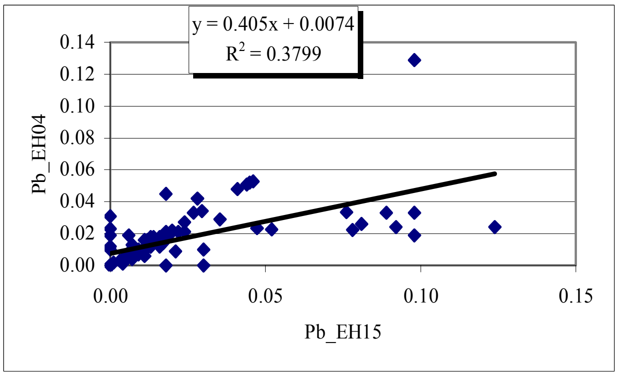


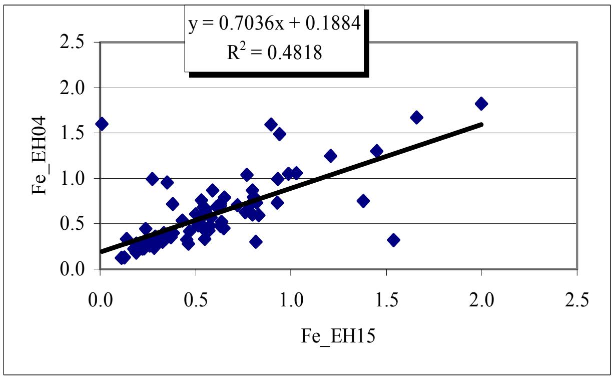
Annex 4-8B1 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH04 and EH15

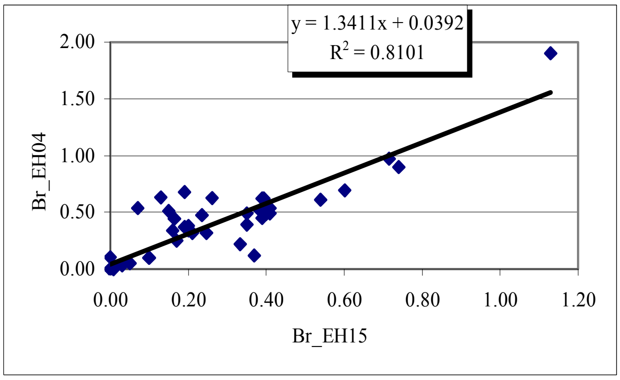


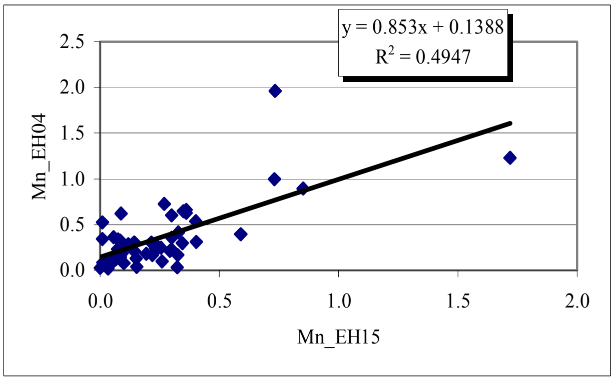


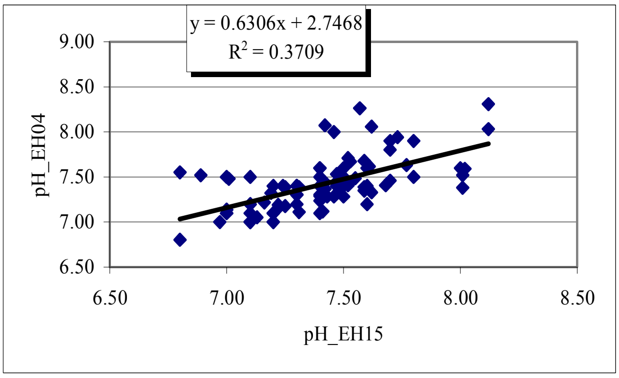




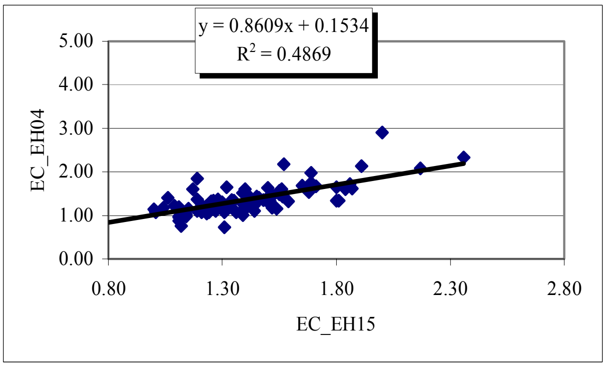


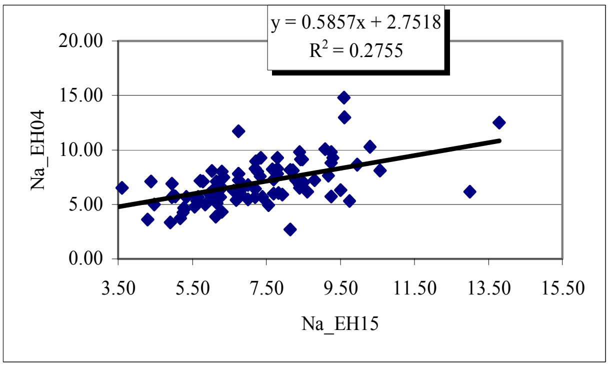


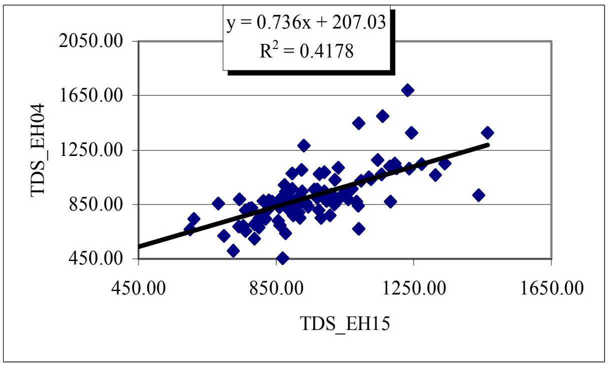


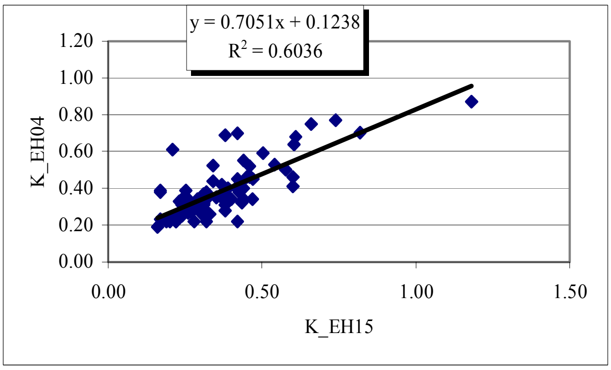


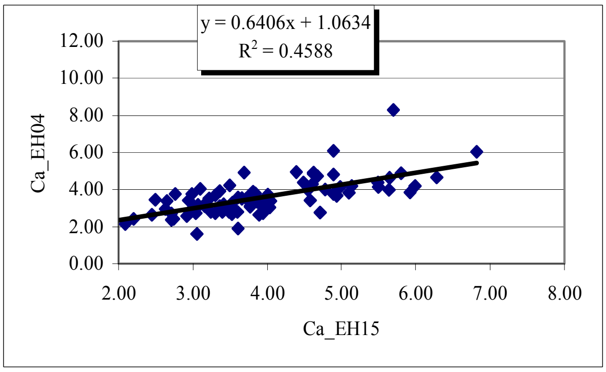
Annex 4-8B1 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH04 and EH15

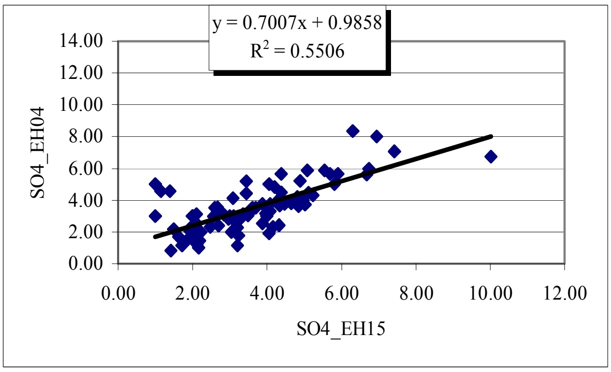


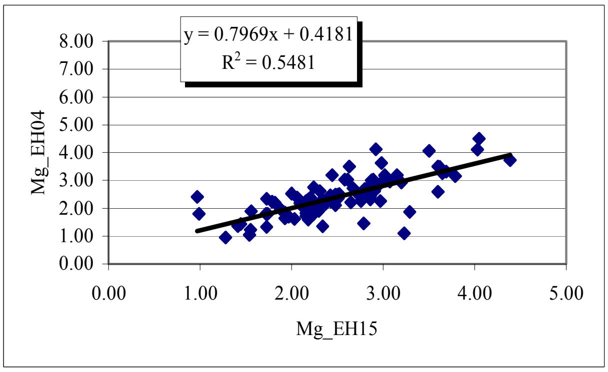


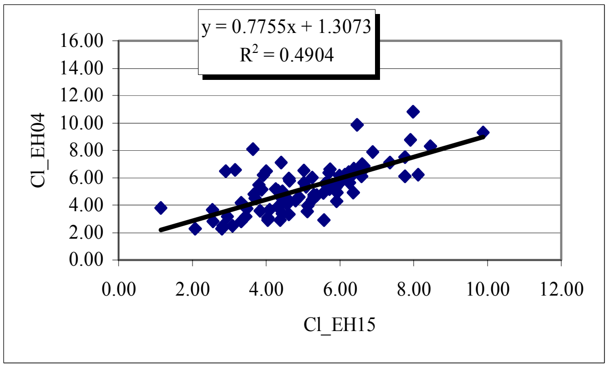




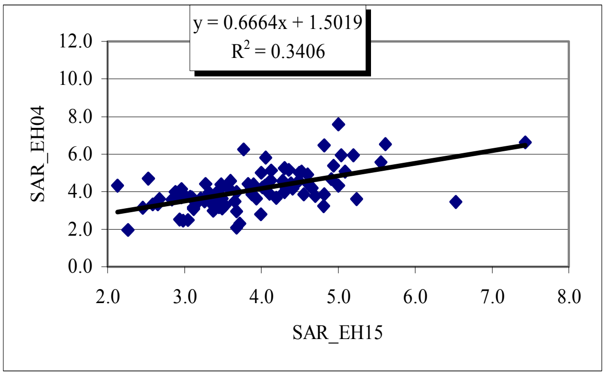


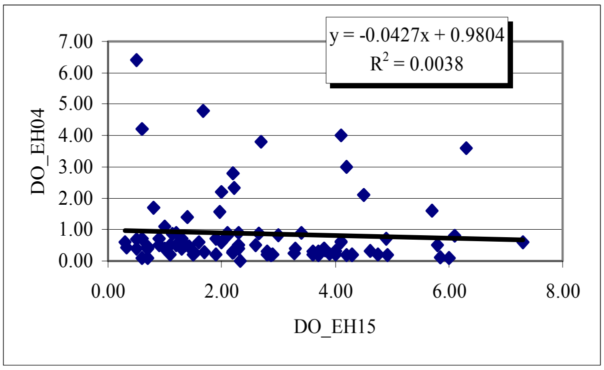


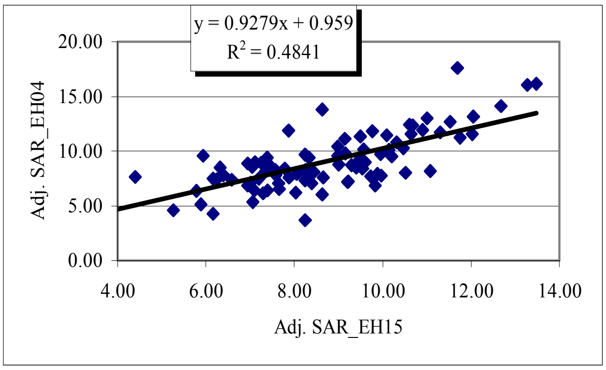


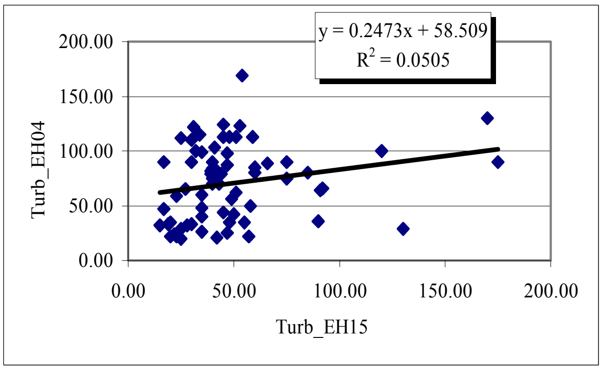


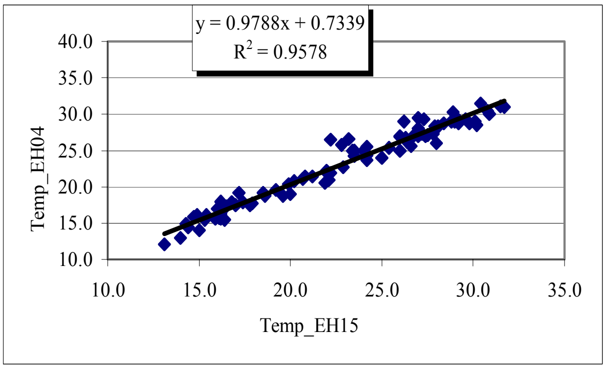
Annex 4-8B1 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH04 and EH15

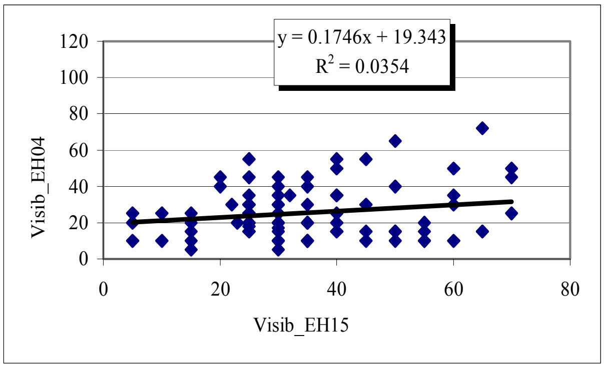


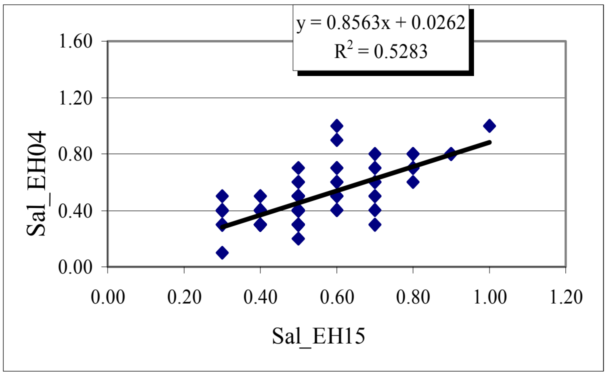


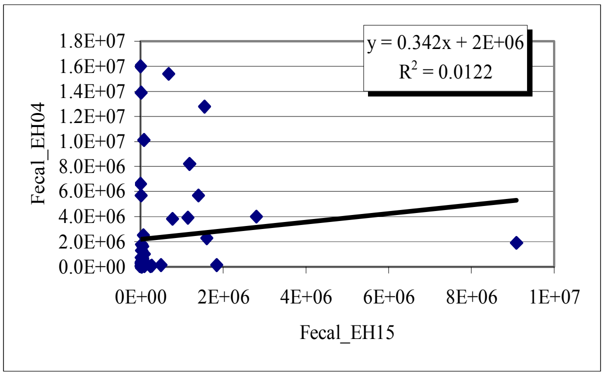




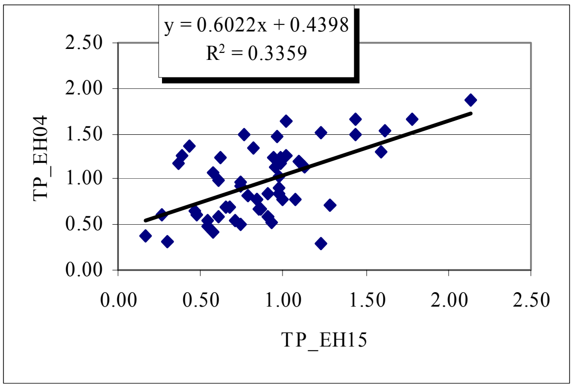


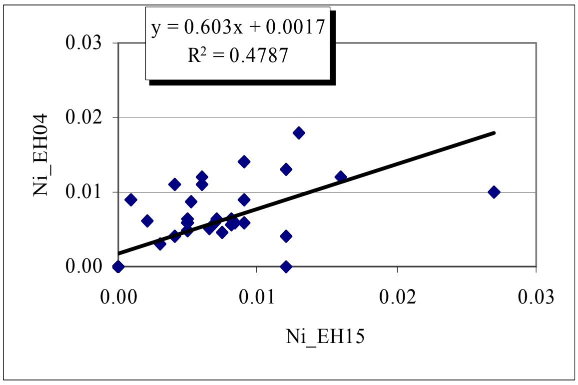


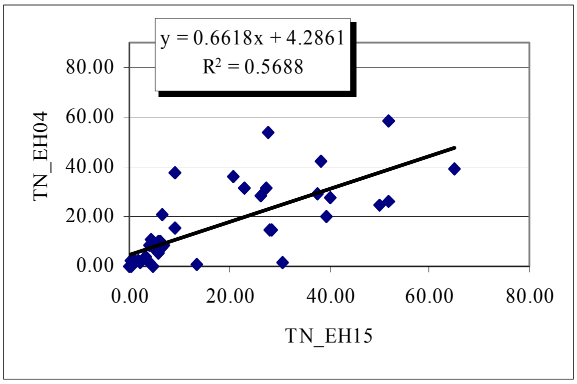


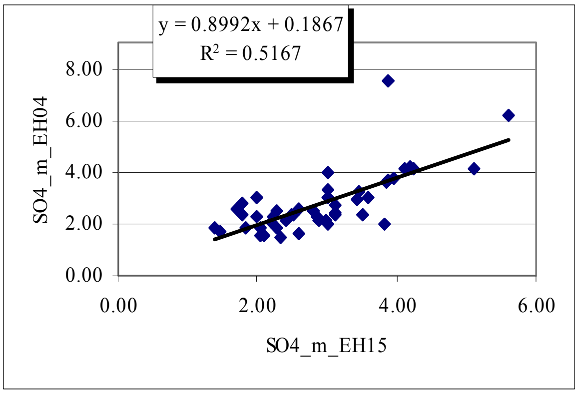


Annex 4-8B1 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH04 and EH15

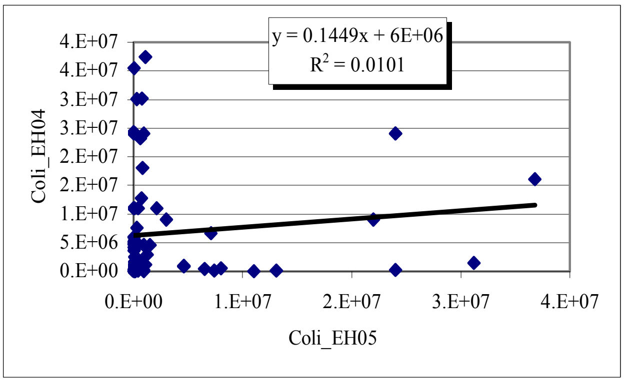


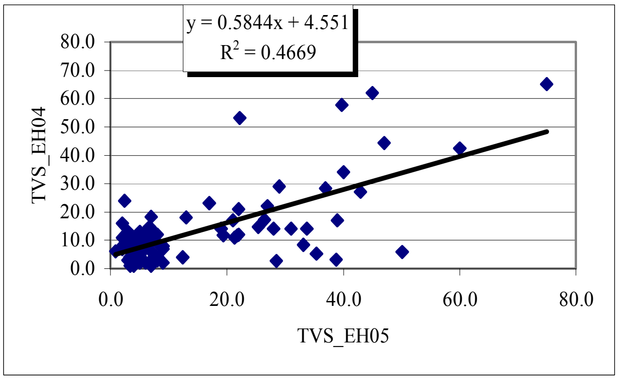


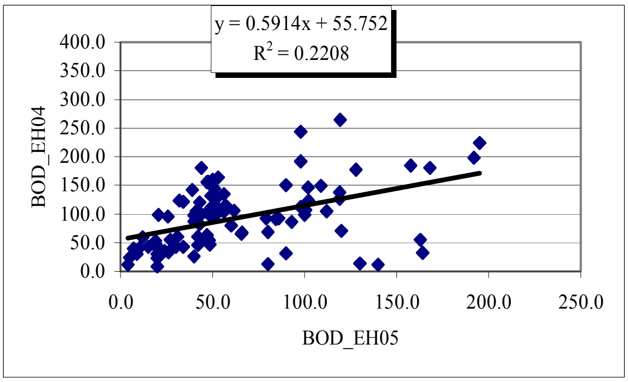


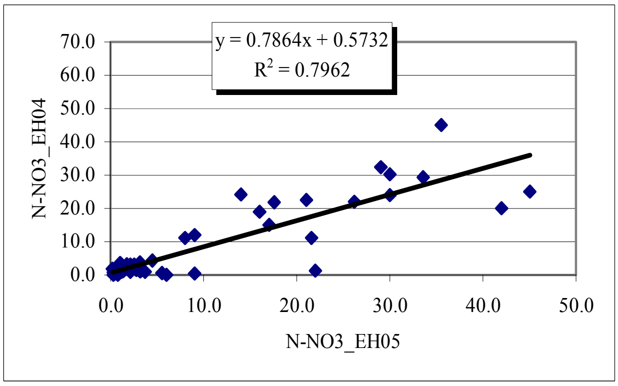


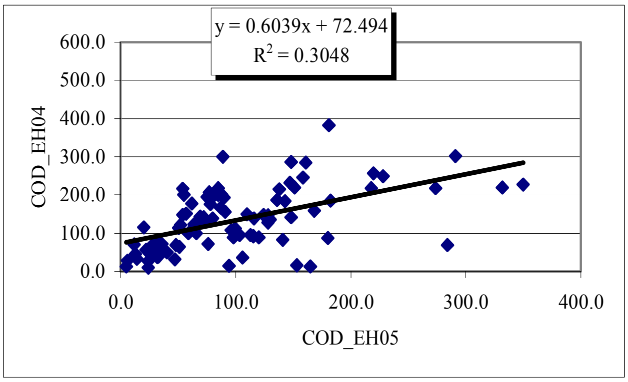
Annex 4-8B2: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH04 and EH05

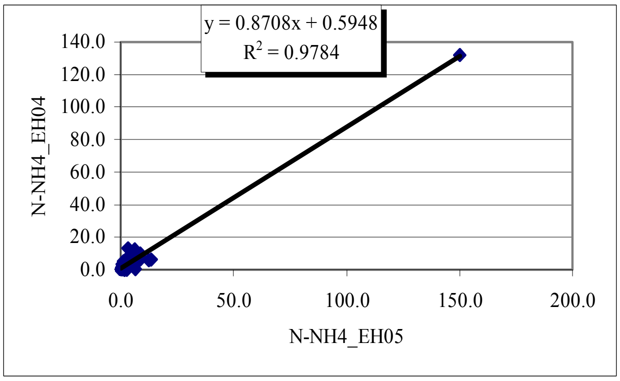


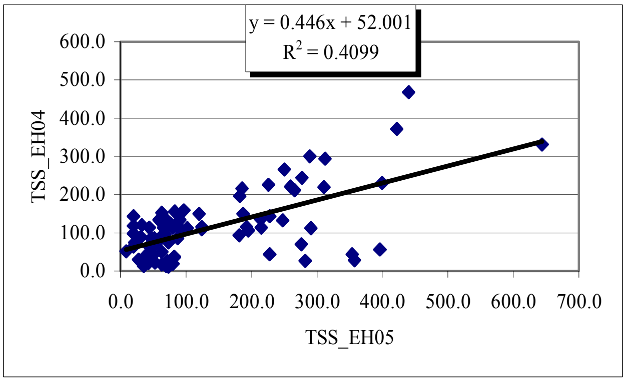


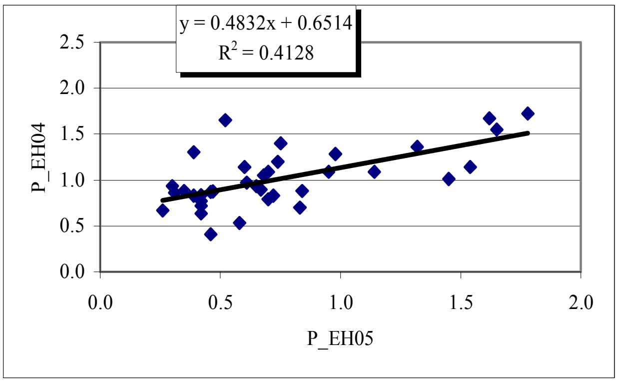




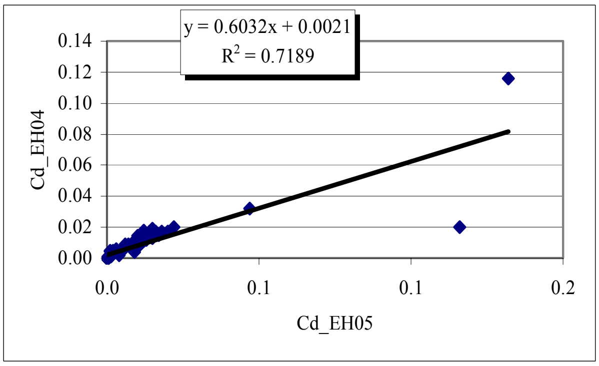


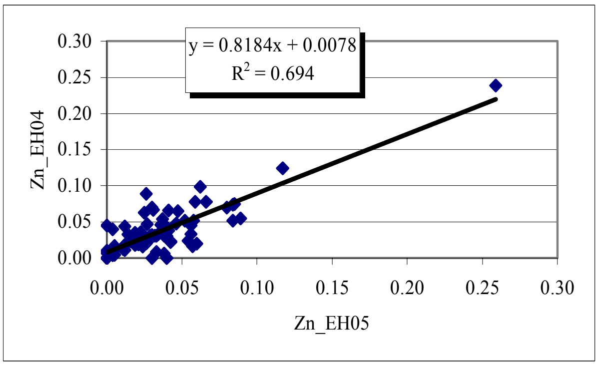


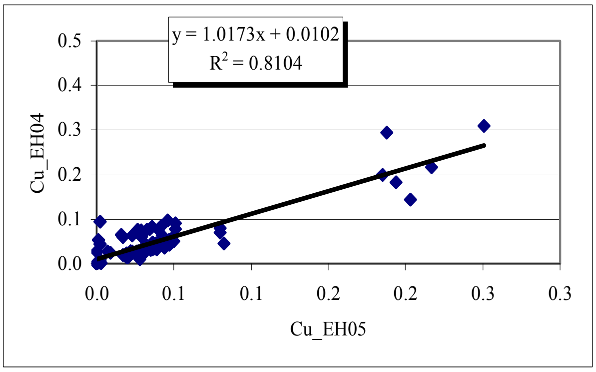


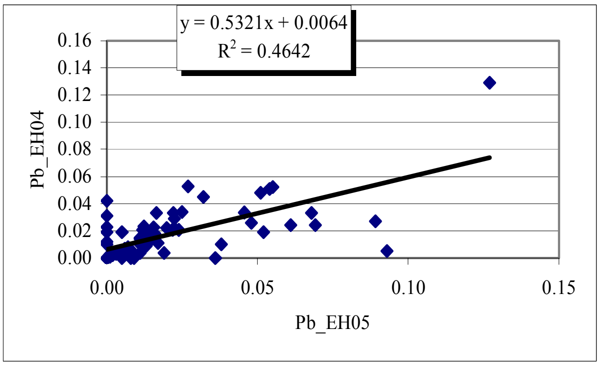


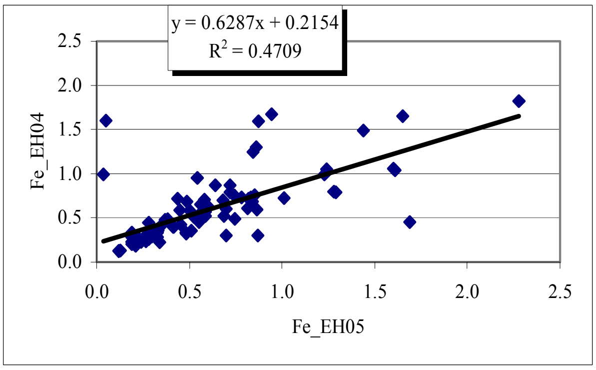
Annex 4-8B2 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH04 and EH05

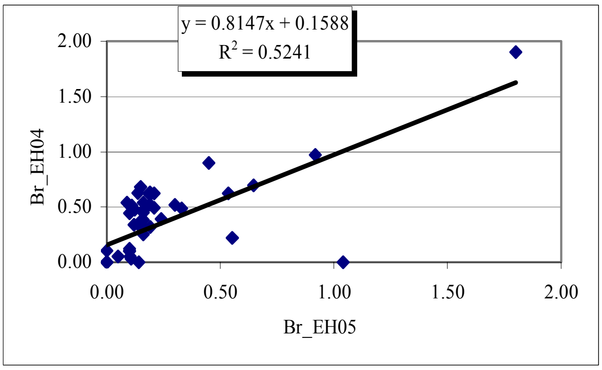


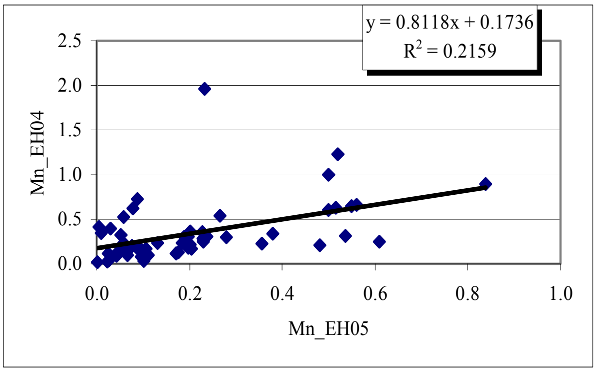


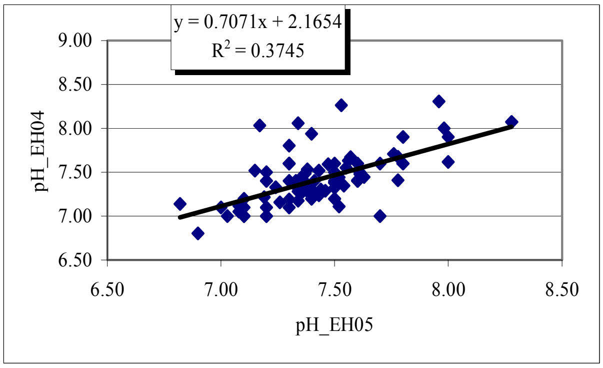




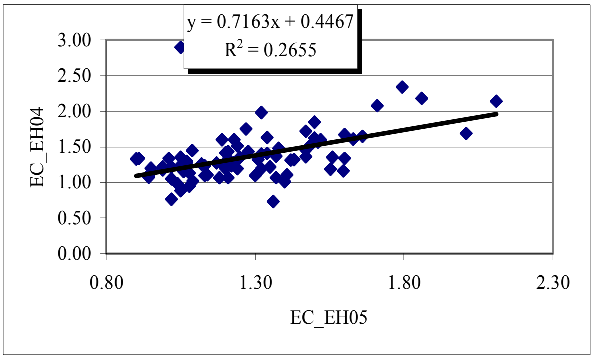


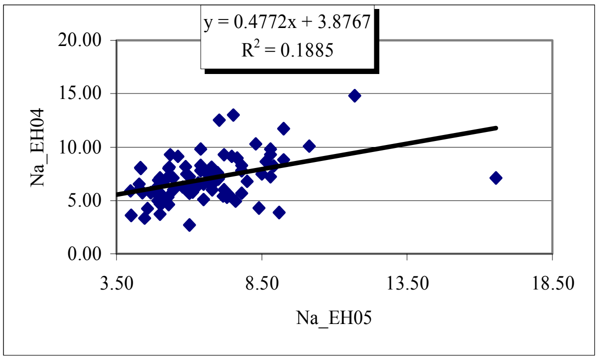


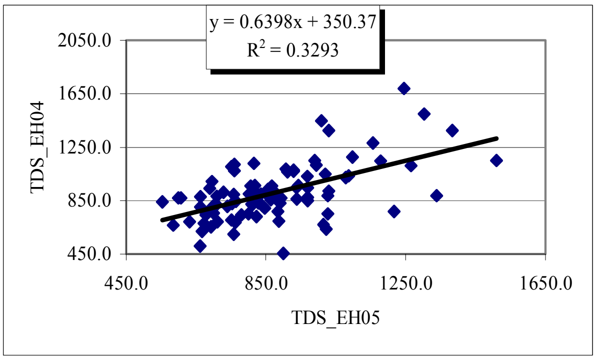


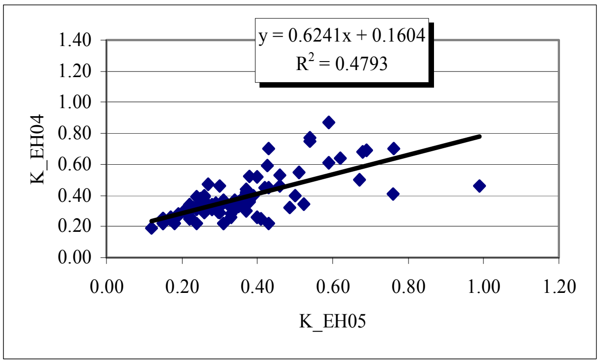


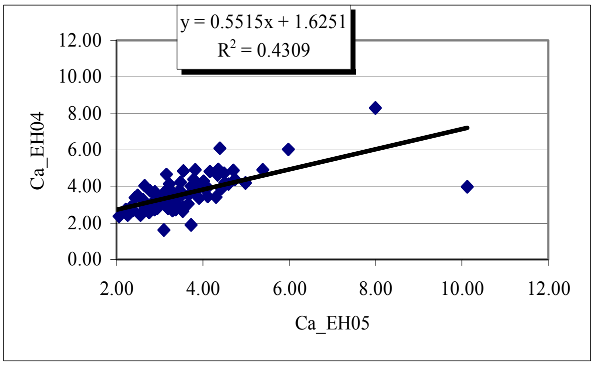
Annex 4-8B2 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH04 and EH05

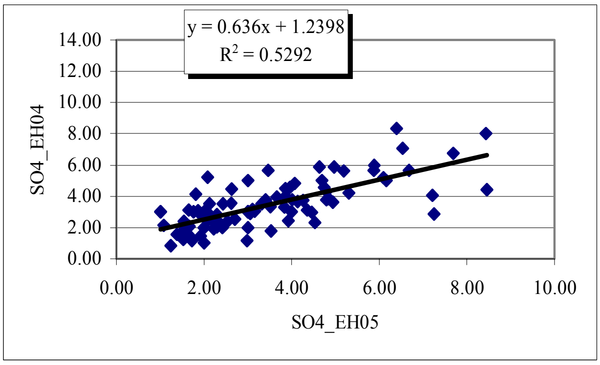


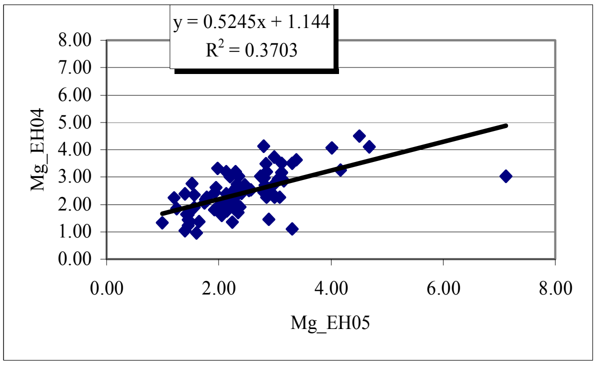


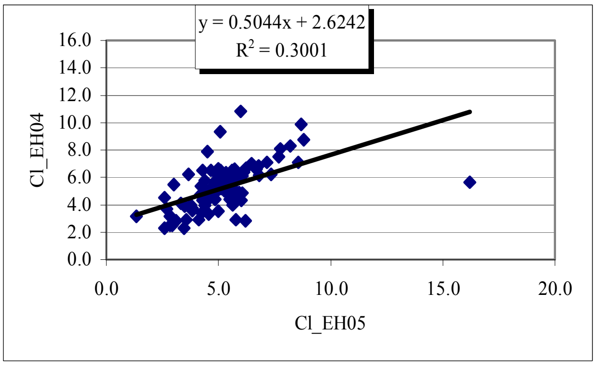




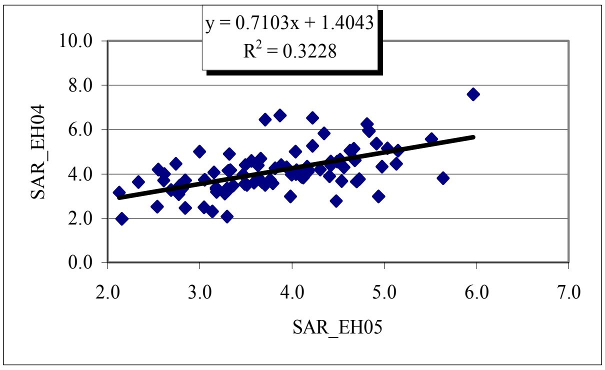


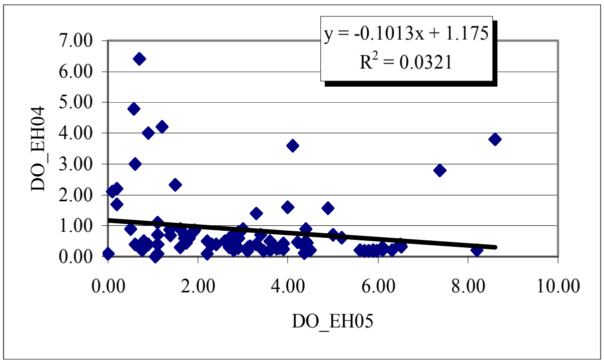


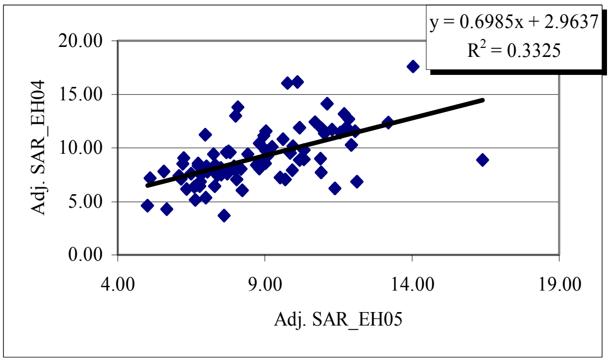


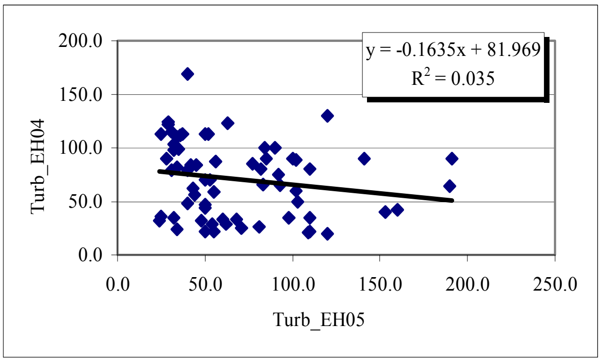


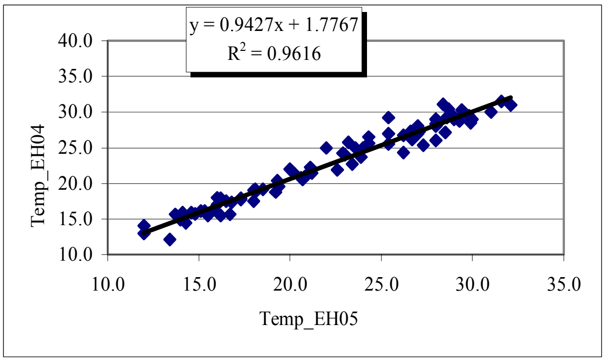
Annex 4-8B2 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH04 and EH05

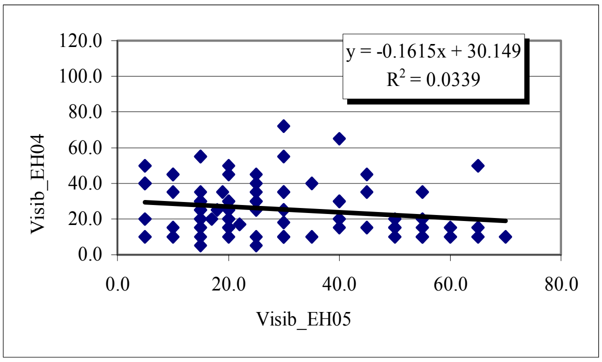


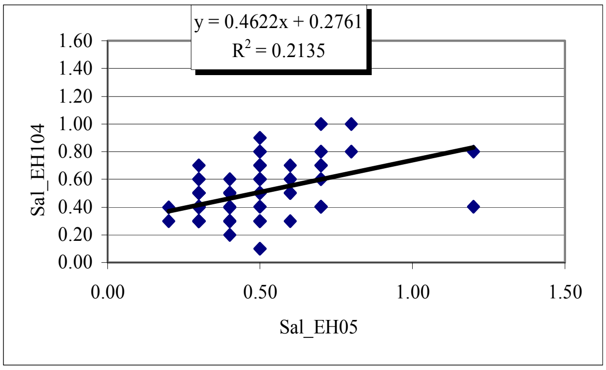


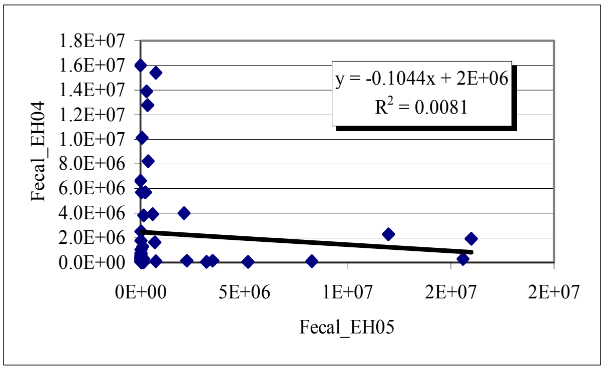




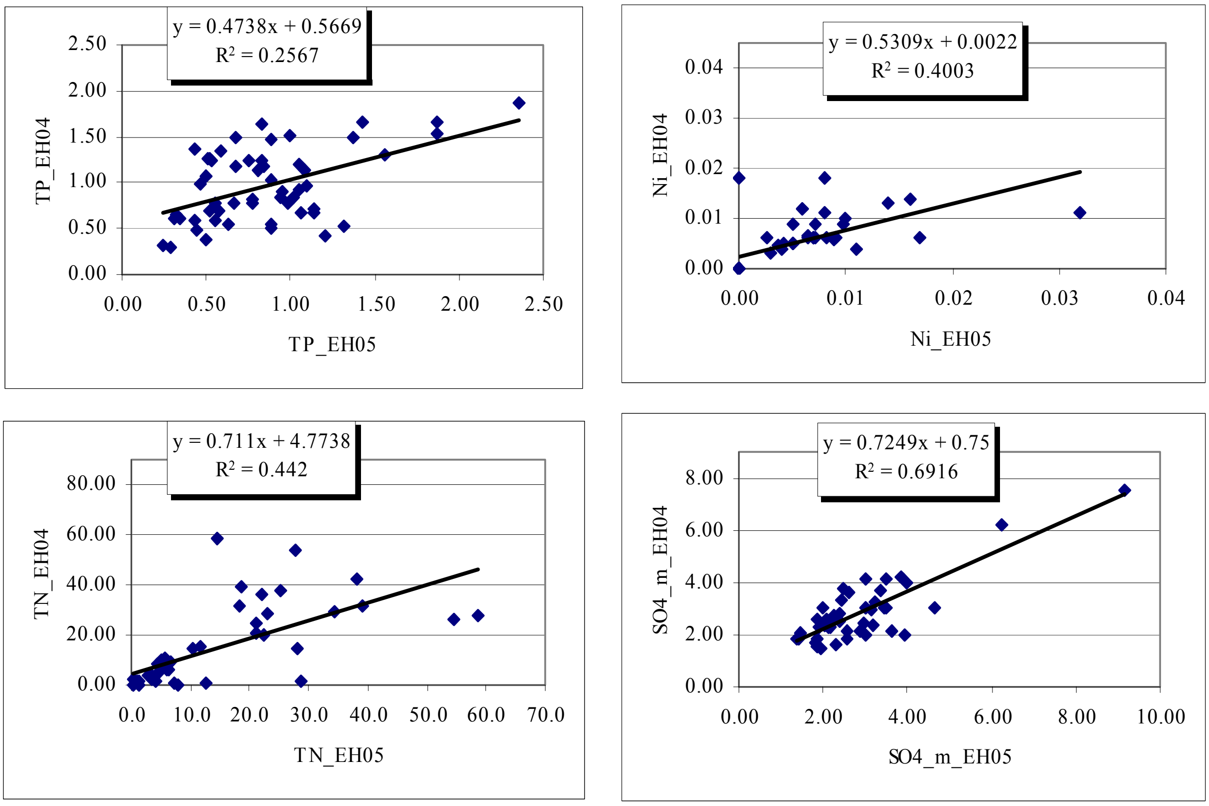




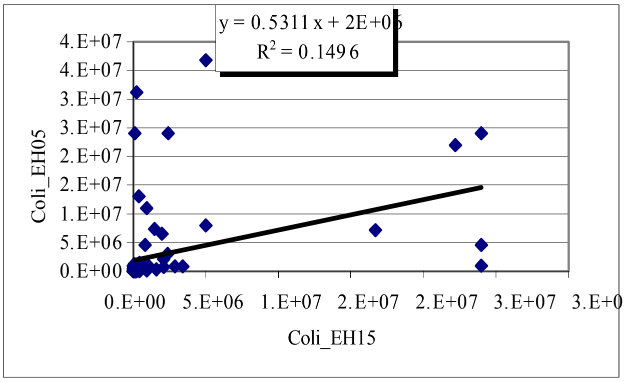


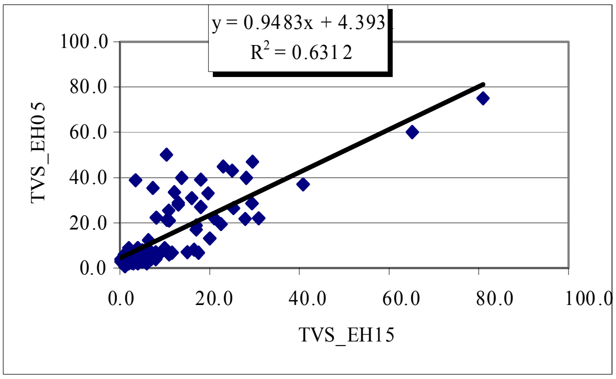


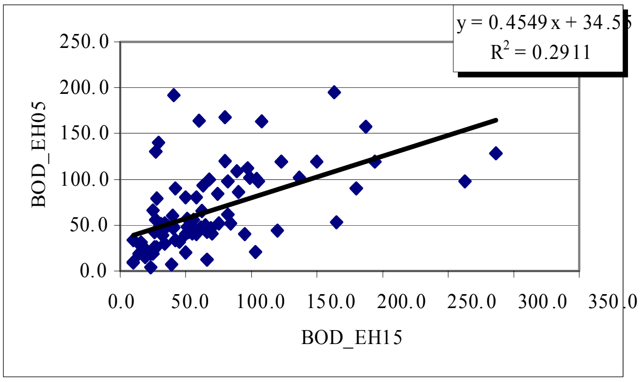
Annex 4-8B2 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH04 and EH05

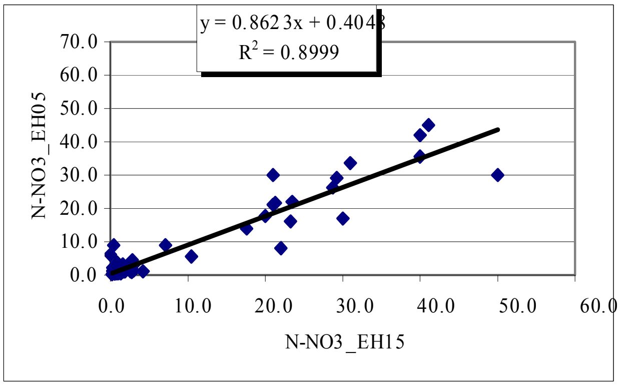


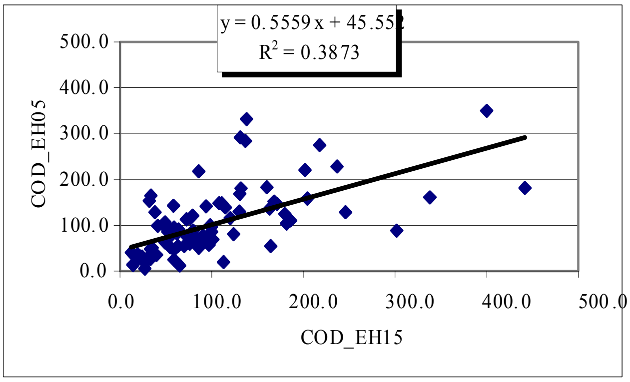
Annex 4-8B3: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH15 and EH05

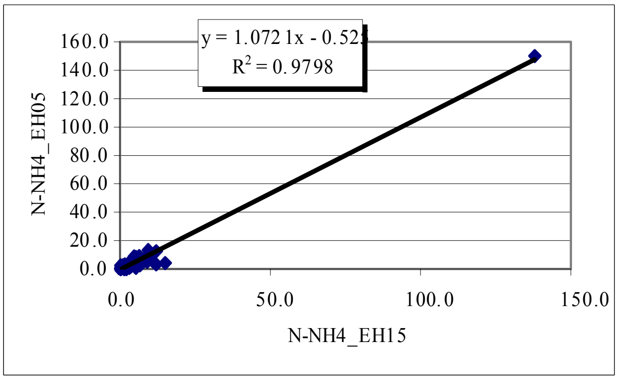


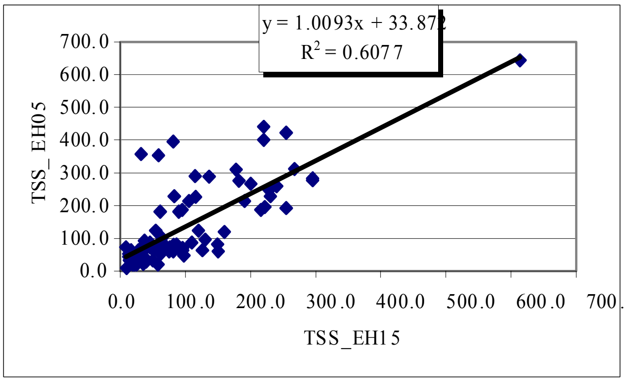


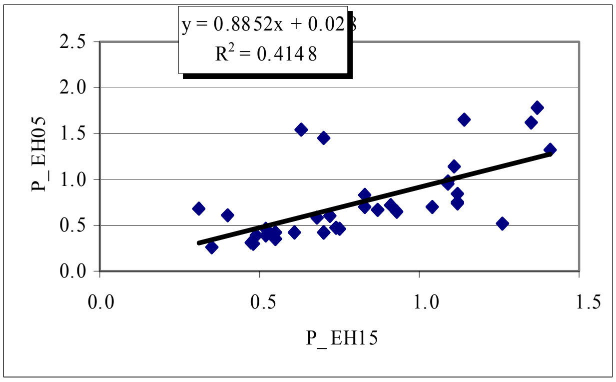




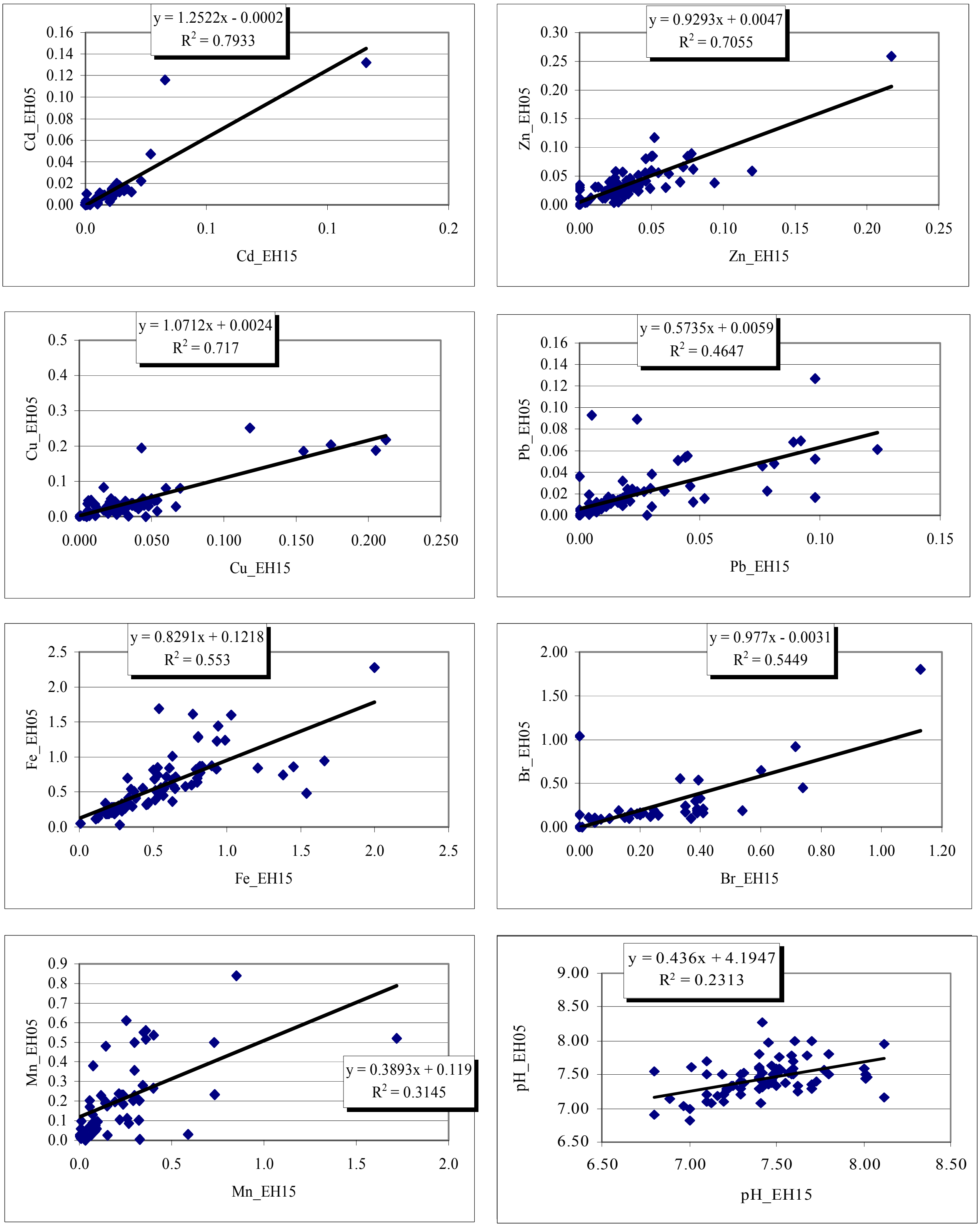




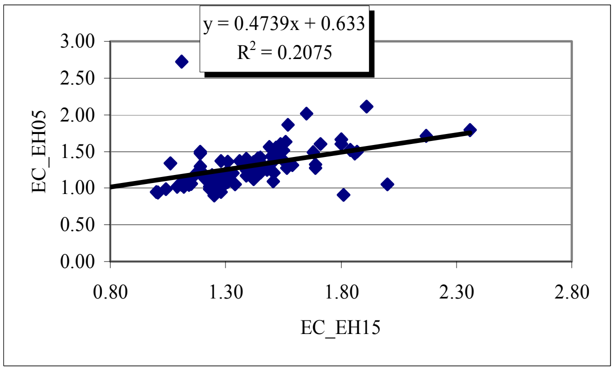


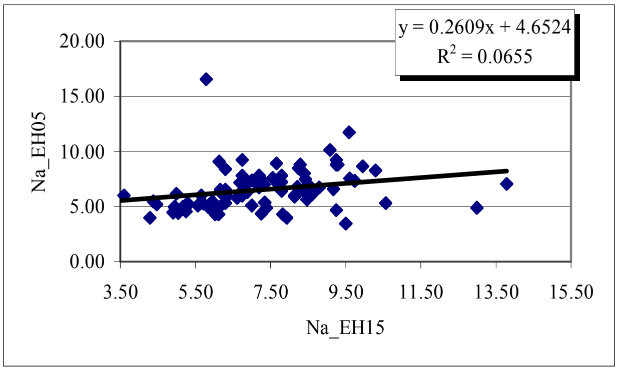


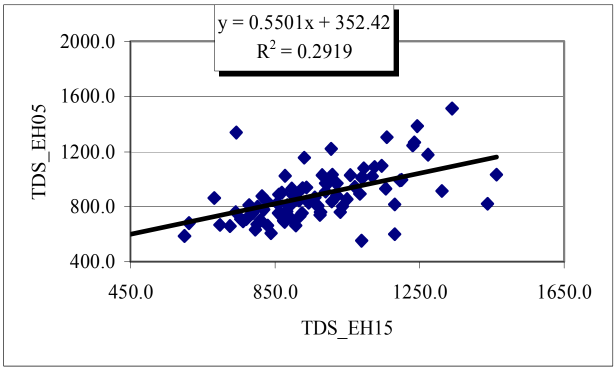
Annex 4-8B3 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH15 and EH05

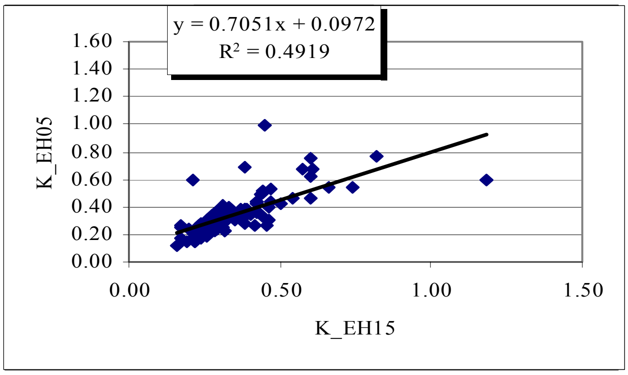


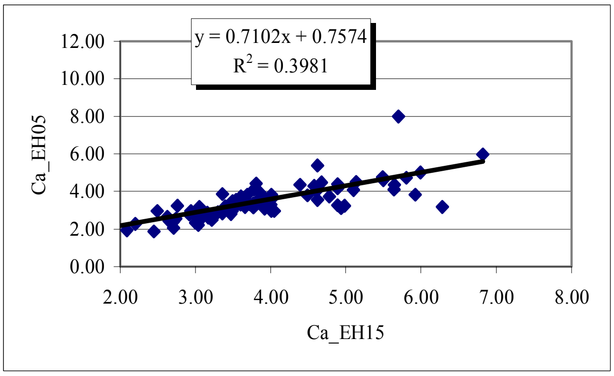
Annex 4-8B3 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH15 and EH05

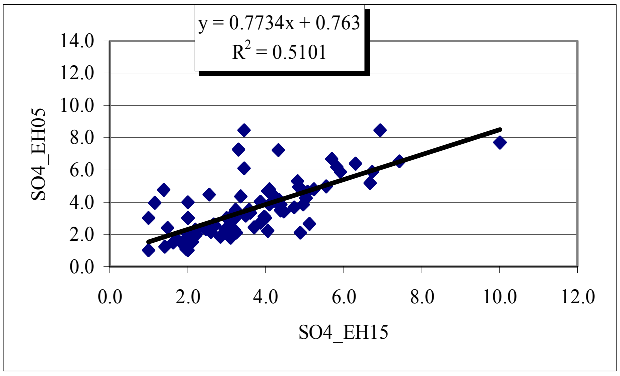


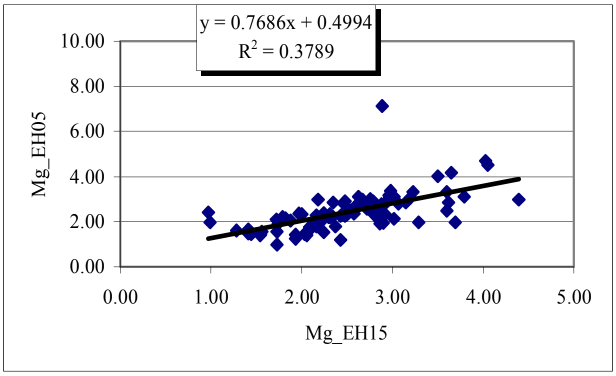


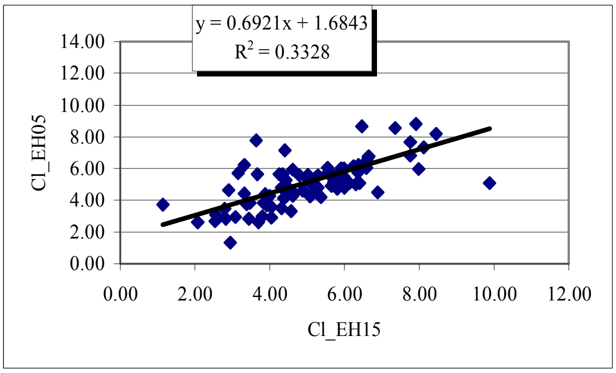




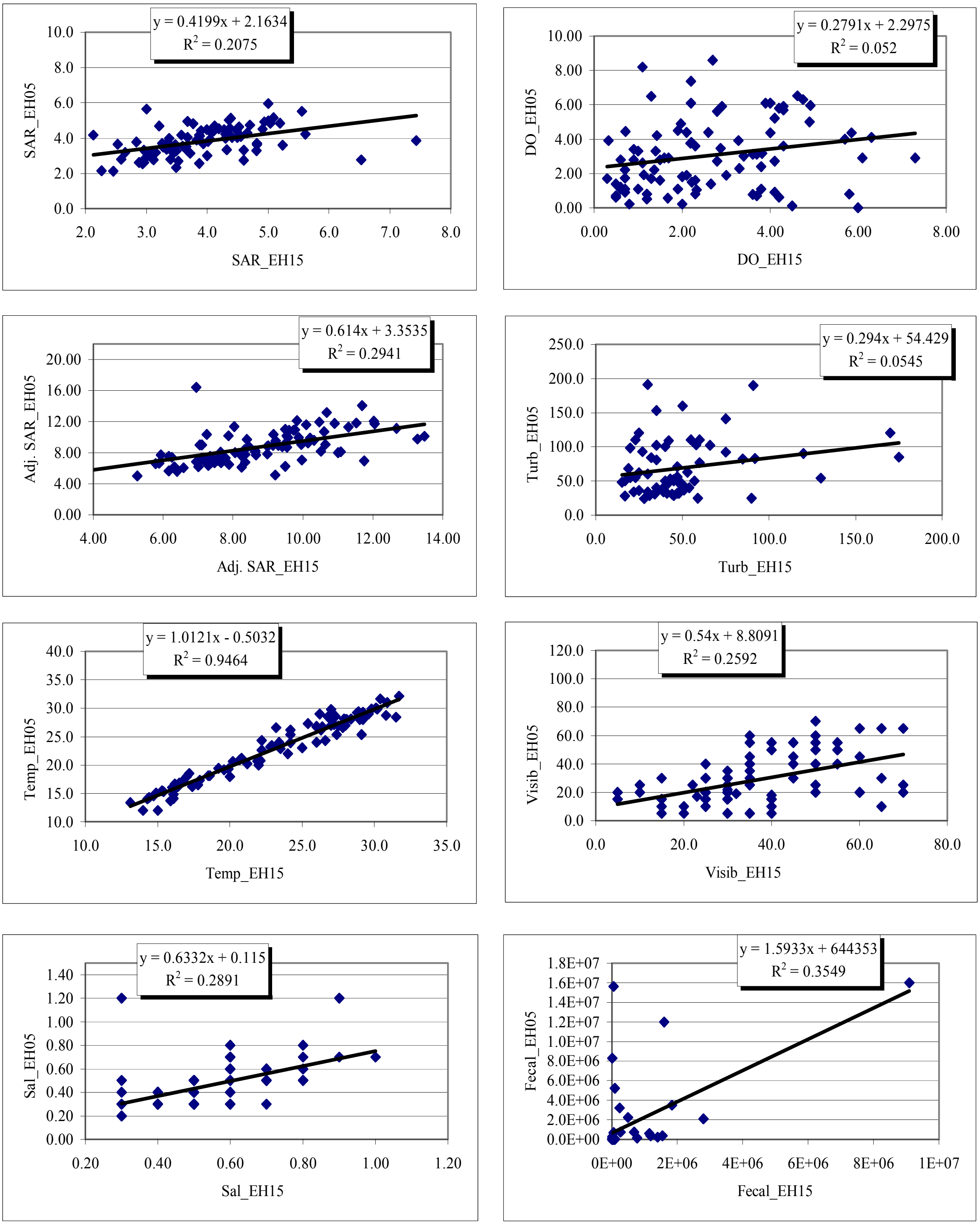




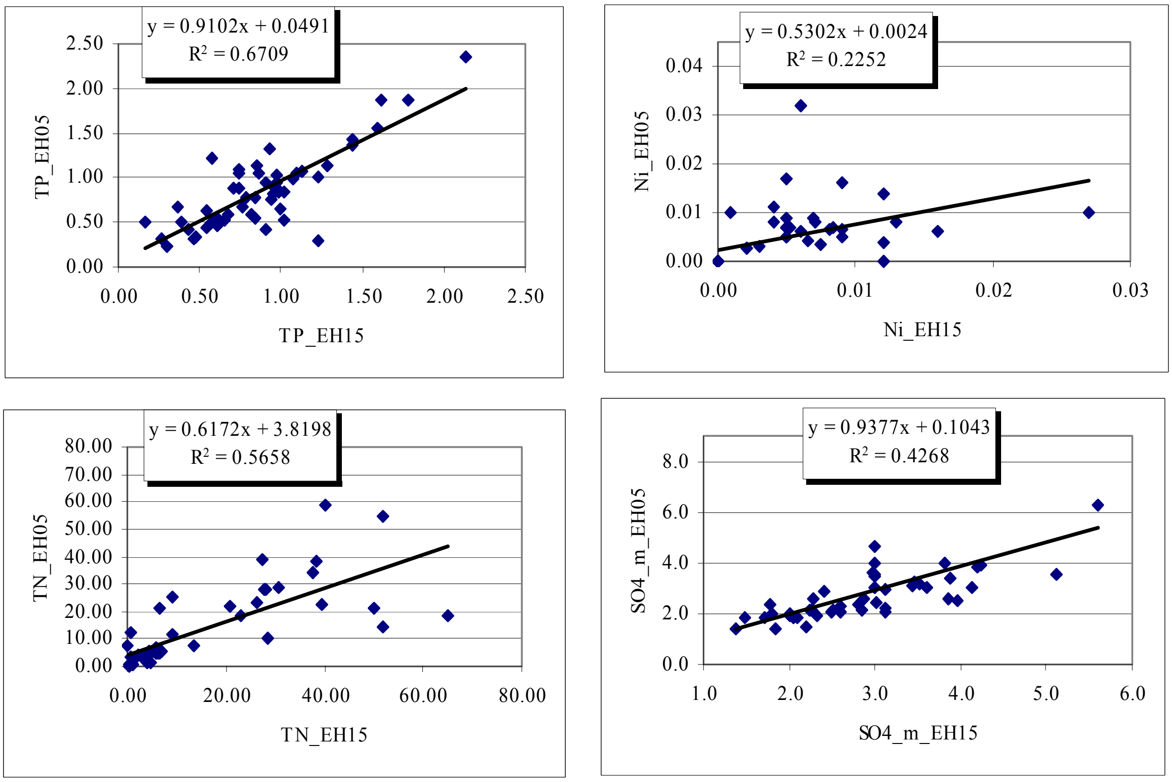




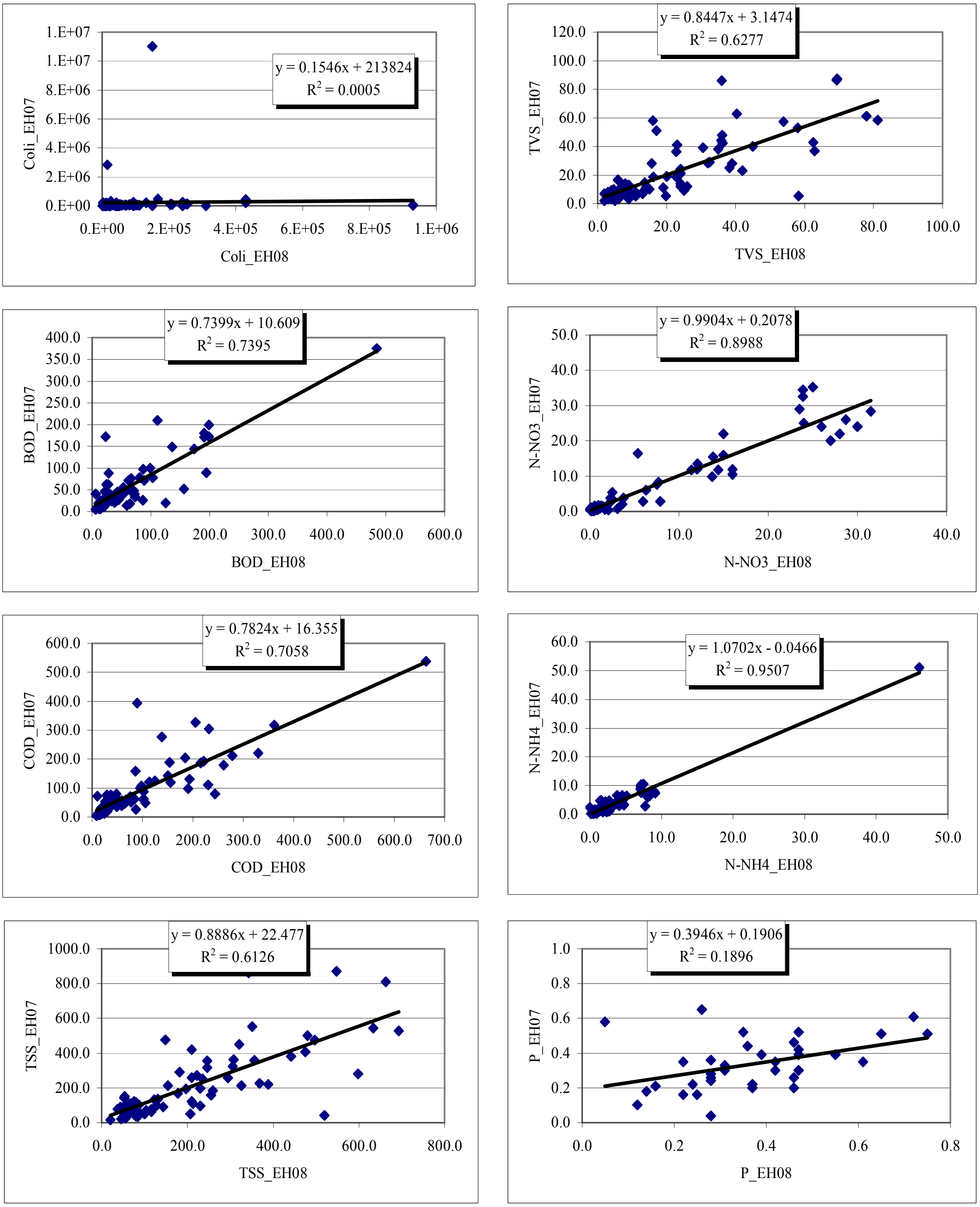
Annex 4-8B3 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH15 and EH05



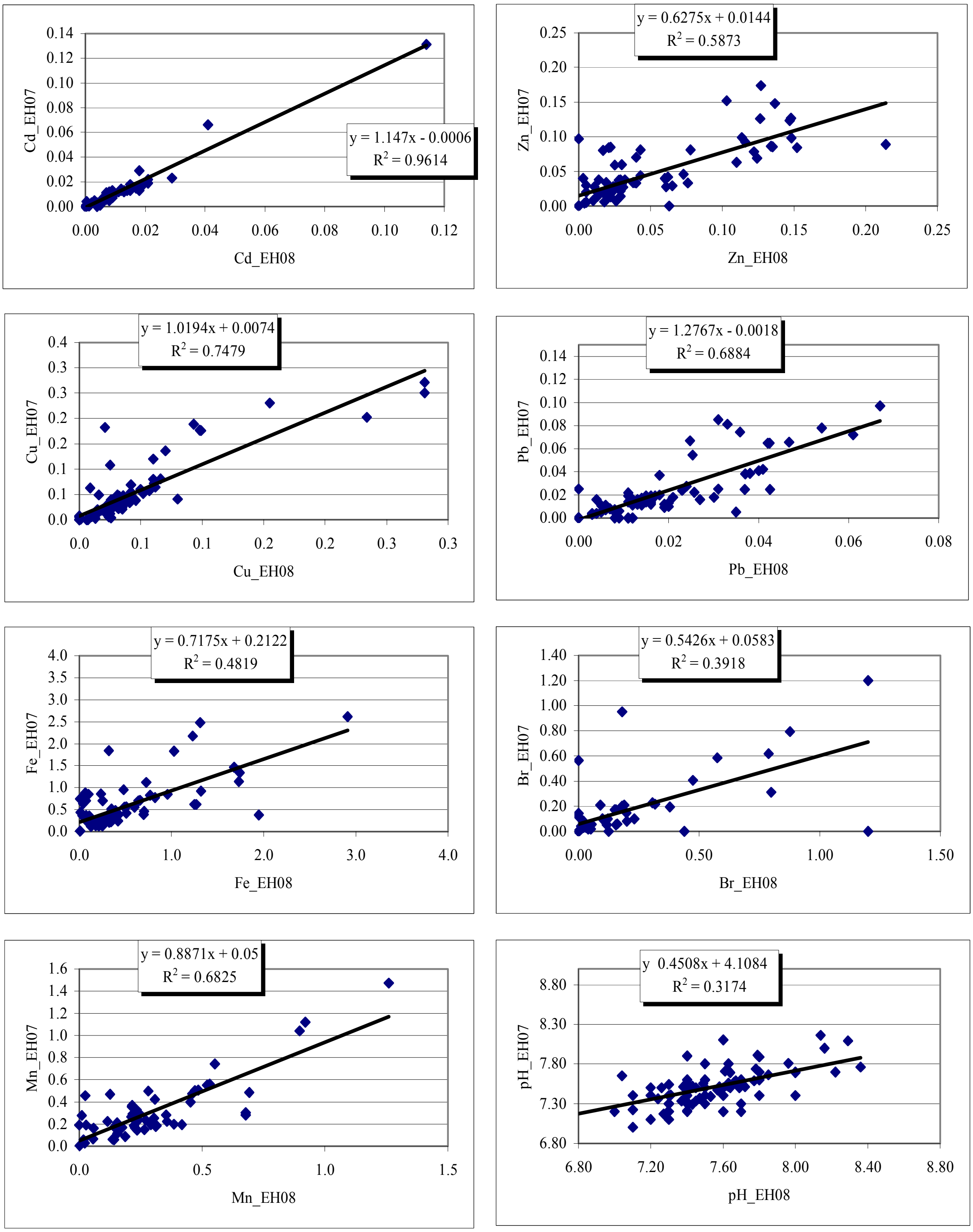
Annex 4-8B3 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH15 and EH05



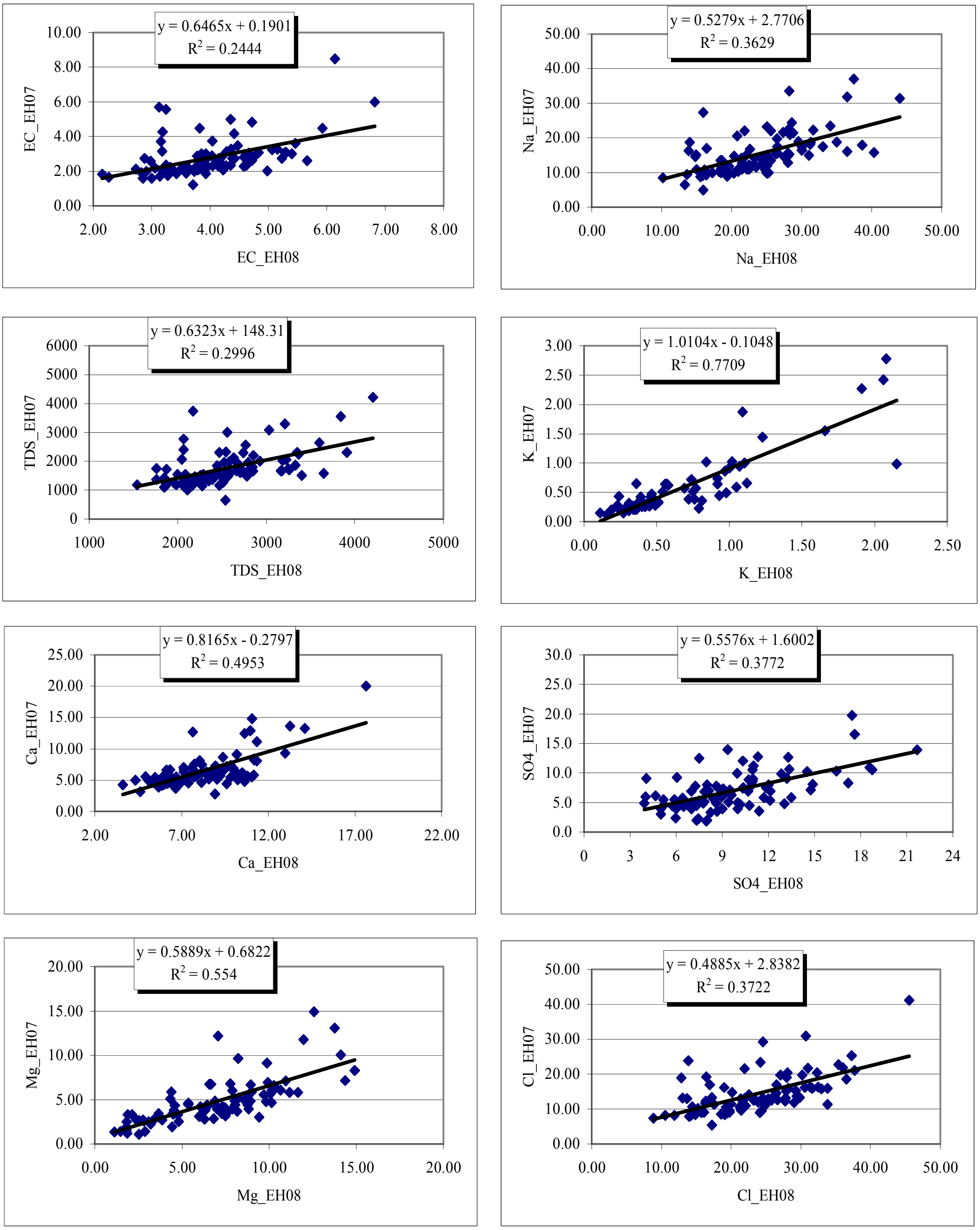
Annex 4-8C1: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH08 and EH07



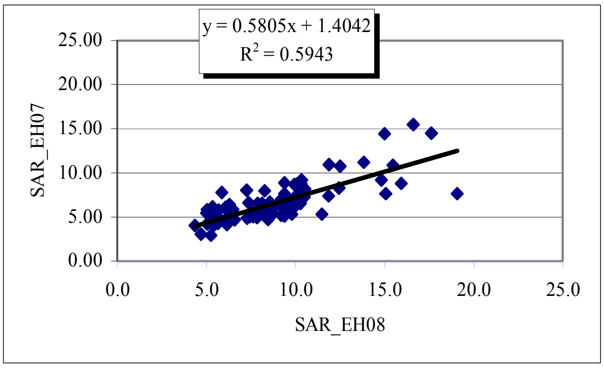
Annex 4-8C1 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH08 and EH07

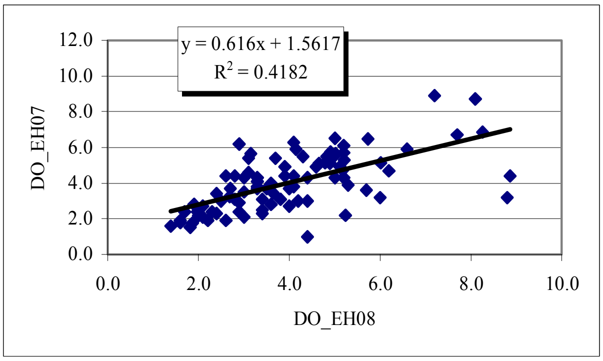


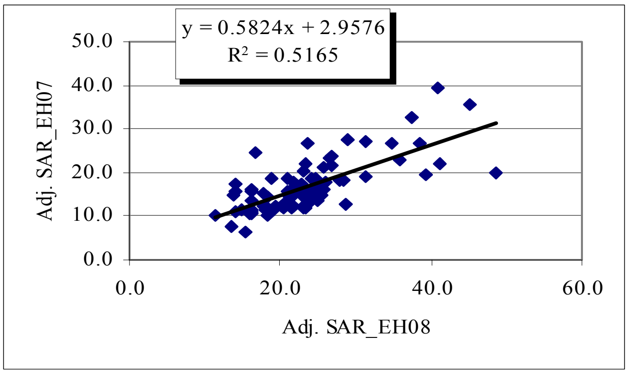
Annex 4-8C1 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH08 and EH07

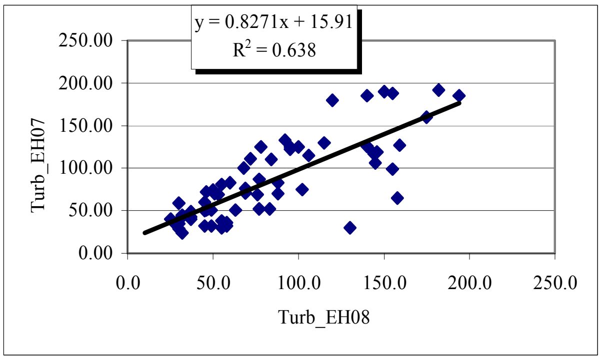


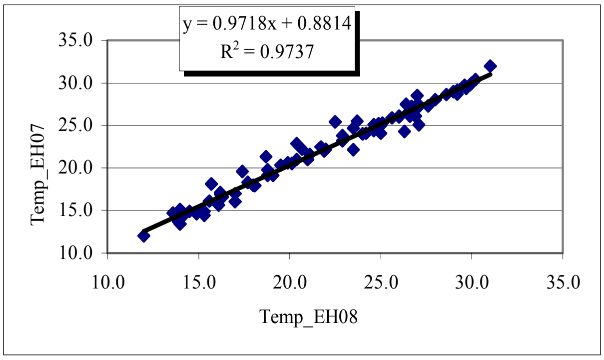
Annex 4-8C1 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH08 and EH07

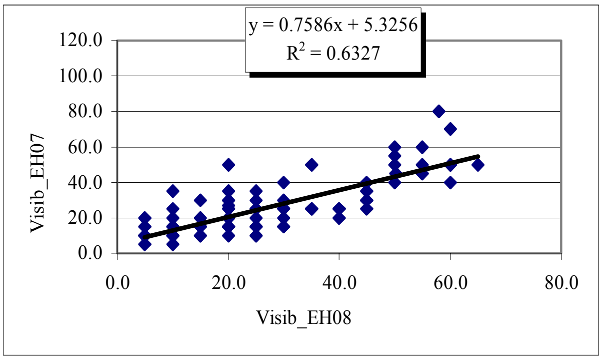


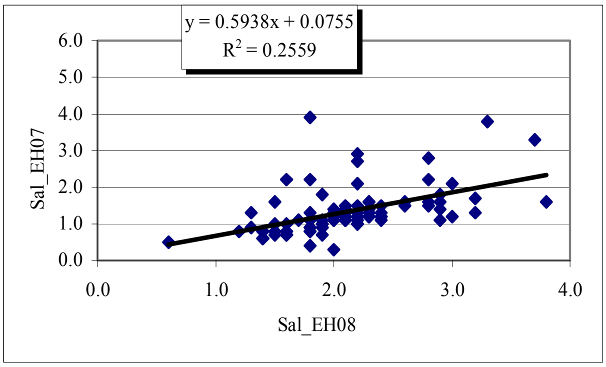


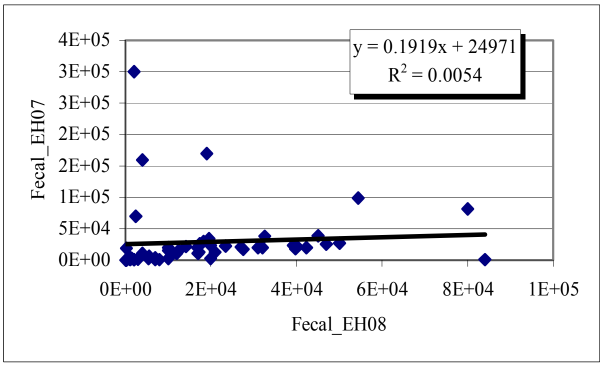




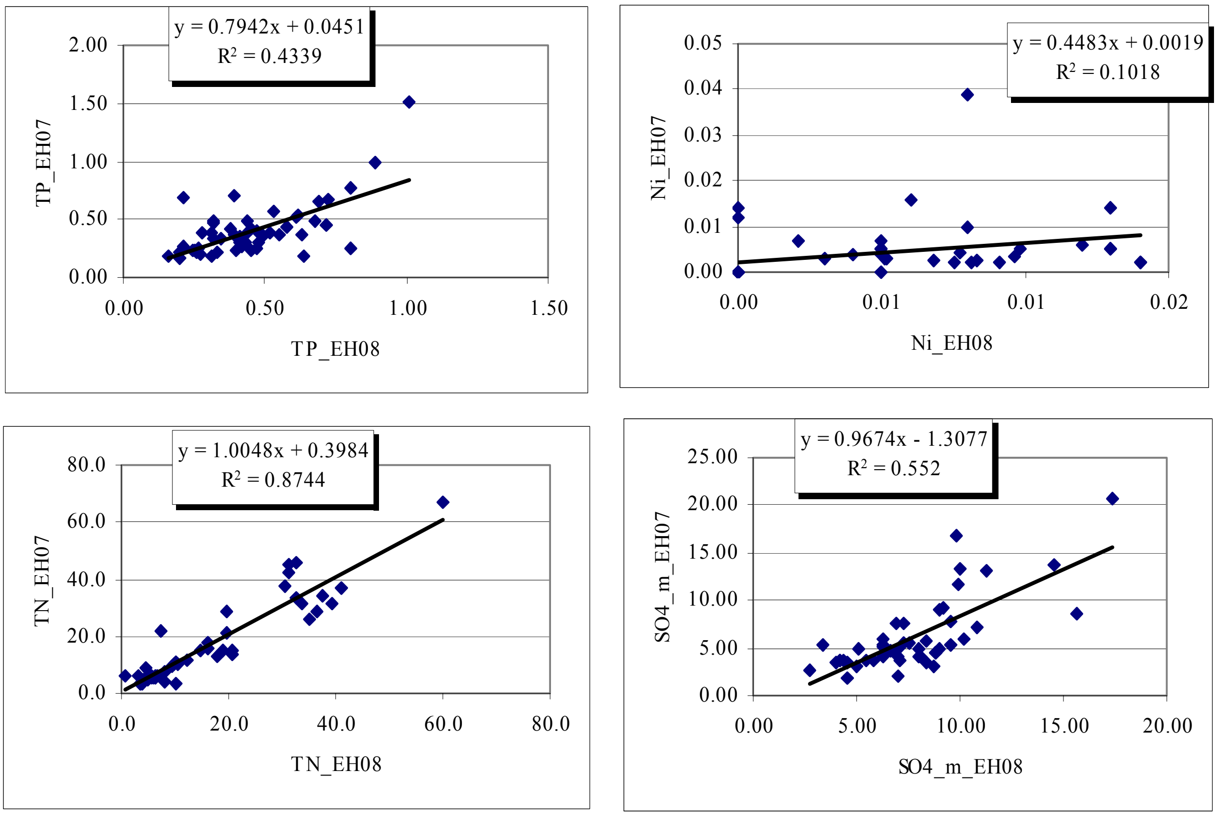




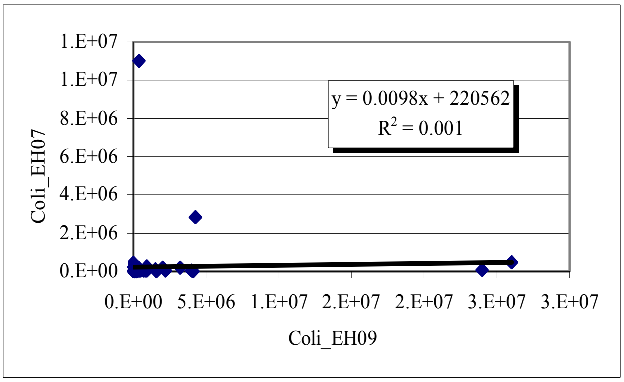


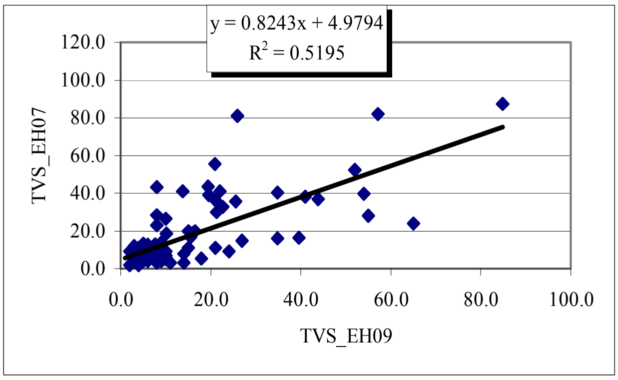


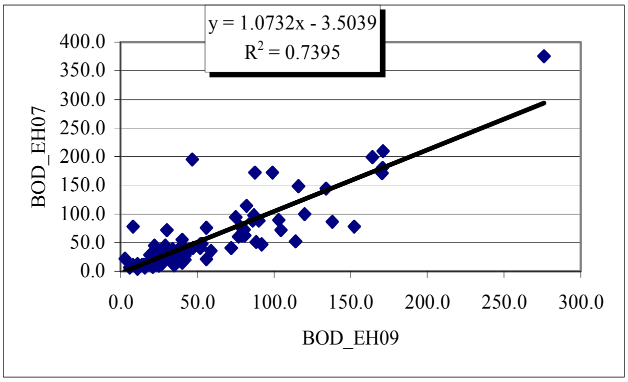
Annex 4-8C1 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH08 and EH07

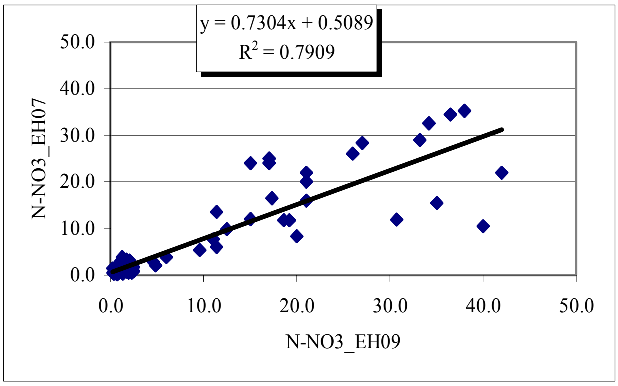


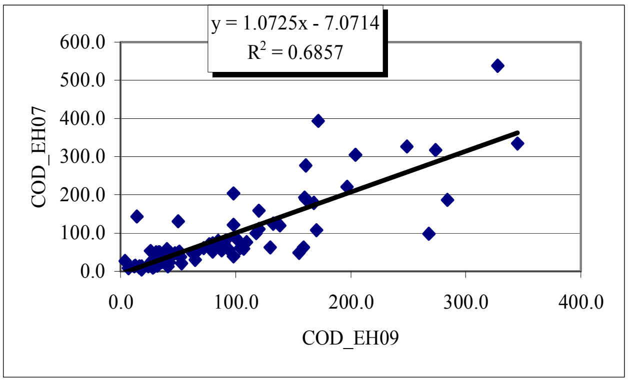
Annex 4-8C2: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH09 and EH07

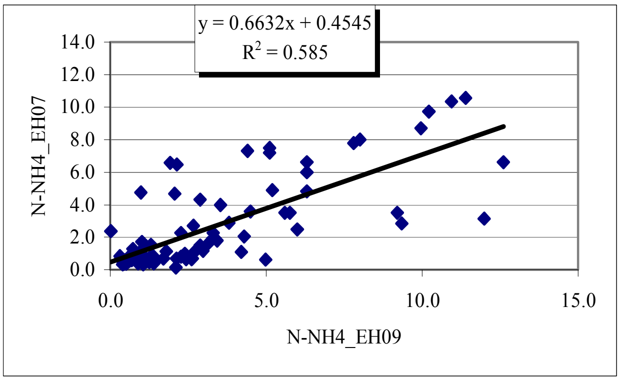


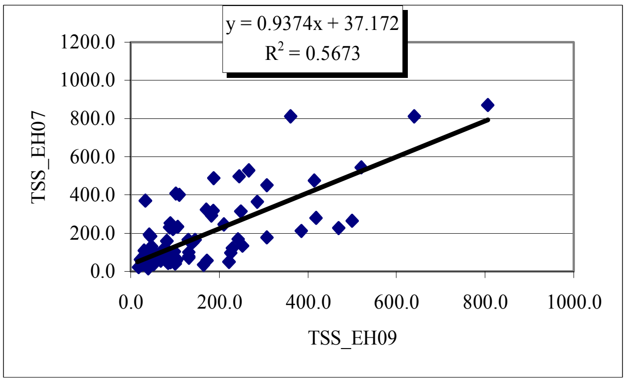


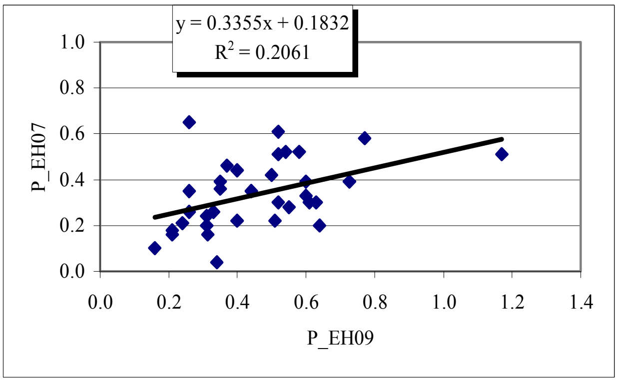




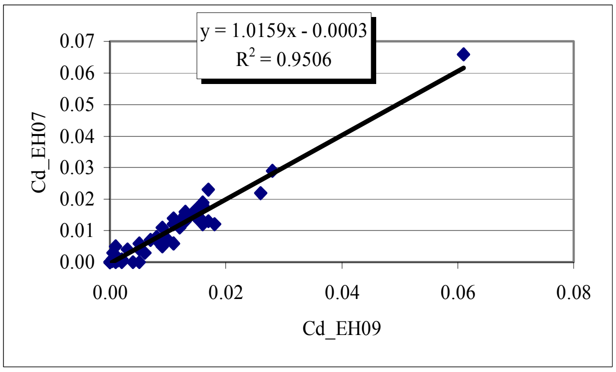


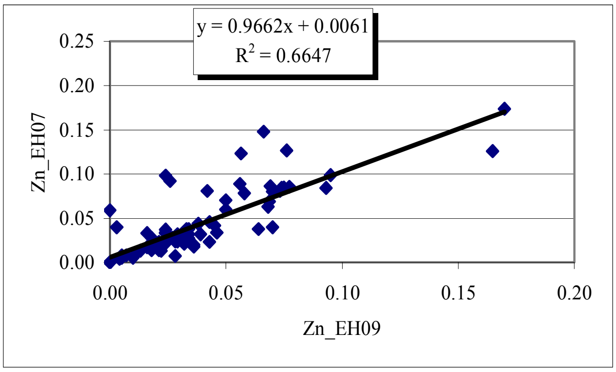


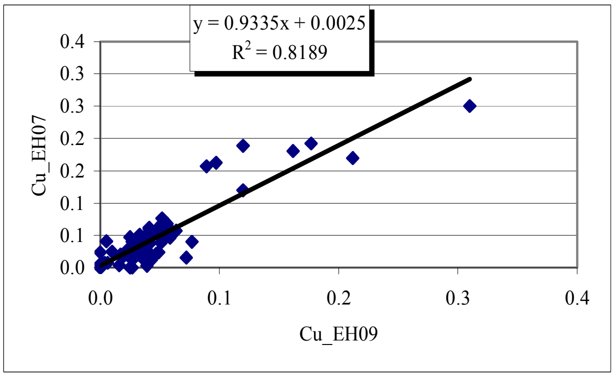


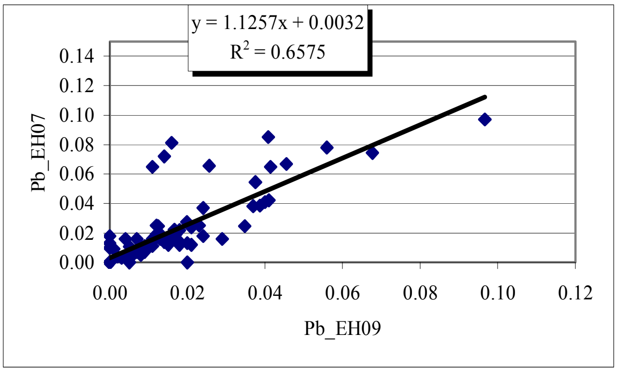


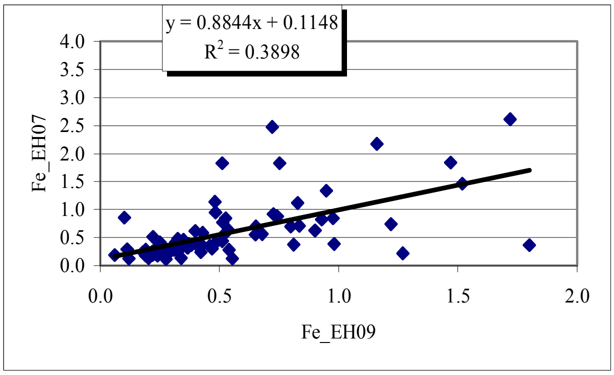
Annex 4-8C2 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH09 and EH07

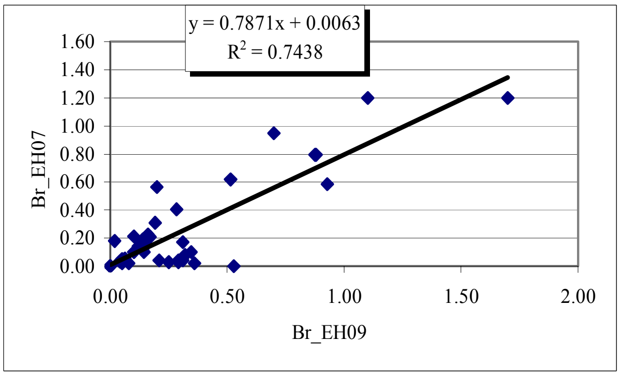


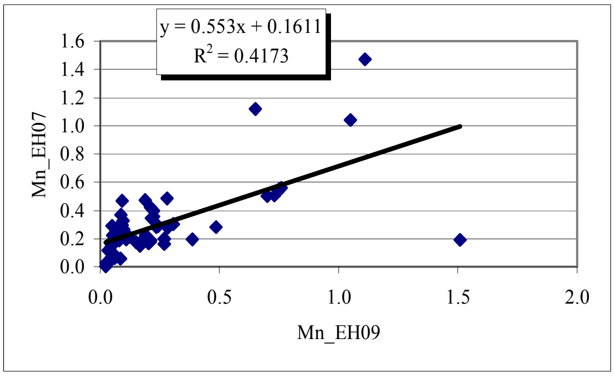


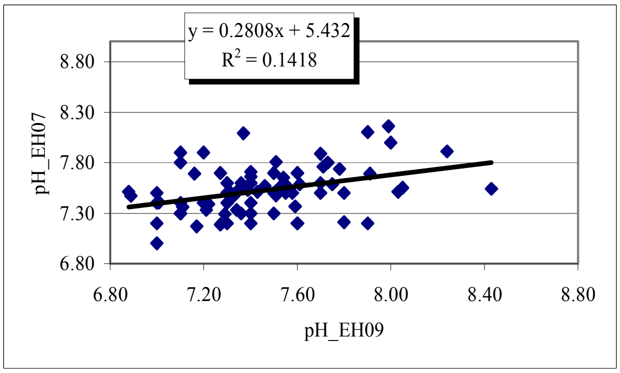




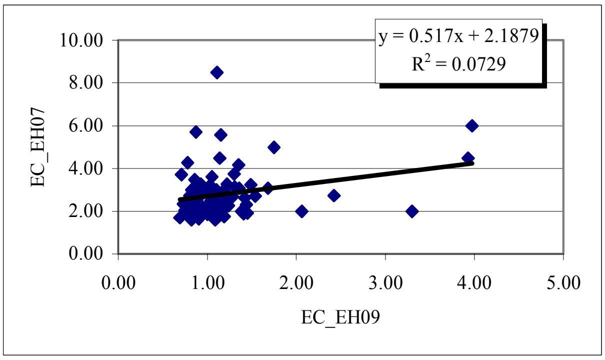


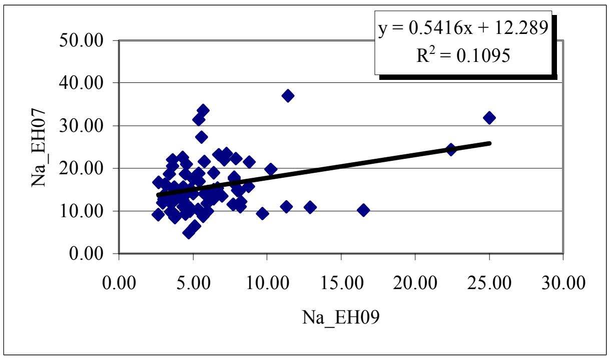


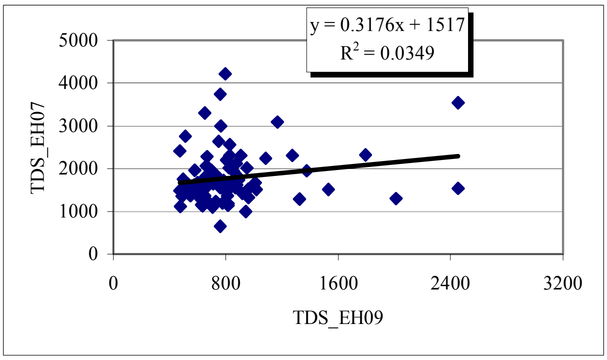


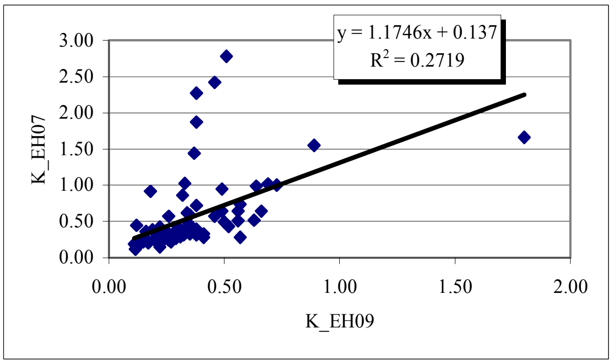


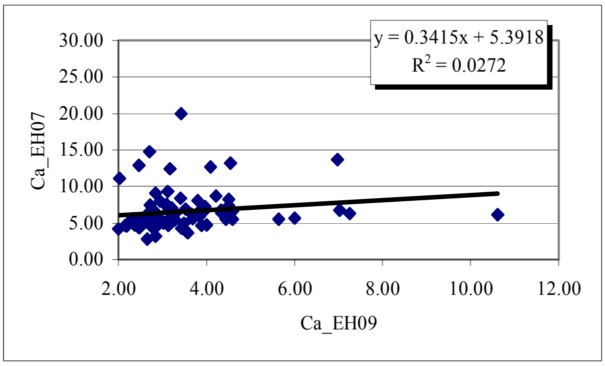
Annex 4-8C2 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH09 and EH07

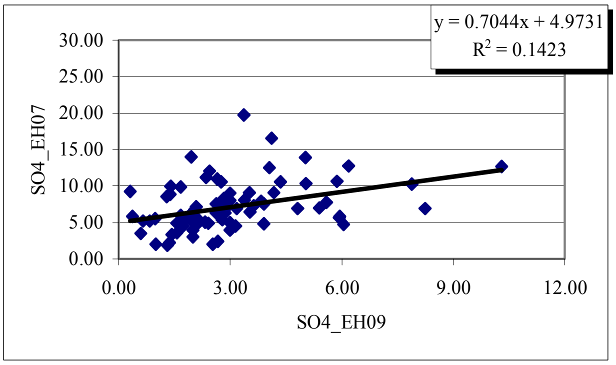


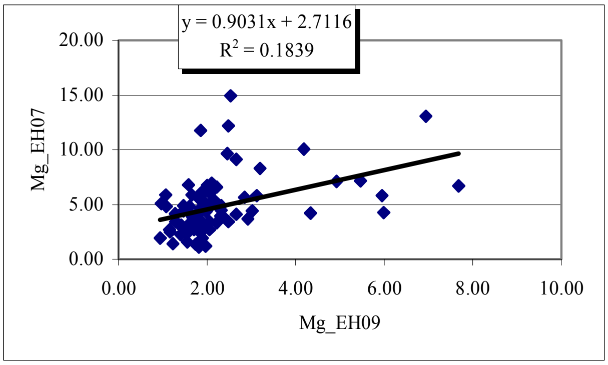


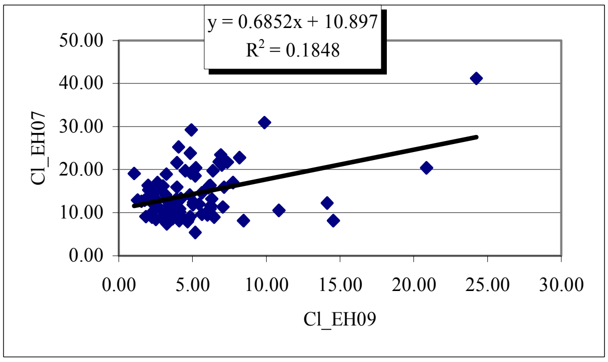




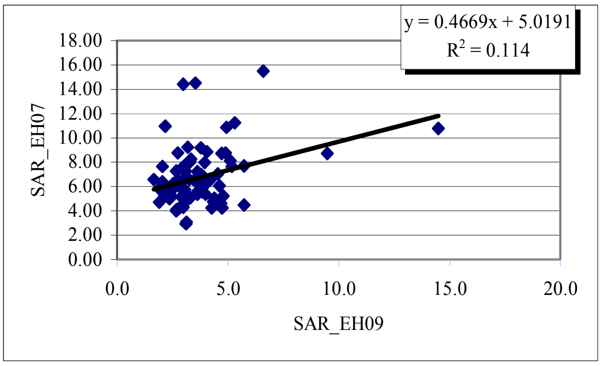


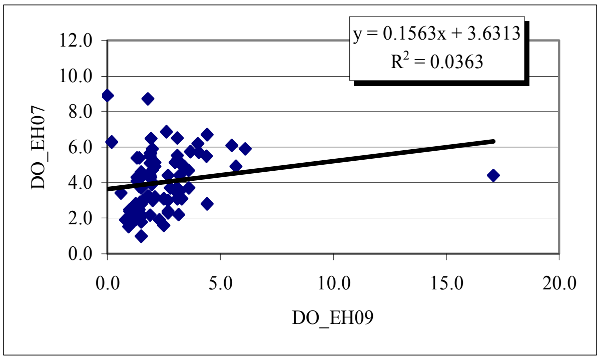


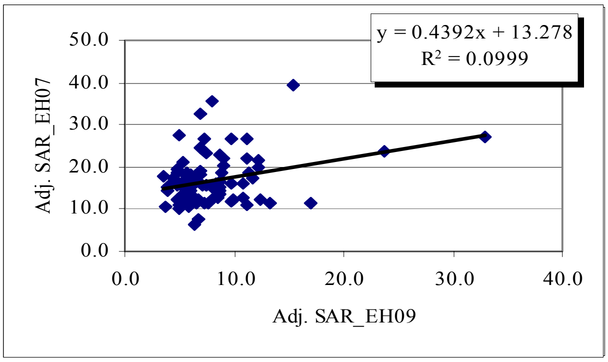


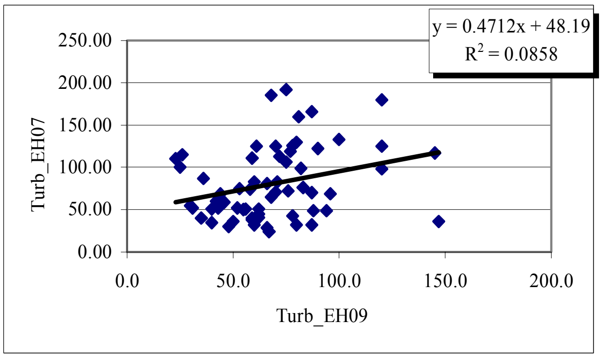


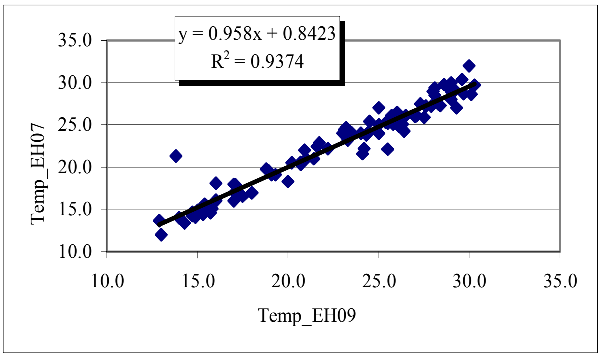
Annex 4-8C2 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH09 and EH07

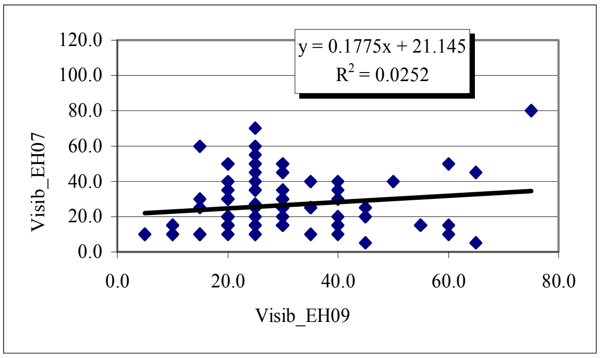


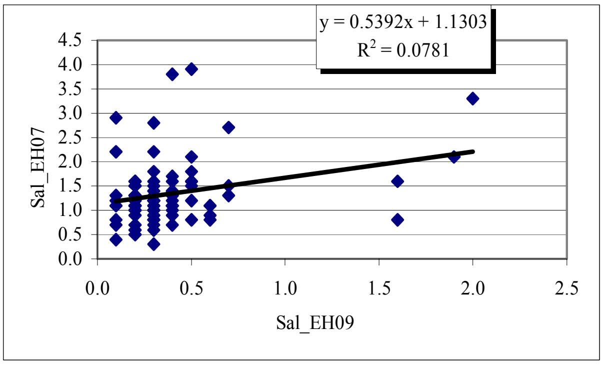


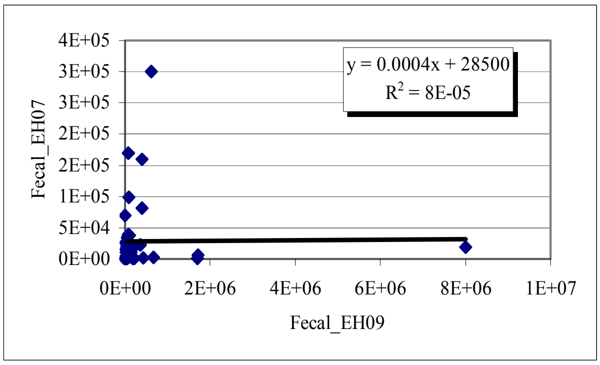




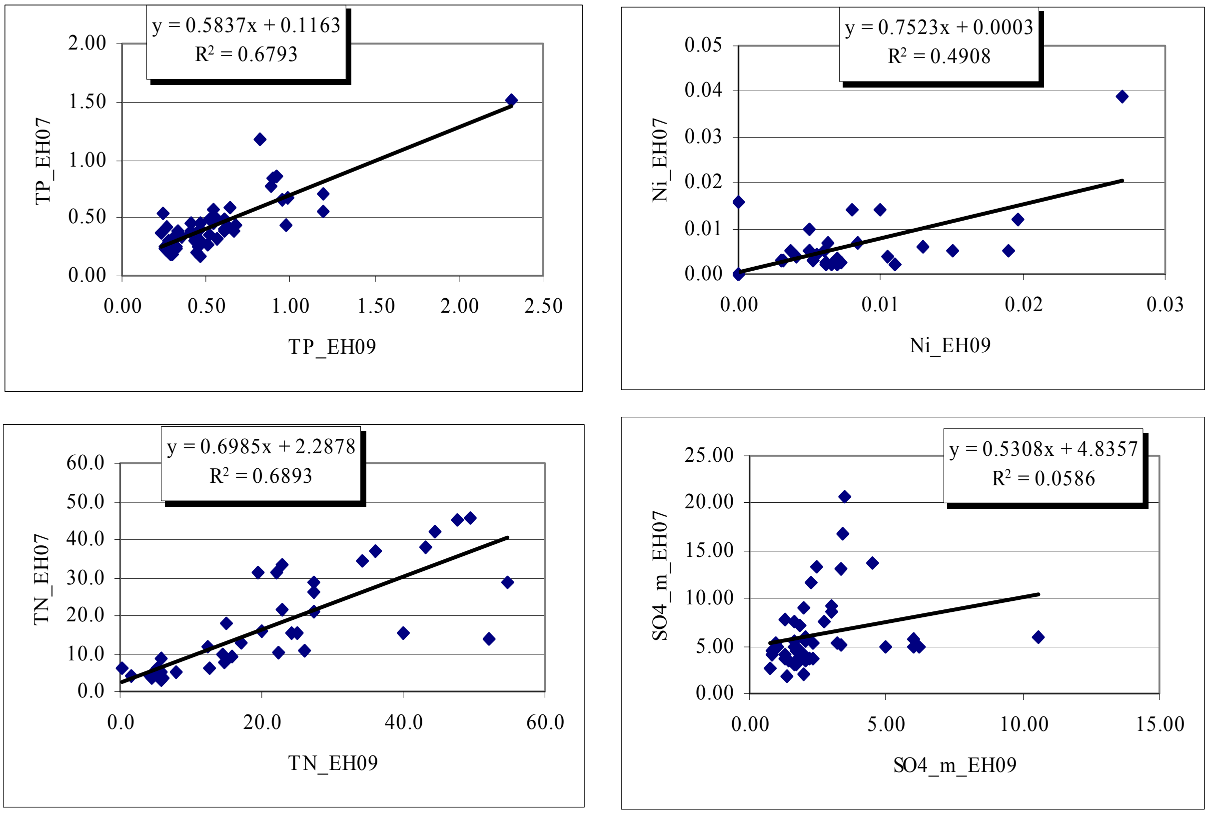




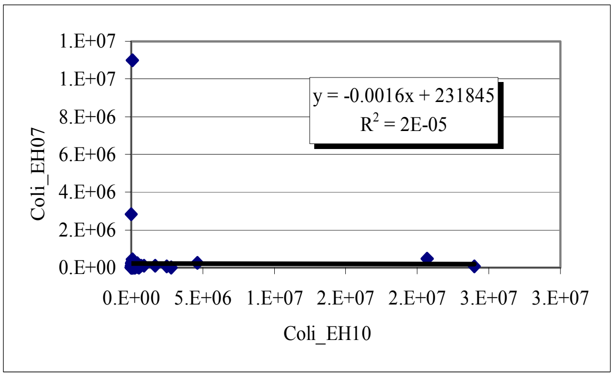


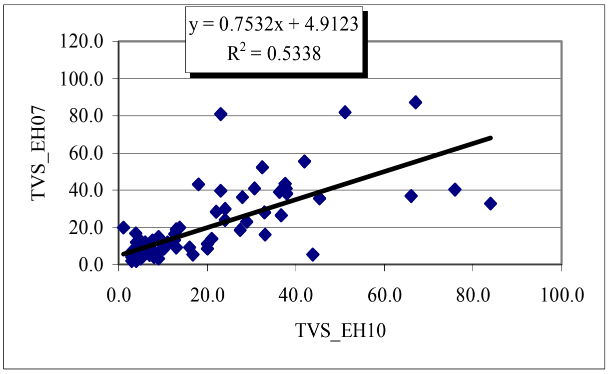


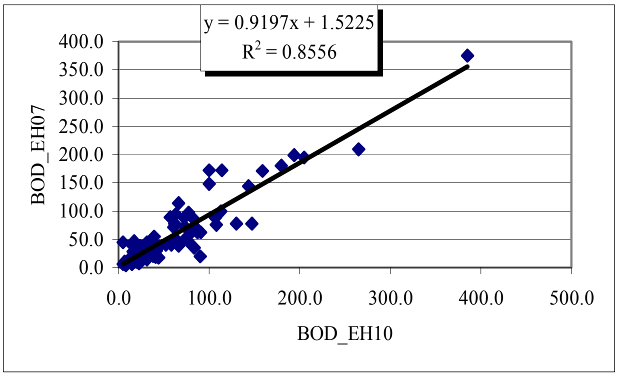
Annex 4-8C2 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH09 and EH07

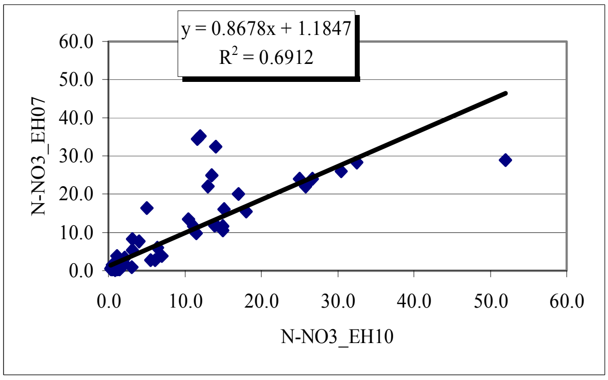


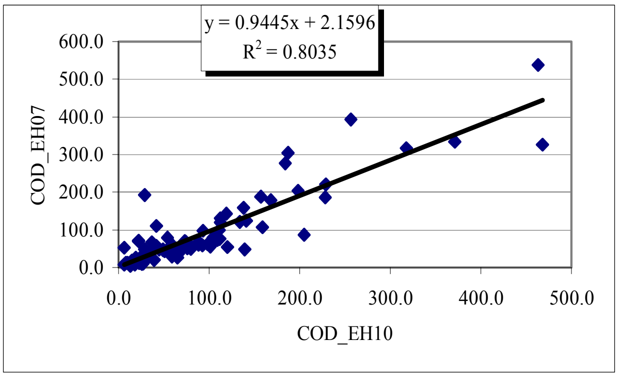
Annex 4-8C3: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH10 and EH07

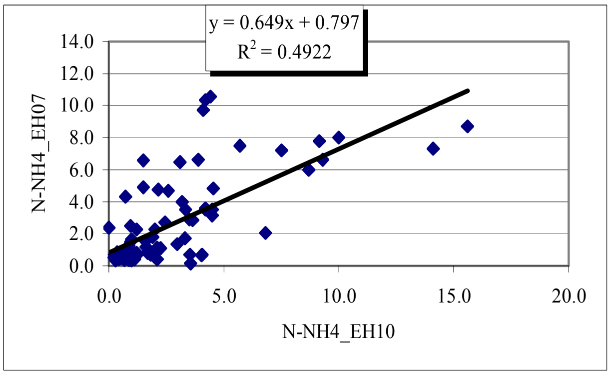


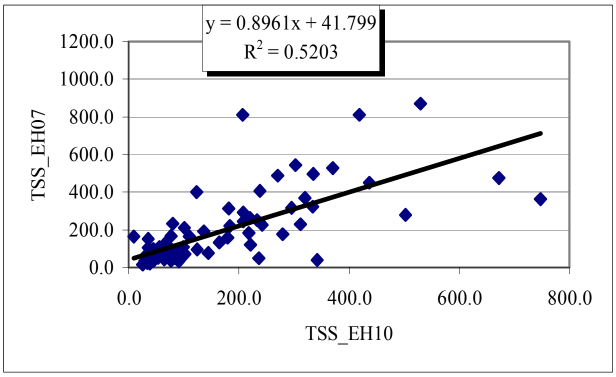


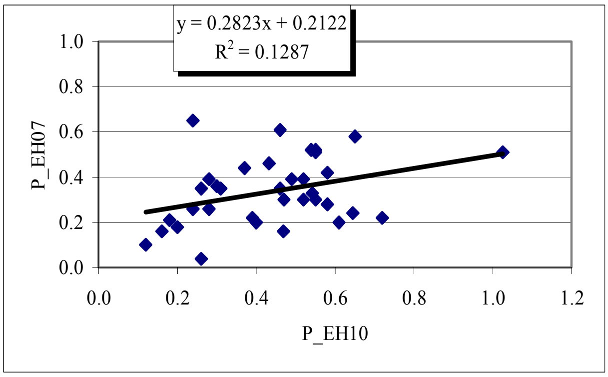




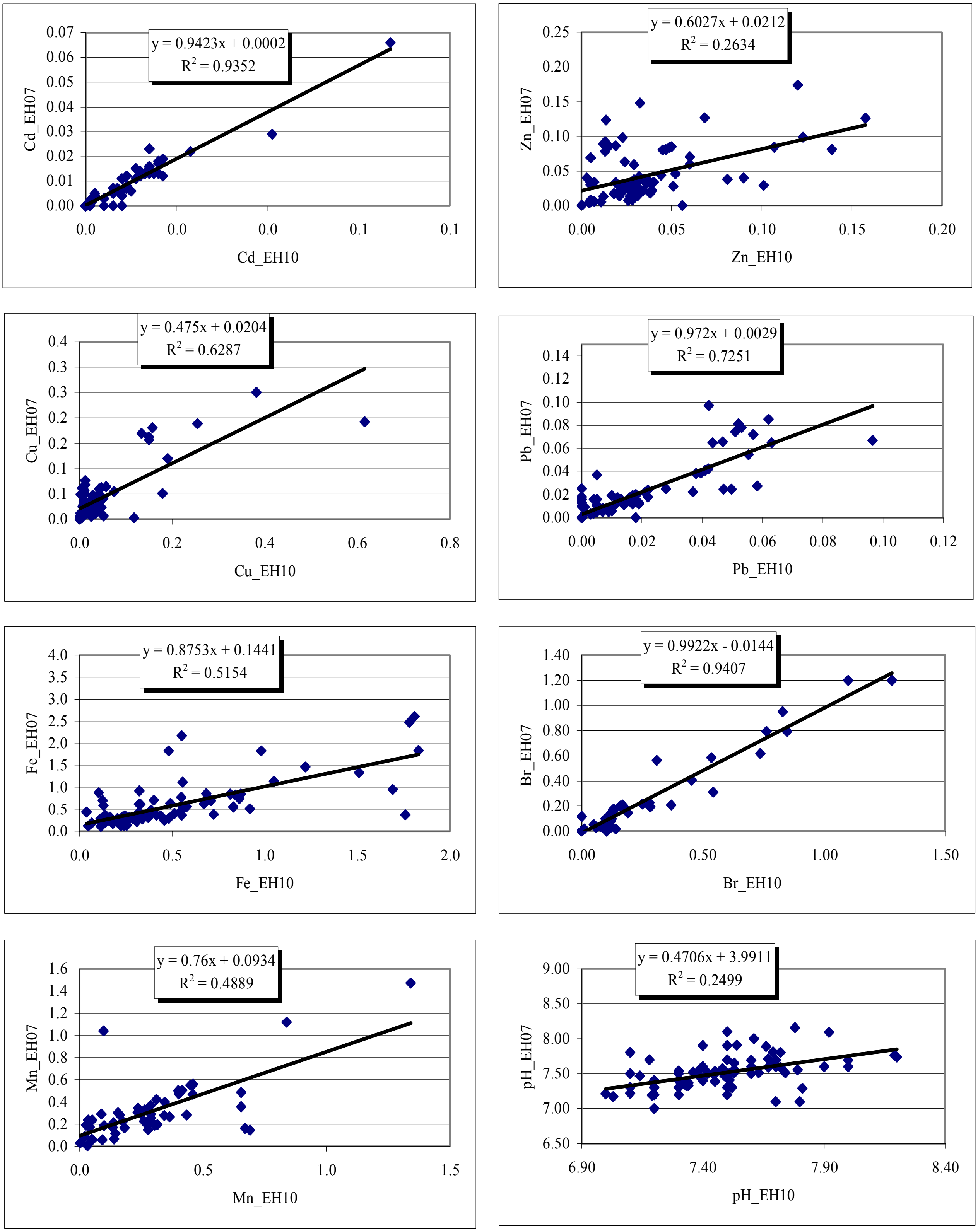




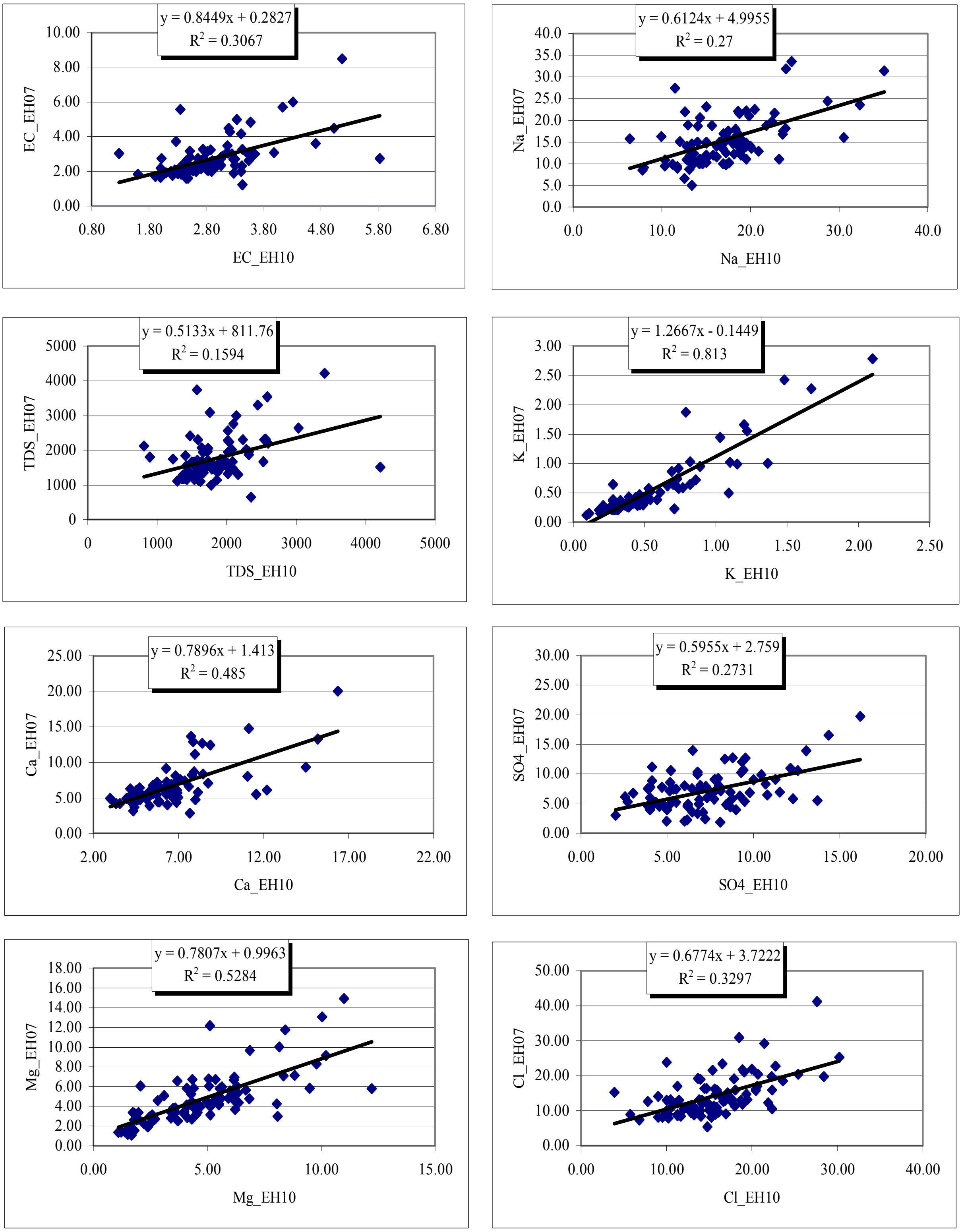




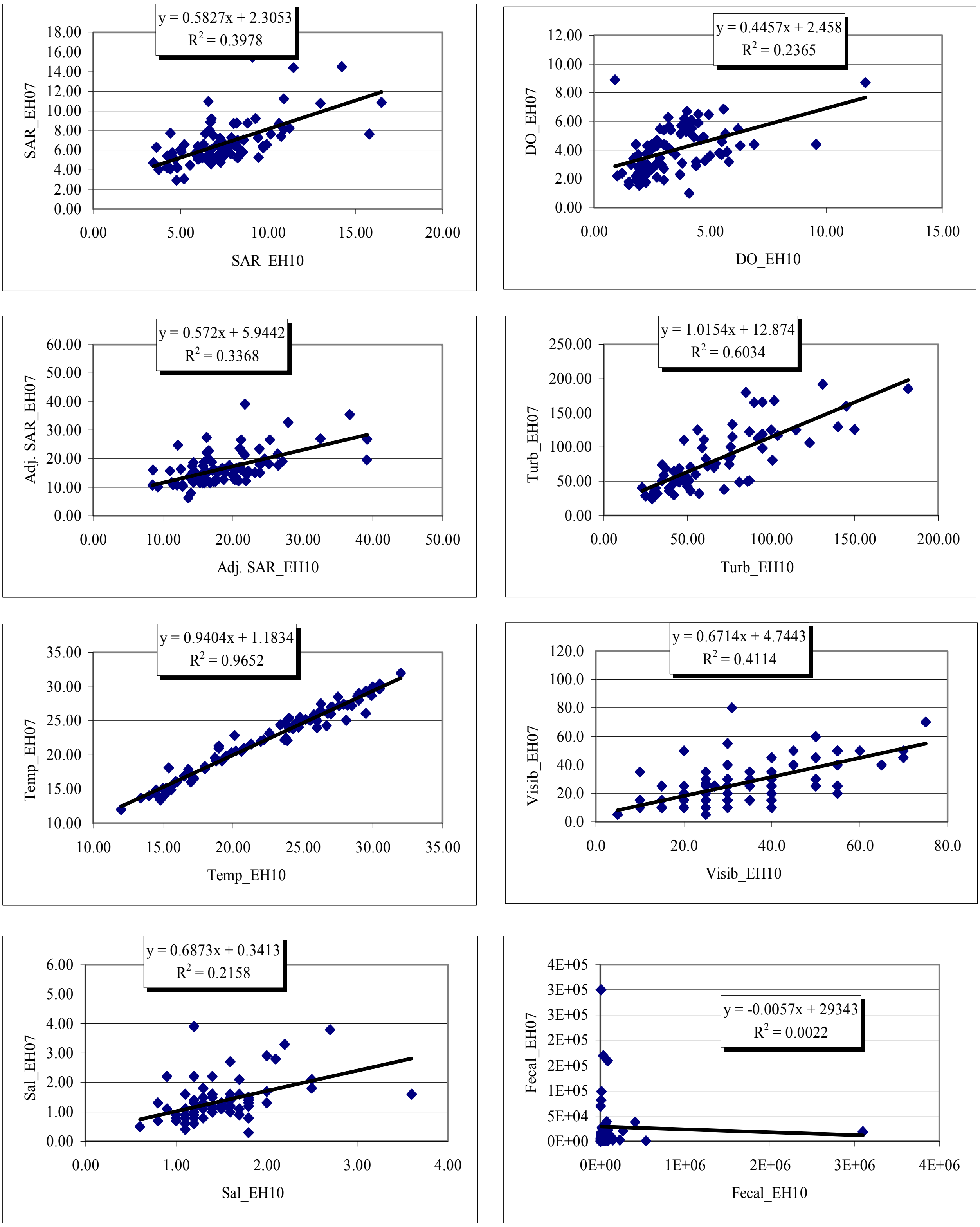
Annex 4-8C3 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH10 and EH07



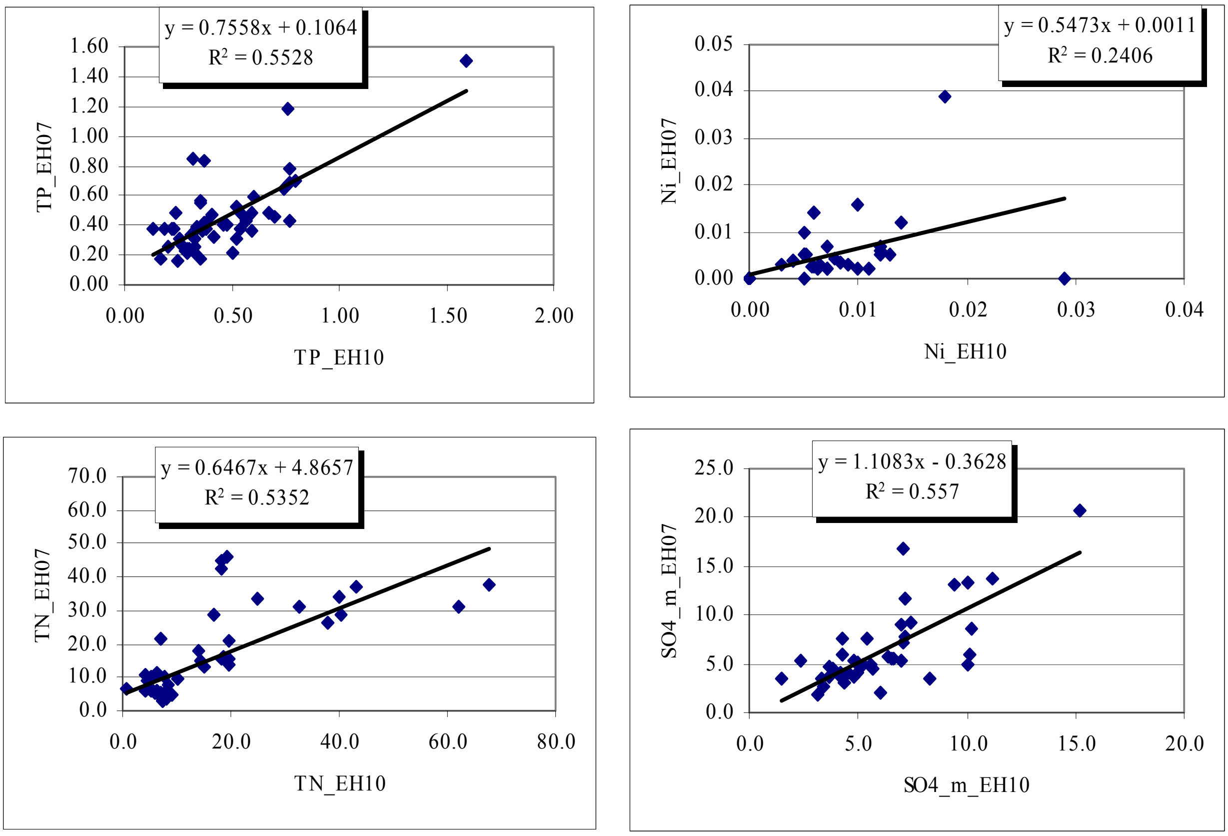
Annex 4-8C3 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH10 and EH07



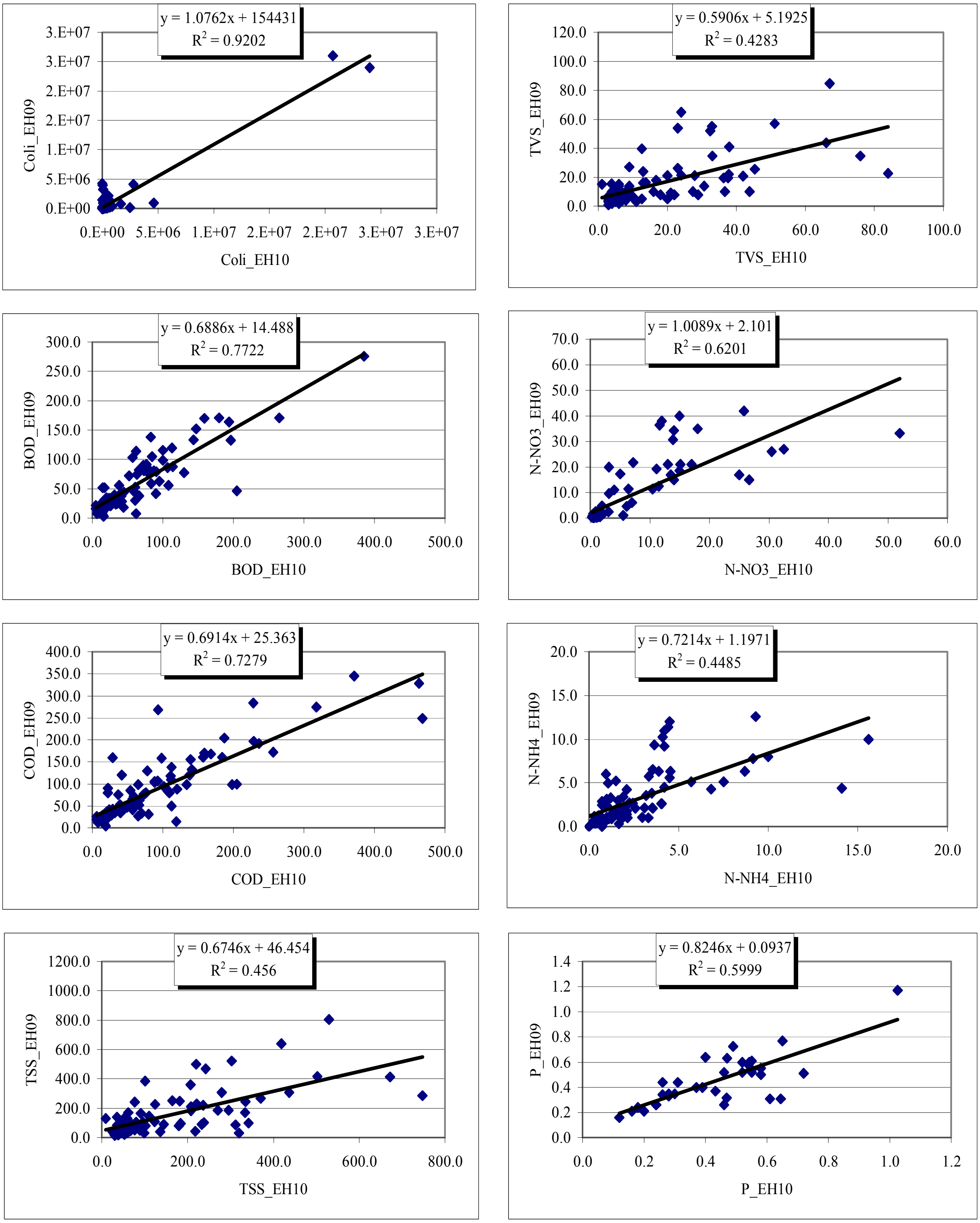
Annex 4-8C3 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH10 and EH07



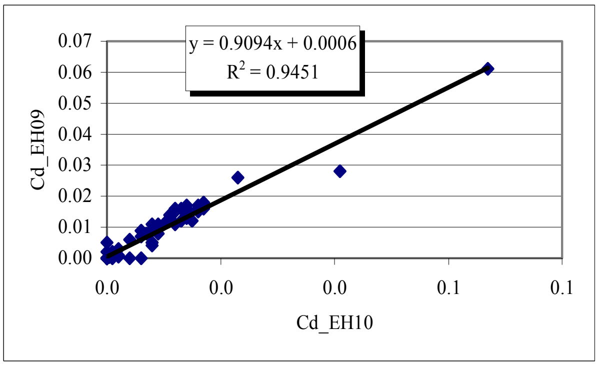
Annex 4-8C3 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH10 and EH07

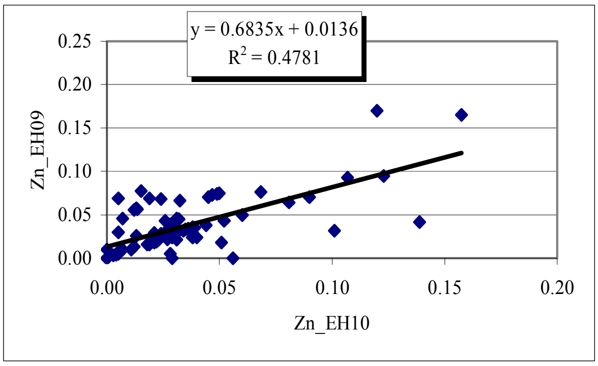


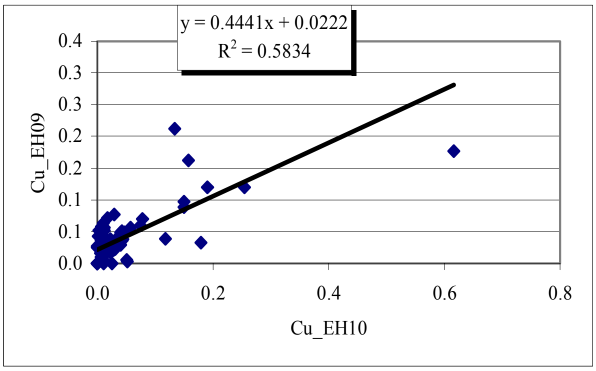
Annex 4-8C4: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH10 and EH09

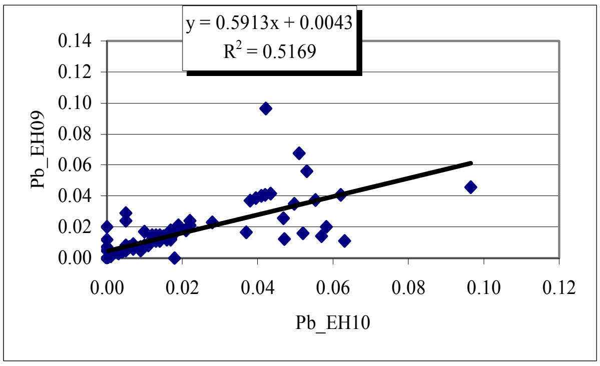


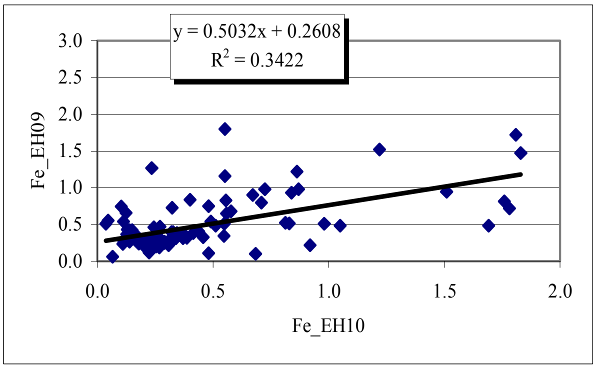
Annex 4-8C4 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH10 and EH09

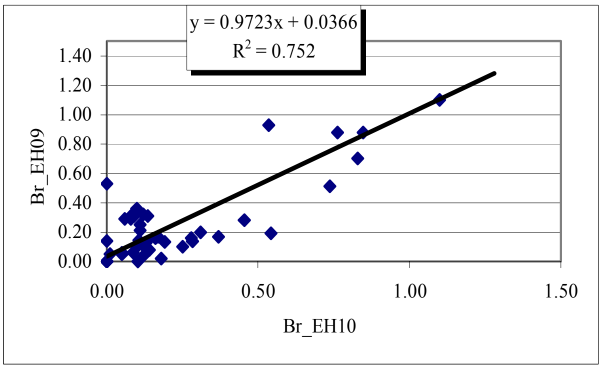


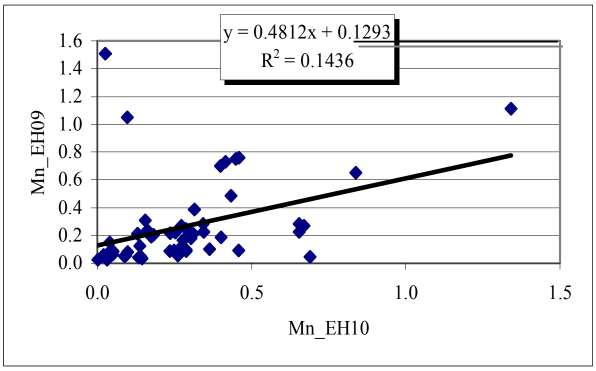


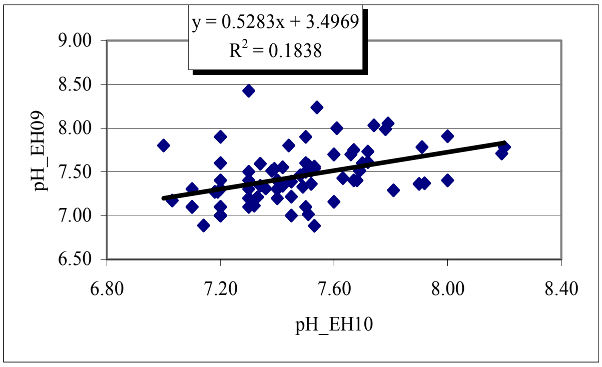




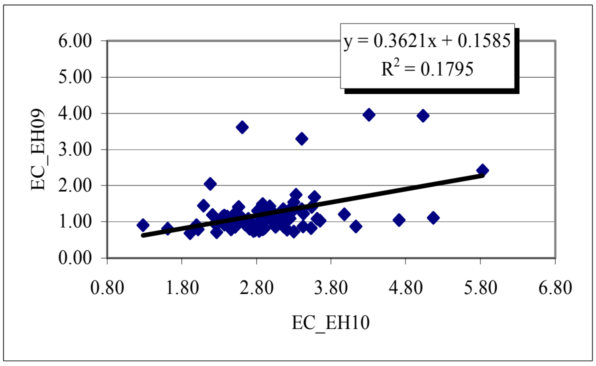


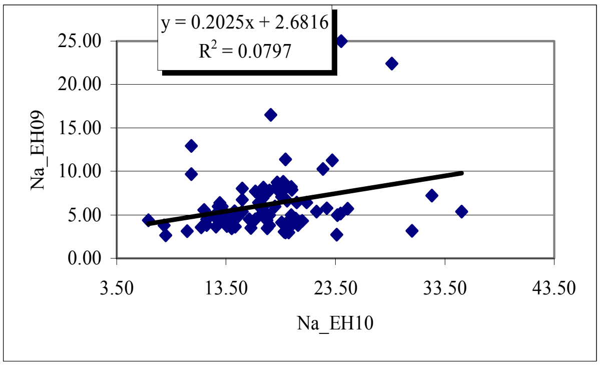


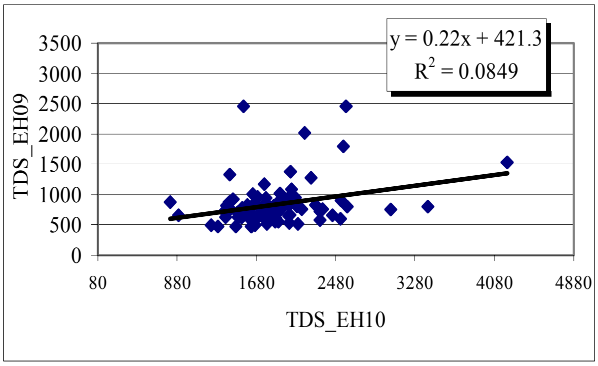


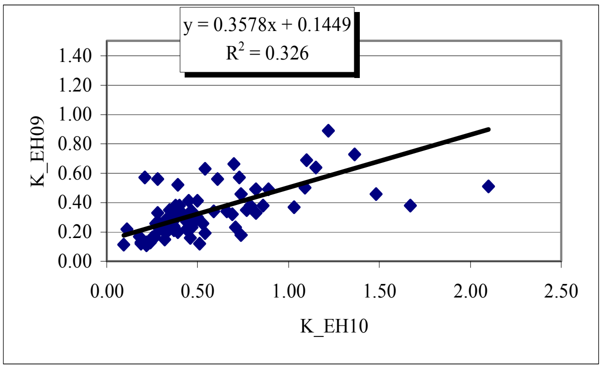


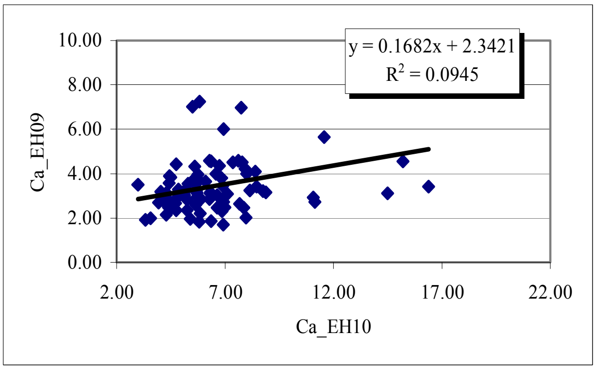
Annex 4-8C4 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH10 and EH09

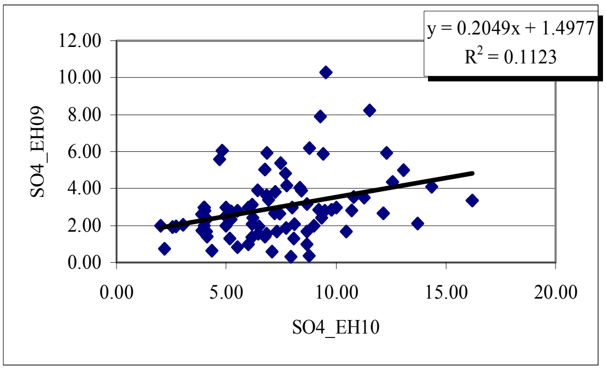


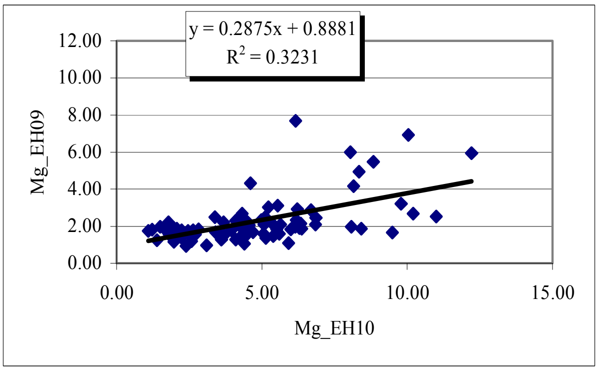


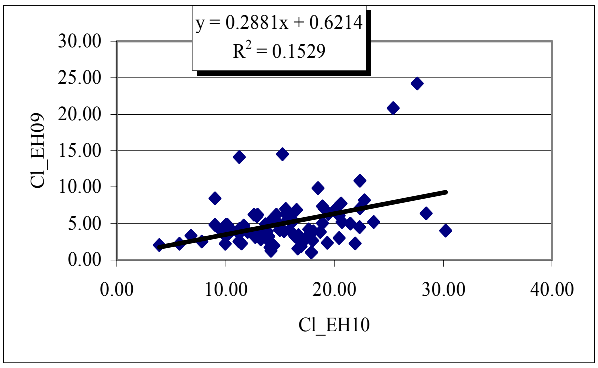




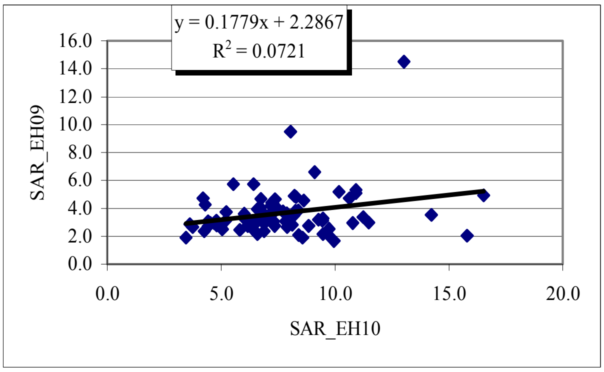


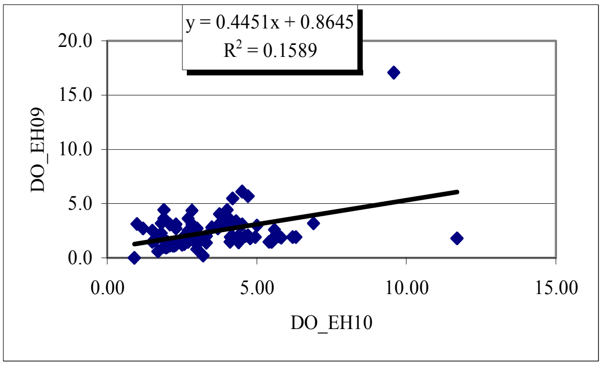


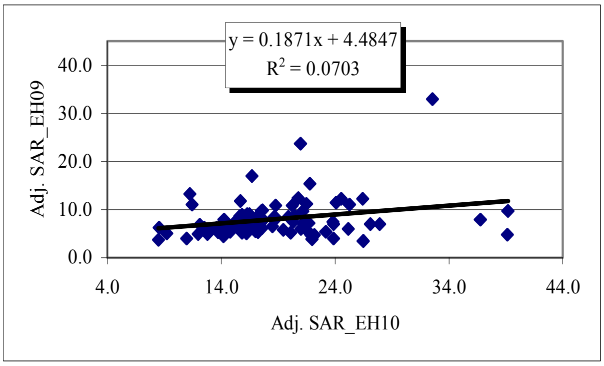


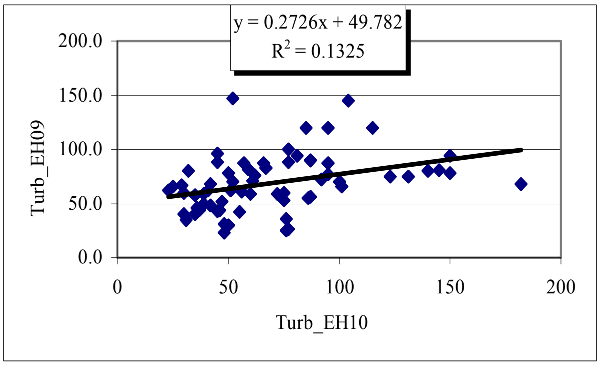


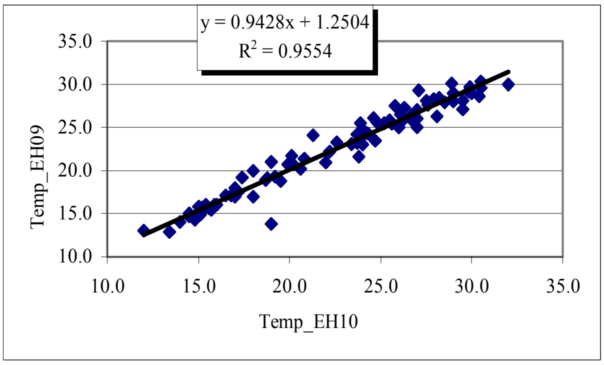
Annex 4-8C4 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH10 and EH09

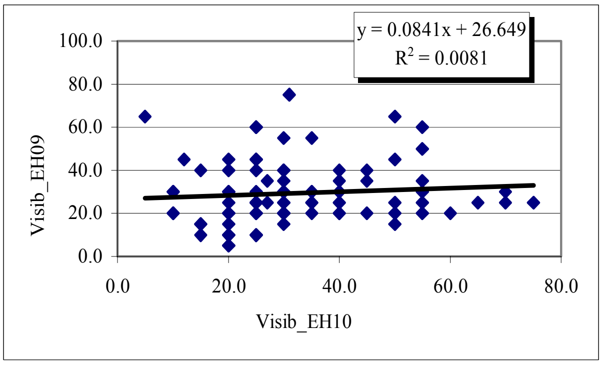


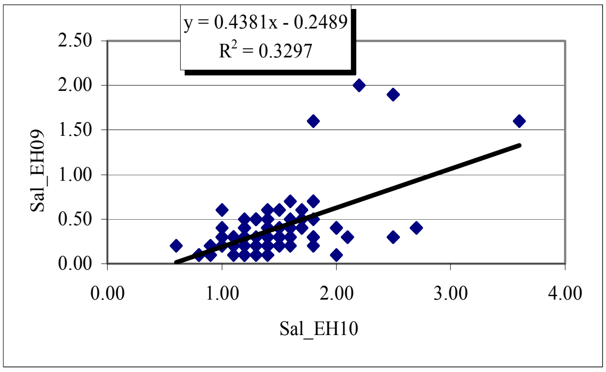


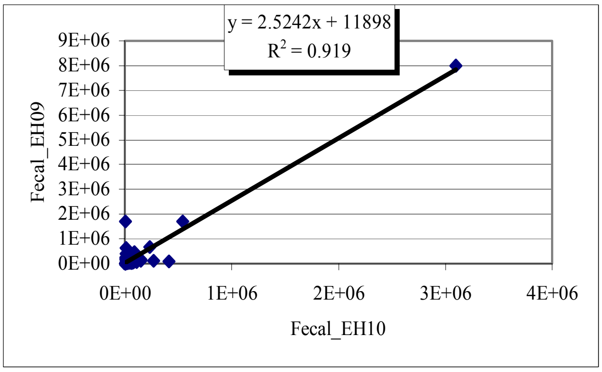




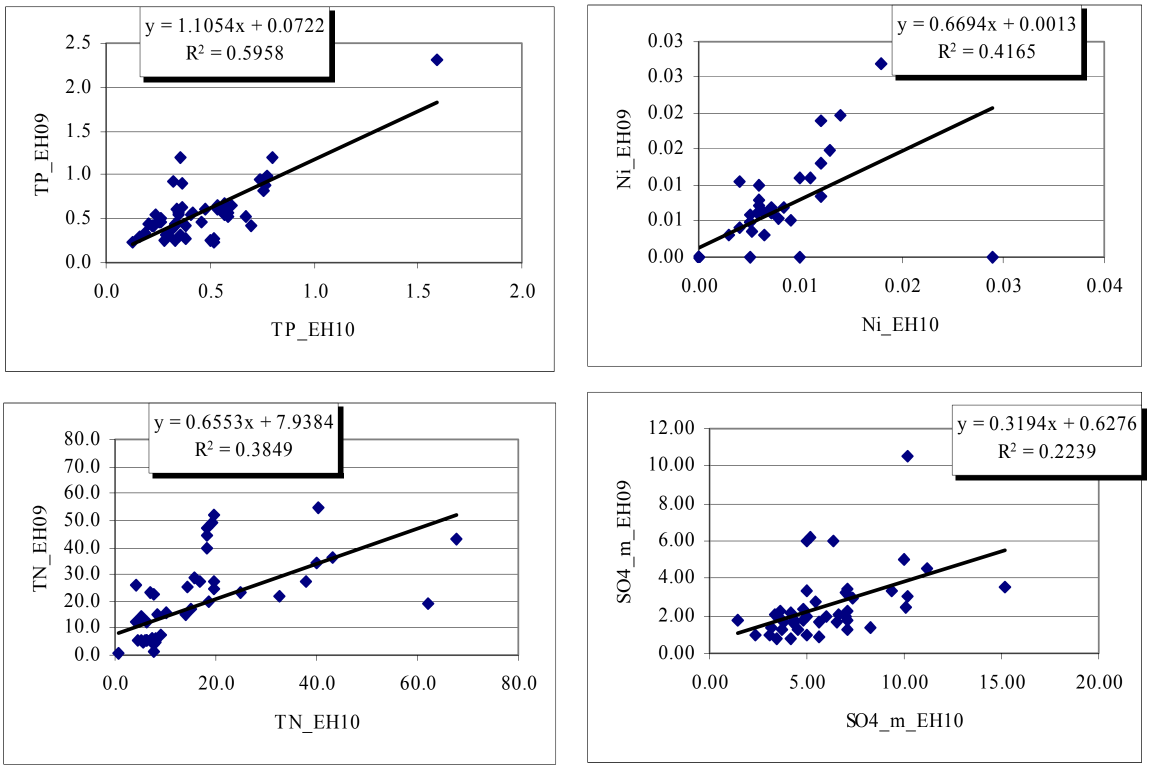




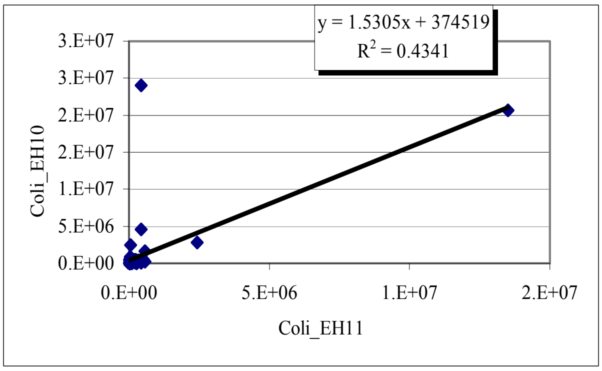


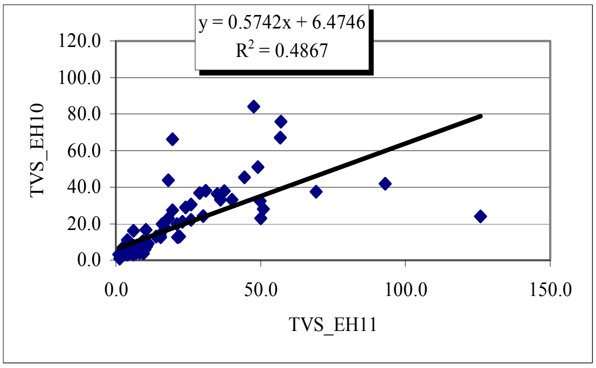


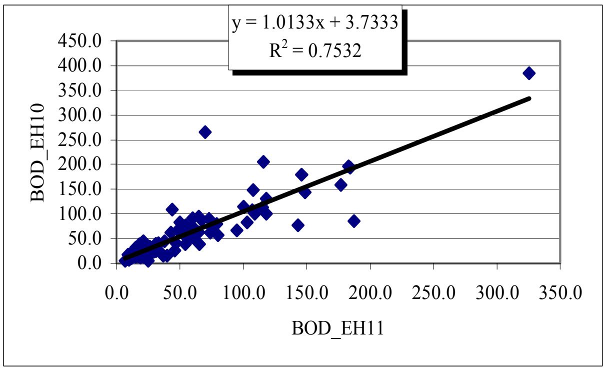
Annex 4-8C4 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH10 and EH09

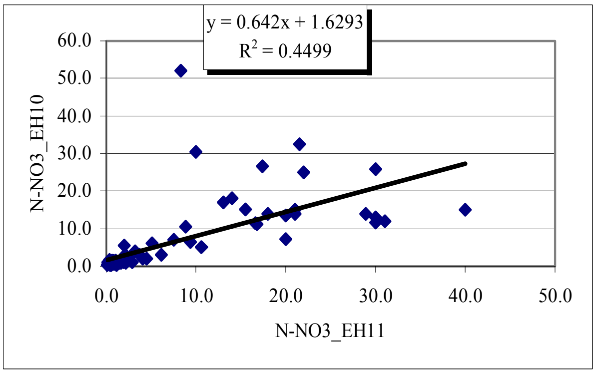


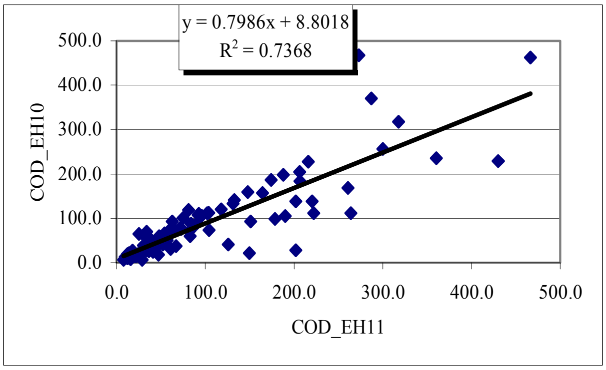
Annex 4-8C5: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH11 and EH10

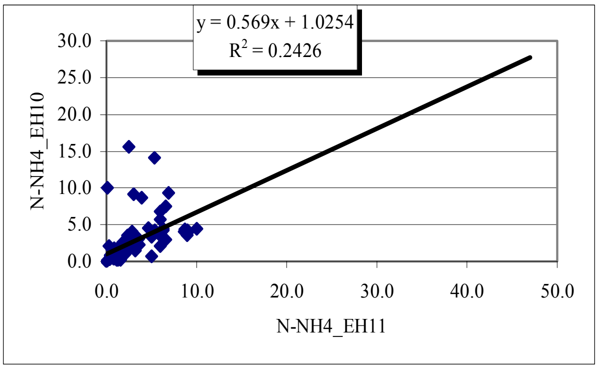


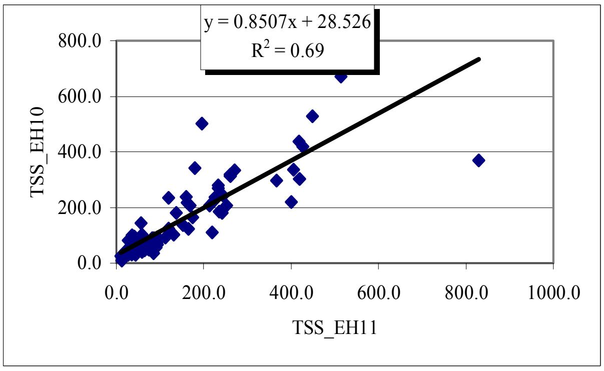


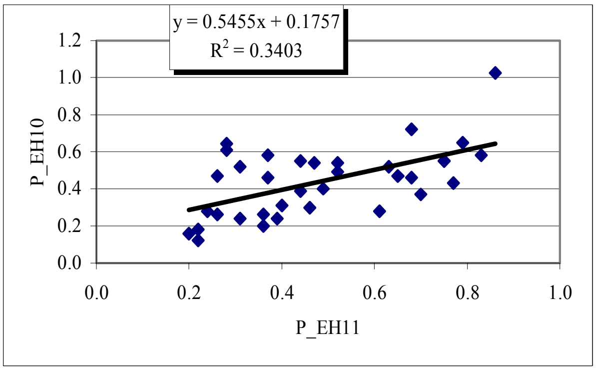




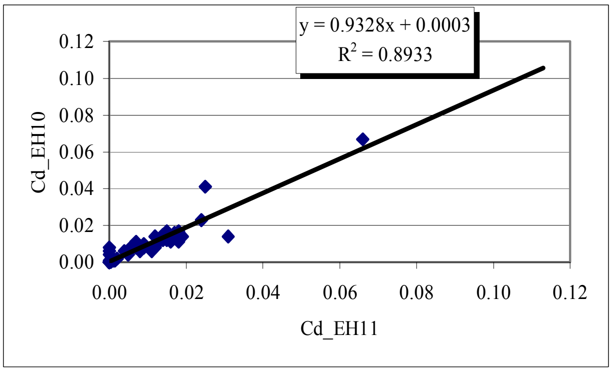


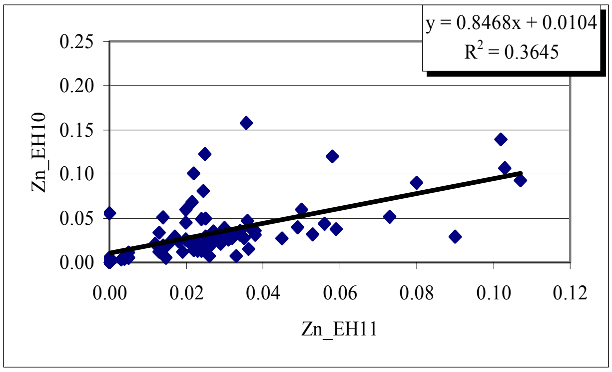


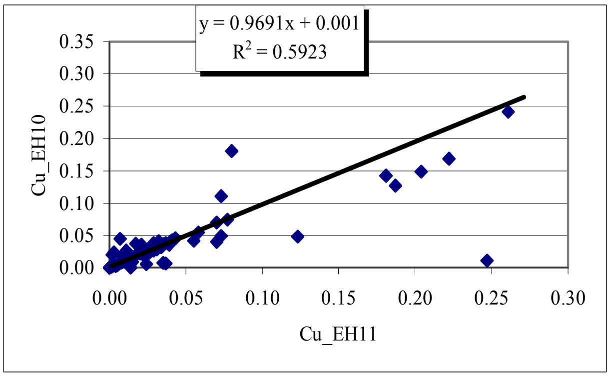


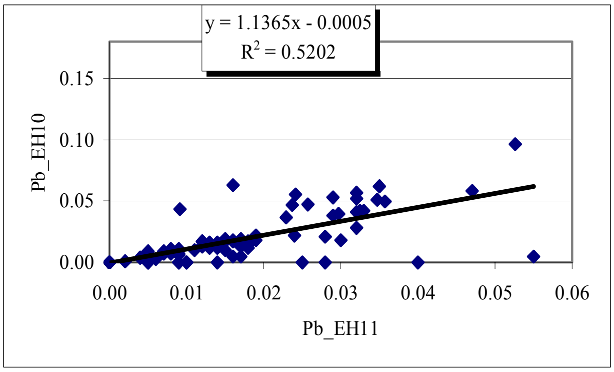


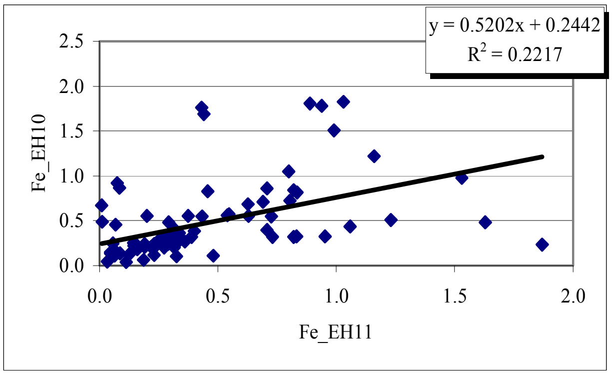
Annex 4-8C5 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH11and EH10

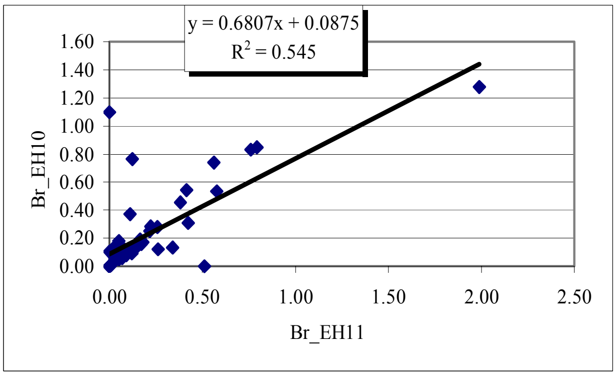


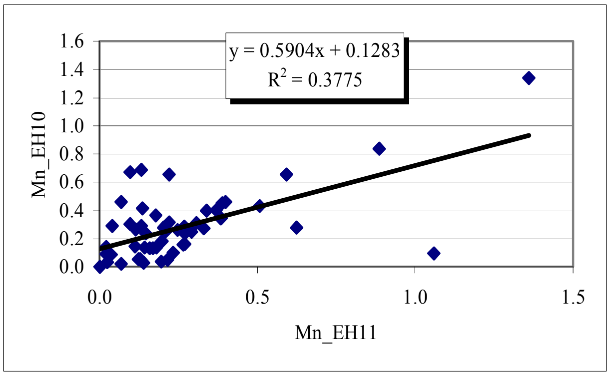


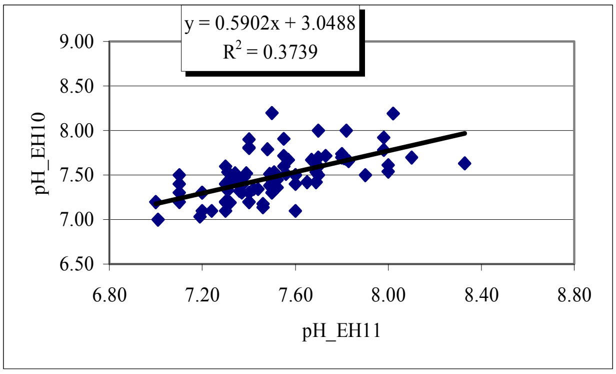




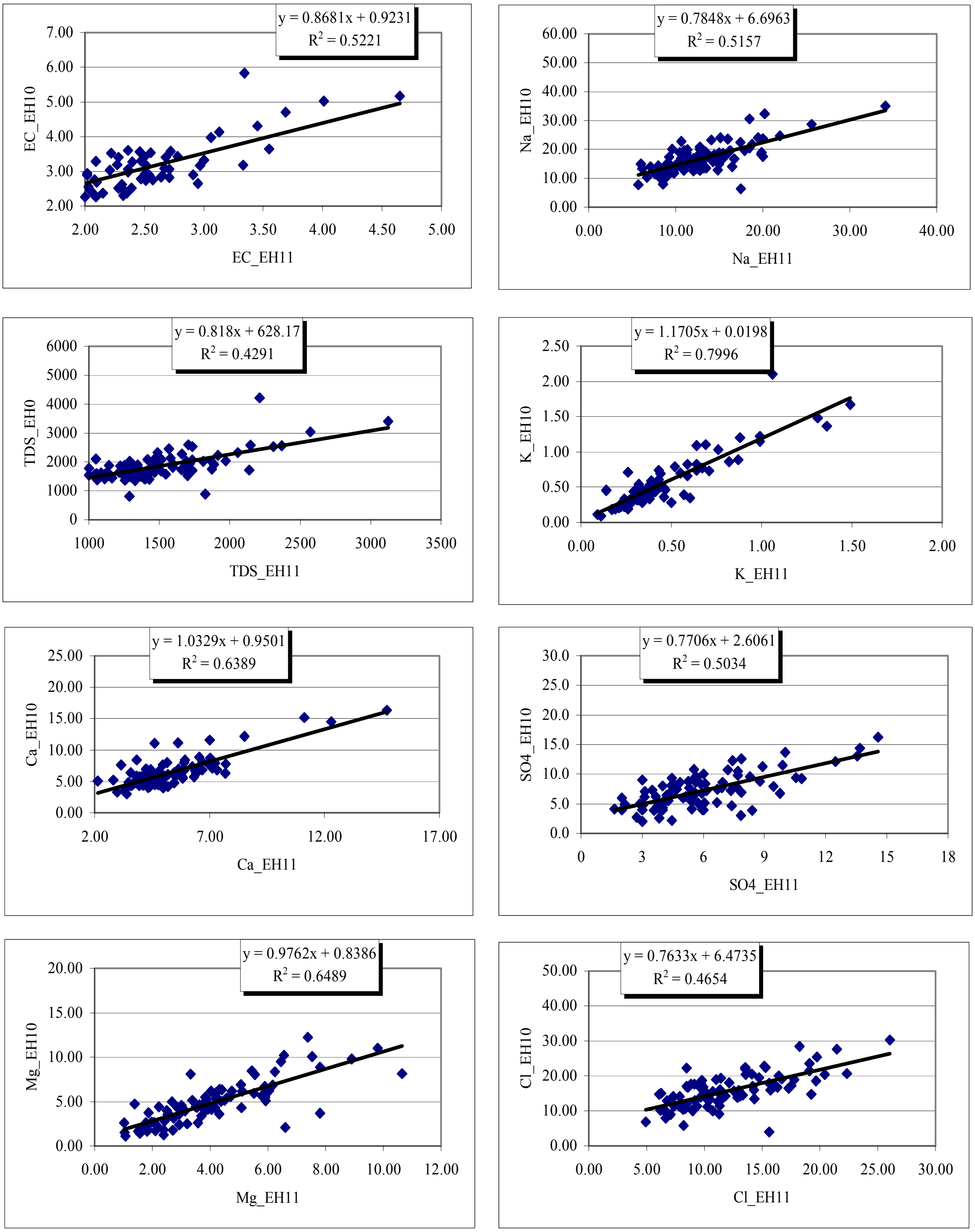




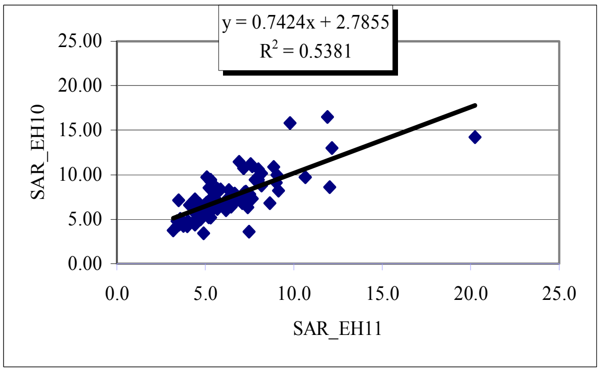


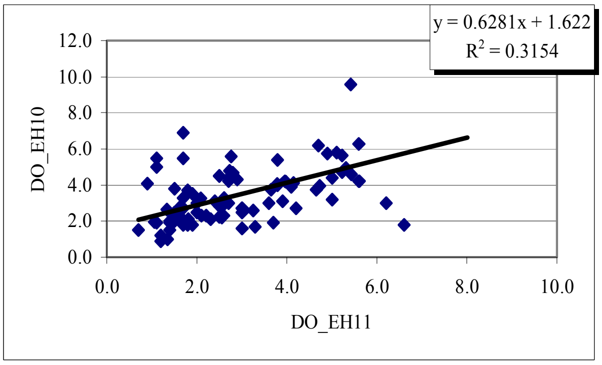


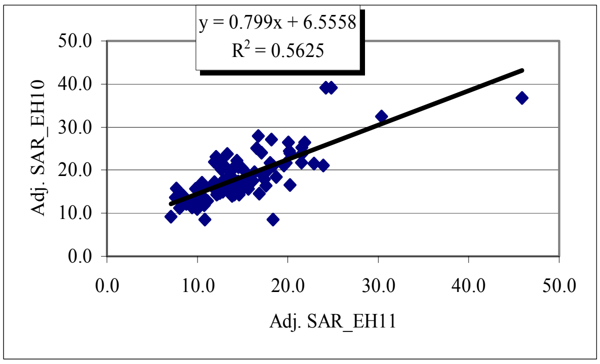
Annex 4-8C5 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH11and EH10

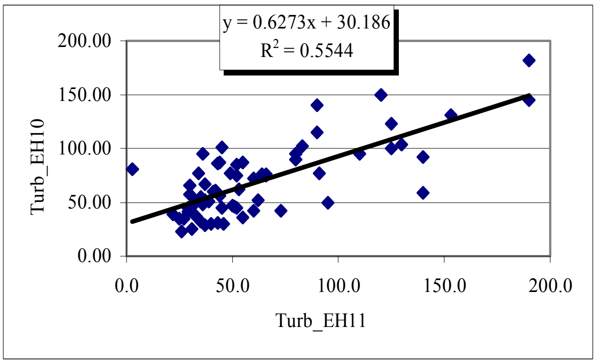


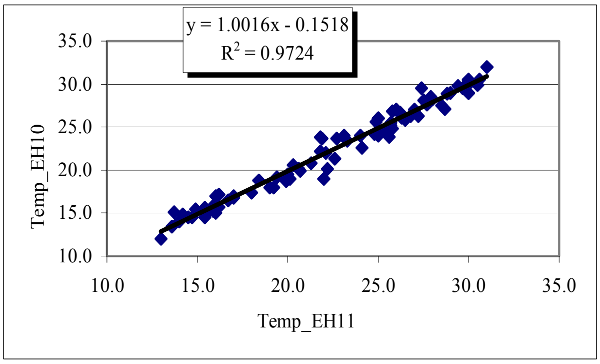
Annex 4-8C5 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH11and EH10

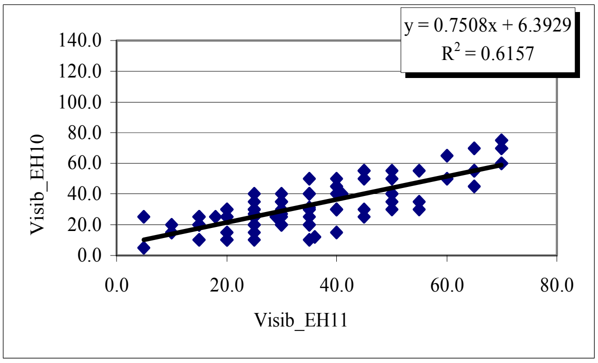


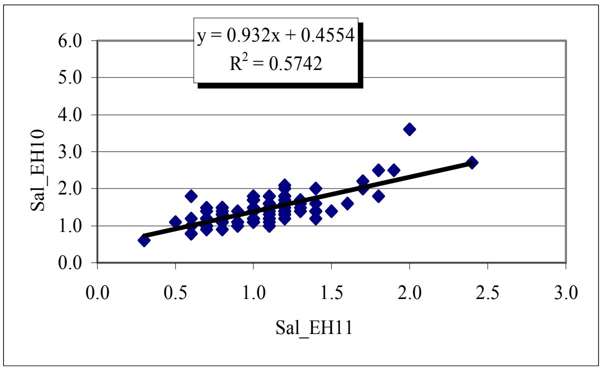


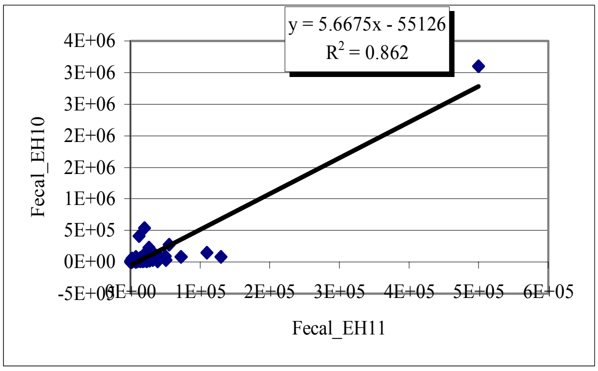




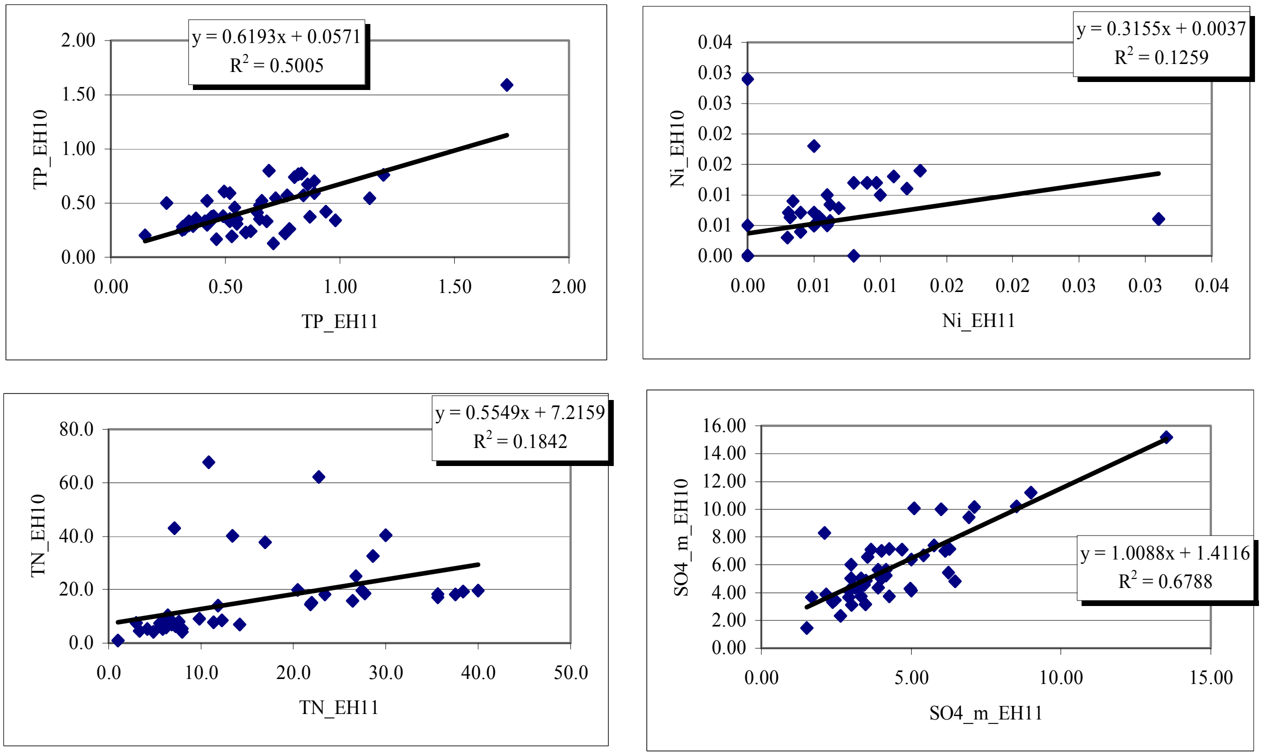




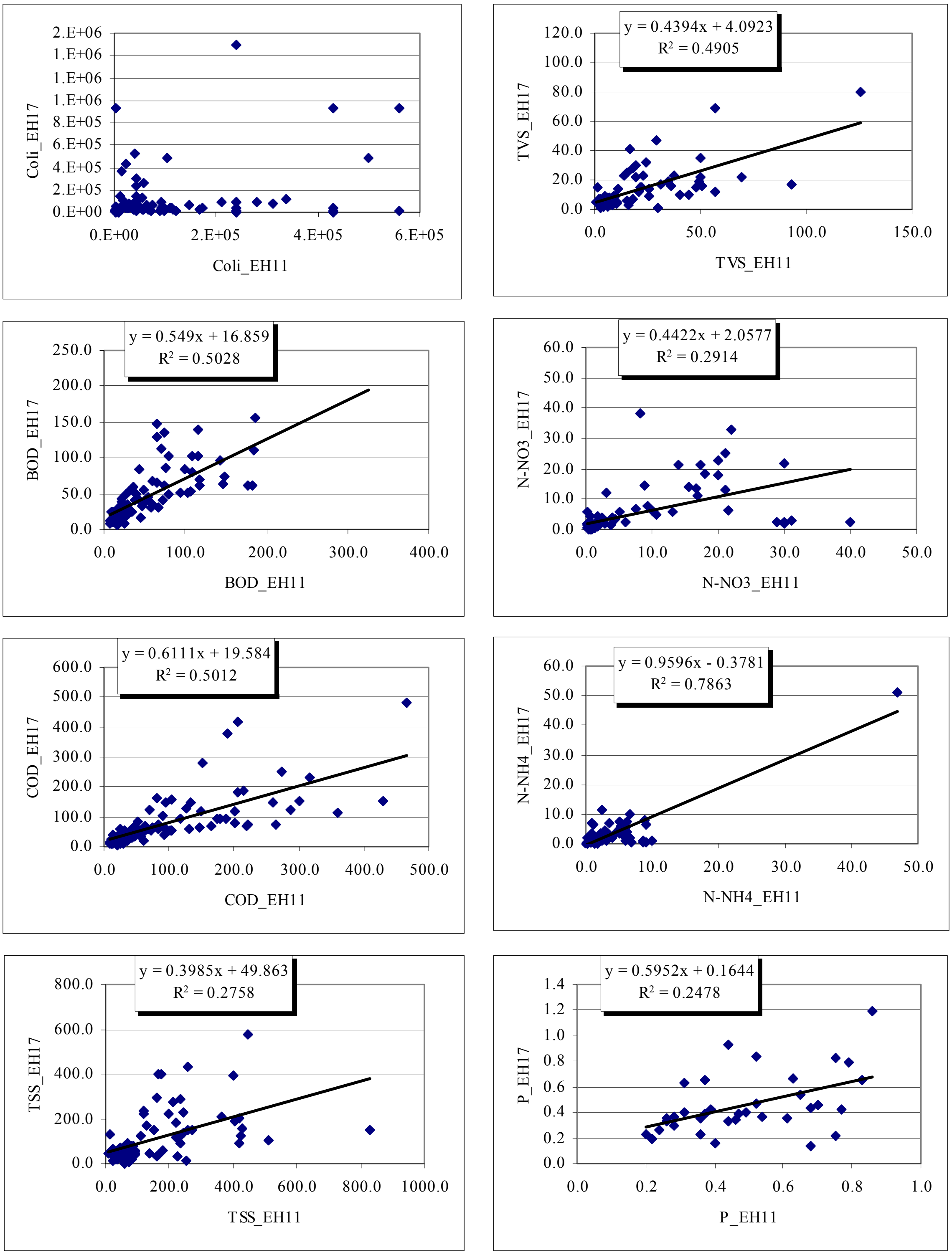




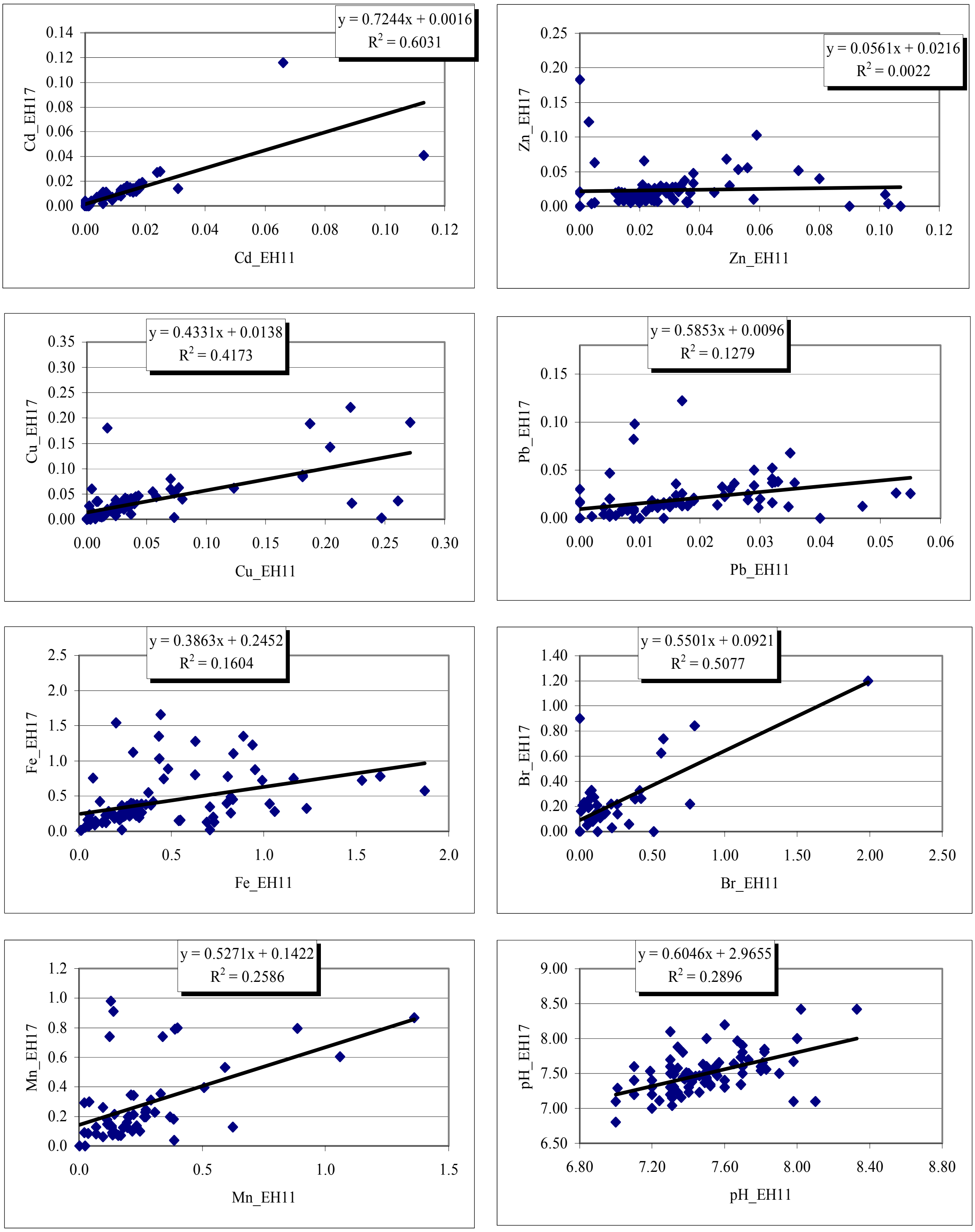
Annex 4-8C5 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH11and EH10



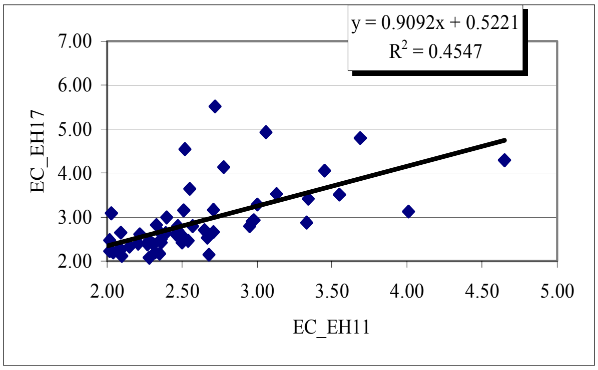
Annex 4-8D1: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH11 and EH17

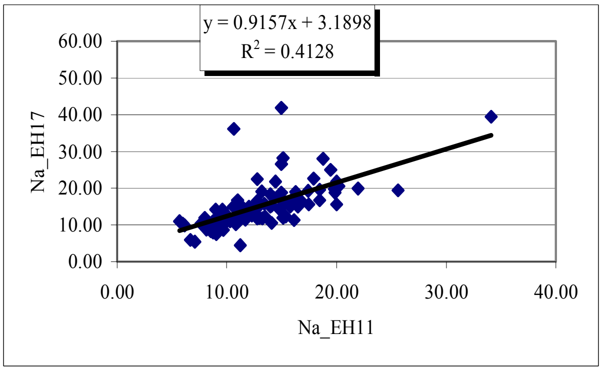


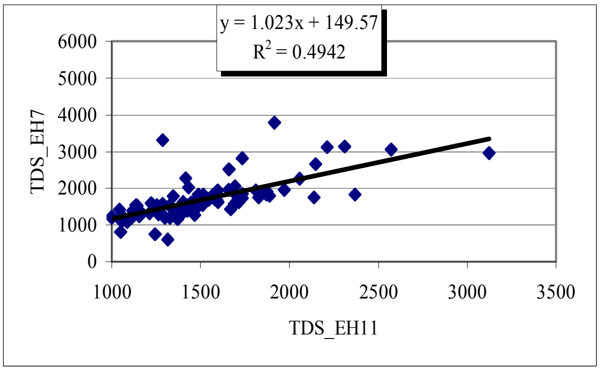
Annex 4-8D1 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH11 and EH17

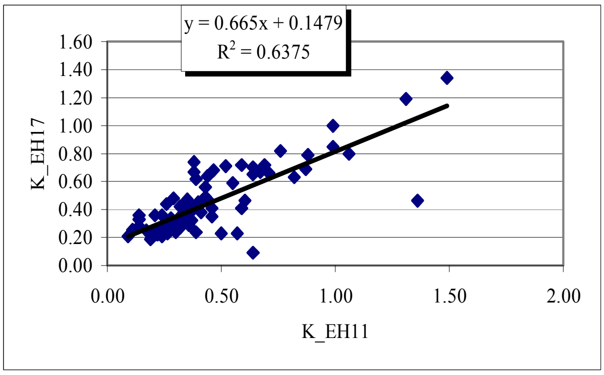


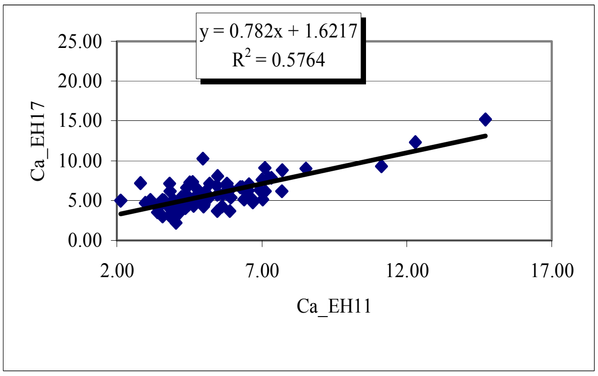
Annex 4-8D1 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH11 and EH17

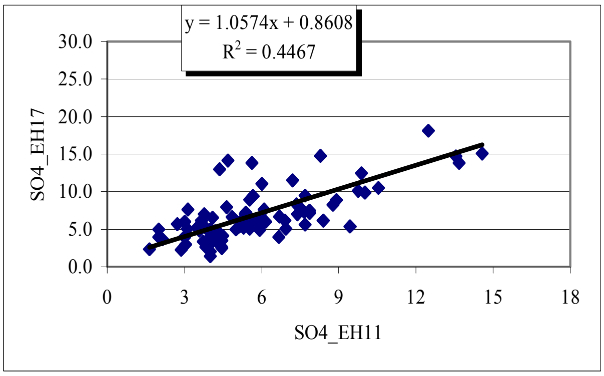


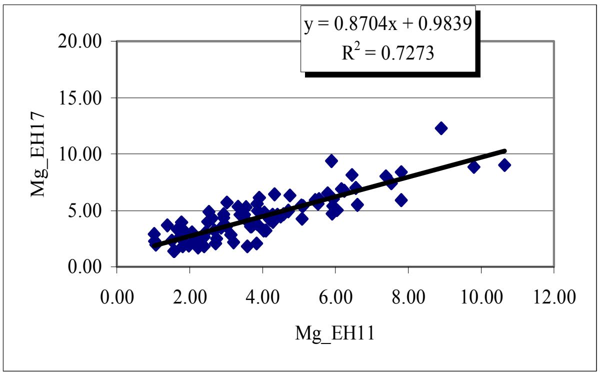


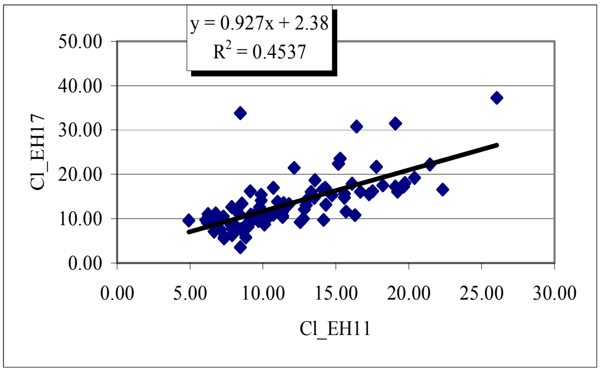




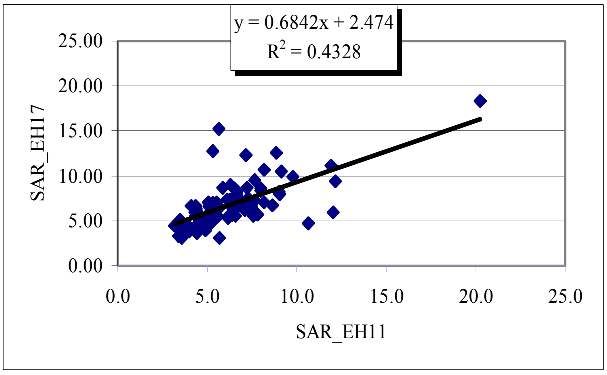


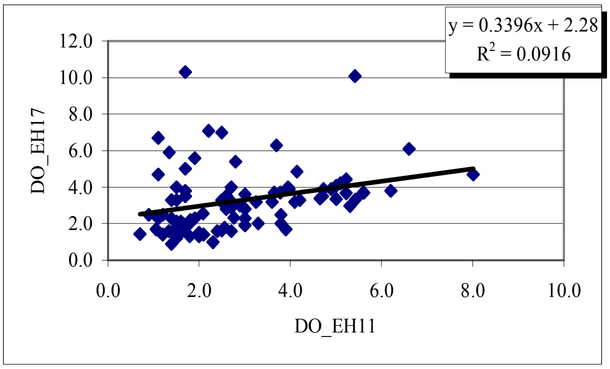


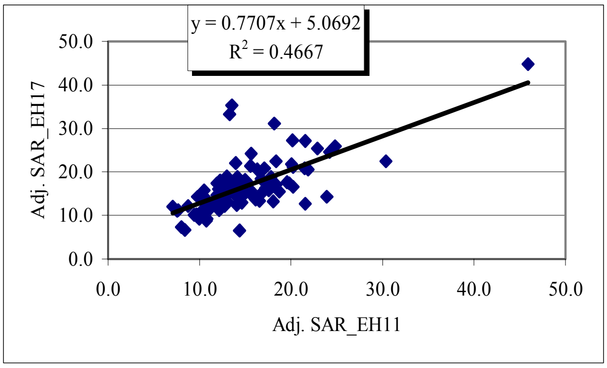


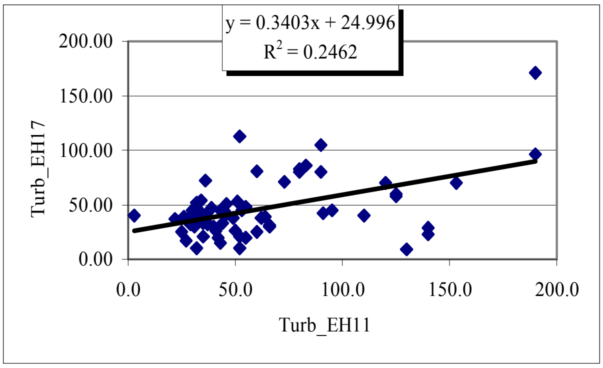


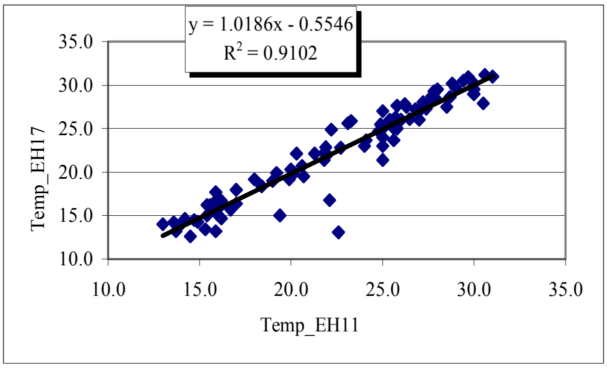
Annex 4-8D1 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH11 and EH17

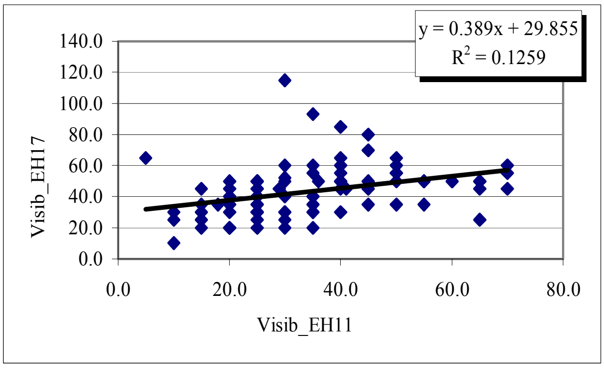


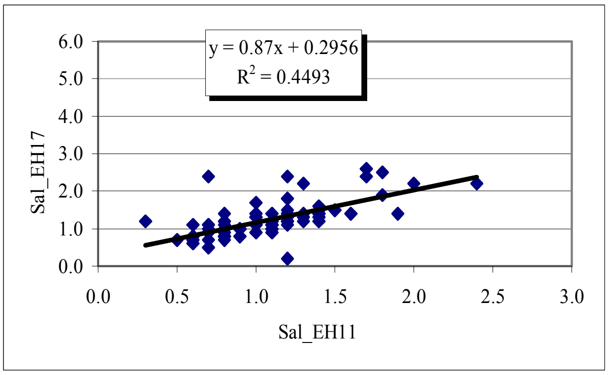


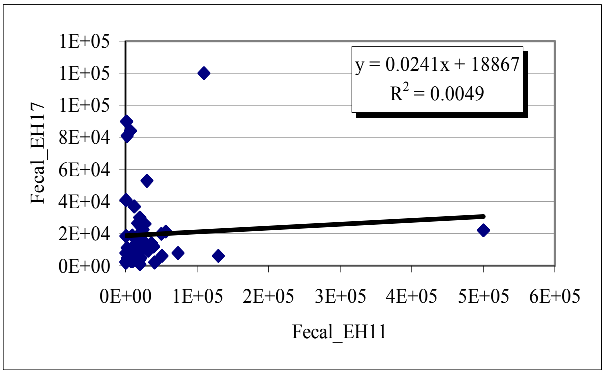




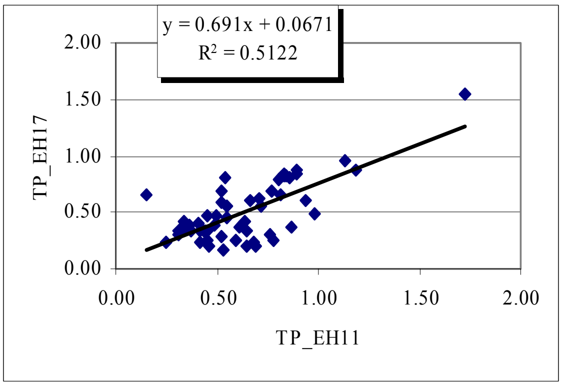


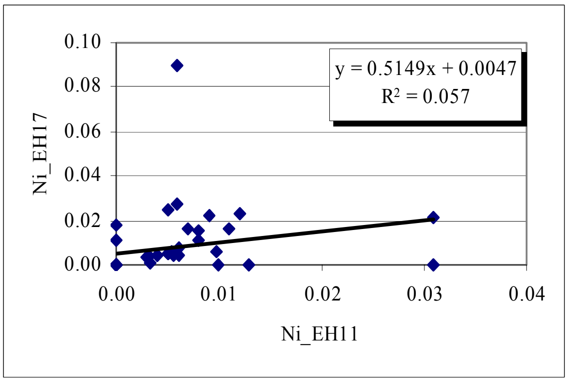


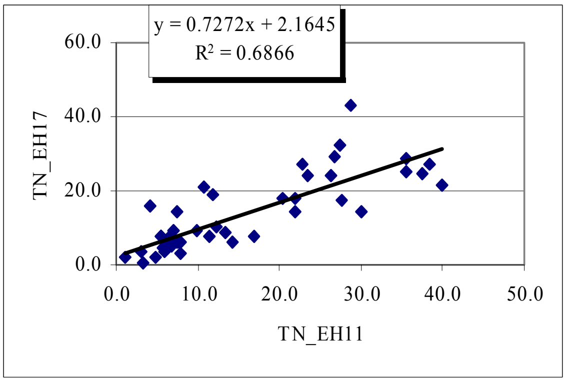


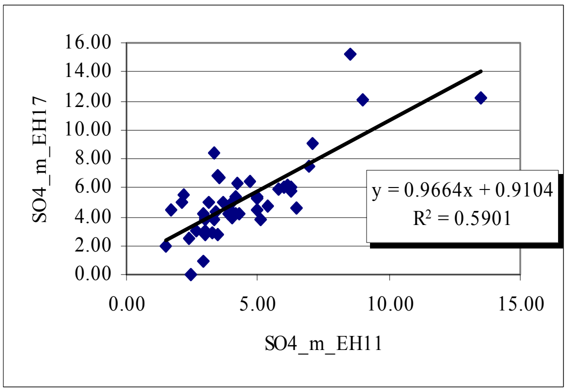


Annex 4-8D1 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH11 and EH17

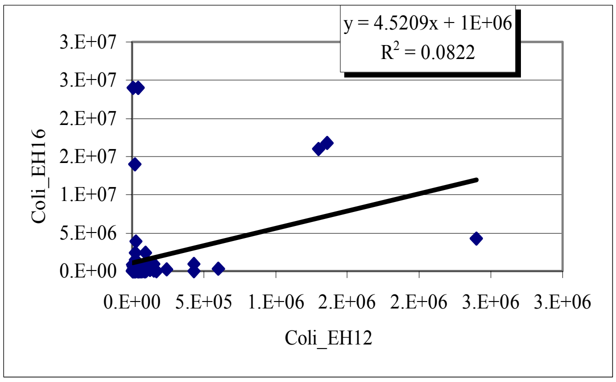


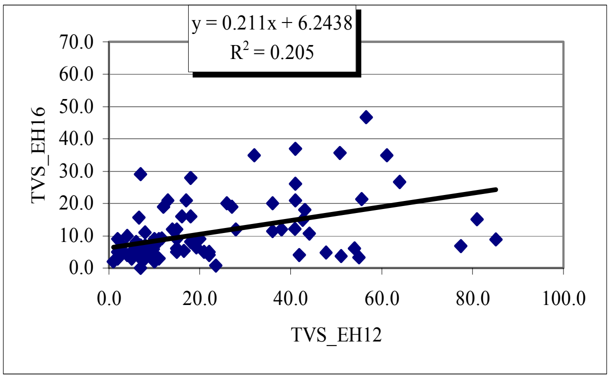


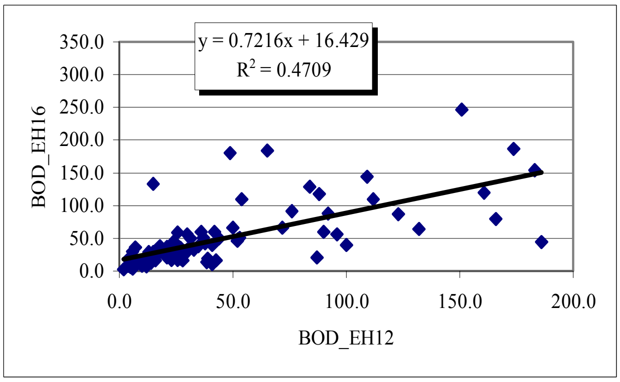


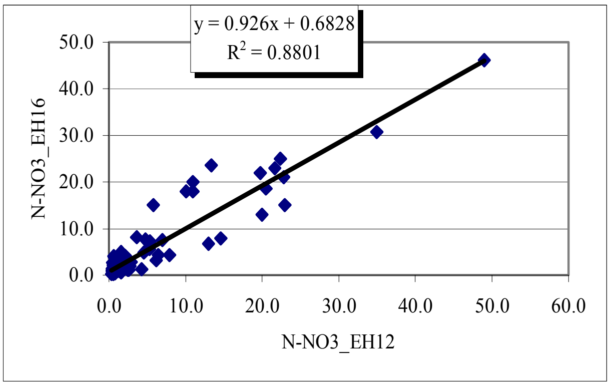


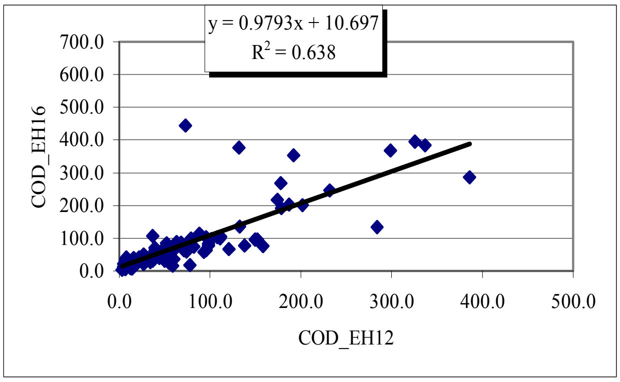
Annex 4-8D2: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH12 and EH16

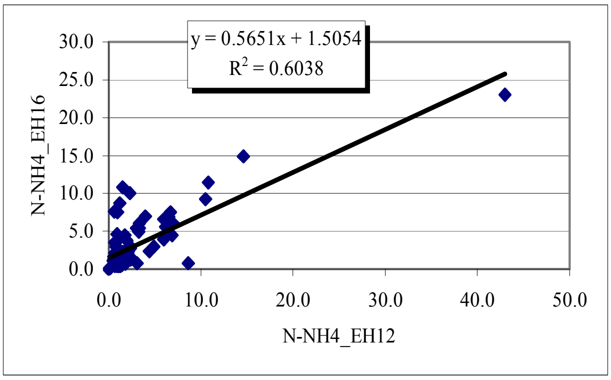


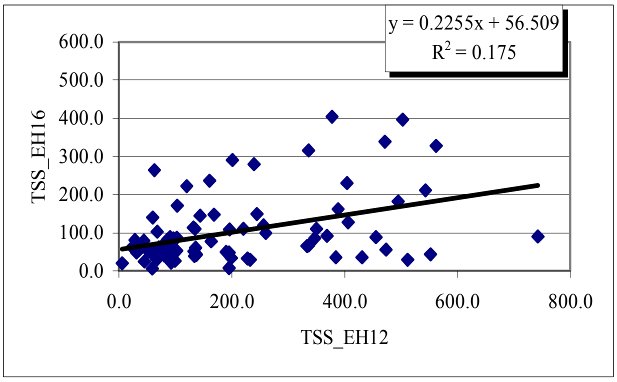


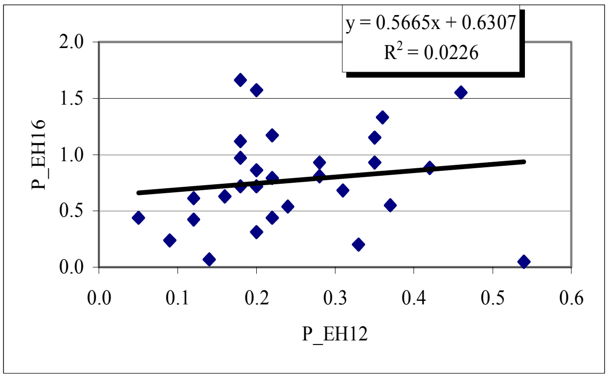




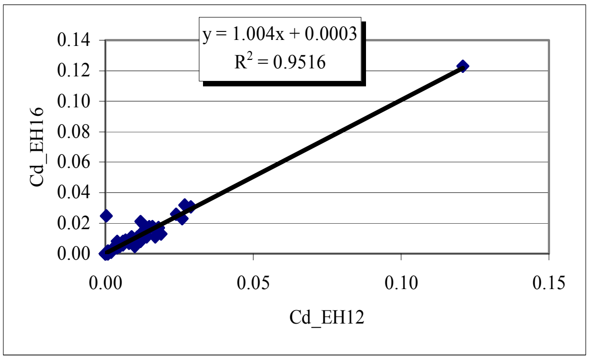


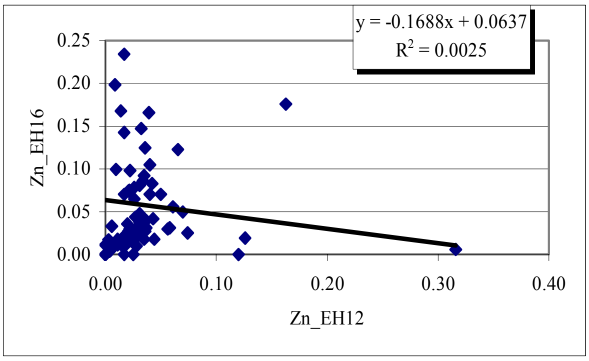


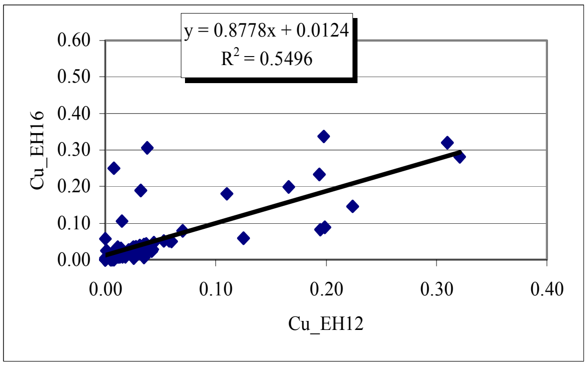


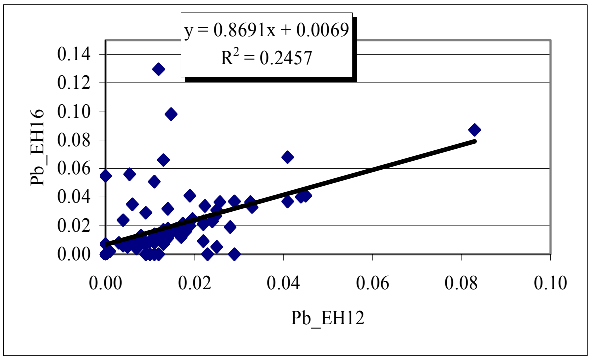


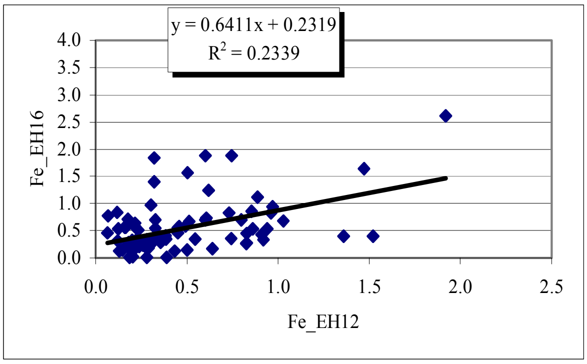
Annex 4-8D2 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH12 and EH16

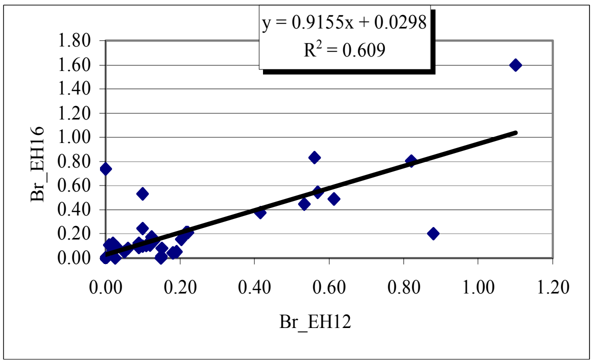


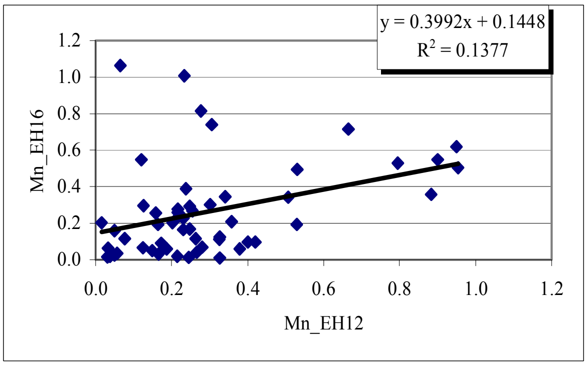


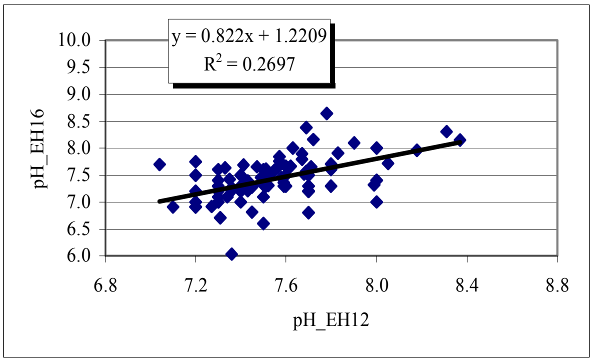




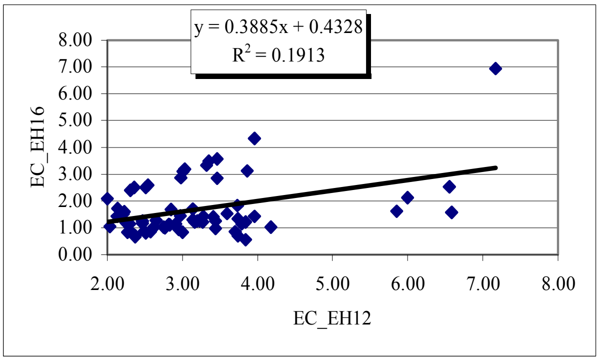


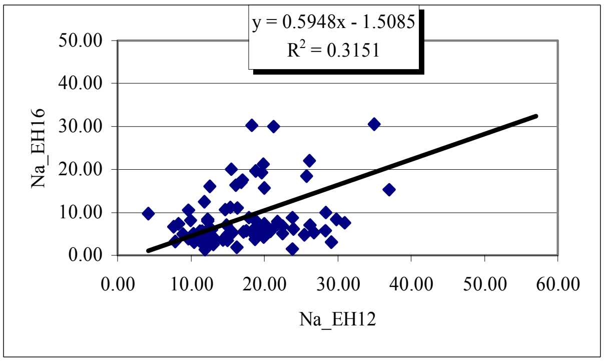


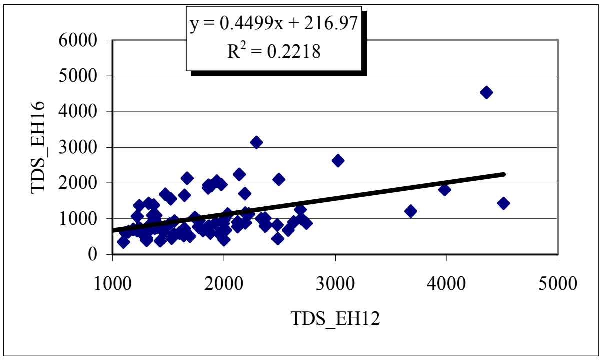


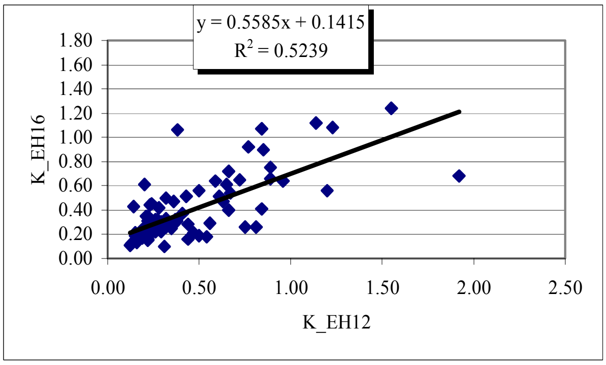


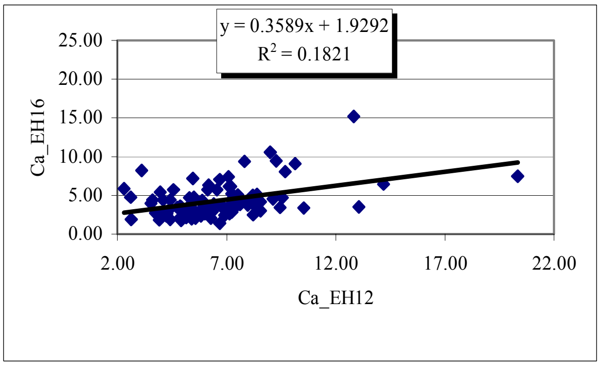
Annex 4-8D2 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH12 and EH16

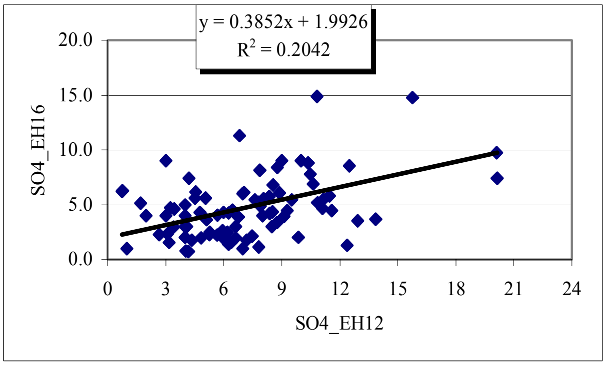


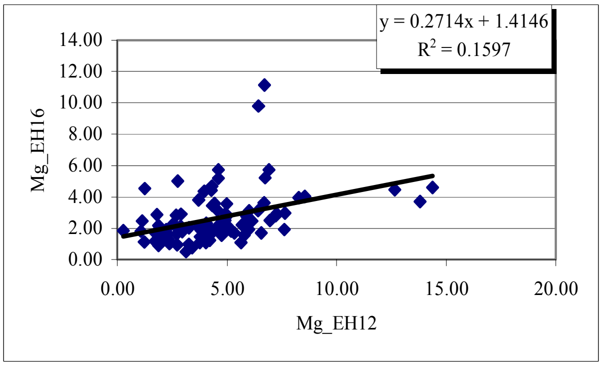


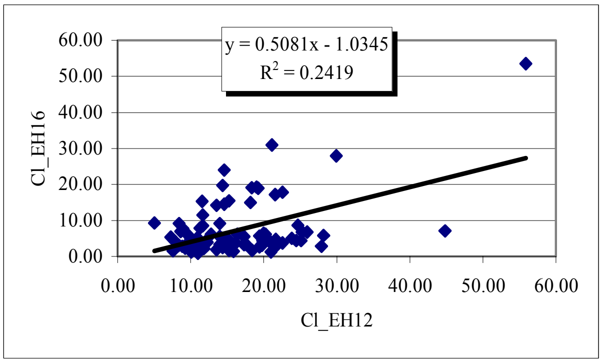




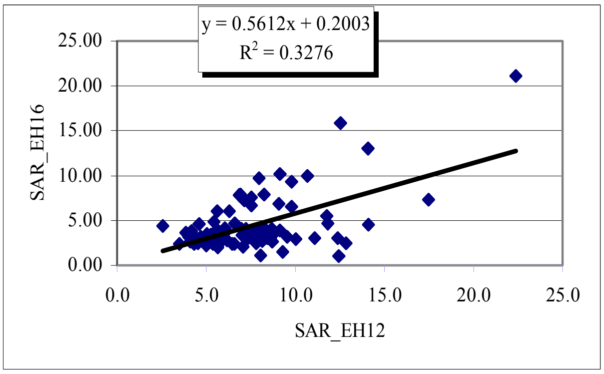


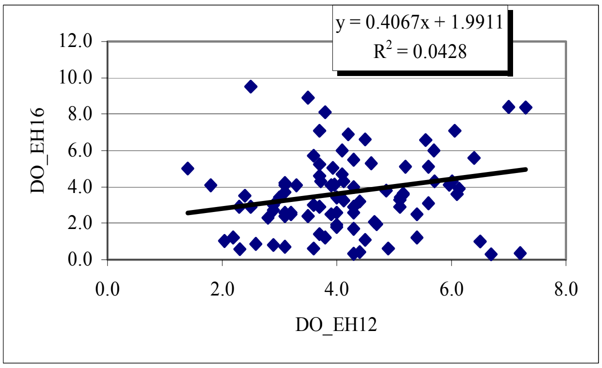


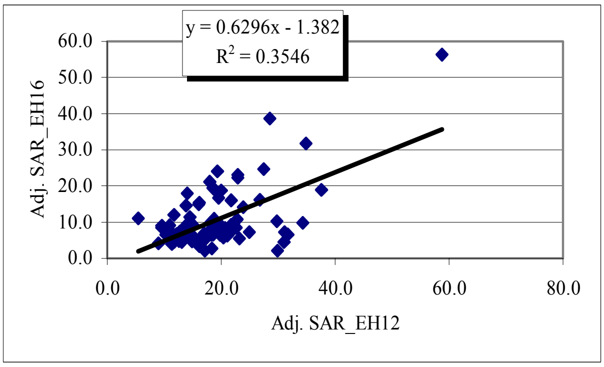


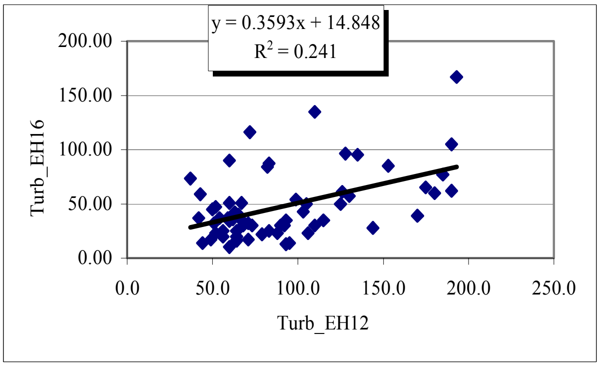


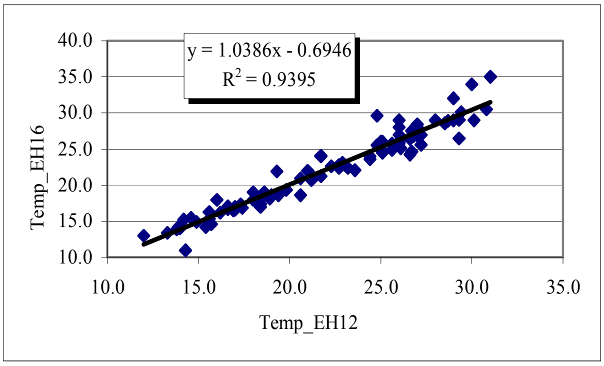
Annex 4-8D2 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH12 and EH16

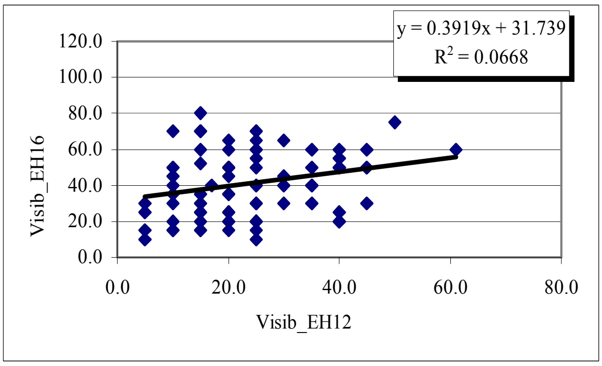


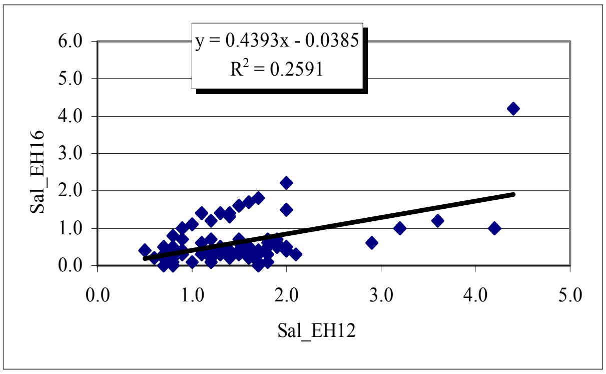


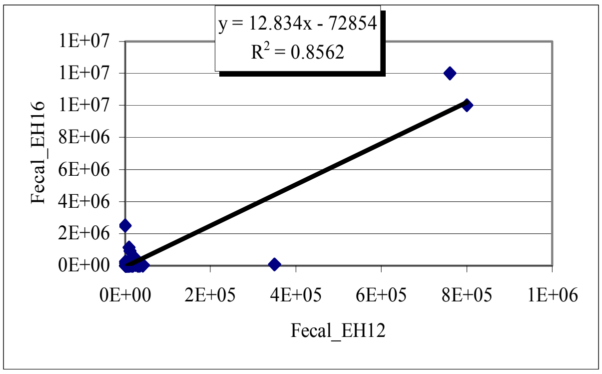




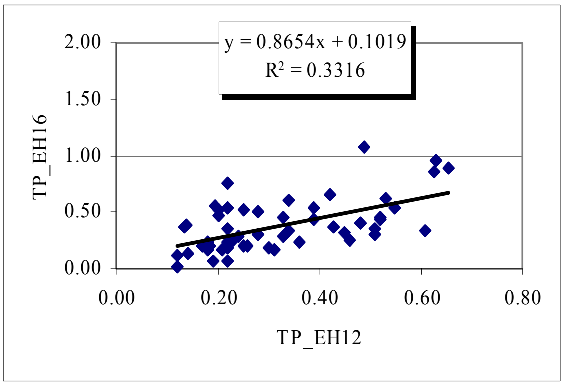


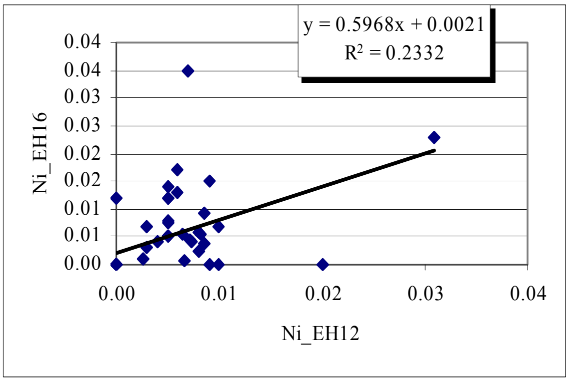


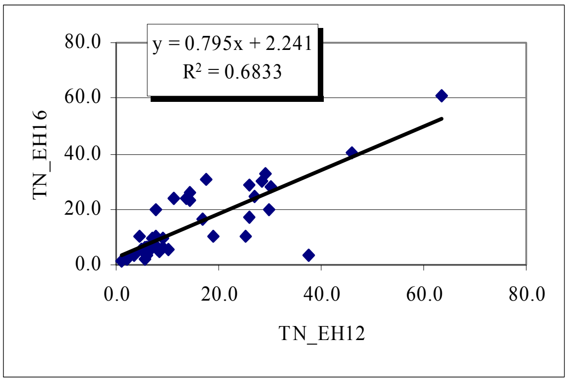


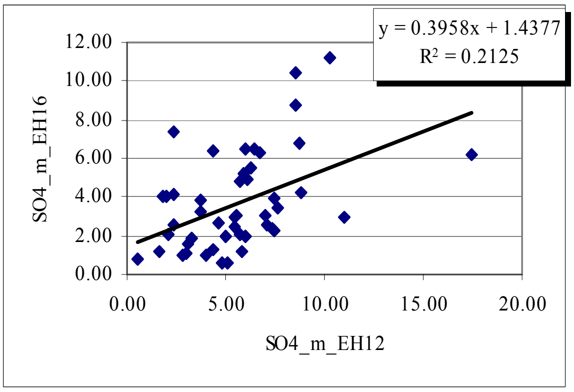


Annex 4-8D2 cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH12 and EH16

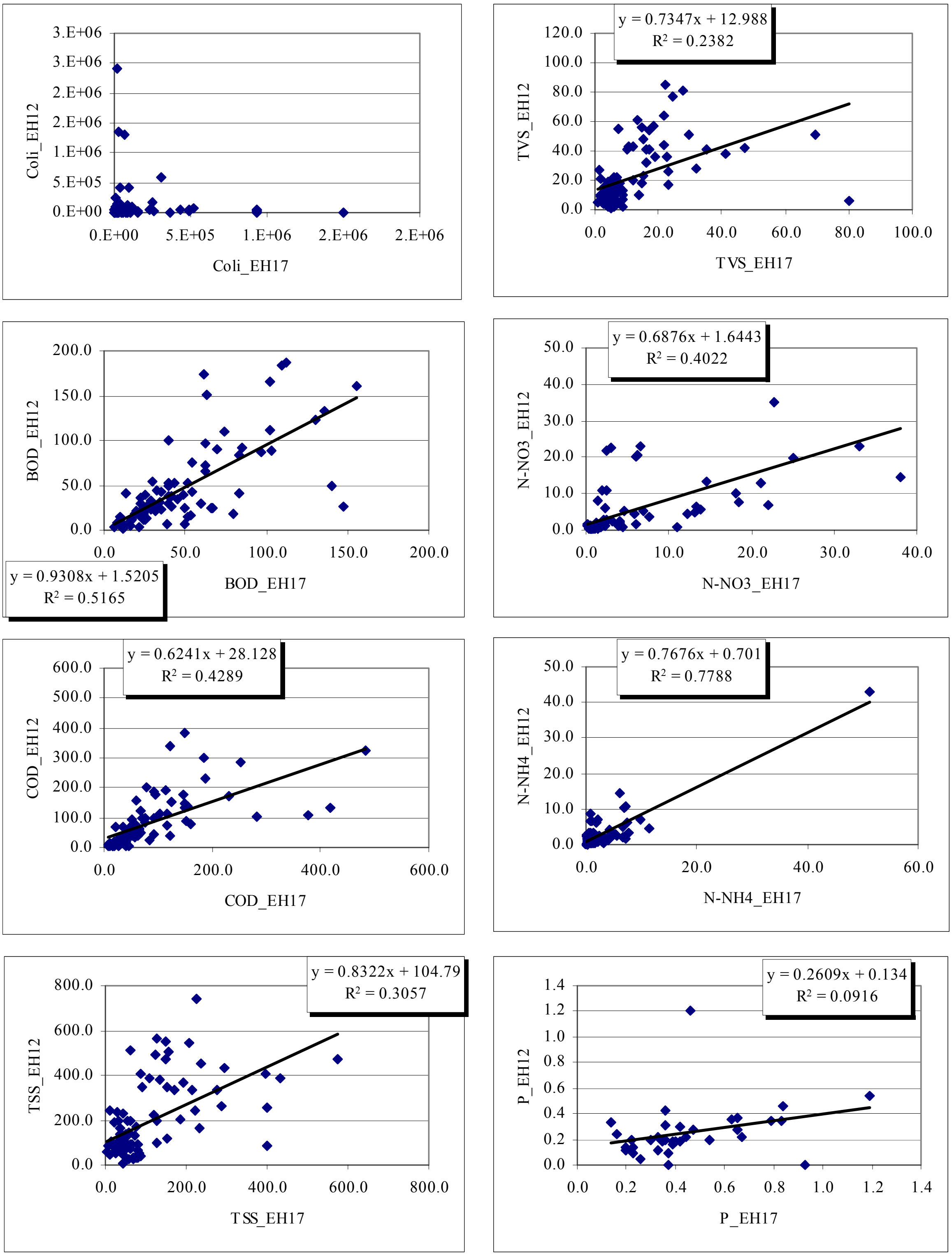




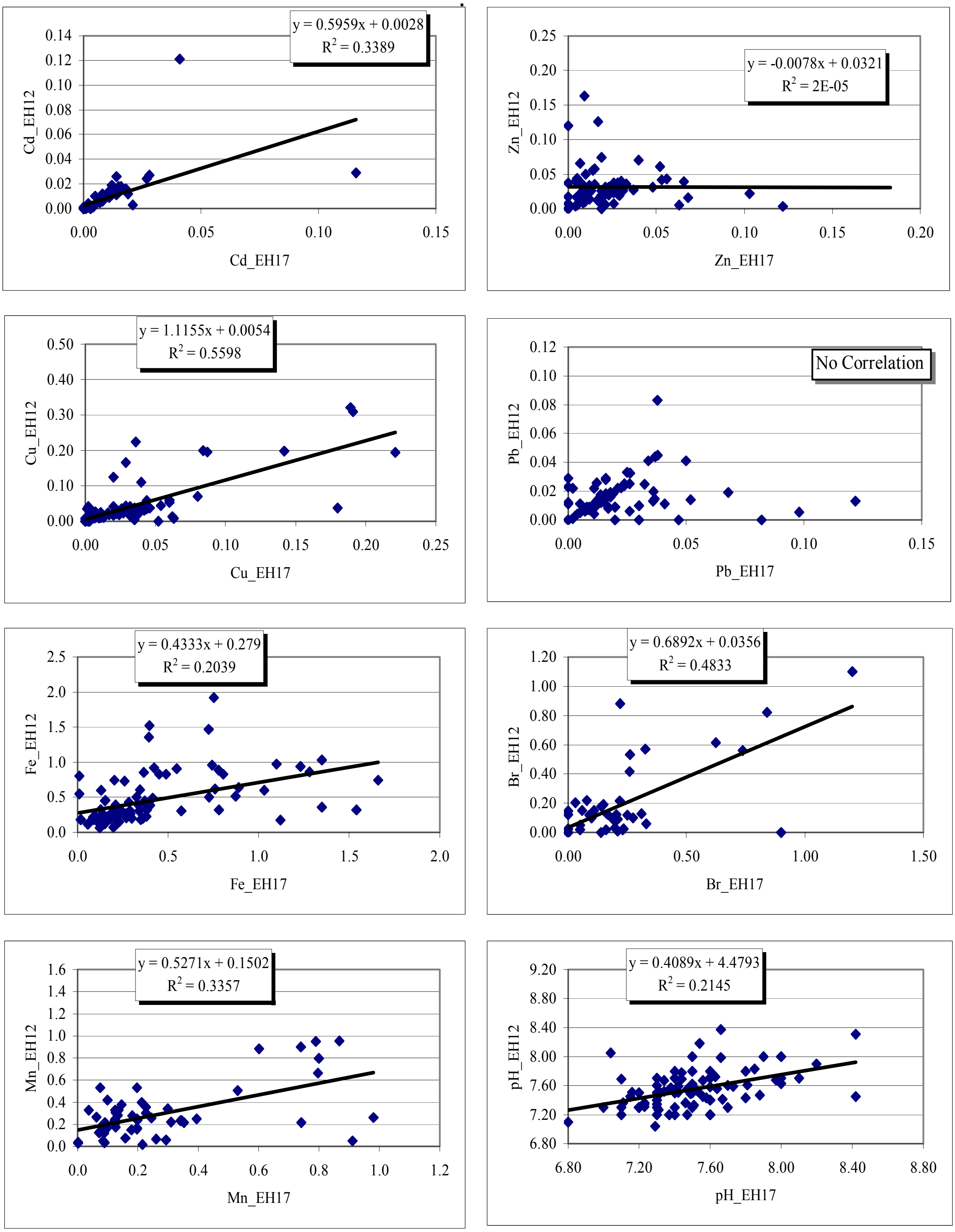




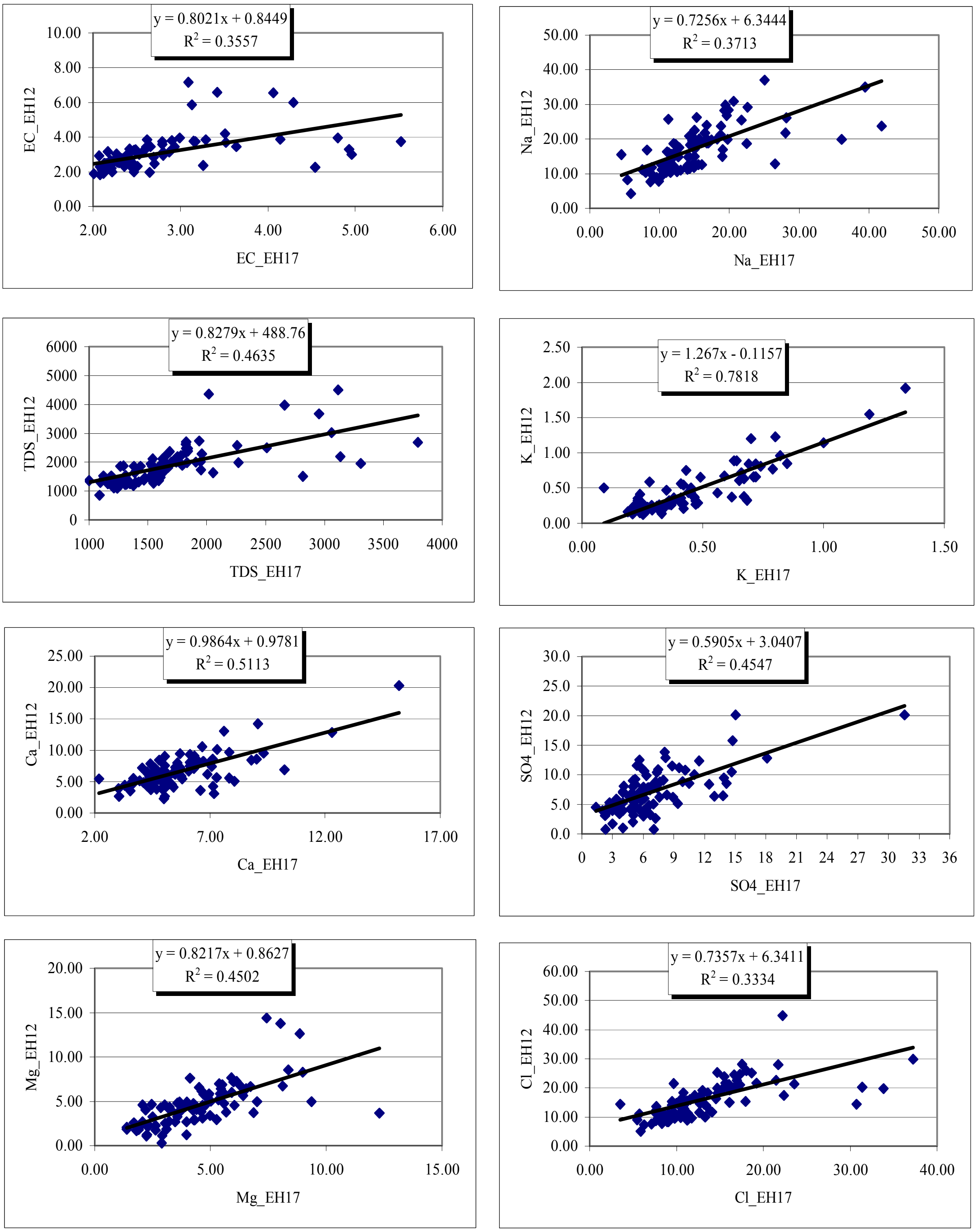
Annex 4-8D3: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH17 and EH12



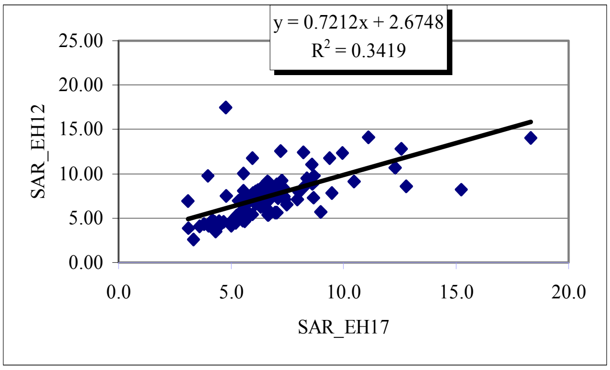
Annex 4-8D3 Cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH17 and EH12

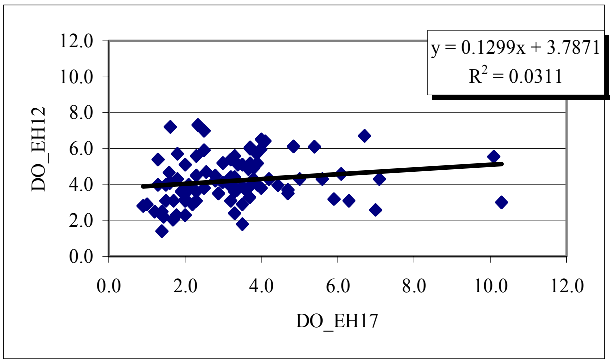


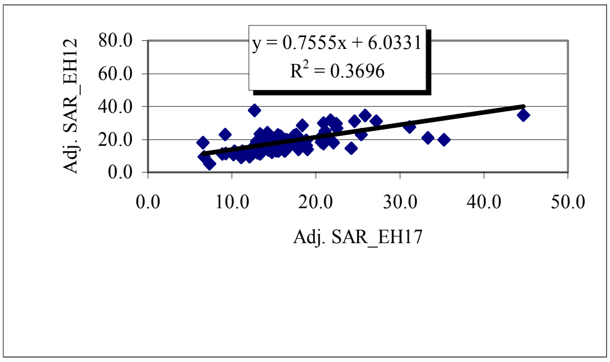
Annex 4-8D3 Cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH17 and EH12

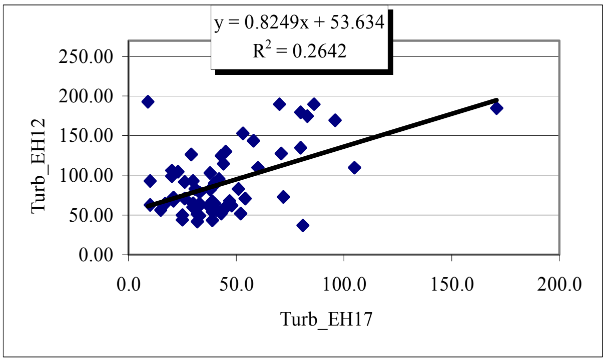


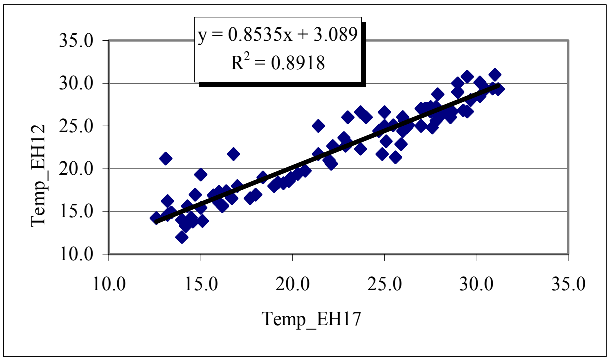
Annex 4-8D3 Cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH17 and EH12

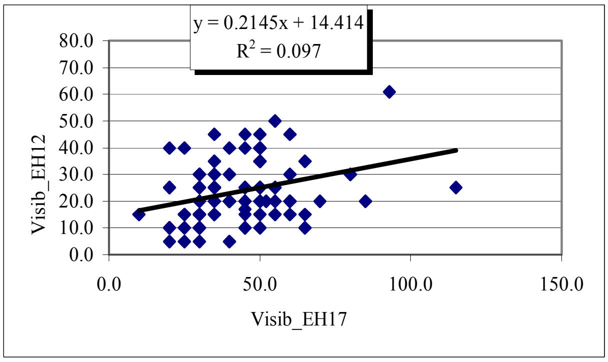


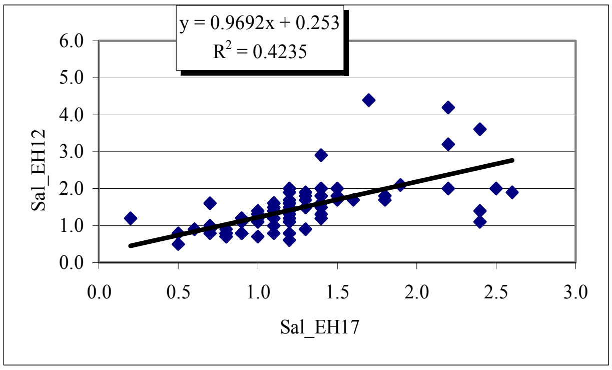


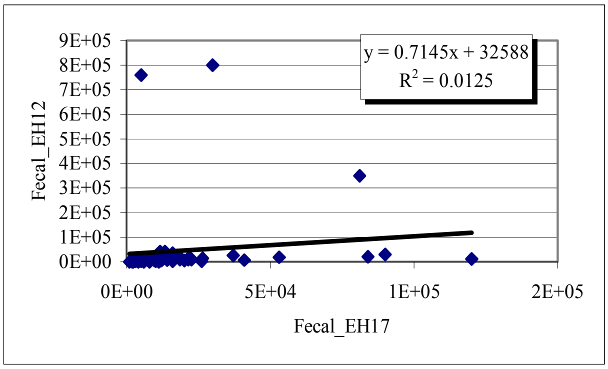




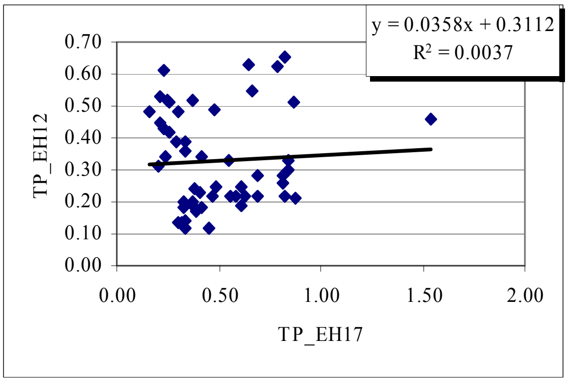


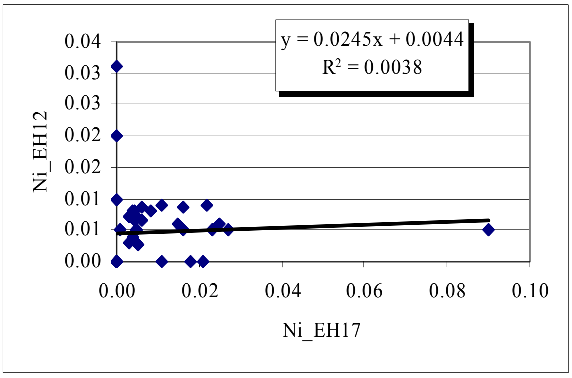


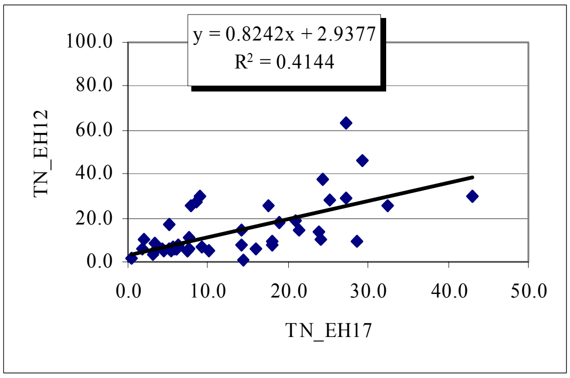


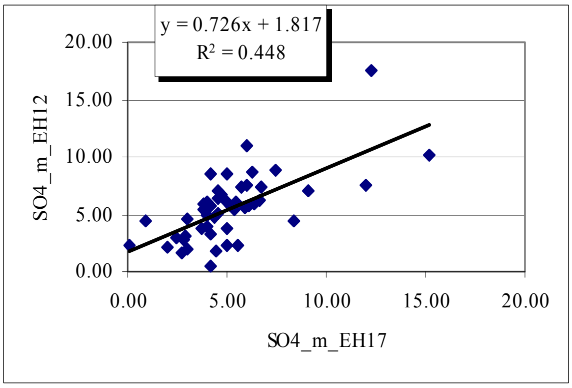


Annex 4-8D3 Cont.: Linear regression analysis results for the WQPs in Hadus drain monitoring locations EH17 and EH12





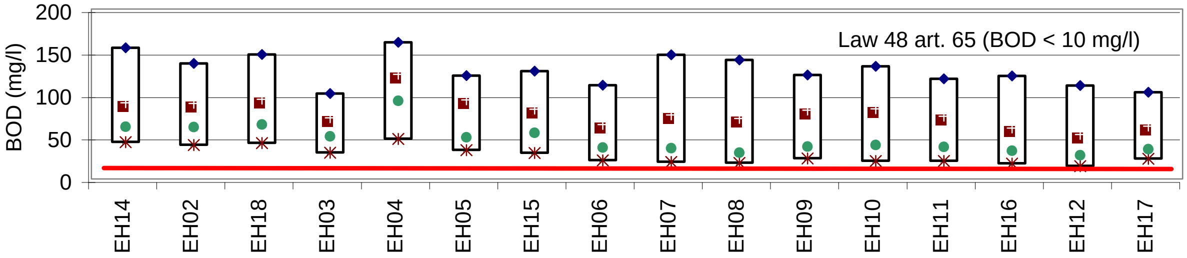




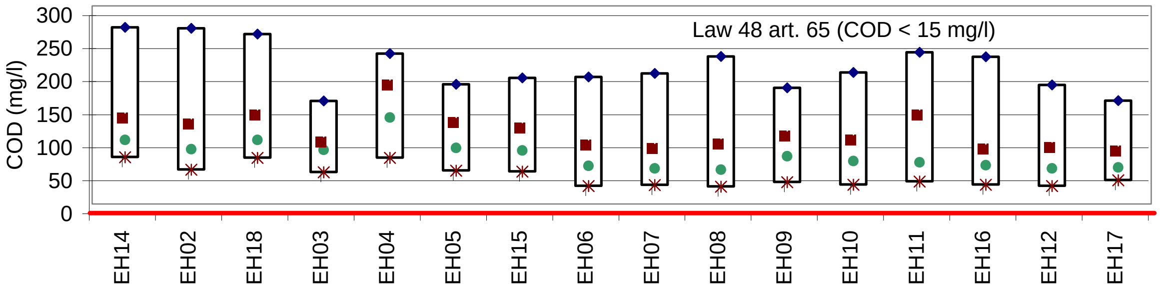
ANNEX 4-9

PERCENTILE AND CORRELATION ANALYSES FOR SOME WQPs IN HADUS DRAIN

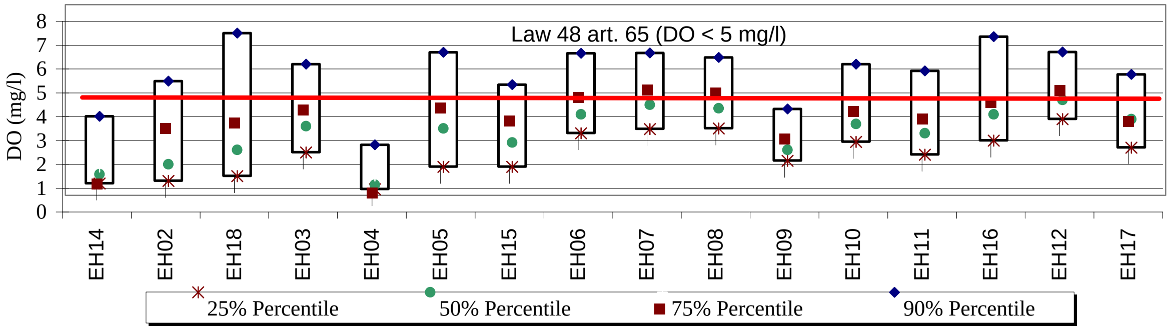
Annex 4-9: Percentile analyses and correlation coefficients for some WQPs measured at Hadus drain monitoring sites



	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
EH18	0.95	0.89	1.00													
EH15	0.64	0.65	0.62	0.54	0.62	0.54	1.00									
EH11	0.62	0.60	0.58	0.53	0.60	0.44	0.79	0.76	0.87	0.85	0.89	0.87	1.00			
EH17	0.37	0.38	0.35	0.34	0.52	0.42	0.62	0.68	0.78	0.80	0.73	0.77	0.80	0.69	0.83	1.00

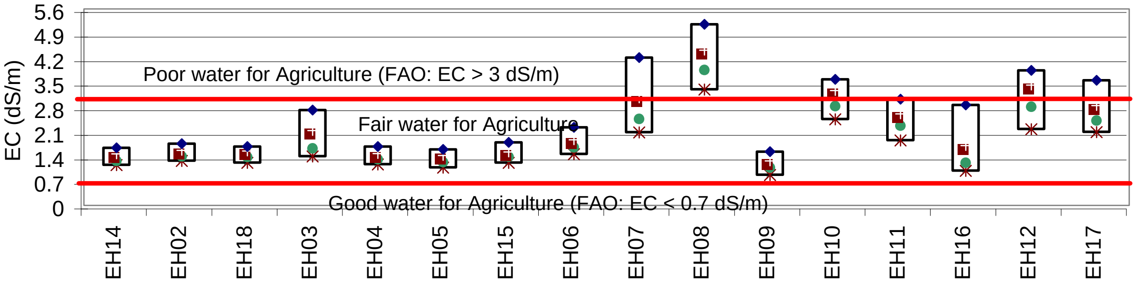


	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
EH18	0.86	0.76	1.00													
EH15	0.73	0.58	0.61	0.61	0.68	0.62	1.00									
EH11	0.77	0.64	0.60	0.70	0.69	0.64	0.81	0.80	0.86	0.86	0.84	0.86	1.00			
EH17	0.65	0.61	0.54	0.41	0.60	0.51	0.64	0.76	0.66	0.75	0.67	0.71	0.71	0.65	0.66	1.00

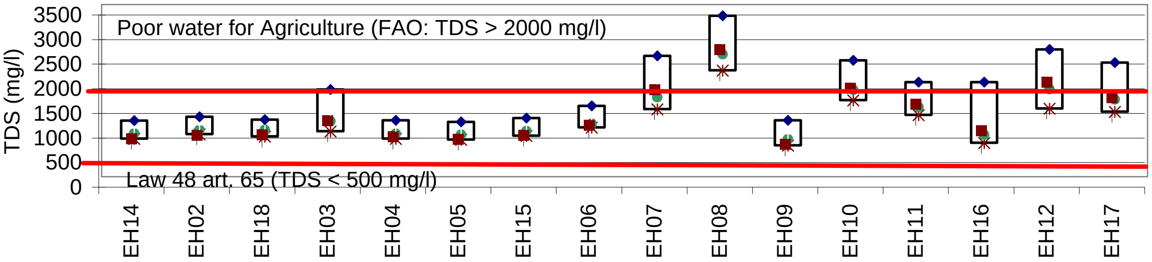


	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
EH18	0.66	0.70	1.00													
EH15	0.04	0.17	0.31	0.21	0.13	0.22	1.00									
EH11	-0.02	0.17	0.08	0.29	-0.06	0.35	0.46	0.17	0.47	0.48	0.01	0.55	1.00			
EH17	-0.13	-0.03	-0.05	0.04	-0.22	0.08	0.23	0.06	0.11	0.11	0.22	0.11	0.26	-0.07	0.14	1.00

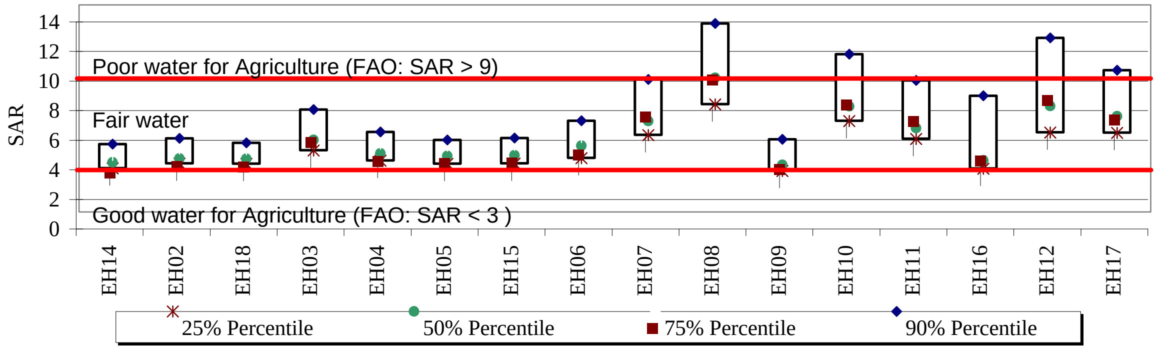
Annex 4-9: Percentile analyses and correlation coefficients for some WQPs measured at Hadus drain monitoring sites



	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
EH18	0.78	0.49	1.00													
EH15	0.65	0.30	0.74	0.59	0.69	0.62	1.00									
EH11	0.55	0.12	0.52	0.48	0.54	0.37	0.50	0.50	0.63	0.78	0.31	0.72	1.00			
EH17	0.40	0.11	0.48	0.44	0.49	0.37	0.44	0.44	0.43	0.70	0.16	0.62	0.67	0.19	0.60	1.00

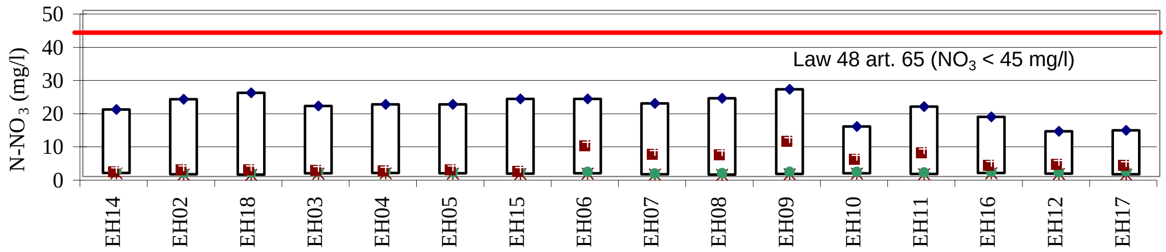


	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
EH18	0.84	0.47	1.00													
EH15	0.53	0.32	0.60	0.38	0.64	0.55	1.00									
EH11	0.49	0.15	0.59	0.40	0.26	0.36	0.42	0.46	0.57	0.78	0.28	0.66	1.00			
EH17	0.40	0.19	0.51	0.42	0.37	0.43	0.41	0.49	0.44	0.76	0.24	0.56	0.70	0.21	0.68	1.00

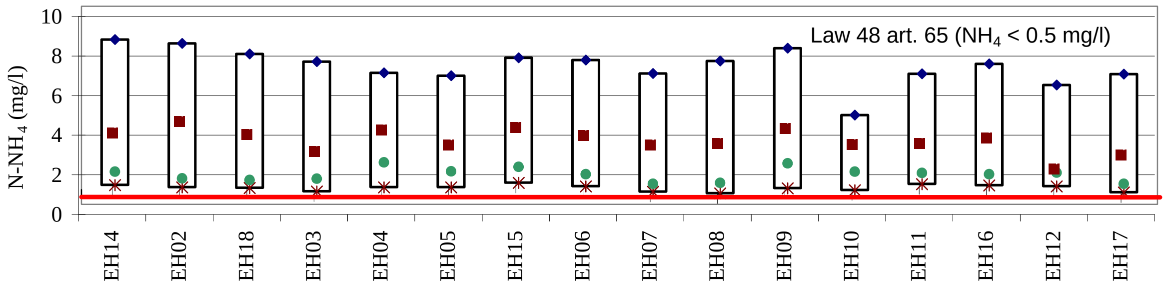


	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
EH18	0.73	0.52	1.00													
EH15	0.57	0.36	0.59	0.38	0.59	0.46	1.00									
EH11	0.20	0.16	0.27	0.23	0.14	0.05	0.54	0.43	0.64	0.67	0.30	0.73	1.00			
EH17	0.17	0.04	0.18	0.27	0.24	0.17	0.45	0.40	0.61	0.68	0.25	0.65	0.66	0.32	0.58	1.00

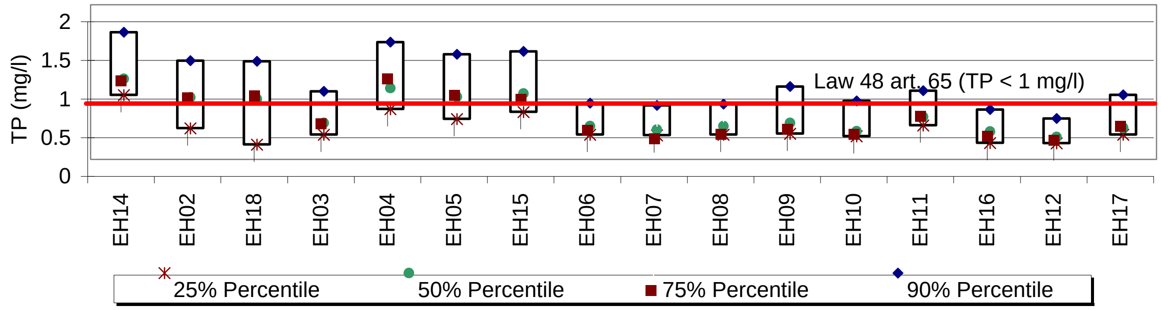
Annex 4-9: Percentile analyses and correlation coefficients for some WQPs measured at Hadus drain monitoring sites



	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
EH18	0.95	0.74	1.00													
EH15	0.84	0.71	0.89	0.85	0.90	0.95	1.00									
EH11	0.47	0.56	0.54	0.56	0.49	0.57	0.55	0.84	0.84	0.84	0.90	0.67	1.00			
EH17	0.65	0.56	0.78	0.76	0.62	0.77	0.73	0.66	0.59	0.63	0.55	0.75	0.52	0.54	0.60	1.00

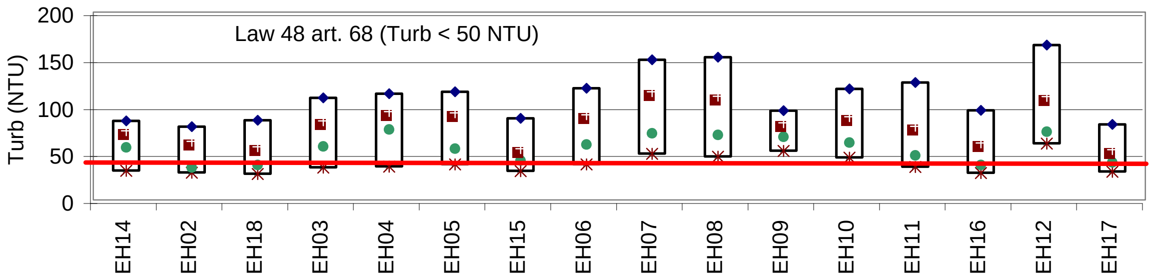


	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
EH18	0.87	0.75	1.00													
EH15	0.60	0.51	0.66	0.99	0.99	0.99	1.00									
EH11	0.26	0.36	0.33	0.91	0.90	0.91	0.90	0.94	0.64	0.92	0.75	0.48	1.00			
EH17	0.38	0.33	0.48	0.95	0.93	0.93	0.93	0.93	0.44	0.90	0.36	0.53	0.89	0.71	0.88	1.00

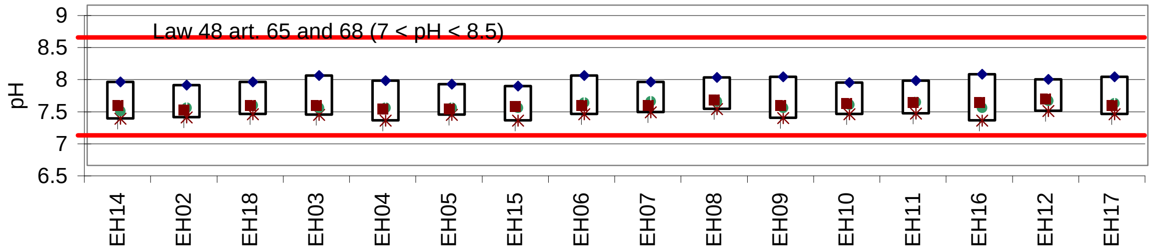


	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
EH18	0.07	0.82	1.00													
EH15	0.51	0.51	0.58	0.44	0.60	0.82	1.00									
EH11	0.49	0.34	0.31	0.50	0.38	0.47	0.52	0.70	0.65	0.56	0.59	0.71	1.00			
EH17	0.26	0.56	0.68	0.67	0.21	0.57	0.58	0.69	0.58	0.62	0.55	0.75	0.71	-0.03	0.08	1.00

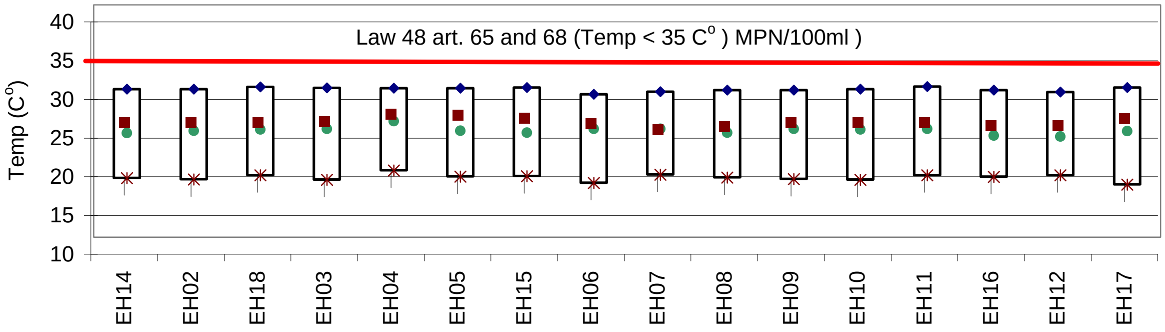
Annex 4-9: Percentile analyses and correlation coefficients for some WQPs measured at Hadus drain monitoring sites



	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
EH18	0.71	0.89	1.00													
EH15	0.29	0.40	0.41	0.30	0.22	0.23	1.00									
EH11	0.33	0.33	0.39	0.45	-0.02	0.52	0.35	0.48	0.68	0.84	0.22	0.74	1.00			
EH17	0.25	0.22	0.19	0.19	0.29	0.18	0.35	0.57	0.39	0.45	0.10	0.55	0.50	0.36	0.51	1.00

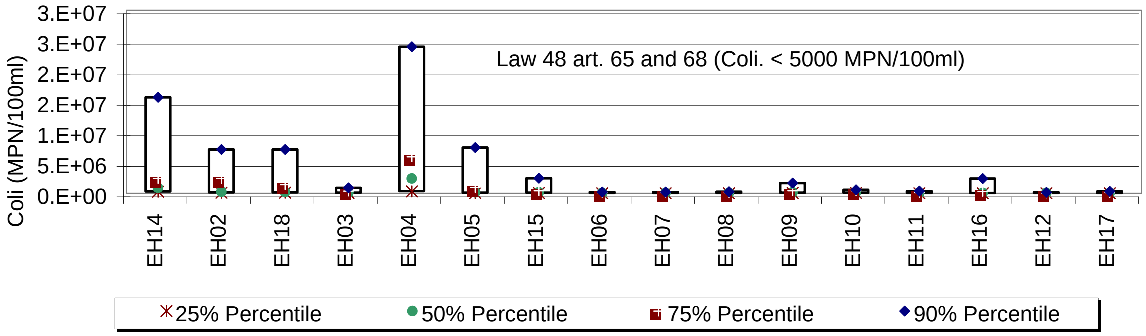


	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
EH18	0.72	0.78	1.00													
EH15	0.54	0.46	0.52	0.39	0.61	0.48	1.00									
EH11	0.34	0.32	0.35	0.42	0.47	0.27	0.51	0.46	0.54	0.57	0.46	0.61	1.00			
EH17	0.27	0.28	0.33	0.41	0.47	0.41	0.44	0.30	0.38	0.39	0.37	0.39	0.54	0.35	0.46	1.00

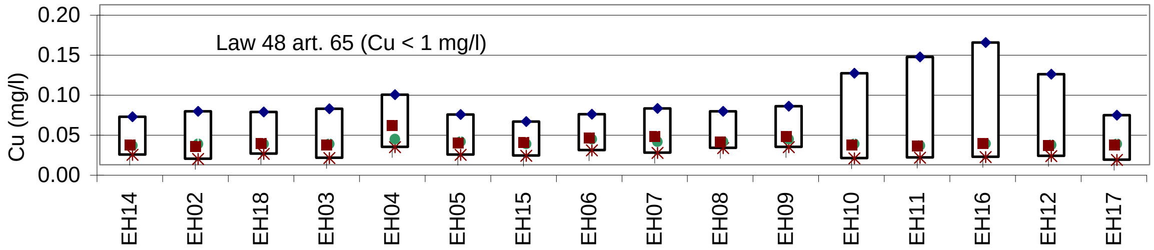


	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
EH18	0.99	0.95	1.00													
EH15	0.97	0.93	0.97	0.97	0.98	0.97	1.00									
EH11	0.97	0.92	0.97	0.97	0.97	0.96	0.98	0.98	0.98	0.99	0.98	0.99	1.00			
EH17	0.94	0.89	0.94	0.92	0.94	0.91	0.94	0.94	0.95	0.95	0.94	0.95	0.95	0.91	0.94	1.00

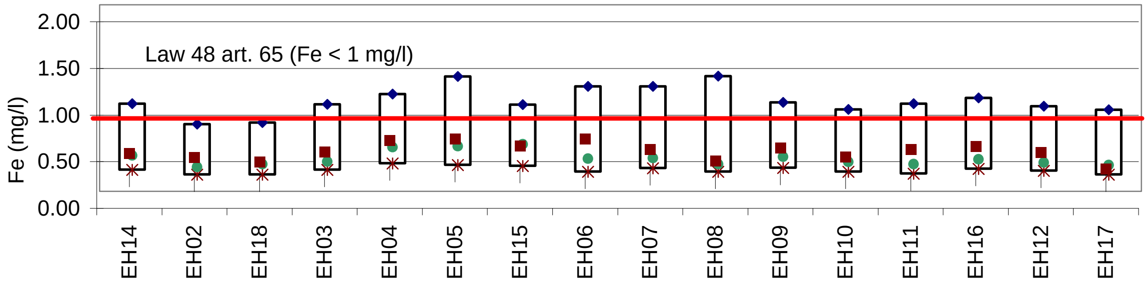
Annex 4-9: Percentile analyses and correlation coefficients for some WQPs measured at Hadus drain monitoring sites



	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
EH18	0.41	0.50	1.00													
EH15	0.42	0.17	0.47	0.39	0.22	0.39	1.00									
EH11	0.57	0.02	0.47	0.13	0.06	0.39	0.45	0.18	0.03	0.05	0.73	0.66	1.00			
EH17	0.07	-0.06	0.08	-0.04	-0.08	0.03	0.01	-0.05	0.02	0.08	0.04	0.02	0.08	-0.12	-0.07	1.00

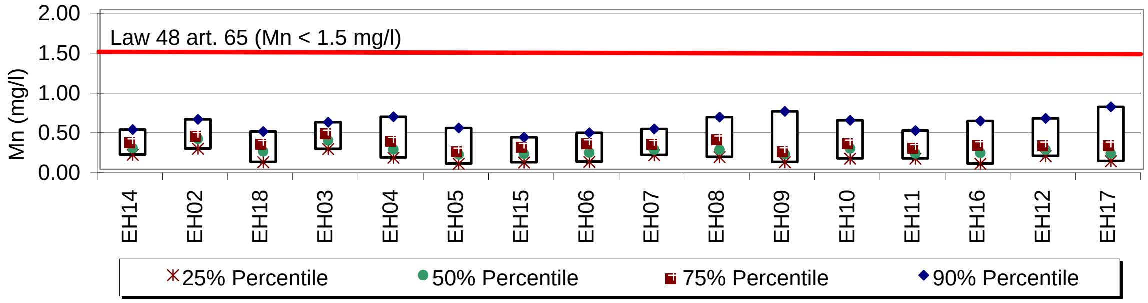


	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
EH18	0.98	0.97	1.00													
EH15	0.65	0.74	0.69	0.59	0.78	0.85	1.00									
EH11	0.52	0.53	0.54	0.58	0.59	0.60	0.67	0.60	0.79	0.75	0.68	0.77	1.00			
EH17	0.70	0.75	0.74	0.61	0.73	0.70	0.81	0.73	0.74	0.79	0.78	0.75	0.65	0.70	0.75	1.00

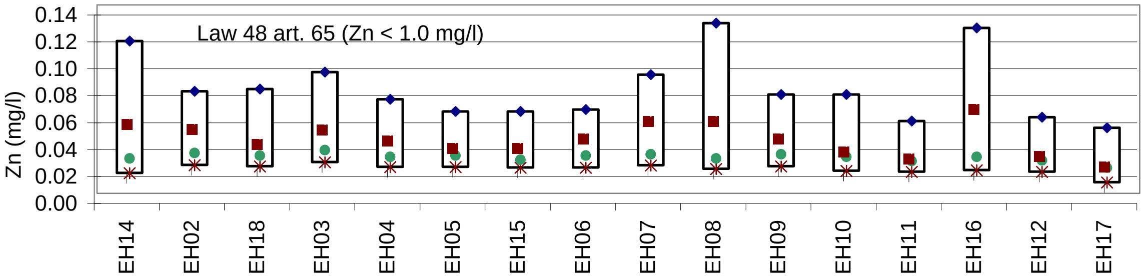


	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
EH18	0.62	0.61	1.00													
EH15	0.50	0.38	0.49	0.48	0.68	0.75	1.00									
EH11	0.43	0.38	0.54	0.43	0.41	0.38	0.27	0.45	0.58	0.58	0.48	0.49	1.00			
EH17	0.47	0.52	0.55	0.70	0.61	0.65	0.55	0.61	0.54	0.65	0.47	0.56	0.43	0.43	0.45	1.00

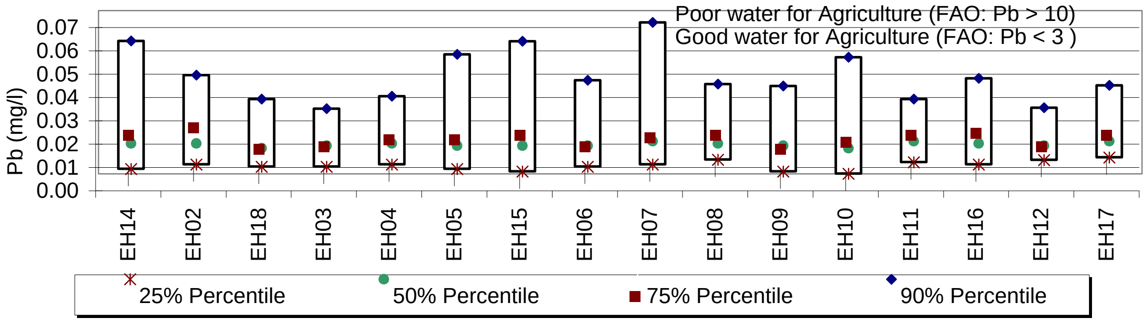
Annex 4-9: Percentile analyses and correlation coefficients for some WQPs measured at Hadus drain monitoring sites



	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
EH18	0.28	-0.19	1.00													
EH15	0.55	-0.12	0.25	0.27	0.70	0.56	1.00									
EH11	0.50	-0.10	0.39	0.21	0.72	0.40	0.72	0.78	0.85	0.83	0.59	0.61	1.00			
EH17	0.69	0.12	0.22	0.07	0.60	0.52	0.54	0.63	0.55	0.50	0.69	0.35	0.51	0.29	0.59	1.00

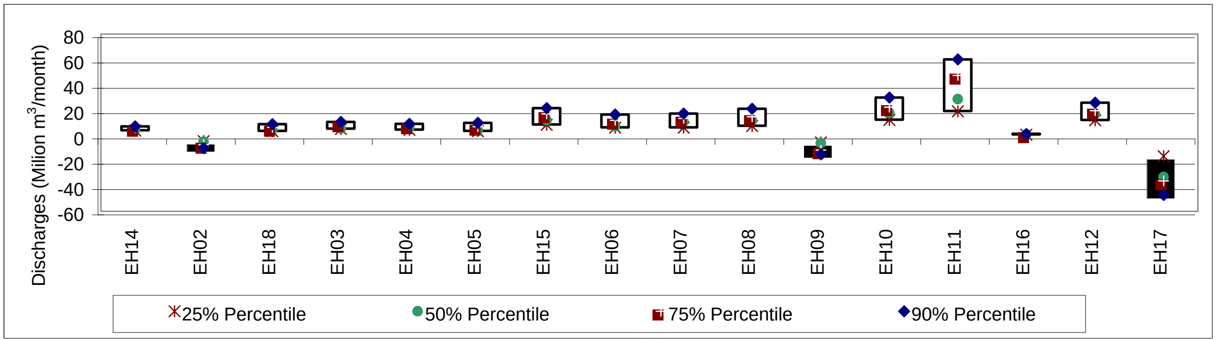


	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
EH18	0.96	0.97	1.00													
EH15	0.74	0.69	0.75	0.42	0.72	0.84	1.00									
EH11	0.36	0.42	0.46	0.20	0.34	0.36	0.40	0.32	0.34	0.32	0.29	0.61	1.00			
EH17	0.02	-0.03	0.04	0.02	0.14	0.09	0.31	0.36	-0.06	-0.09	0.19	-0.04	0.04	-0.06	0.00	1.00



	EH14	EH02	EH18	EH03	EH04	EH05	EH15	EH06	EH07	EH08	EH09	EH10	EH11	EH16	EH12	EH17
EH18	0.71	0.72	1.00													
EH15	0.65	0.67	0.40	0.41	0.61	0.68	1.00									
EH11	0.61	0.63	0.63	0.58	0.59	0.50	0.66	0.60	0.63	0.63	0.62	0.72	1.00			
EH17	0.48	0.48	0.41	0.43	0.26	0.40	0.31	0.42	0.48	0.57	0.38	0.42	0.35	0.35	0.26	1.00

Annex 4-9: Percentile analyses and correlation coefficients for some WQPs measured at Hadus drain monitoring sites



	QEH14	QEH02	QEH18	QEH03	QEH04	QEH05	QEH15	QEH06	QEH07	QEH08	QEH09	QEH10	QEH11	Q EH16	QEH12	Q EH17
QEH18	0.14	0.04	1.00													
QEH15	0.30	0.41	0.21	-0.01	0.52	0.41	1.00									
QEH11	0.03	0.33	0.17	0.09	0.34	0.18	0.41	0.27	0.20	0.16	0.17	0.14	1.00			
Q EH17	0.16	0.31	0.14	0.11	0.38	0.30	0.42	0.26	0.23	0.19	0.24	0.28	0.84	0.10	0.41	1.00

Note: Negative values indicate the case of extracting water for reuse.

ANNEX 4-10

SITE SIMILARITY RESULTS FOR THE SITE GROUPS (2, 3 AND 4)

MONITORING LOCATIONS DECISIVE FACTORS

This annex presents the site similarity results for the three site groups (2, 3 and 4).

1. SITE GROUP 2 (EH04, EH05, EH15 and EH06)

2.1 Key players and monitoring objectives analyses

- For BOD, COD, TDS, N-NH_4 and Coli, all monitoring locations in site group 2 violate Law 48 (local standards). EH04 has relatively different quality levels (oxygen budget, salts and bacterial indicator). Therefore, EH04 should appear in any proposed network.
- EH05 is essential for the monitoring objectives "*Make waste-load allocations*" and "*Determine Water Quantities*" in order to facilitate the calculation of pollutants loads, which are added to the system. EH05 also seems to be a key player concerning some quality indicators such as oxygen budget, salts and nutrients.
- For the other monitoring objectives and when EH15 (main stream point) is monitored, EH05 can be excluded from based on the correlation analysis which showed high correlations between EH05 and EH15 in relation with most of the examined parameters such as BOD, COD, EC, TDS, N-NO_3, N-NH_4, TP, Temp, Cu, Fe, Mn, Zn and Pb. In the mean time, the parameters SAR, pH and Coli showed lesser correlation but the coefficients remain statistically significant.
- EH15 as a checkpoint on the main stream has to be included in any proposed network. It has high correlation coefficients with other locations (EH18, EH03, EH04 and EH05) in relation with most of the examined parameters such as BOD, COD, EC, TDS, SAR, N-NO_3, N-NH_4, TP, pH, Temp, Coli, Cu, Fe, Mn, Zn and Pb.
- EH06 is essential for the monitoring objectives "*Make waste-load allocations*" and "*Determine Water Quantities*" in order to facilitate the calculation of pollutants loads.
- For the other monitoring objectives and when EH11 (main stream point) is monitored, EH06 can be excluded based on the correlation analysis, which showed high correlations between EH06 and EH11 in relation with the parameters BOD, COD, N-NO_3, N-NH_4, TP, Temp, Cu, Mn and Pb. In the meantime, the parameters EC, TDS, SAR, Turb, pH and Fe showed lesser correlation but the coefficients remain statistically significant.

1.2 Statistical Analyses

- The 36 WQPs investigated in this section can be divided into 4 parameter groups A2, B2, C2 and D2 as followings:
- ***<u>Parameter Group (A2)</u>*** includes 3 parameters namely pH, DO and Visib. These three parameters participated in the three approaches (Means, Yearly Avg. and Monthly).
- The "Means" approach (4 and 6 clusters solutions) indicated that there are significant differences between the monitoring locations EH05, EH04 and EH15.
- For the location pair EH04&EH05, the parameters pH and Visib were similar in the two approaches (Yearly Avg. and Monthly). In the meantime, DO was neither similar nor correlated.
- The Pearson correlation coefficients (R) for the three parameters were as followings:

	pH	Visib	DO
R (Pearson)	0.612**	-0.184	-0.179

- For the location pair EH15&EH04, the parameter pH was similar in the two approaches (Yearly Avg. and Monthly). In the meantime, DO was neither similar nor correlated. Concerning the Visib, the two approaches indicated different results. However, The Pearson correlation coefficients (R) for the three parameters were as followings:

	pH	Visib	DO
R (Pearson)	0.609**	0.188	-0.062

- For the location pair EH15&EH05, the parameters pH and DO were similar in the two approaches (Yearly Avg. and Monthly). In the meantime, the Visib was significantly correlated at 0.01 level with 0.509 Pearson coefficient.
- ***<u>Parameter Group (B2)</u>*** includes 8 parameters namely Cu, Fe, TDS, Ca, Mg, K, SO_4 and Cl. These eight parameters participated in the two approaches (Yearly Avg. and Monthly).
- The yearly Avg. and Monthly approaches indicated that the parameters Fe, Ca, Mg, SO_4 and Cl were similar in the location pair EH05&EH04. Although the other three parameters Cu, TDS and K were similar in the Yearly Avg. approach, the Monthly approach indicated dissimilarity. The Pearson correlation coefficients (R) for the latest three parameters were as followings:

"**" Correlation is significant at the .01 level.

	Cu	TDS	K
R (Pearson)	0.90**	0.574**	0.692**

- The yearly Avg. and Monthly approaches indicated that the parameters Fe, K, Mg, SO_4 and Cl were similar in the location pair EH15&EH04. Although the other three parameters Cu, TDS and Ca were similar in the Yearly Avg. approach, the Monthly approach indicated dissimilarity. The Pearson correlation coefficients (R) for the latest three parameters were as followings:

	Cu	TDS	Ca
R (Pearson)	0.775**	0.646**	0.677**

- The yearly Avg. and Monthly approaches indicated that 6 parameters (Cu, Fe, Mg, K, SO_4 and Cl) were similar in the location pair EH15&EH05. They also indicated that the TDS measurements were not similar for the same pair. Although the Ca measurements were similar in the Yearly Avg. approach, the Monthly approach indicated dissimilarity. The Pearson correlation coefficients (R) for the latest two parameters were as followings:

	TDS	Ca
R (Pearson)	0.540**	0.631**

- ***Parameter Group (C2)*** includes 9 parameters namely BOD, COD, TSS, TVS, N-NH_4, P, Temp, Turb and TP. These nine parameters participated in the two approaches (Means and Monthly).
- The "Mean" approach indicated that the monitoring locations EH04, EH05 and EH15 are dissimilar.
- For the pair EH05&EH04, the two approaches indicated that BOD, COD, P and Temp were not similar. The other five parameters showed different results. Only, conclusion can be drawn for the N-NH_4. The high correlation coefficients supported the results of the "Monthly approach" which indicated similarity. Therefore, N-NH_4 was considered as a similar parameter for the location pair EH05&EH04. The Pearson correlation coefficients (R) for these nine parameters were as followings:

"**" Correlation is significant at the .01 level.

	TSS	TVS	N-NH_4	Turb	TP
R (Pearson)	0.640**	0.683**	0.989**	-0.187	0.507**

	BOD	COD	P	Temp
R (Pearson)	0.470**	0.552**	0.642**	0.981**

- For the pair EH15&EH04, the two approaches indicated that BOD, COD, TSS, TVS, P and Turb were dissimilar. The other three parameters showed different results. However, conclusion can be drawn for the N-NH_4 and Temp where the high correlation coefficients supported the results of the “Monthly approach” which indicated similarity. Therefore, these two parameters were considered as similar parameters for the location pair EH15&EH04. The Pearson correlation coefficients (R) for the nine parameters were as followings:

	BOD	COD	TSS	TVS	P	Turb
R (Pearson)	0.623**	0.685**	0.662**	0.662**	0.677**	0.225

	N-NH_4	Temp	TP
R (Pearson)	0.991**	0.979**	0.580**

- For the pair EH15&EH05, the two approaches indicated that TSS, TVS and Turb were dissimilar. The other six parameters showed different results. However, conclusion can be drawn for the N-NH_4 and Temp where the high correlation coefficients supported the results of the “Monthly approach” which indicated similarity. Therefore, these two parameters were considered as similar parameters for the location pair EH15&EH05. The Pearson correlation coefficients (R) for the nine parameters were as followings:

	BOD	COD	TSS	TVS	P	Turb
R (Pearson)	0.540**	0.622**	0.780**	0.794**	0.644**	0.233

	N-NH_4	Temp	TP
R (Pearson)	0.990**	0.973**	0.819**

- ***Parameter Group (D2)*** includes 16 parameters namely Coli, N-NO_3, Cd, Mn, Zn, Pb, Br, EC, Na, SAR, Adj_SAR, Sal, Fecal, TN, Ni, SO_{4_m}. These sixteen parameters participated only in the last approach (Monthly).

“**” Correlation is significant at the .01 level.

- The results indicated that eight WQPs (N-NO_3, Cd, Zn, Pb, Adj_SAR, TN, Ni and SO_{4_m}) were similar for the location pairs EH05&EH04, EH15&EH04 and EH15&EH05. Also, for these three pairs, two parameters (EC and Sal) were dissimilar.
- Five parameters (Coli, Mn, Br, SAR and Fecal) were dissimilar for the location pairs EH05&EH04 and EH15&EH04. In the meantime, these five parameters were similar for the pair EH05&EH15.
- Na measurements were only similar for the pair EH15&EH04.
- For the Pairs EH05&EH04, EH15&EH04 and EH15&EH05, the Pearson correlation coefficients (R) for the dissimilar parameters were as followings:

	Coli	Mn	Br	EC	Na	SAR	Sal	Fecal
EH05&EH04	0.101	0.465**	0.727**	0.515**	0.434**	0.568**	0.462**	-0.09

	Coli	Mn	Br	EC	SAR	Sal	Fecal
EH15&EH04	0.204	0.703**	0.90**	0.698**	0.584**	0.727**	0.11

	EC	Na	Sal
EH15&EH05	0.456**	0.256**	0.538**

- Annex 4-10-A1 shows the summary results of the statistical analyses, which were employed for 36 WQPs, measured at some monitoring locations in site group 2.
- The location pair EH04&EH05 had 16 similar WQPs, 16 correlated at 0.01-confidence level and 4 dissimilar-uncorrelated parameters.
- The location pair EH15&EH04 had 17 similar WQPs, 14 correlated at 0.01-confidence level and 5 dissimilar-uncorrelated parameters.
- The location pair EH05&EH15 had 23 similar WQPs, 12 correlated at 0.01-confidence level and 1 dissimilar-uncorrelated parameters.
- <u>Based on the statistical analyses, the monitoring location EH05 can be excluded without loosing substantial information. Most of the variability related to this location can be easily obtained from the monitoring locations EH04 and EH15.</u>

"**" Correlation is significant at the .01 level.

Annex 4-10-A1: Statistical analyses summary results for 36 parameters measured at the possible similar pairs in site group 2

	Water Quality Parameters				Total
	EH04 - EH05				
	Group A2	Group B2	Group C2	Group D2	
Means	3NS	-	9NS	-	
Yearly Avg.	2S + 1NS	8S	-	-	
Monthly	2S + 1NS_NC	5S + 3C	5S + 3C + 1NS_NC	8S + 6C + 2NS_NC	
Similar Parameters	2	5	1	8	16
Correlated	0	3	7	6	16
Dissimilar - Uncorrelated	1	0	1	2	4
Total No. of Parameters	3	8	9	16	36

	EH15 - EH04				Total
	Group A2	Group B2	Group C2	Group D2	
Means	3NS	-	9NS	-	
Yearly Avg.	2S + 1NS	8S	-	-	
Monthly	1S + 2NS_NC	5S + 3C	3S + 5C + 1NS_NC	9S + 5C + 2NS_NC	
Similar Parameters	1	5	2	9	17
Correlated	0	3	6	5	14
Dissimilar - Uncorrelated	2	0	1	2	5
Total No. of Parameters	3	8	9	16	36

	EH05 - EH15				Total
	Group A2	Group B2	Group C2	Group D2	
Means	3NS	-	9NS	-	
Yearly Avg.	3S	7S + 1NS	-	-	
Monthly	2S + 1C	6S + 2C	6S + 2C + 1NS_NC	13S + 3C	
Similar Parameters	2	6	2	13	23
Correlated	1	2	6	3	12
Dissimilar - Uncorrelated	0	0	1	0	1
Total No. of Parameters	3	8	9	16	36

“S”	*Similar parameters*	*“NC”*	*Uncorrelated*
“NS”	*Dissimilar*	*“NS_NC”*	*Dissimilar-Uncorrelated*
“C”	*Correlated*	*“-“*	*Not participated in the related approach*

- Annex 4-10-A2 presents the relations between the monitoring location EH05 and the other two locations EH04 and EH15 concerning the 36 WQPs employed in the statistical analyses.

Annex 4-10-A2: The relations between the monitoring location EH05 and the other two locations EH04 and EH15

Parameters	Group 2	
	EH05 - EH04	EH15 - EH05
$N\text{-}NO_3$ (mg/l)	S	S
$N\text{-}NH_4$ (mg/l)	S	S
Cd (mg/l)	S	S
Fe (mg/l)	S	S
Zn (mg/l)	S	S
Pb (mg/l)	S	S
pH	S	S
Mg (meq/l)	S	S
SO_4 (meq/l)	S	S
Cl (meq/l)	S	S
Adj_SAR	S	S
TN (mg/l)	S	S
Ni (mg/l)	S	S
SO_{4_m} (meq/l)	S	S

Parameters	Group 2	
	EH05 - EH04	EH15 - EH05
Ca (meq/l)	S	C
Visib (Cm)	S	C

Parameters	Group 2	
	EH05 - EH04	EH15 - EH05
Turb (NTU)	NS-NC	NS-NC

Parameters	Group 2	
	EH05 - EH04	EH15 - EH05
BOD (mg/l)	C	C
COD (mg/l)	C	C
TSS (mg/l)	C	C
TVS (mg/l)	C	C
P (mg/l)	C	C
EC (dS/m)	C	C
TDS (mg/l)	C	C
Na (meq/l)	C	C
Temp (C^o)	C	C
Sal	C	C
TP (mg/l)	C	C

Parameters	Group 2	
	EH05 - EH04	EH15 - EH05
Coli (MPN/100ml)	NS-NC	S
Cu (mg/l)	C	S
Mn (mg/l)	C	S
Br (mg/l)	C	S
K (meq/l)	C	S
SAR	C	S
DO (mg/l)	NS-NC	S
Fecal (MPN/100ml)	NS-NC	S

“S”	*Similar parameters*	*“NC”*	*Uncorrelated*
“NS”	*Dissimilar*	*“NS_NC”*	*Dissimilar-Uncorrelated*
“C”	*Correlated*		

2. SITE GROUP 3 (EH07, EH08, EH09 and EH10)

2.1 Key players and monitoring objectives analyses

- For BOD, COD, TDS, N-NH_4 and Coli, all monitoring locations in site group 3 are violating Law 48 standards. According to FAO standards, most of TDS measurements can be considered as fair water except EH08, which can be described as poor water for irrigation.

- EH07 is essential for the monitoring objectives "*Make waste-load allocation*s" and "*Determine Water Quantities*" in order to facilitate the calculation of pollutant loads, which are added to the system.

- Although both EH07 and EH08 can be seen as key-players in Hadus system, EH08 was given higher priority based on the statistical results. The number of similar parameters between EH07 and EH08 are 22 (Wilcoxon signed rank test results). The other dissimilar parameters are mainly due to the higher salts levels at EH08 (Wilcoxon signed rank test results, MANOVA, DA and Range tests). Most of the parameters representing the salts levels in EH07 and EH08 (EC, TDS, Na, K, Ca, SO_4, Mg, Cl, SAR and Adj. SAR) are significantly correlated and there are significant regression equations to describe their relations (Correlation and Regression Analyses).

- EH09 is a reuse pump station and has relatively different levels in some WQPs especially DO, EC, TDS and SAR comparing with the other locations in site group 3. Therefore, It can appear in all proposed networks except the network for "*Determine fate and transport of pollutants*". This is due to the field observation, which indicates that most of EH09 water is reused (unofficially) before it flows to Hadus main drain.

- EH10 is essential for the monitoring objectives "*Make waste-load allocations*" and "*Determine Water Quantities*" in order to facilitate the calculation of pollutants loads, which are added to the system.

- For the other monitoring objectives and when EH11 (main stream point) is monitored, EH10 can be excluded based on the correlation analysis, which showed high correlations between EH10 and EH11 in relation with the examined parameters BOD, COD, DO, EC, TDS, SAR, N-NO_3, TP, Turb, pH, Temp, Coli, Cu, Mn, Zn and Pb. In the meantime, the parameters N-NH_4 and Fe showed lesser correlation but the coefficients remain statistically significant.

- <u>EH11 as a checkpoint on the main stream has to be included in any proposed network.</u> It has high correlation coefficients with other locations (EH15, EH06, EH07, EH08 and EH10) in relation with most of the examined parameters such as BOD, COD, EC, TDS, SAR, N-NO$_3$, N-NH$_4$, TP, pH, Temp, Cu, Fe, Mn and Pb.

2.2 Statistical Analyses

The 36 WQPs investigated in this section can be divided into 4 parameter groups A3, B3, C3 and D3 as followings:

- ***Parameter Group (A3)*** includes 5 parameters namely COD, pH, Temp, DO and Turb. These five parameters participated in the three approaches (Means, Yearly Avg. and Monthly).
- For these five parameters, the three approaches indicated that there were insignificant differences between the monitoring locations EH07 and EH08 except the Temp, which was dissimilar in the Monthly approach. However, the high Pearson correlation coefficient (0.987**) for the Temp supported the results of both “Means and Yearly Avg.” which indicated similarity. Therefore, the five parameters were considered as similar parameters for the location pair EH07&EH08.
- The first two approaches considered the two locations EH07 and EH09 as similar sites for the five parameters except DO where, the Yearly avg. approach indicated dissimilarity. The three approaches indicated that there were insignificant differences between the monitoring locations EH07 and EH09 for two WQPs (COD and Temp). The Pearson correlation coefficients (R) for the other three parameters were as followings:

	pH	DO	Turb
Pearson (R)	0.377**	0.191	0.293

- The first two approaches considered the two locations EH07 and EH10 as similar sites for the five parameters. The three approaches indicated that there were insignificant differences between the monitoring locations EH07 and EH10 for three WQPs (COD, pH and Temp). The Pearson correlation coefficients (R) for the other two parameters were as followings:

	DO	Turb
Pearson (R)	0.486**	0.777**

- The three approaches indicated that there were insignificant differences between the monitoring locations EH09 and EH10 for four WQPs (COD, pH, Temp, and Turb). The DO

“**” Correlation is significant at the .01 level.

measurements were not similar in the last two approaches. The Pearson correlation coefficient (R) for the DO parameter was 0.399**.

- ***Parameter Group (B3)*** includes eight parameters namely Cu, Fe, EC, TDS, Na, SO_4, Cl, and Sal. These eight parameters participated in the two approaches (Yearly Avg. and Monthly).
- The two approaches indicated that there were insignificant differences between the monitoring locations EH07 and EH08 for two WQPs (Cu and Fe). Also, they indicated that the other six parameters (EC, TDS, Na, SO_4, Cl, and Sal) were dissimilar. The Pearson correlation coefficients (R) for these dissimilar parameters were as following:

	EC	TDS	Na	SO_4	Cl	Sal
Pearson (R)	0.494**	0.547**	0.602**	0.614**	0.610**	0.506**

- The two approaches indicated that there were insignificant differences between the monitoring locations EH07 and EH09 for two WQPs (Cu and Fe). Also, they indicated that the other six parameters (EC, TDS, Na, SO_4, Cl, and Sal) were dissimilar. The Pearson correlation coefficients (R) for these dissimilar parameters were as following:

	EC	TDS	Na	SO_4	Cl	Sal
Pearson (R)	0.270	0.187	0.331**	0.377**	0.432**	0.279

- For the monitoring locations EH07 and EH10, the two approaches indicated that the parameters Cu and SO_4 were similar. The yearly Avg. approach indicated that the other six parameters were similar where the Monthly approach indicated dissimilarity. The Pearson correlation coefficients (R) for these dissimilar parameters were as following:

	Fe	EC	TDS	Na	Cl	Sal
Pearson (R)	0.718**	0.554**	0.399**	0.520**	0.574**	0.465**

- For the monitoring locations EH09 and EH10, the two approaches indicated that the parameters Cu and Fe were similar. They also indicated that the parameters EC, TDS, Na, SO_4, Cl and Sal were not. <u>Although, the Monthly approach indicated that some of these dissimilar parameters were significantly correlated even with relatively small coefficients, only EC and Sal would be considered as significantly correlated</u>. The Pearson correlation coefficients (R) for these dissimilar parameters were as following:

"**" Correlation is significant at the .01 level.

	EC	TDS	Na	SO_4	Cl	Sal
Pearson (R)	0.424^{**}	0.291^{**}	0.282^{**}	0.335^{**}	0.391^{**}	0.574^{**}

- ***Parameter Group (C3)*** includes seven parameters namely BOD, TSS, TVS, N-NH_4, P, Visib and TP. These parameters participated in the two approaches (Means and Monthly).
- The two approaches indicated that there were insignificant differences between the monitoring locations EH07 and EH08 for six WQPs (BOD, TSS, TVS, N-NH_4, P and Visib). The TP measurements were not similar in the Monthly approach. The Pearson correlation coefficient (R) for the TP parameter was 0.659^{**}.
- The two approaches indicated that there were insignificant differences between the monitoring locations EH07 and EH09 for the four WQPs BOD, TSS, TVS and Visib. The N-NH_4, P and TP measurements were not similar in the Monthly approach. The Pearson correlation coefficients (R) for these three parameters were as followings.

	N-NH_4	P	TP
Pearson (R)	0.765^{**}	0.454^{**}	0.824^{**}

- The two approaches indicated that there were insignificant differences between the monitoring locations EH07 and EH10 for the four WQPs BOD, TVS, N-NH_4 and TP. The TSS, P and Visib measurements were not similar in the Monthly approach. The Pearson correlation coefficients (R) for these three parameters were as followings:

	TSS	P	Visib
Pearson (R)	0.721^{**}	0.359^{**}	0.641^{**}

- The two approaches indicated that there were insignificant differences between the monitoring locations EH09 and EH10 for the six WQPs BOD, TSS, TVS, N-NH_4, P and Visib. The TP measurements were not similar in the Monthly approach. The Pearson correlation coefficient (R) for the TP parameter was 0.772^{**}.
- ***Parameter Group (D3)*** includes sixteen parameters namely Coli, N-NO_3, Cd, Mn, Zn, Pb, Br, Ca, Mg, K, SAR, Adj_SAR, Fecal, TN, Ni and SO_{4_m}. These parameters participated only in one approach (Monthly).

"**" Correlation is significant at the .01 level.

- The Monthly approach indicated that there were insignificant differences between the monitoring locations EH07 and EH08 for ten WQPs (Coli, N-NO_3, Cd, Mn, Zn, Pb, Br, Fecal, TN and Ni). Also, they indicated that the Ca, Mg, K, SAR, Adj_SAR and SO_{4_m} measurements were not similar. The Pearson correlation coefficients (R) for these dissimilar parameter were as followings.

	Ca	Mg	K	SAR	Adj. SAR	SO_{4_m}
Pearson (R)	0.704**	0.744**	0.878**	0.771**	0.719**	0.743**

- For the monitoring sites EH07 and EH09, the results showed that the measurements of Cd, Zn, Br and Ni were similar and the other twelve parameters were not. The Pearson correlation coefficients (R) for these dissimilar parameters were as following:

	Coli	N-NO_3	Mn	Pb	Ca	Mg
Pearson (R)	0.031	0.889**	0.646**	0.811**	0.165	0.429**
	K	SAR	Adj_SAR	Fecal	TN	SO_{4_m}
Pearson (R)	0.521**	0.334**	0.316**	0.009	0.830**	0.242

- For the monitoring sites EH07 and EH10, the results showed that ten parameters (N-NO_3, Cd, Mn, Zn, Pb, Ca, Mg, TN, Ni, and SO_{4_m}) were similar and the other six parameters were not. The Pearson correlation coefficients (R) for these dissimilar parameters were as following:

	Coli	Br	K	SAR	Adj_SAR	Fecal
Pearson (R)	-0.005	0.970**	0.902**	0.630**	0.580**	-0.047

- For the monitoring sites EH10 and EH09, the results showed that nine parameters (Coli, N-NO_3, Cd, Mn, Zn, Pb, Br, TN and Ni) were similar and the other seven parameters were not. The Pearson correlation coefficients (R) for these dissimilar parameters were as following:

	Ca	Mg	K	SAR	Adj_SAR	Fecal	SO_{4_m}
Pearson (R)	0.307*	0.568**	0.571**	0.260	0.265	0.959**	0.473**

"**" Correlation is significant at the .01 level.

- Annex 4-10-B1 shows the summary results of the statistical analyses, which were employed for 36 WQPs, measured at some monitoring locations in site group 3.
- The location pair EH08&EH07 had 23 similar WQPs, 13 correlated at 0.01-confidence level and 0 dissimilar-uncorrelated parameters.
- The location pair EH09&EH07 had 12 similar WQPs, 15 correlated at 0.01-confidence level and 9 dissimilar-uncorrelated parameters.
- The location pair EH10&EH07 had 19 similar WQPs, 15 correlated at 0.01-confidence level and 2 dissimilar-uncorrelated parameters.
- The location pair EH10&EH09 had 21 similar WQPs, 8 correlated at 0.01-confidence level and 7 dissimilar-uncorrelated parameters. However, the correlation and linear regression analyses employed for the location pair EH10&EH11 (Annex 4-8-C5) show that these seven dissimilar-uncorrelated parameters (TDS, Na, SO_4, Cl, Ca, SAR and Adj_SAR) can be estimated from the measurements at EH11 using statistically significant relations.
- Based on the statistical analyses, the monitoring locations EH07 and EH10 can be excluded without loosing substantial information. Most of the variability related to these locations can be easily obtained from the monitoring locations EH08, EH09 and EH11.
- Annex 4-10-B2 presents the relations between the monitoring locations EH08&EH07 and EH10&EH09 concerning the 36 WQPs employed in the statistical analyses.

“**” Correlation is significant at the .01 level.

Annex 4-10-B1: Statistical analyses summary results for 36 parameters measured at the possible similar pairs in site group 3

	Water Quality Parameters				Total
	EH08 - EH07				
	Group A3	Group B3	Group C3	Group D3	
Means	5S	-	7S	-	
Yearly Avg.	5S	2S + 6NS	-	-	
Monthly	4S + 1C	2S + 6C	6S + 1C	10S + 6C	
Similar Parameters	5	2	6	10	23
Correlated	0	6	1	6	13
Dissimilar - Uncorrelated	0	0	0	0	0
Total No. of Parameters	5	8	7	16	36

	EH09 - EH07				Total
	Group A3	Group B3	Group C3	Group D3	
Means	5S	-	7S	-	
Yearly Avg.	4S + 1NS	2S + 6NS	-	-	
Monthly	2S + 1C + 2NS_NC	2S + 3C + 3NS_NC	4S + 3C	4S + 8C + 4NS_NC	
Similar Parameters	2	2	4	4	12
Correlated	1	3	3	8	15
Dissimilar - Uncorrelated	2	3	0	4	9
Total No. of Parameters	5	8	7	16	36

	EH10 - EH07				Total
	Group A3	Group B3	Group C3	Group D3	
Means	5S	-	7S	-	
Yearly Avg.	5S	8S	-	-	
Monthly	3S + 2C	2S + 6C	4S + 3C	10S + 4C + 2NS_NC	
Similar Parameters	3	2	4	10	19
Correlated	2	6	3	4	15
Dissimilar - Uncorrelated	0	0	0	2	2
Total No. of Parameters	5	8	7	16	36

	EH10 - EH09				Total
	Group A3	Group B3	Group C3	Group D3	
Means	5S	-	7S	-	
Yearly Avg.	4S + 1NS	2S + 6NS	-	-	
Monthly	4S + 1C	2S + 6C	6S + 1C	9S+ 4C + 3NS_NC	
Similar Parameters	4	2	6	9	21
Correlated	1	2	1	4	8
Dissimilar - Uncorrelated	0	4	0	3	7
Total No. of Parameters	5	8	7	16	36

“S”	*Similar parameters*	*“NC”*	*Uncorrelated*
“NS”	*Dissimilar*	*“NS_NC”*	*Dissimilar-Uncorrelated*
“C”	*Correlated*	*“-“*	*Not participated in the related approach*

For the pair EH10-EH09, the Monthly approach indicated that all the dissimilar parameters were significantly correlated even with relatively low coefficients. However, only EC and sal (greater coefficients) were considered as significantly correlated.

Annex 4-10-B2: The relations between the monitoring locations EH08&EH07 and EH10&EH09

Parameters	Group 3	Group 3
	EH10- EH09	EH07- EH08
Coli (MPN/100ml)	S	S
BOD (mg/l)	S	S
COD (mg/l)	S	S
TSS (mg/l)	S	S
TVS (mg/l)	S	S
N-NO$_3$ (mg/l)	S	S
N-NH$_4$ (mg/l)	S	S
P (mg/l)	S	S
Cd (mg/l)	S	S
Cu (mg/l)	S	S
Fe (mg/l)	S	S
Mn (mg/l)	S	S
Zn (mg/l)	S	S
Pb (mg/l)	S	S
Br (mg/l)	S	S
pH	S	S
Temp (C^o)	S	S
Turb (FTU)	S	S
Visib (Cm)	S	S
TN (mg/l)	S	S
Ni (mg/l)	S	S

Parameters	Group 3	Group 3
	EH10- EH09	EH07- EH08
DO (mg/l)	C	S
Fecal (MPN/100ml)	C	S

Parameters	Group 3	Group 3
	EH10- EH09	EH07- EH08
TDS (mg/l)	NS-NC	C
Ca (meq/l)	NS-NC	C
Na (meq/l)	NS-NC	C
SO$_4$ (meq/l)	NS-NC	C
Cl (meq/l)	NS-NC	C
SAR	NS-NC	C
Adj_SAR	NS-NC	C

Parameters	Group 3	Group 3
	EH10- EH09	EH07- EH08
EC (dS/m)	C	C
Mg (meq/l)	C	C
K (meq/l)	C	C
Sal	C	C
TP (mg/l)	C	C
SO$_{4\_m}$ (meq/l)	C	C

"S"	*Similar parameters*	*"NC"*	*Uncorrelated*
"NS"	*Dissimilar*	*"NS_NC"*	*Dissimilar-Uncorrelated*
"C"	*Correlated*		

3. SITE GROUP 4 (EH11, EH12, EH16 and EH17)

3.1 Key players and monitoring objectives analyses

- EH11 as a checkpoint on the main stream has to be included in any proposed network. It has high correlation coefficients with other locations (EH15, EH06, EH07, EH08 and EH10) in relation with most of the examined parameters such as BOD, COD, EC, TDS, SAR, N-NO_3, N-NH_4, TP, pH, Temp, Cu, Fe, Mn and Pb.
- EH12 has relatively high discharges and can be considered as a key-player in Hadus drain system especially for the WQ indicators: oxygen budget, salts, physical parameters and some heavy metals. Therefore, it has to appear in any proposed network except the one for "Assess compliance with standards". This is due to the high correlation between EH12 and EH17 in relation with the parameters BOD, COD, EC, TDS, SAR, N-NO_3, N-NH_4, Temp and Cu. In the meantime, the parameters Turb, pH, Fe and Mn showed lesser correlation but the coefficients remain statistically significant.
- EH16 is essential for the monitoring objectives "*Make waste-load allocations*" and "*Determine Water Quantities*" in order to facilitate the calculation of pollutants loads, which are added to the system. It has almost the lowest discharges and the information about its quality can be detected by tracing the measurements at EH12 and EH17.
- EH17 is reuse pump station with considerable discharges to the main stream of El-Salam Canal. It can be seen as a checkpoint, which has strong correlations with the monitoring sites EH11 and EH12. Therefore, it has to appear in any proposed network.

3.2 Statistical Analyses

The 36 WQPs investigated in this section can be divided into 4 parameter groups A4, B4, C4 and D4 as followings:

- ***Parameter Group (A4)*** includes 5 parameters namely BOD, pH, Temp, Turb and Visib. These five parameters participated in the three approaches (Means, Yearly Avg. and Monthly).
- The first approach (Means) indicated that the five parameters were dissimilar for the location pair EH11 and EH17. In contrary, Yearly Avg. and Monthly showed that BOD, pH and Temp were similar. The yearly Avg. indicated that Turb and Visib were similar for the same pair and they were only considered as correlated in the Monthly approach. The Pearson correlation coefficients (R) for these dissimilar parameters were as following:

	Turb	Visib
Pearson (R)	0.496**	0.355**

- The first approach (Means) indicated that the five parameters were dissimilar for the location pair EH12 and EH16. In contrary, Yearly Avg. and Monthly showed that BOD and Temp were similar. The yearly Avg. indicated that pH measurements were similar for the same pair and they were only considered as correlated in the Monthly approach. The Visib and Turb were dissimilar in both Yearly Avg. and Monthly approaches. However, the Turb measurements were considered as correlated in the Monthly approach. The Pearson correlation coefficients (R) for these dissimilar parameters were as following:

	pH	Turb	Visib
Pearson (R)	0.519**	0.491**	0.258*

- The first approach (Means) indicated that the five parameters were not similar for the location pair EH12 and EH17. In contrary, Yearly Avg. and Monthly showed that BOD, pH and Temp were similar. The Visib and Turb were not similar in both Yearly Avg. and Monthly approaches. However, the Turb measurements were considered as correlated in the Monthly approach. Although, the Monthly approach indicated that Visib measurements were significantly correlated even with relatively low coefficients, they were considered as uncorrelated. The Pearson correlation coefficients (R) for these dissimilar parameters were as following:

	Turb	Visib
Pearson (R)	0.514**	0.311**

- ***__Parameter Group (B4)__*** includes 10 parameters namely Cu, Zn, EC, TDS, Na, SO_4, Cl, SAR, Adj_SAR and Sal. These ten parameters participated in the two approaches (Yearly Avg. and Monthly).

- For the monitoring sites EH11 and EH17, in the contrary of the yearly Avg. approach, which showed similarity, the Monthly indicated that the ten parameters were only significantly correlated. The Pearson correlation coefficients (R) for these ten parameters were as following:

	Cu	Zn	EC	TDS	Na
Pearson (R)	0.646**	0.047	0.674**	0.703**	0.643**
	SO_4	Cl	SAR	Adj_SAR	Sal
Pearson (R)	0.668**	0.674**	0.653**	0.683**	0.670**

"**" Correlation is significant at the .01 level.

- For the monitoring sites EH12 and EH16, in the contrary of the yearly Avg. approach, which showed similarity, the Monthly indicated that the parameter Zn was neither similar nor correlated. In both approaches, the Cu measurements were similar while the other eight parameters were not. The Pearson correlation coefficients (R) for these dissimilar parameters were as following:

	Zn	EC	TDS	Na	SO_4
Pearson (R)	-0.05	0.437**	0.471**	0.561**	0.452**
	Cl	SAR	Adj_SAR	Sal	
Pearson (R)	0.492**	0.561**	0.595**	0.509**	

- For the monitoring sites EH17 and EH12, while the yearly Avg. approach showed similarity for all parameters except Sal, the Monthly indicated that only two parameters Cu and SO_4 were similar. The Pearson correlation coefficients (R) for these ten parameters were as following:

	Cu	Zn	EC	TDS	Na
Pearson (R)	0.748**	-0.004	0.596**	0.681**	0.609**
	SO_4	Cl	SAR	Adj_SAR	Sal
Pearson (R)	0.674**	0.577**	0.581**	0.608**	0.651**

- ***Parameter Group (C4)*** includes 7 parameters namely COD, TSS, TVS, N-NH_4, P, DO and TP. These seven parameters participated in the two approaches (Means and Monthly).

- For the monitoring sites EH11 and EH17, while the Means approach showed dissimilarity for these seven parameters, the Monthly indicated that two parameters (P and DO) were similar. The Pearson correlation coefficients (R) for these seven parameters were as following:

	COD	TSS	TVS	N-NH_4
Pearson (R)	0.708**	0.525**	0.700**	0.887**
	P	DO	TP	
Pearson (R)	0.469**	0.303**	0.716**	

- For the monitoring sites EH12 and EH16, while the Means approach showed dissimilarity for the seven parameters, the Monthly indicated that three parameters (COD, N-NH_4 and TP) were similar. The Pearson correlation coefficients (R) for these parameters were as following:

	COD	TSS	TVS	N-NH$_4$
Pearson (R)	0.799^{**}	0.418^{**}	0.453^{**}	0.777^{**}
	P	DO	TP	
Pearson (R)	0.143	0.207	0.576^{**}	

- For the monitoring sites EH17 and EH12, while the Means approach showed dissimilarity for the seven parameters, the Monthly indicated that two parameters (COD and N-NH$_4$) were similar. The Pearson correlation coefficients (R) for these parameters were as following:

	COD	TSS	TVS	N-NH$_4$
Pearson (R)	0.655^{**}	0.553^{**}	0.488^{**}	0.882^{**}
	P	DO	TP	
Pearson (R)	0.473^{**}	0.176	0.061	

- ***<u>Parameter Group (D4)</u>*** includes 14 parameters namely Coli, N-NO$_3$, Cd, Fe, Mn, Pb, Br, Ca, Mg, K, Fecal, TN, Ni and SO$_{4\_m}$. These parameters participated in only one approach (Monthly).

- For the monitoring sites EH11 and EH17, the results showed that eleven WQPs were similar and the other three parameters (Ca, Mg and SO$_{4\_m}$) were only significantly correlated. The Pearson correlation coefficients (R) for these three parameters were as following:

	Ca	Mg	SO$_{4\_m}$
Pearson (R)	0.759^{**}	0.853^{**}	0.768^{*}

- For the monitoring sites EH12 and EH16, the results showed that nine WQPs were similar and four parameters (Ca, Mg, Fecal and SO$_{4\_m}$) were only significantly correlated. The other parameter (Coli) was neither similar nor correlated. The Pearson correlation coefficients (R) for the dissimilar parameters were as following:

	Coli	Ca	Mg	Fecal	SO$_{4\_m}$
Pearson (R)	0.287	0.427^{**}	0.400^{**}	0.925^{**}	0.461^{**}

- For the monitoring sites EH17 and EH12, the results showed that thirteen WQPs were similar and Na measurements were only significantly correlated. The Pearson correlation coefficient (R) for the Na measurements was 0.609^{**}.

“**” Correlation is significant at the .01 level.

- Annex 4-10-C1 shows the summary results of the statistical analyses, which were employed for 36 WQPs, measured at some monitoring locations in site group 4.
- The location pair EH11&EH17 had 16 similar WQPs, 20 correlated at 0.01-confidence level and 0 dissimilar-uncorrelated parameters.
- The location pair EH12&EH16 had 12 similar WQPs, 19 correlated at 0.01-confidence level and 5 dissimilar-uncorrelated parameters.
- The location pair EH17&EH12 had 18 similar WQPs, 14 correlated at 0.01-confidence level and 4 dissimilar-uncorrelated parameters.
- Annex 4-10-C2 presents the relations between the monitoring locations EH12 and EH16 concerning the 36 WQPs employed in the statistical analyses.
- Although, all pairs in this site group showed significant similarities for many examined parameters, the four locations EH11, EH16, EH12 and EH17 have to appear in the monitoring network proposed by the statistical analyses. This was decided due to the following reasons:

1. The numbers of similar parameters in the three pairs were 16, 12 and 18. This was obtained mainly from only one approach (Monthly), which indicated similarity for 11, 9 and 13 parameters.
2. The different approaches produced many contradicted results for the parameters, which were participated in more than one approach.
3. The relative importance for the three locations EH11, EH12 and EH17 called for their existence.
4. In addition to their far positions, the location EH16 has relative low discharges compared to EH12. Therefore, the detected correlations between them may not be physically explained.

Annex 4-10-C1: Statistical analyses summary results for 36 parameters measured at the possible similar pairs in site group 4

	Water Quality Parameters				Total
	EH11 - EH17				
	Group A4	Group B4	Group C4	Group D4	
Means	5NS	-	7NS	-	
Yearly Avg.	5S	10S	-	-	
Monthly	3S + 2C	10C	2S + 5C	11S + 3C	
Similar Parameters	3	0	2	11	16
Correlated	2	10	5	3	20
Dissimilar - Uncorrelated	0	0	0	0	0
Total No. of Parameters	5	10	7	14	36

	EH12 - EH16				Total
	Group A4	Group B4	Group C4	Group D4	
Means	5NS	-	7NS	-	
Yearly Avg.	3S + 2NS	2S + 8NS	-	-	
Monthly	2S + 2C + 1NS_NC	1S + 8C + 1NS_NC	3S + 2C + 2NS_NC	9S + 4C + 1NS_NC	
Similar Parameters	2	1	0	9	12
Correlated	2	8	5	4	19
Dissimilar - Uncorrelated	1	1	2	1	5
Total No. of Parameters	5	10	7	14	36

	EH17 - EH12				Total
	Group A4	Group B4	Group C4	Group D4	
Means	5NS	-	7NS	-	
Yearly Avg.	3S + 2NS	9S + 1NS	-	-	
Monthly	3S + 1C + 1NS_NC	2S + 7C + 1NS_NC	2S + 3C + 2NS_NC	13S + 1C	
Similar Parameters	3	2	0	13	18
Correlated	1	7	5	1	14
Dissimilar - Uncorrelated	1	1	2	0	4
Total No. of Parameters	5	10	7	14	36

“S”	*Similar parameters*	*“NC”*	*Uncorrelated*
“NS”	*Dissimilar*	*“NS_NC”*	*Dissimilar-Uncorrelated*
“C”	*Correlated*	*“-“*	*Not participated in the related approach*

Annex 4-10-C2: The relations between the monitoring locations EH12&EH16

Parameters	**Group 4**
	EH16- EH12
BOD (mg/l)	S
N-NO$_3$ (mg/l)	S
Cd (mg/l)	S
Cu (mg/l)	S
Fe (mg/l)	S
Mn (mg/l)	S
Pb (mg/l)	S
Br (mg/l)	S
K (meq/l)	S
Temp (C^o)	S
TN (mg/l)	S
Ni (mg/l)	S

Parameters	**Group 4**
	EH16- EH12
Coli (MPN/100ml)	NS-NC
P (mg/l)	NS-NC
Zn (mg/l)	NS-NC
DO (mg/l)	NS-NC
Visib (Cm)	NS-NC

Parameters	**Group 4**
	EH16- EH12
COD (mg/l)	C
TSS (mg/l)	C
TVS (mg/l)	C
N-NH$_4$ (mg/l)	C
pH	C
EC (dS/m)	C
TDS (mg/l)	C
Ca (meq/l)	C
Mg (meq/l)	C
Na (meq/l)	C
SO$_4$ (meq/l)	C
Cl (meq/l)	C
SAR	C
Adj_SAR	C
Sal	C
Turb (NTU)	C
TP (mg/l)	C
Fecal (MPN/100ml)	C
SO$_{4\_m}$ (meq/l)	C

“S” Similar parameters
“NS” Dissimilar
“C” Correlated
“NC” Uncorrelated
“NS_NC” Dissimilar-Uncorrelated

ANNEX 6-1

KOLMOGOROV-SAMIRNOV TEST'S RESULTS FOR THE DE-SEASONALISED AND DE-TRENDED MEASUREMENTS OF SOME WQPs IN BAHR HADUS BRIDGE (EH11)

Annex 6-1: Kolmogorov-Samirnov test's significant results to check the normality for the de-seasonalised and de-trended measurements of some WQPs in Bahr Hadus Bridge

Parameters	Kolmogorov-Smirnov		
	Statistic	df	Sig.
Coli (MPN/100 ml)	0.400	90	0.000
BOD (mg/l)	0.116	90	0.004
COD (mg/l)	0.116	90	0.004
TSS (mg/l)	0.182	90	0.000
TVS (mg/l)	0.187	90	0.000
N-NO_3 (mg/l)	0.076	90	0.200
N-NH_4 (mg/l)	0.223	90	0.000
P (mg/l)	0.130	36	0.129
Cd (mg/l)	0.260	90	0.000
Cu (mg/l)	0.251	90	0.000
Fe (mg/l)	0.086	90	0.099
Mn (mg/l)	0.180	54	0.000
Zn (mg/l)	0.183	90	0.000
Pb (mg/l)	0.177	90	0.000
Br (mg/l)	0.224	54	0.000
pH	0.093	90	0.055
EC (dS/m)	0.098	90	0.033
TDS (mg/l)	0.096	90	0.041

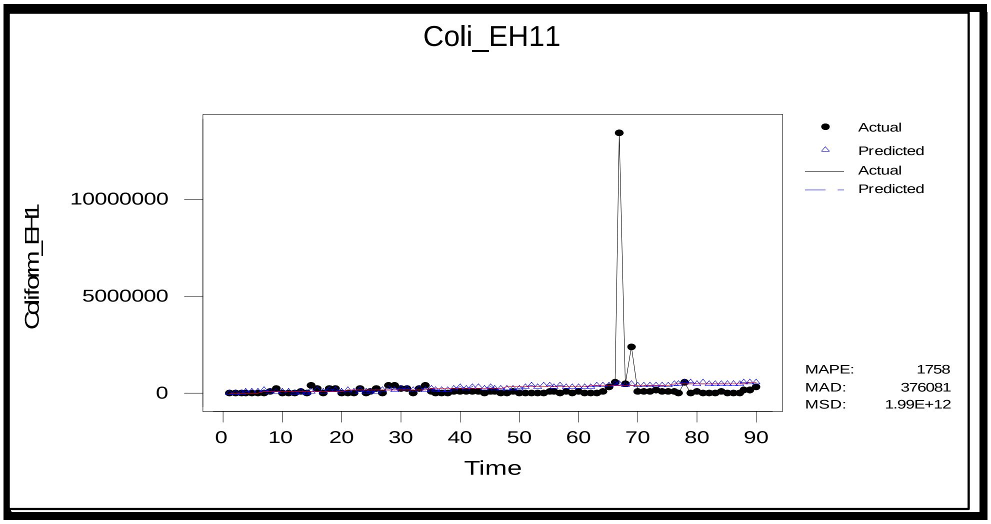
Parameters	Kolmogorov-Smirnov		
	Statistic	df	Sig.
Ca (meq/l)	0.141	90	0.000
Mg (meq/l)	0.146	90	0.000
Na (meq/l)	0.092	90	0.060
K (meq/l)	0.216	90	0.000
SO_4 (meq/l)	0.148	90	0.000
Cl (meq/l)	0.096	90	0.040
SAR	0.099	90	0.030
Adj_SAR	0.114	90	0.006
Temp (C^o)	0.071	90	0.200
Sal	0.091	90	0.063
DO (mg/l)	0.08217	90	0.180
Turb (NTU)	0.13581	66	0.004
Visib (Cm)	0.13526	90	0.000
Fecal (MPN/100 ml)	0.32289	54	1.4291E-15
TP (mg/l)	0.13772	54	0.012
TN (mg/l)	0.12813	54	0.027
Ni (mg/l)	0.20457	54	6.12003E-06
SO_{4_m} (meq/l)	0.12291	49	0.062

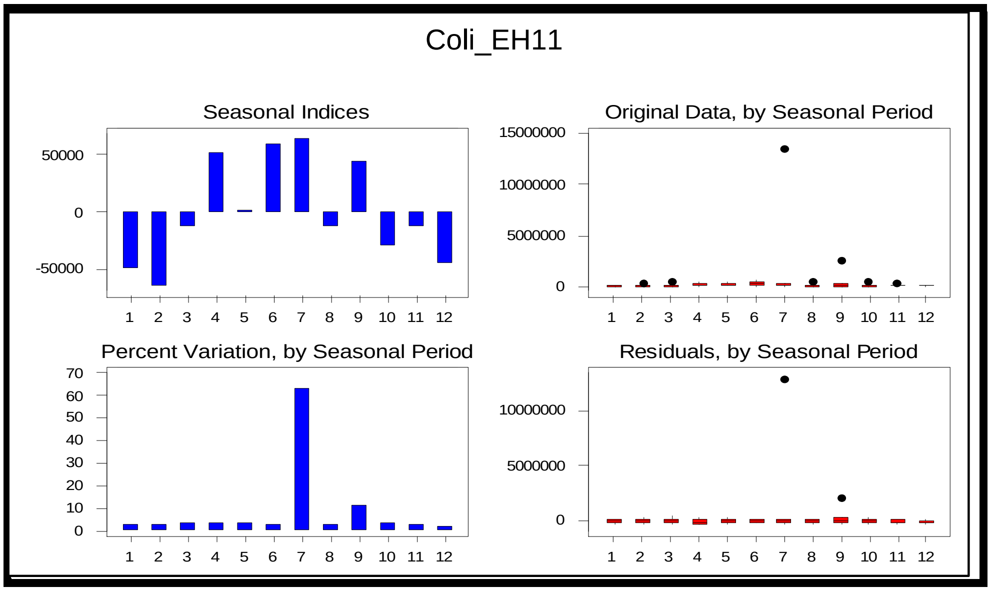
Test Significance: the data follows normal distribution if the significance is greater than or equal 0.05.

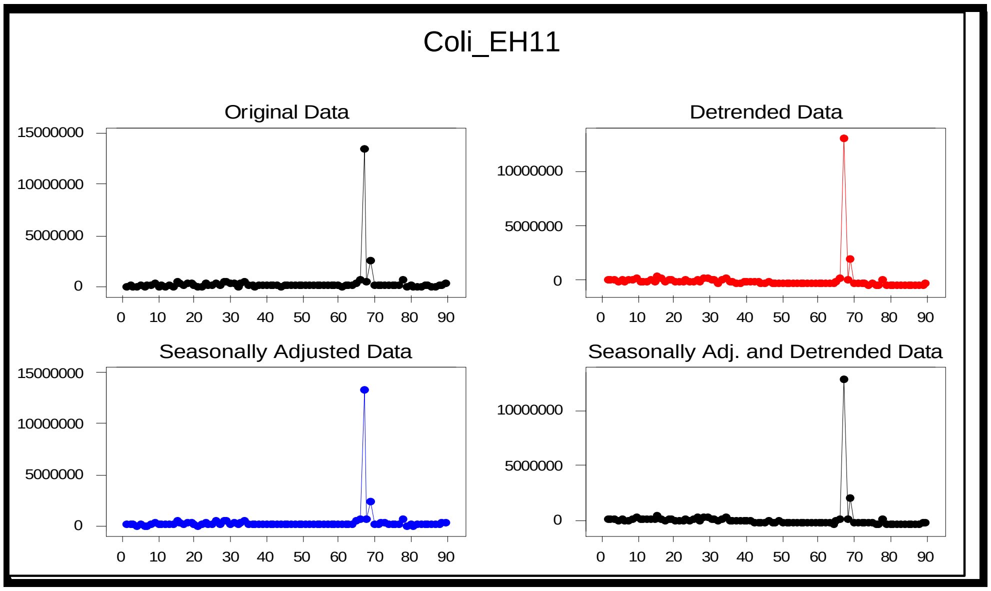
ANNEX 6-2

TIMESERIES DECOMPOSITION FOR THE WQPs MEASURED AT THE MONITORING SITE EH11

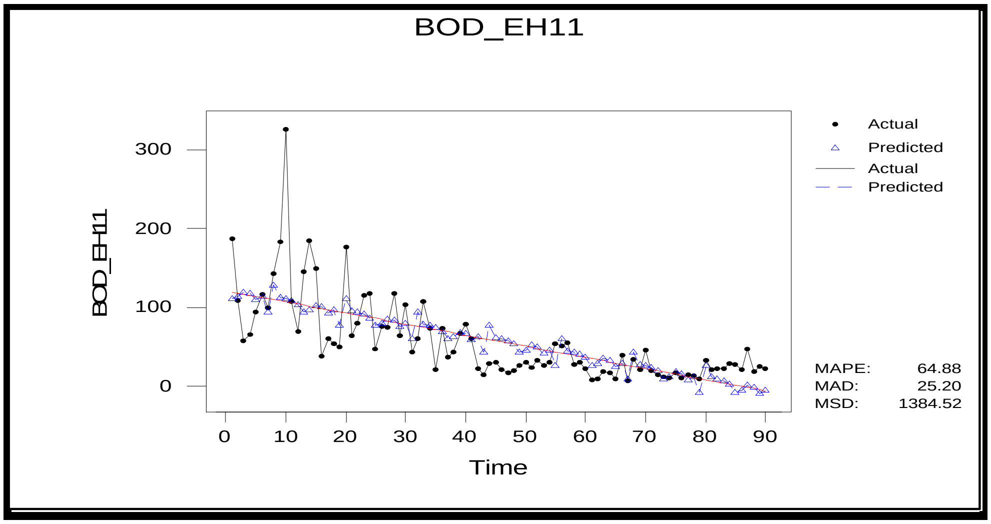
Annex 6-2A1: Timeseries decomposition for Coli (MPN/100ml) measured at the monitoring site EH11

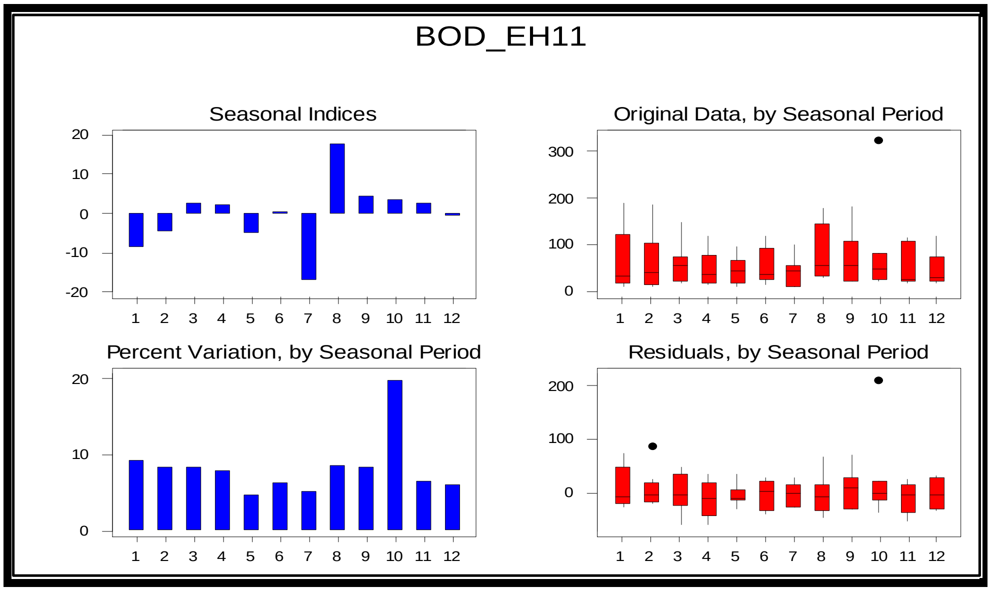


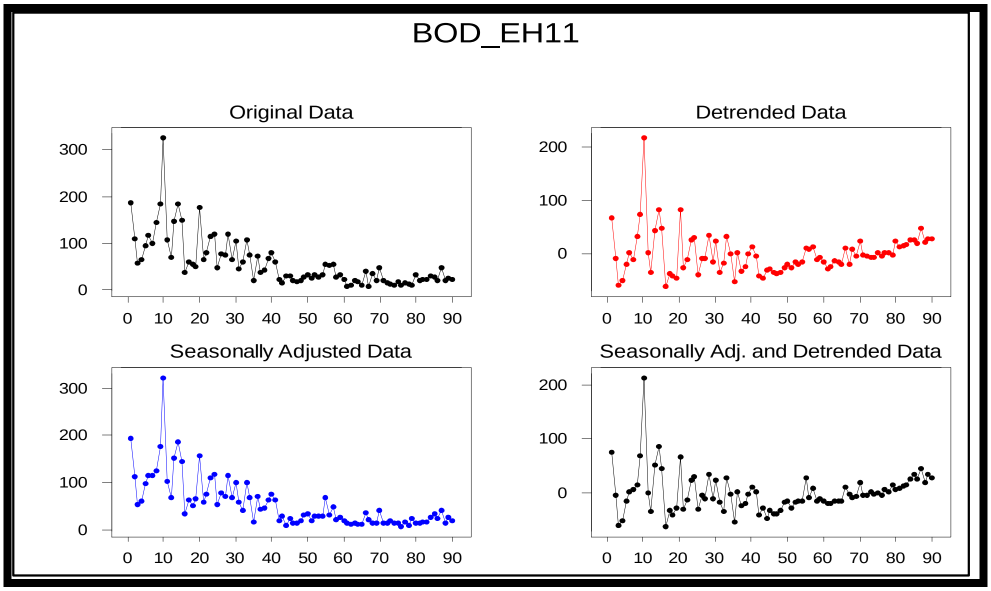




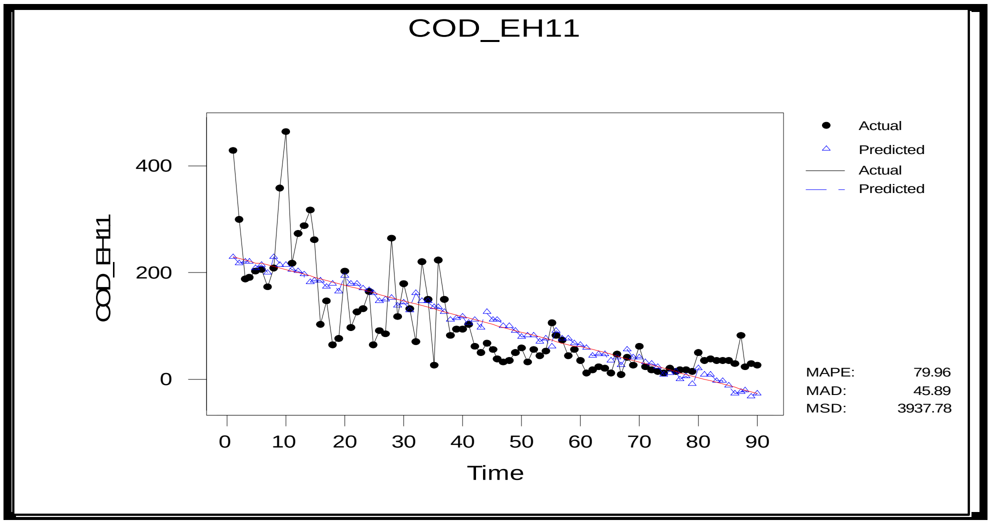
Annex 6-2A2: Timeseries decomposition for BOD (mg/l)) measured at the monitoring site EH11

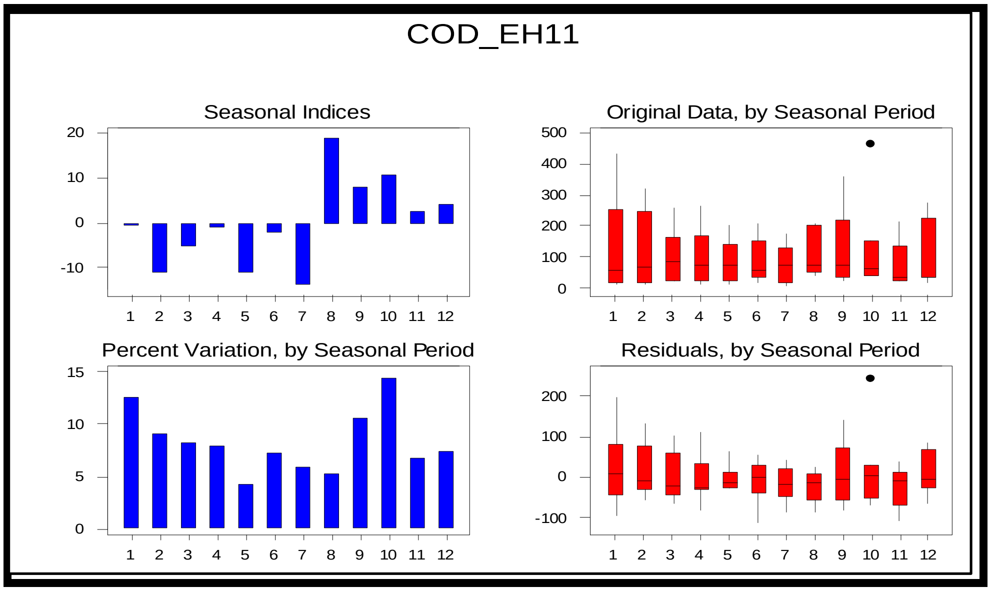


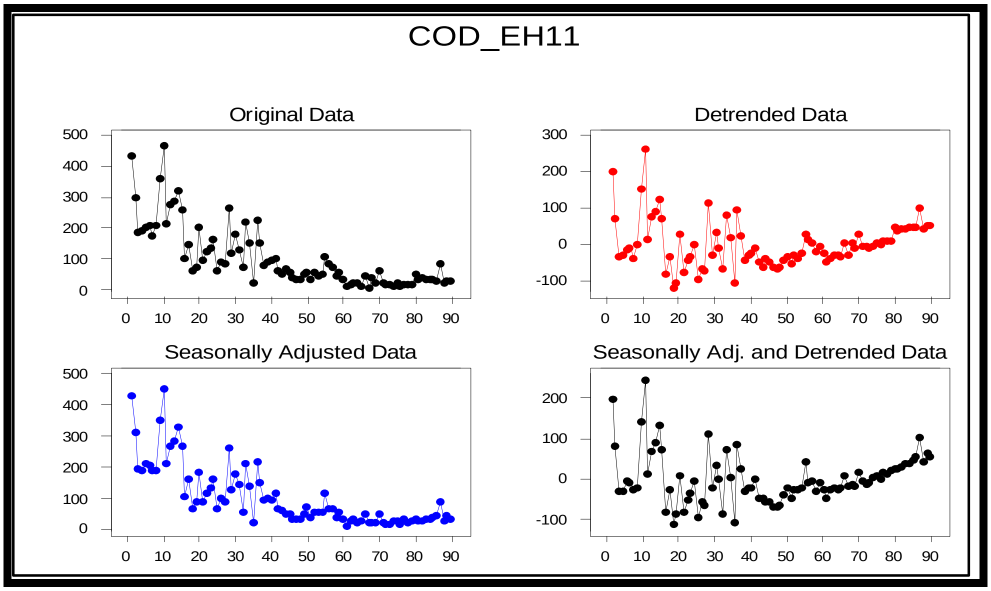




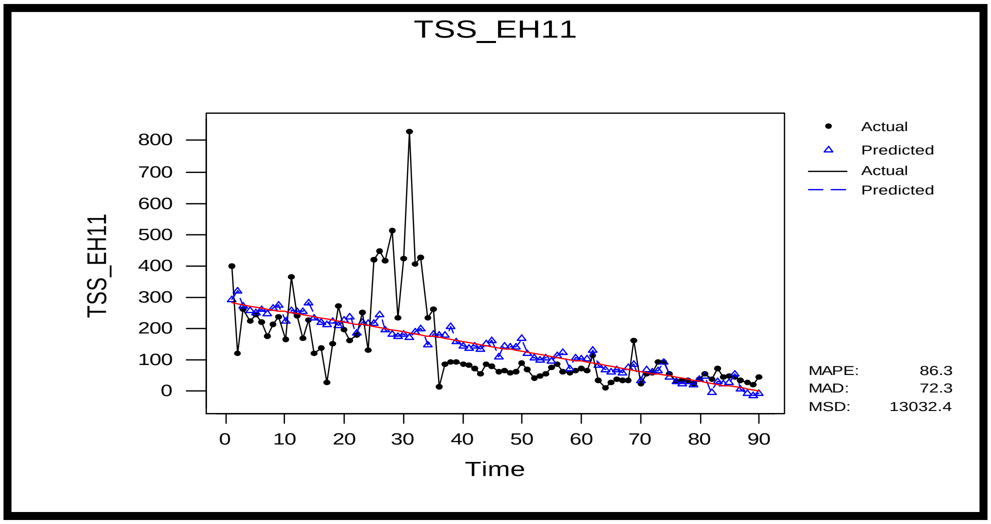
Annex 6-2A3: Timeseries decomposition for COD (mg/l) measured at the monitoring site EH11

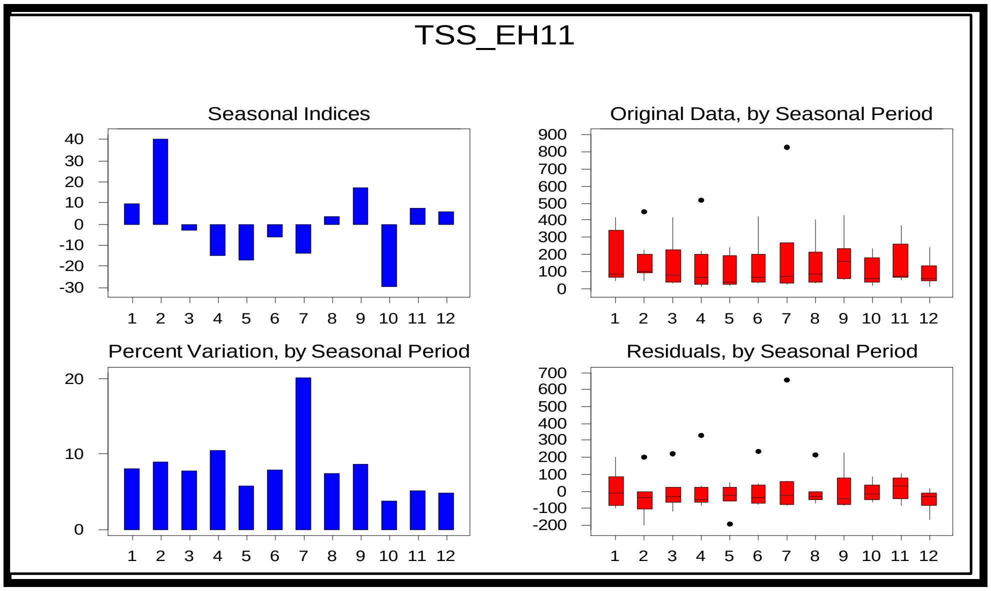


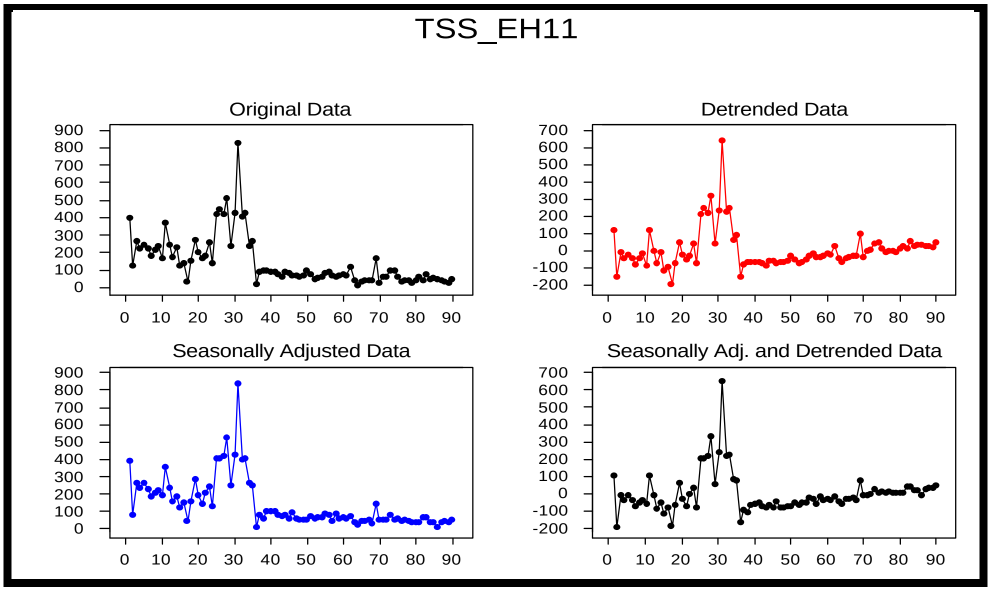




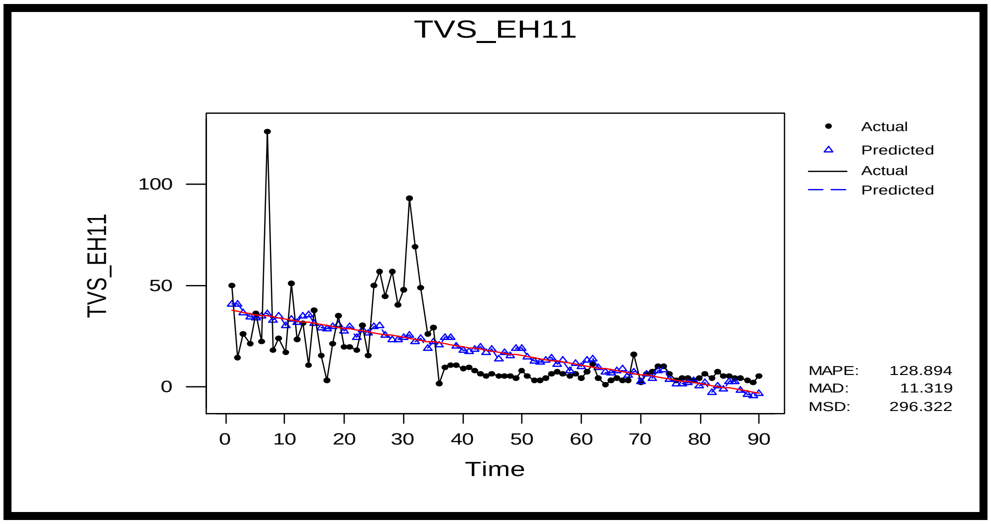
Annex 6-2A4: Timeseries decomposition for TSS (mg/l) measured at the monitoring site EH11

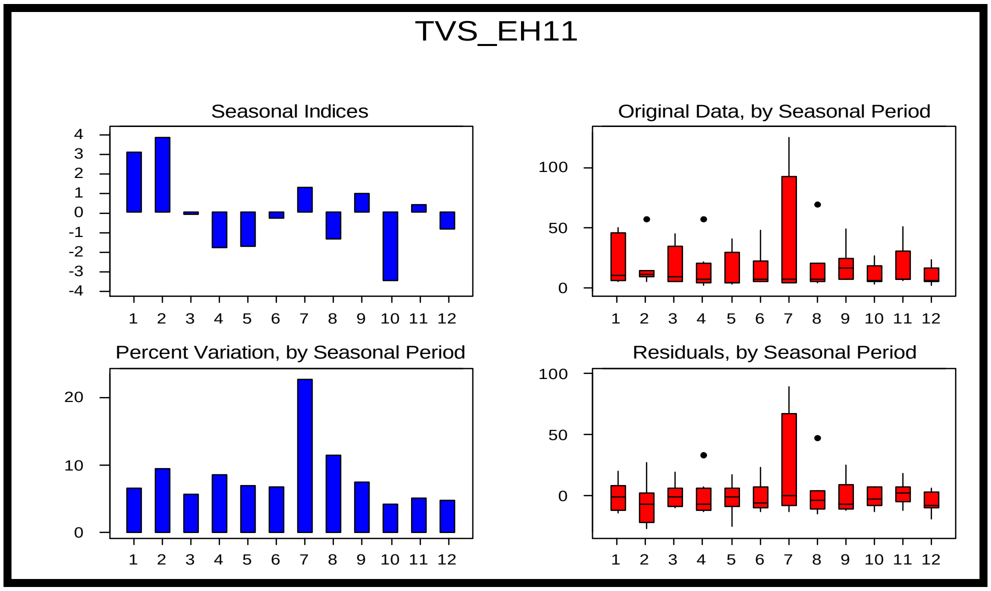


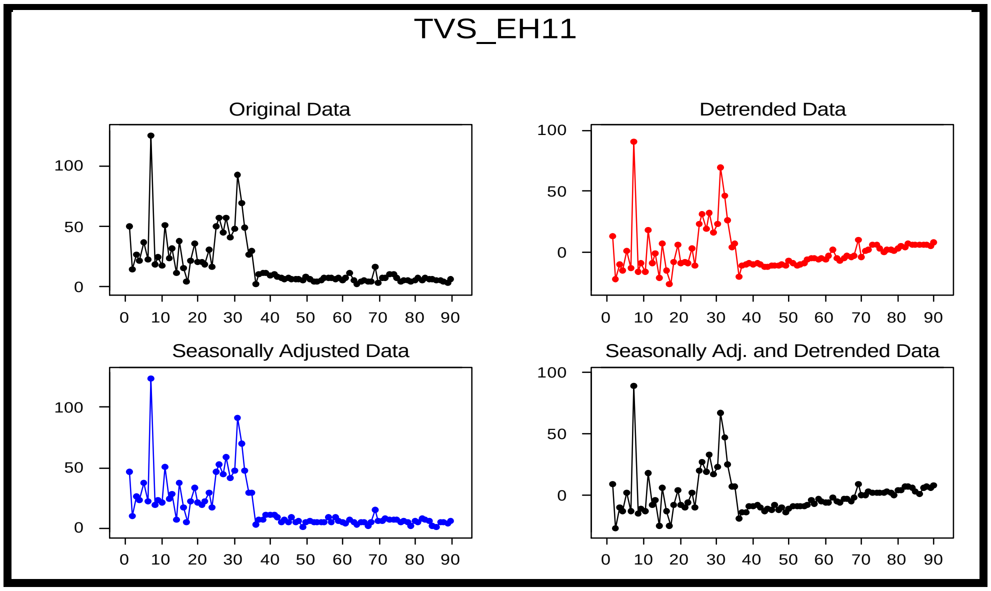




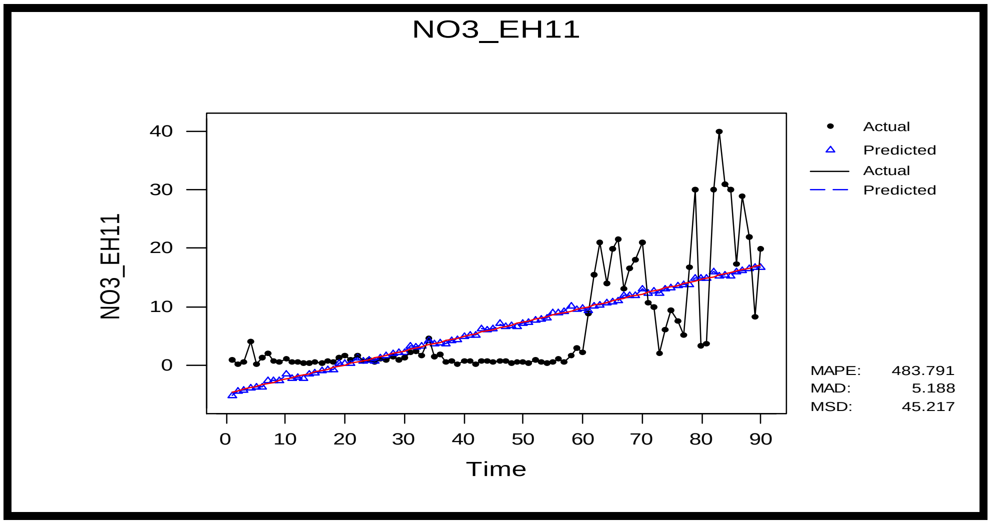
Annex 6-2A5: Timeseries decomposition for TVS (mg/l) measured at the monitoring site EH11

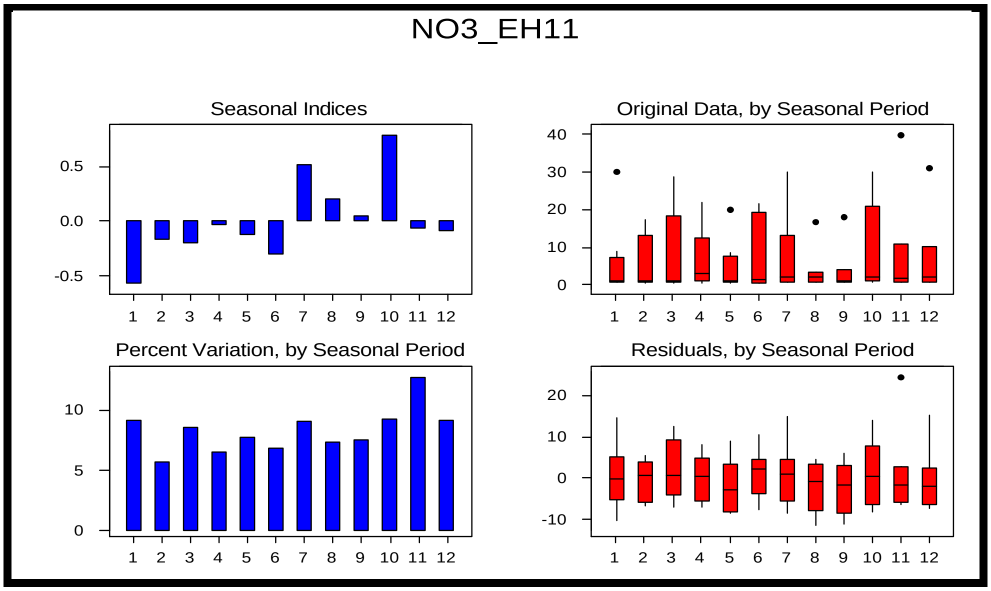


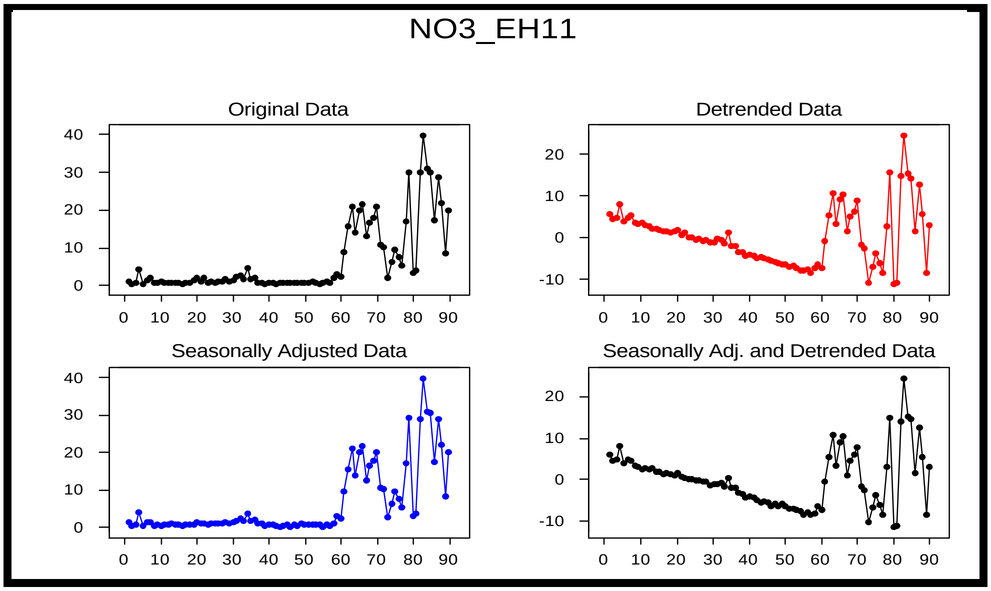




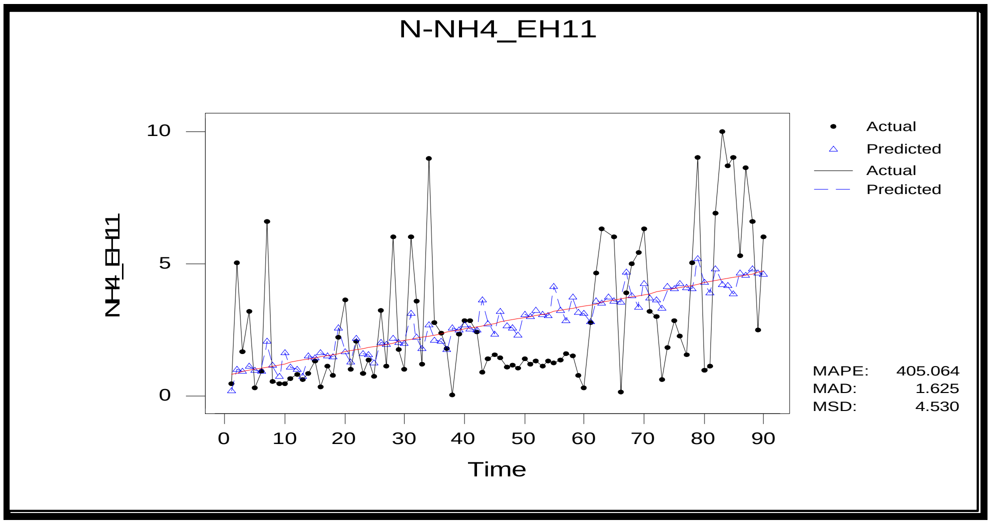
Annex 6-2A6: Timeseries decomposition for NO3 (mg/l) measured at the monitoring site EH11

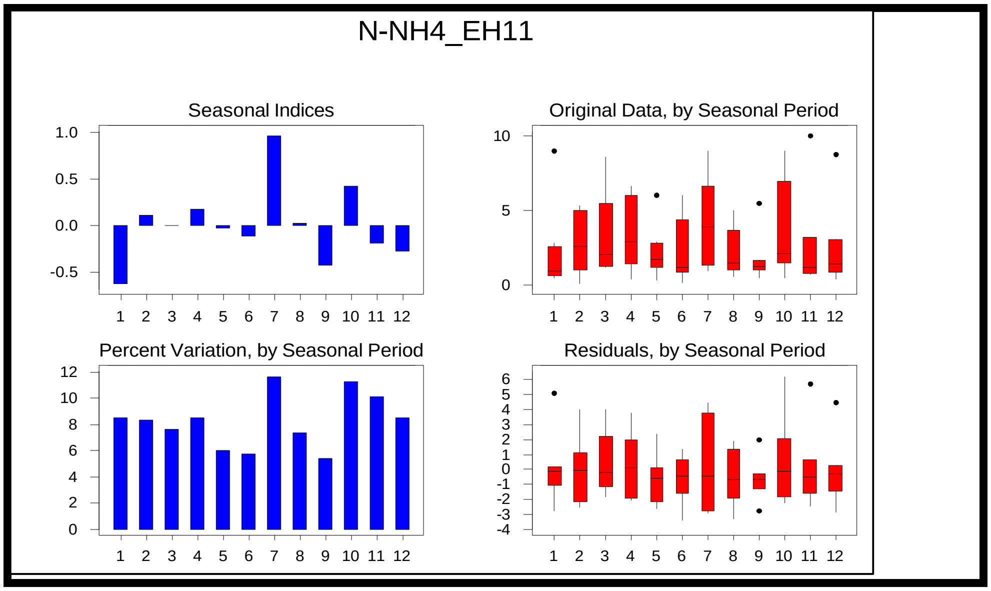


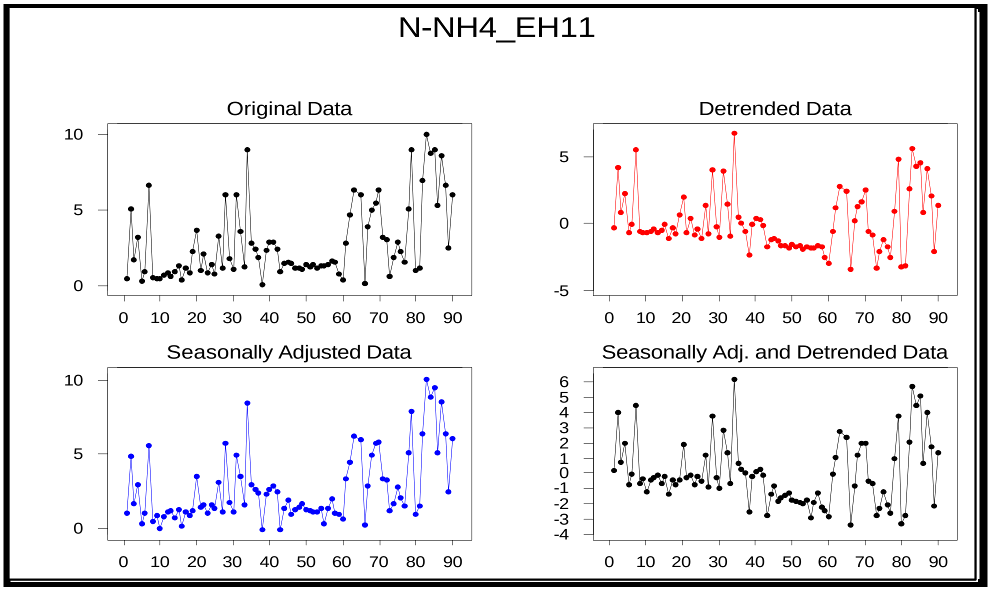




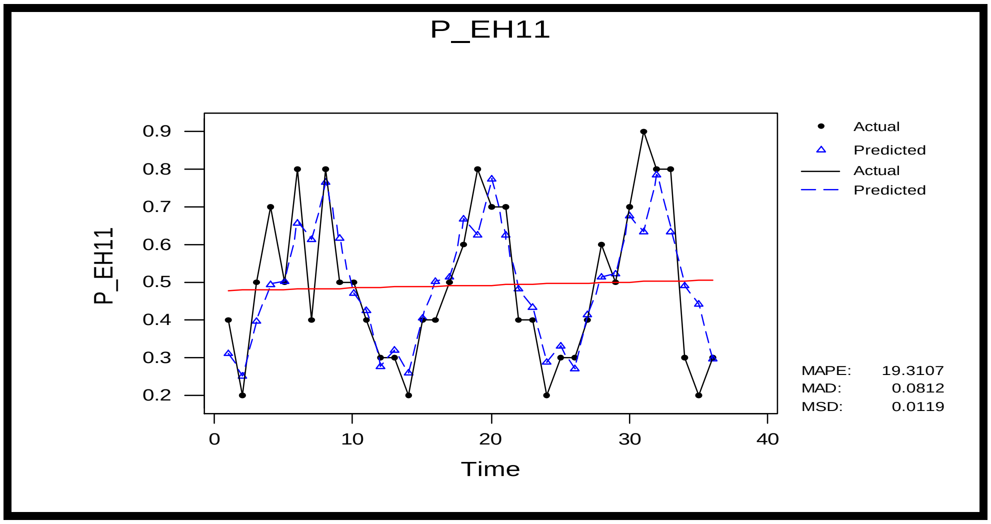
Annex 6-2A7: Timeseries decomposition for NH4 (mg/l) measured at the monitoring site EH11

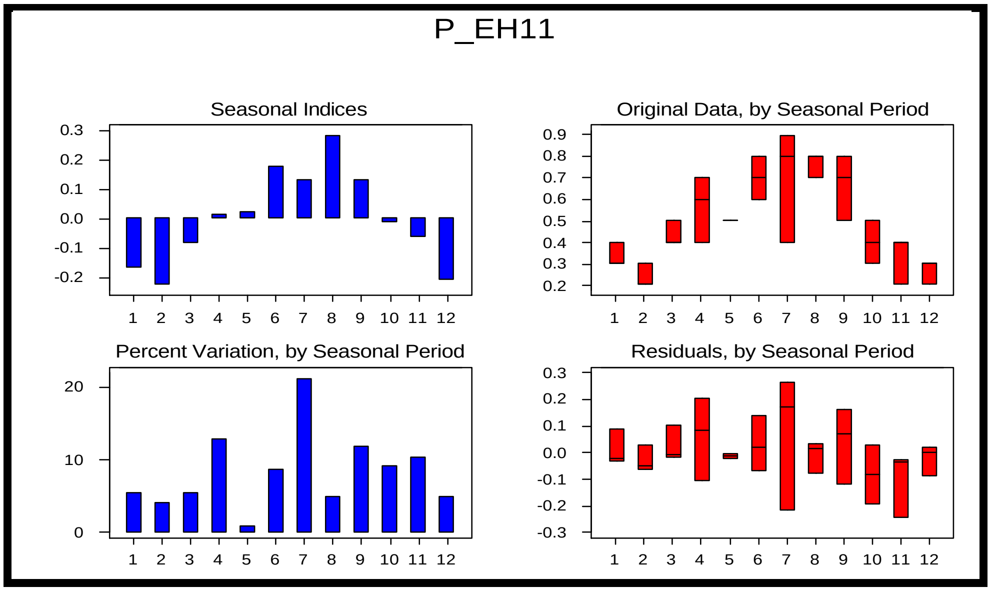


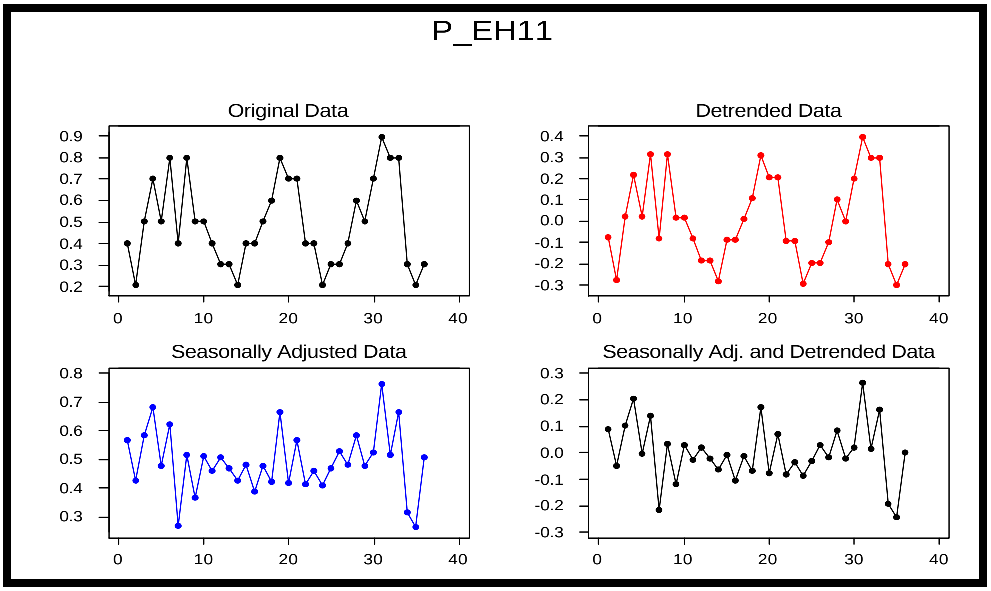




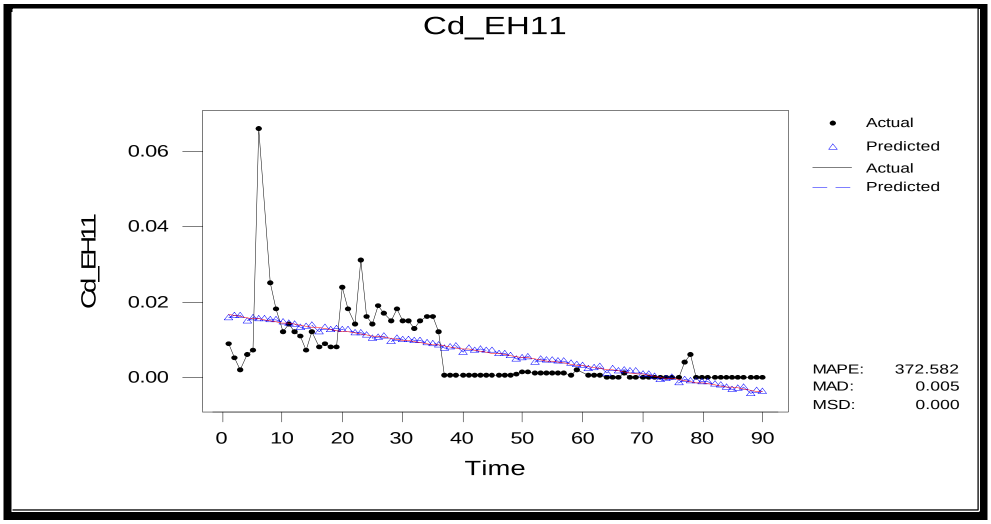
Annex 6-2A8: Timeseries decomposition for P (mg/l) measured at the monitoring site EH11

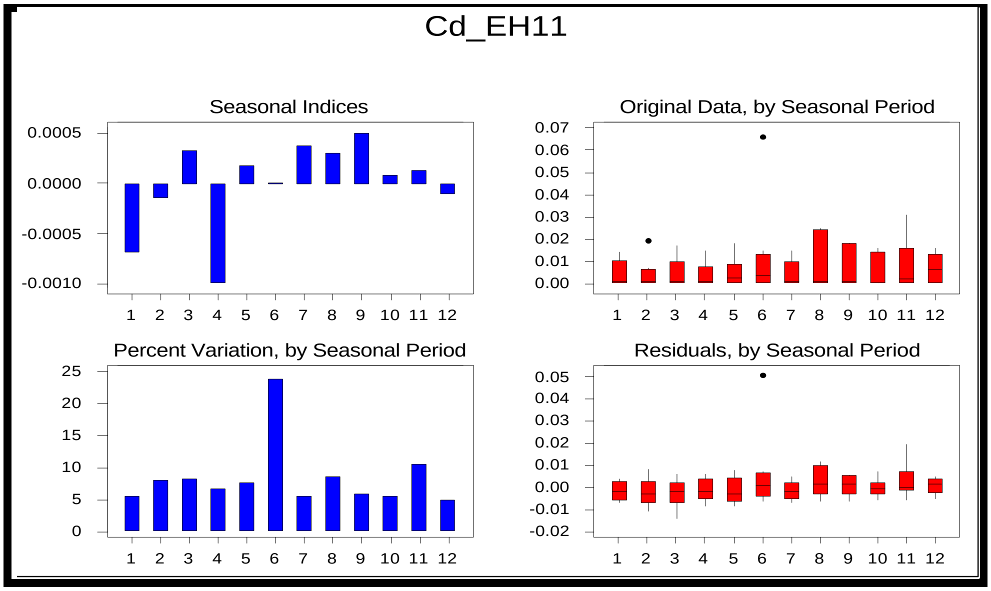


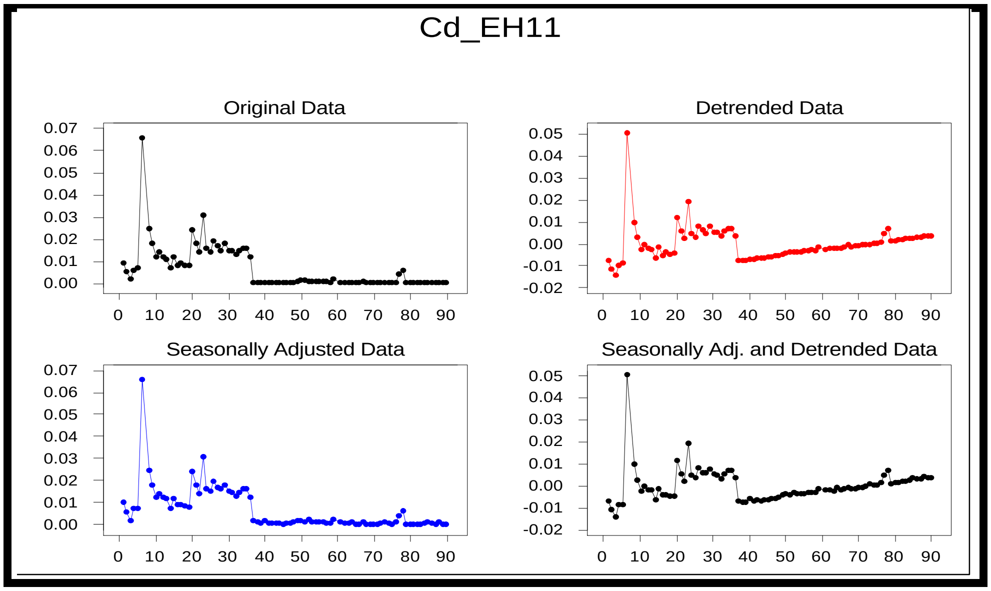




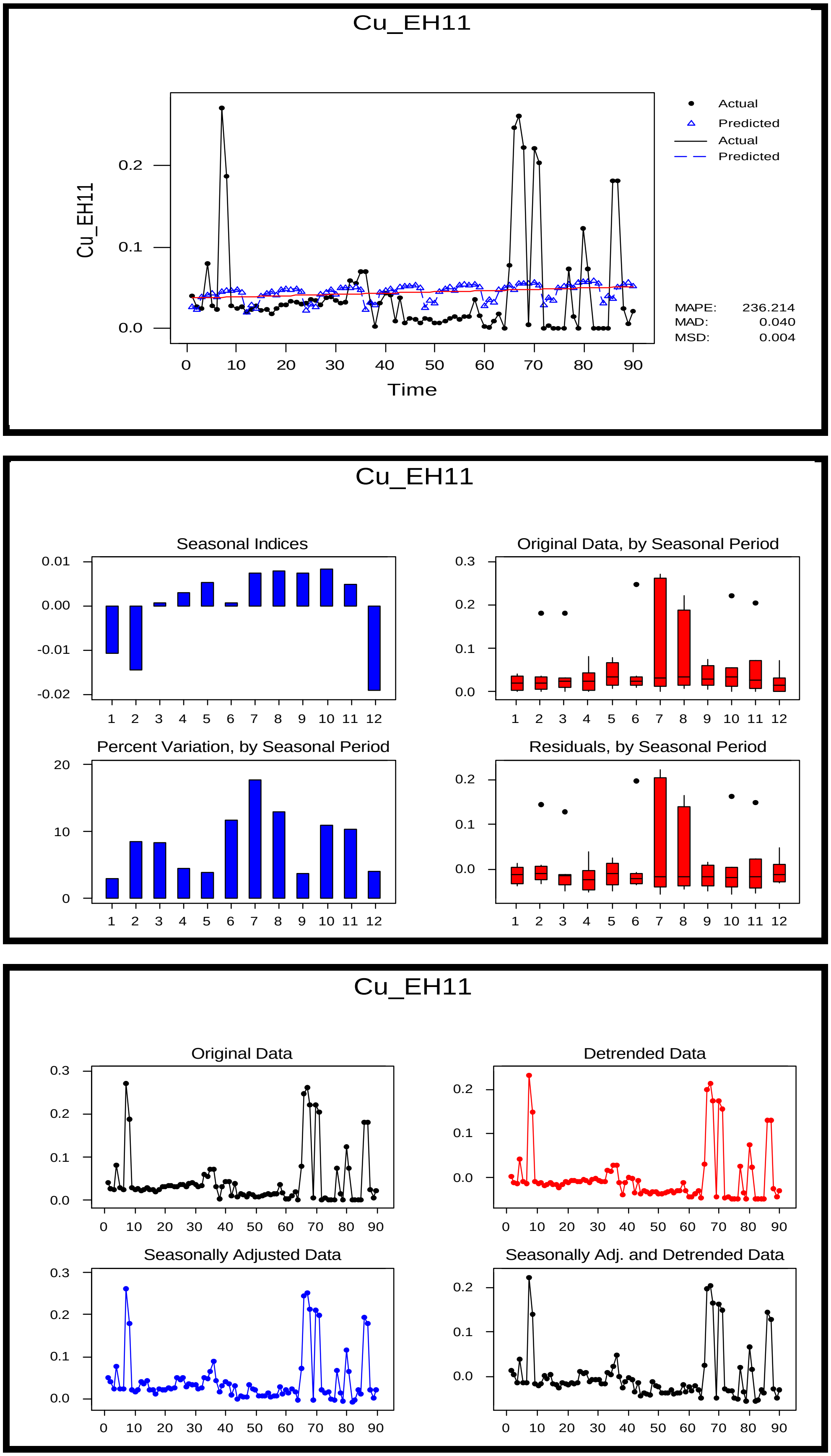
Annex 6-2A9: Timeseries decomposition for Cd (mg/l) measured at the monitoring site EH11



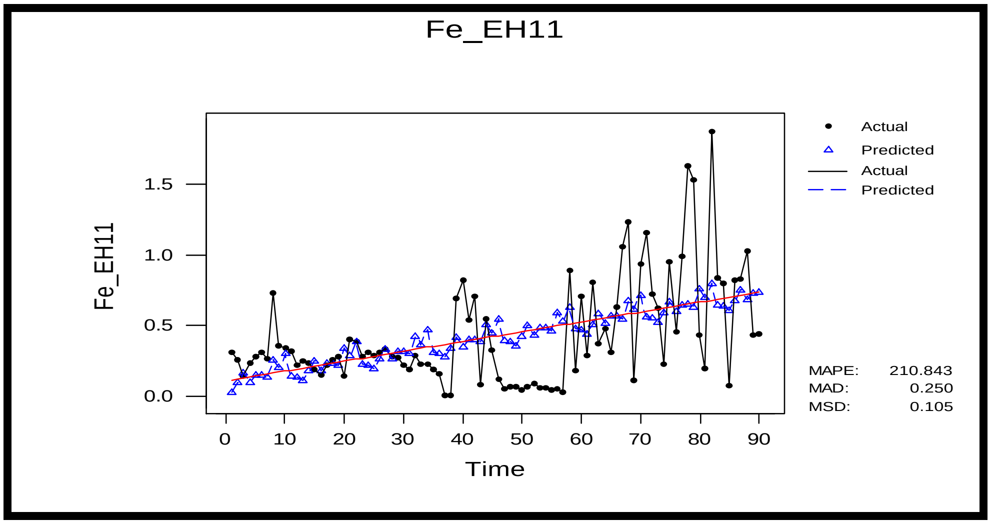


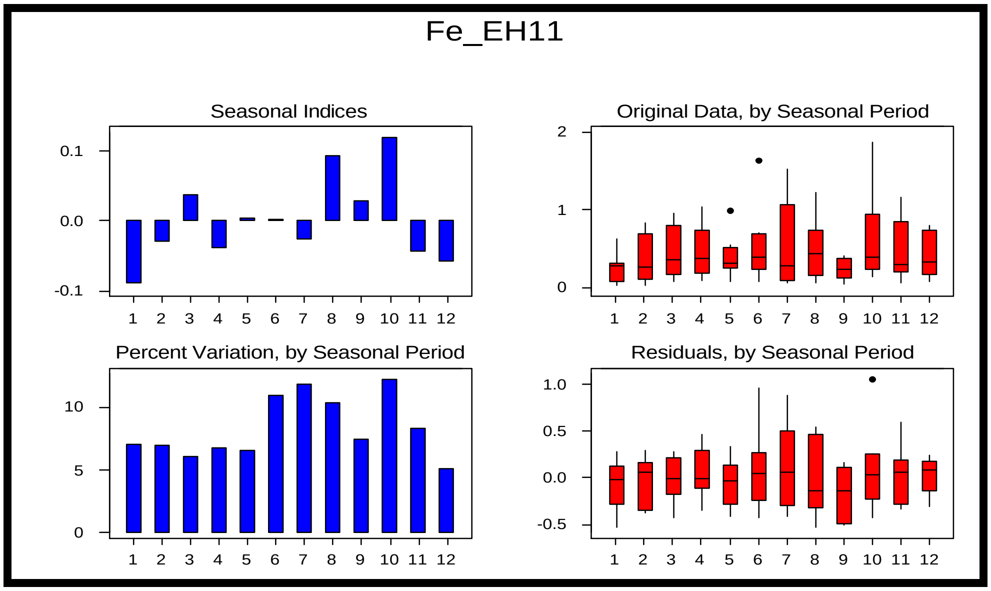


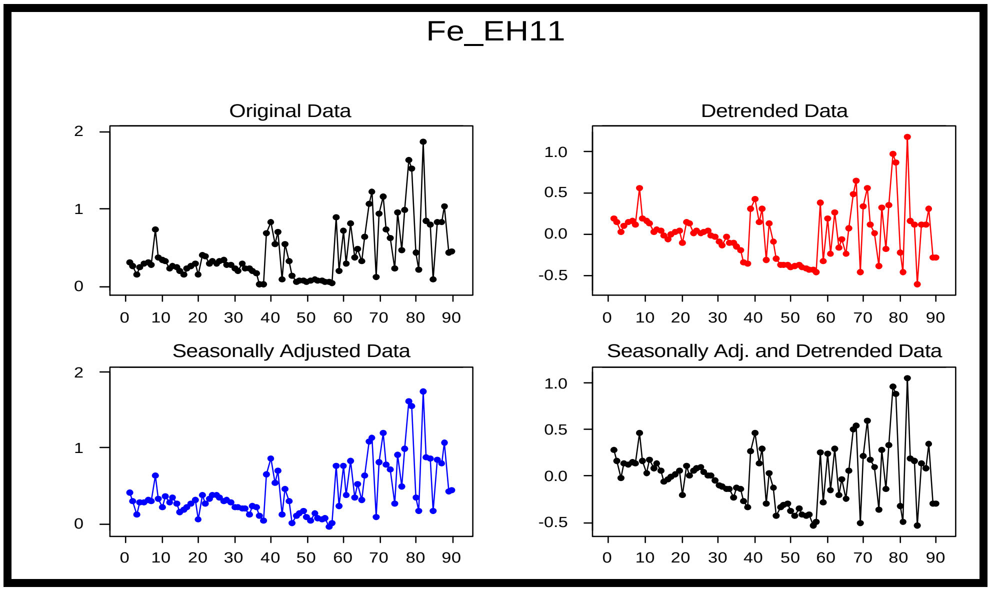
Annex 6-2A10: Timeseries decomposition for Cu (mg/l) measured at the monitoring site EH11



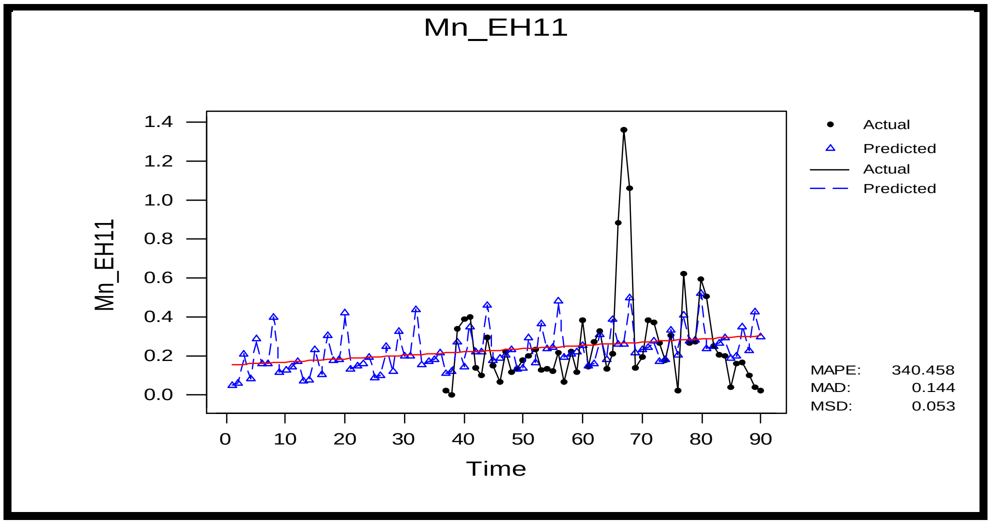
Annex 6-2A11: Timeseries decomposition for Fe (mg/l) measured at the monitoring site EH11

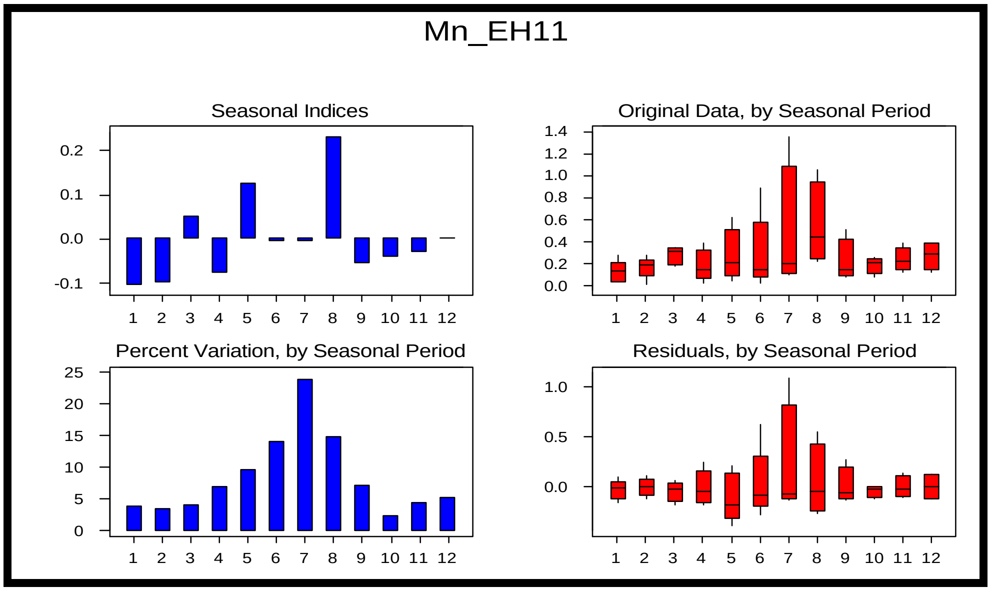


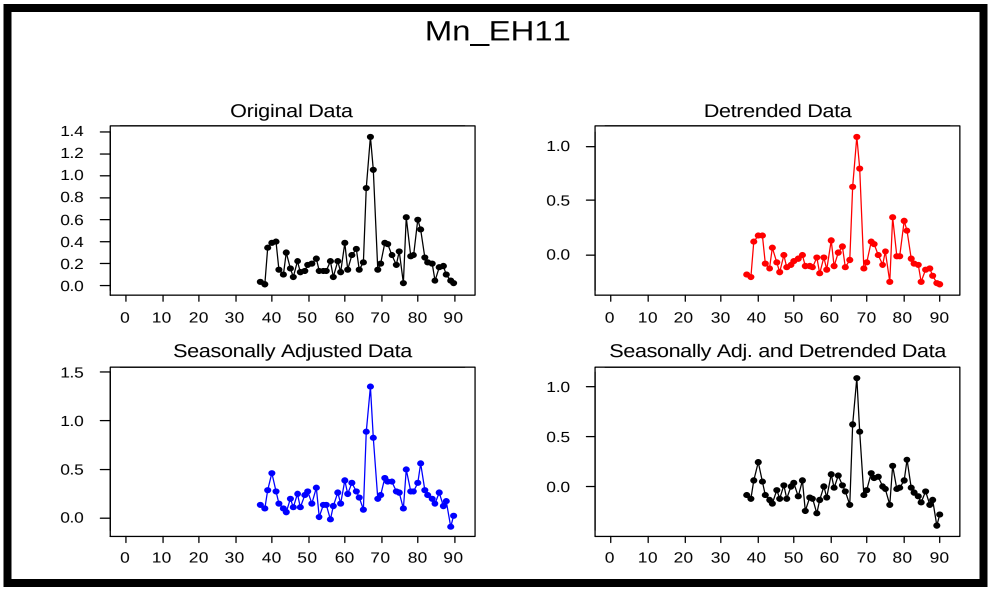




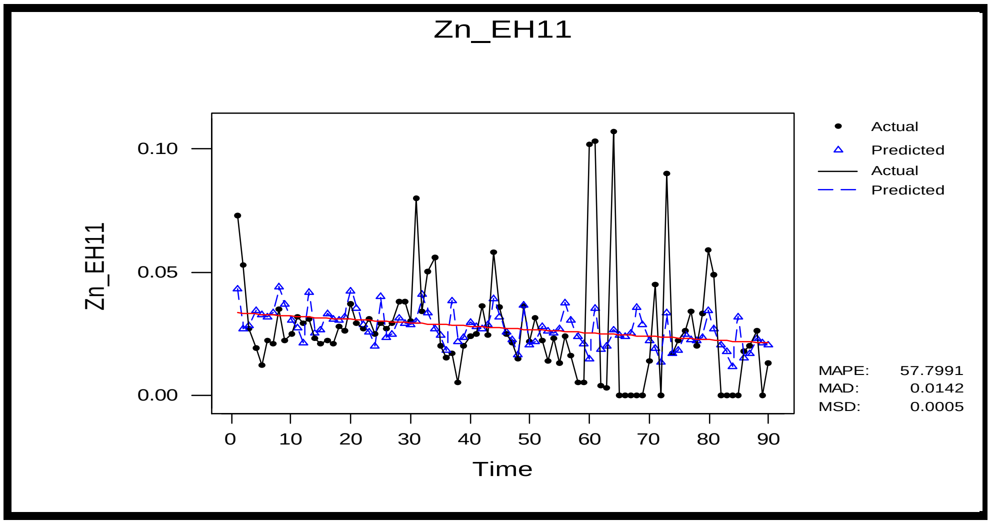
Annex 6-2A12: Timeseries decomposition for Mn (mg/l) measured at the monitoring site EH11

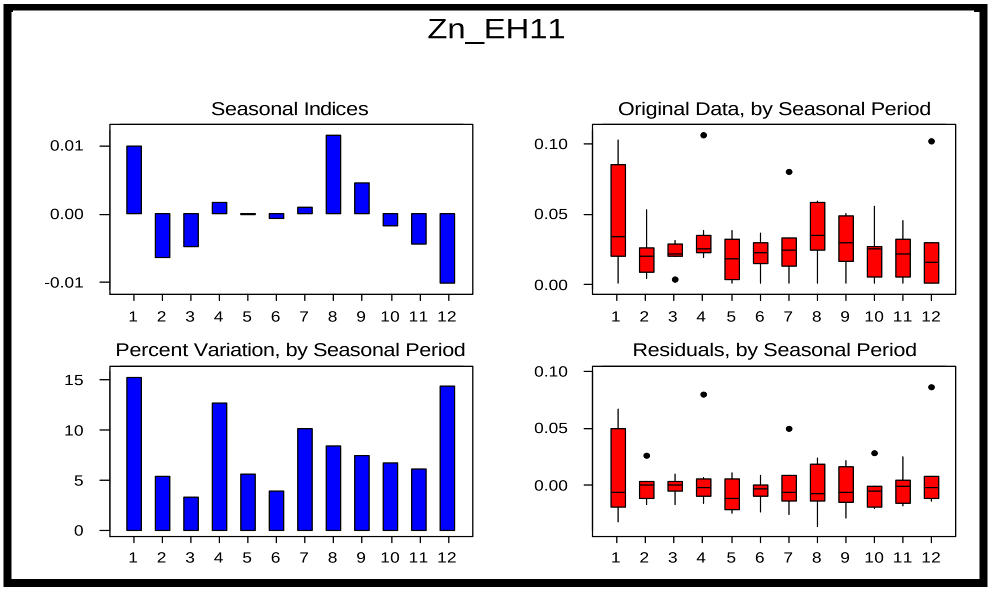


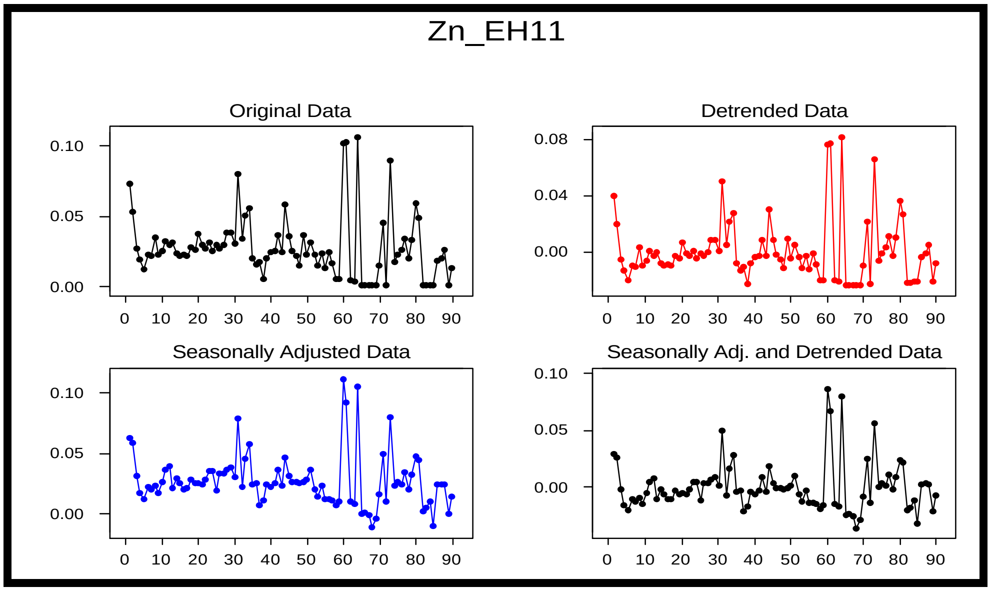




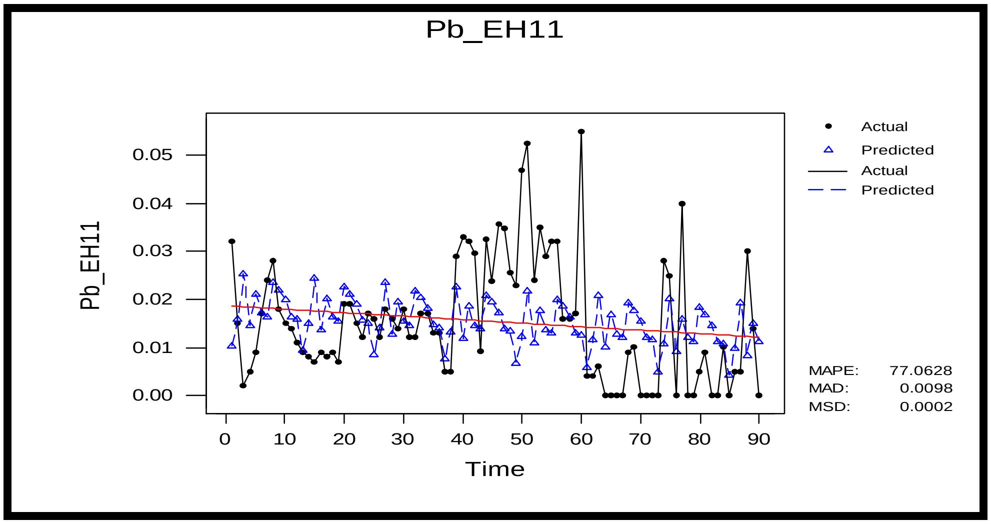
Annex 6-2A13: Timeseries decomposition for Zn (mg/l) measured at the monitoring site EH11

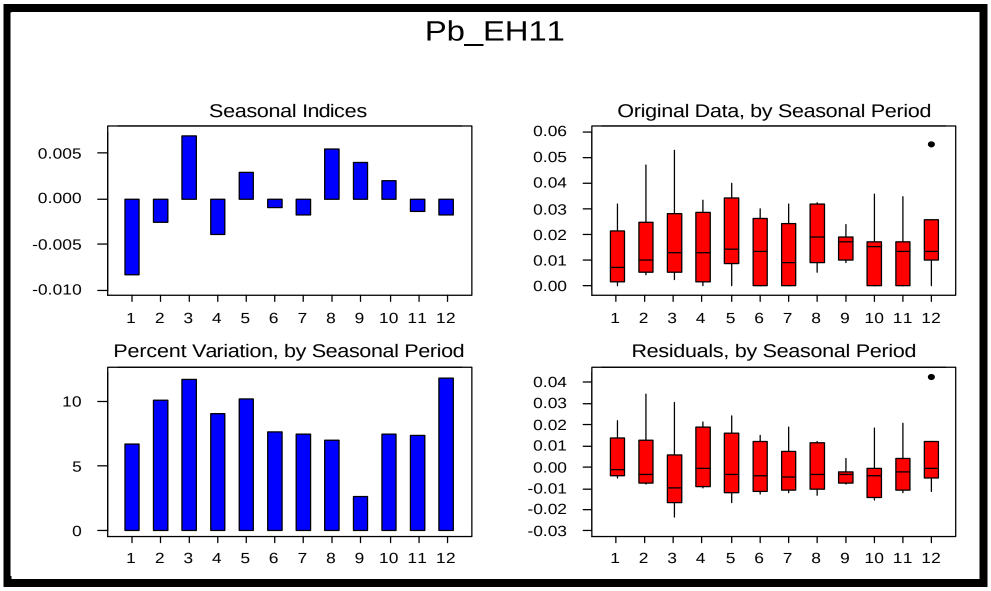


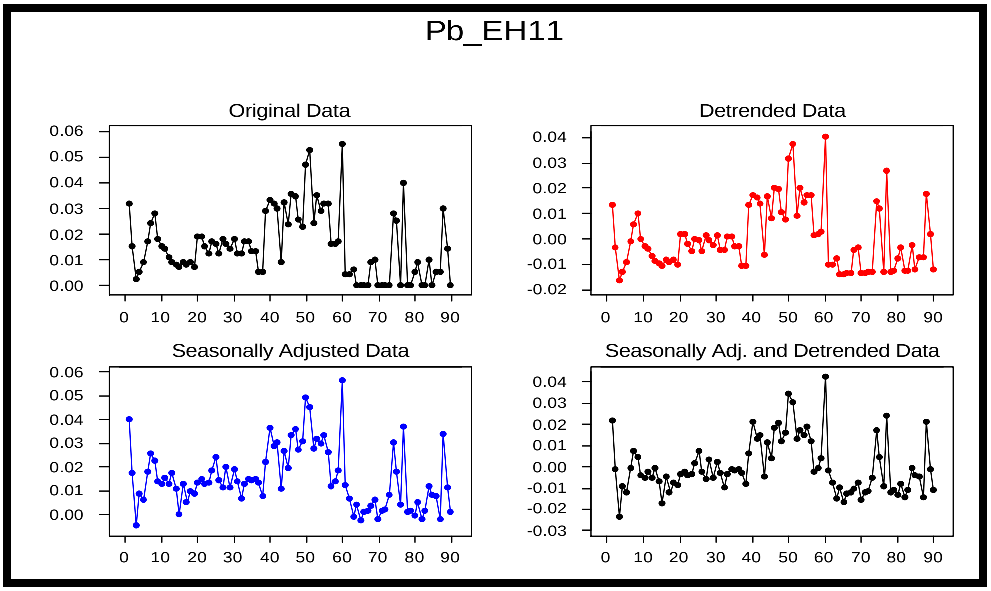




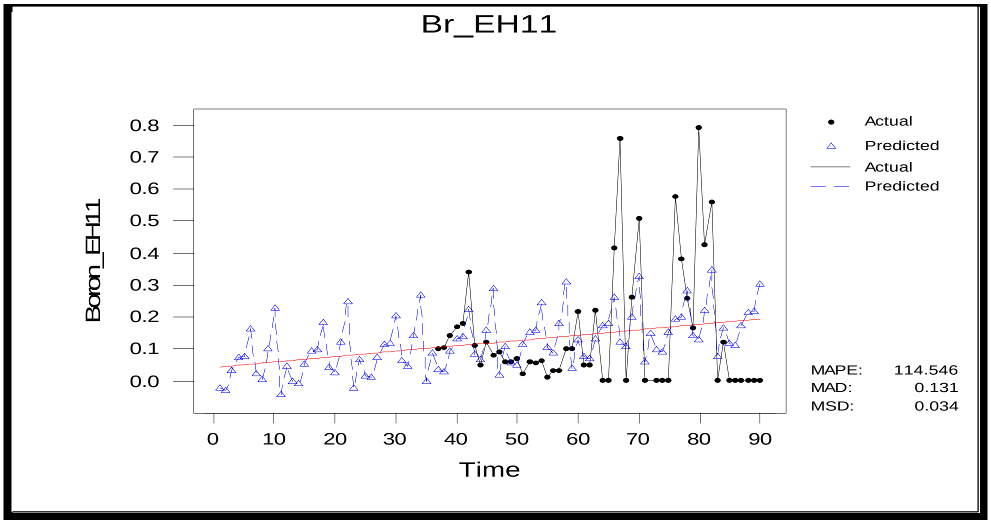
Annex 6-2A14: Timeseries decomposition for Pb (mg/l) measured at the monitoring site EH11

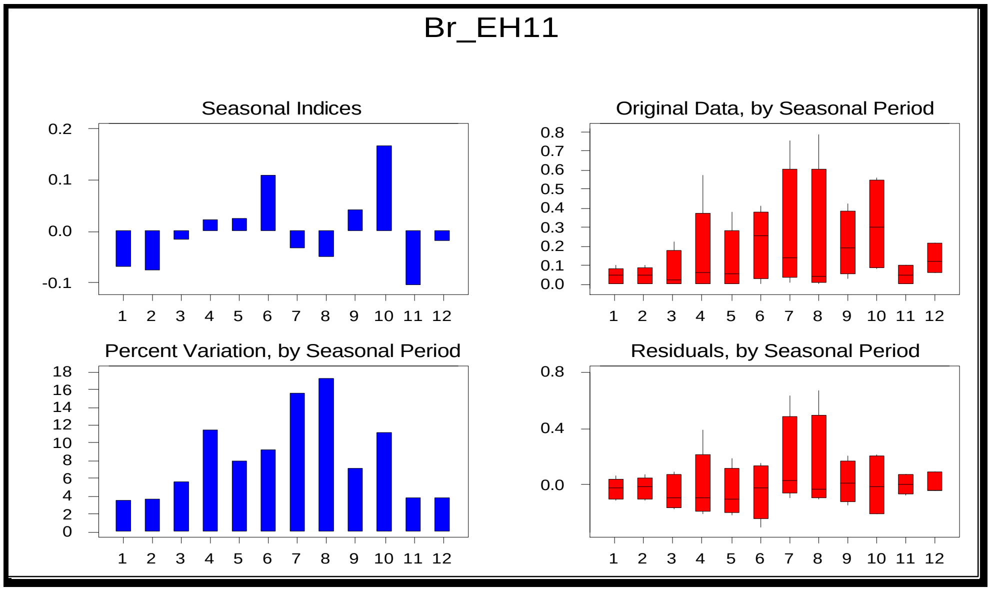


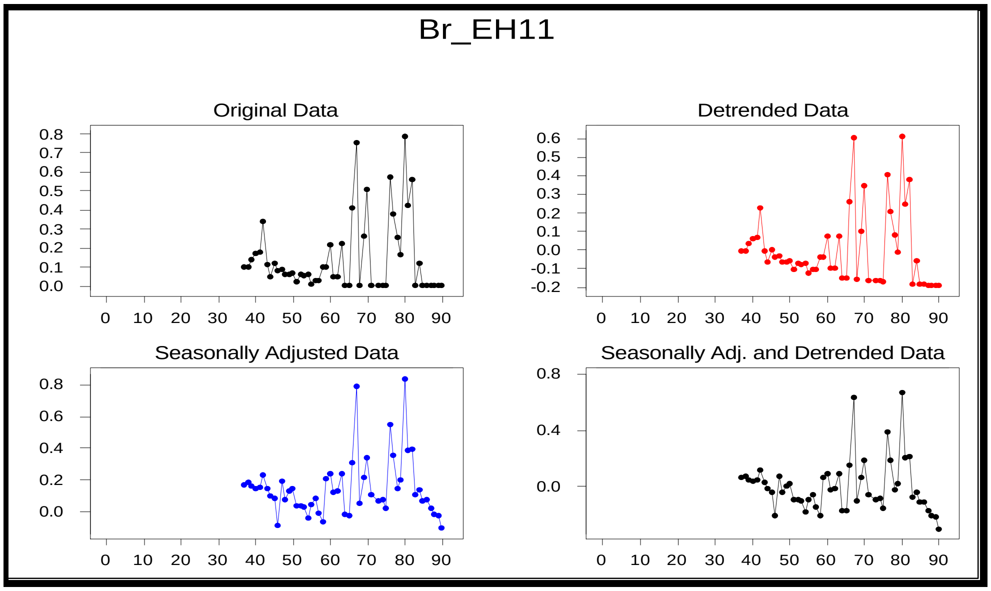




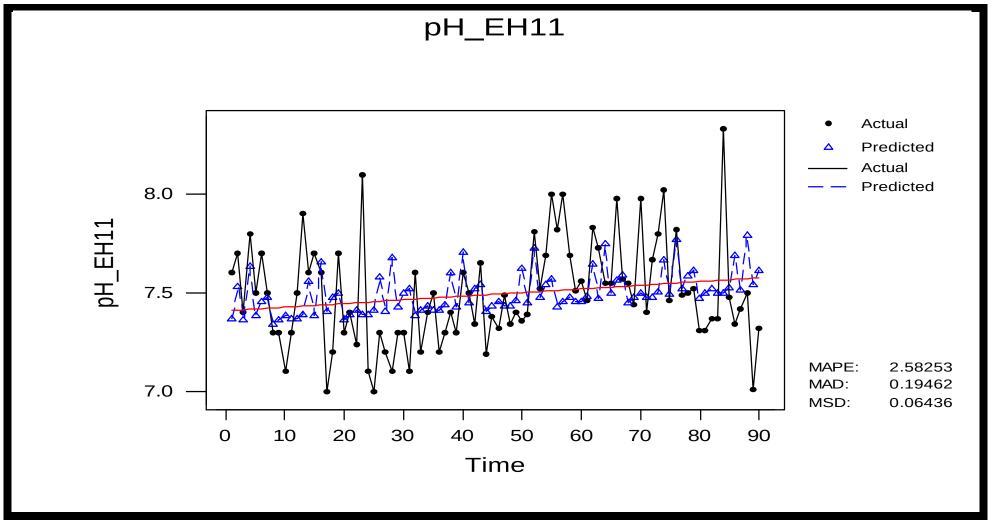
Annex 6-2A15: Timeseries decomposition for Br (mg/l) measured at the monitoring site EH11

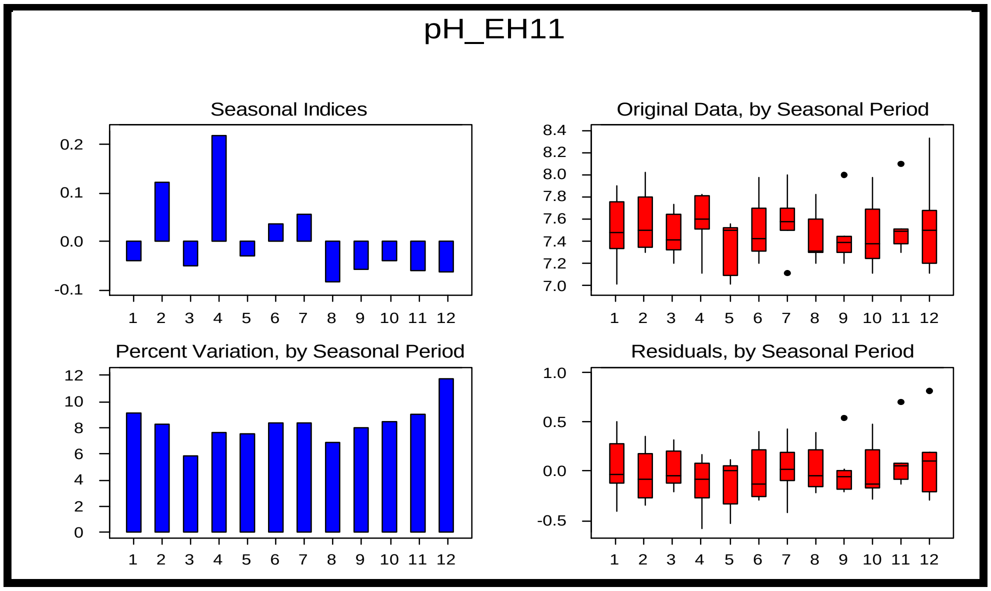


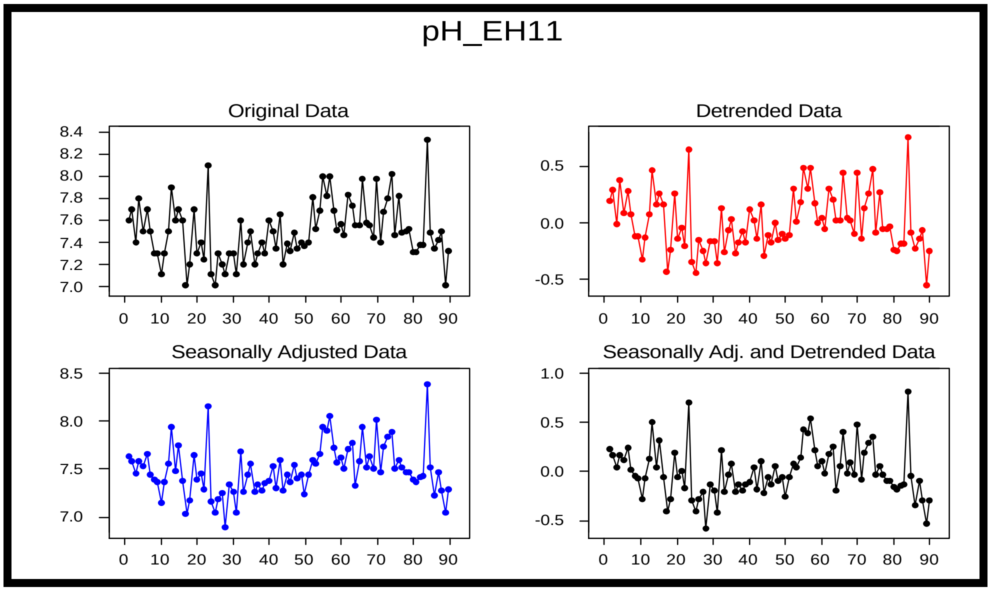




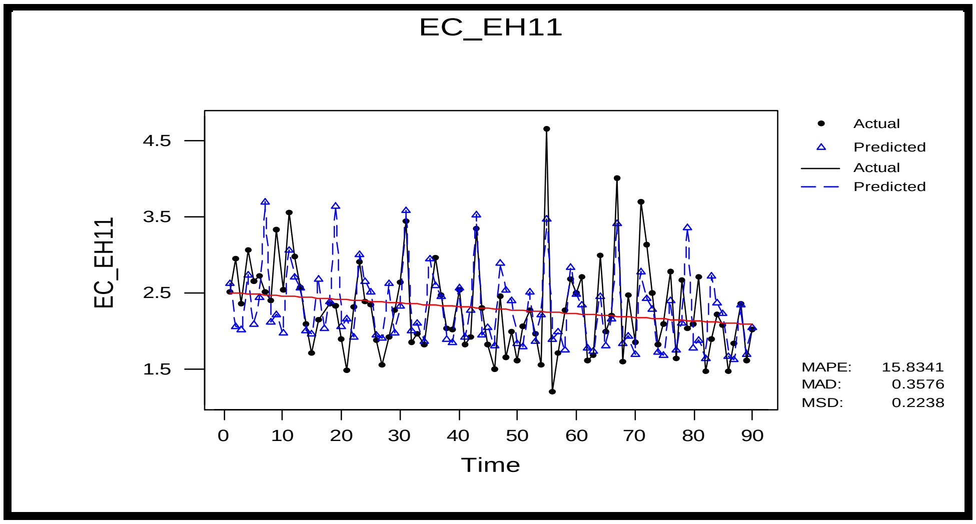
Annex 6-2A16: Timeseries decomposition for pH measured at the monitoring site EH11

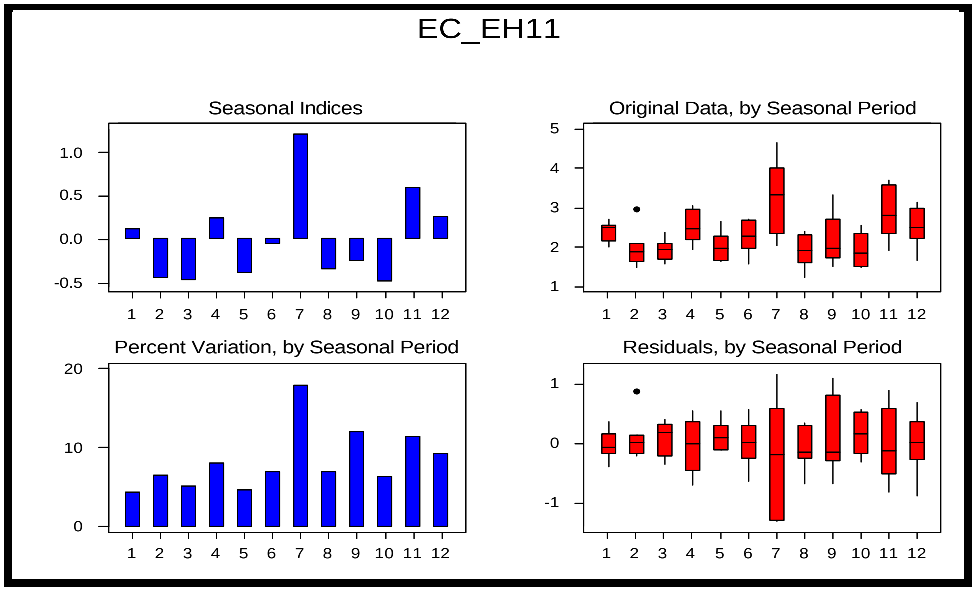


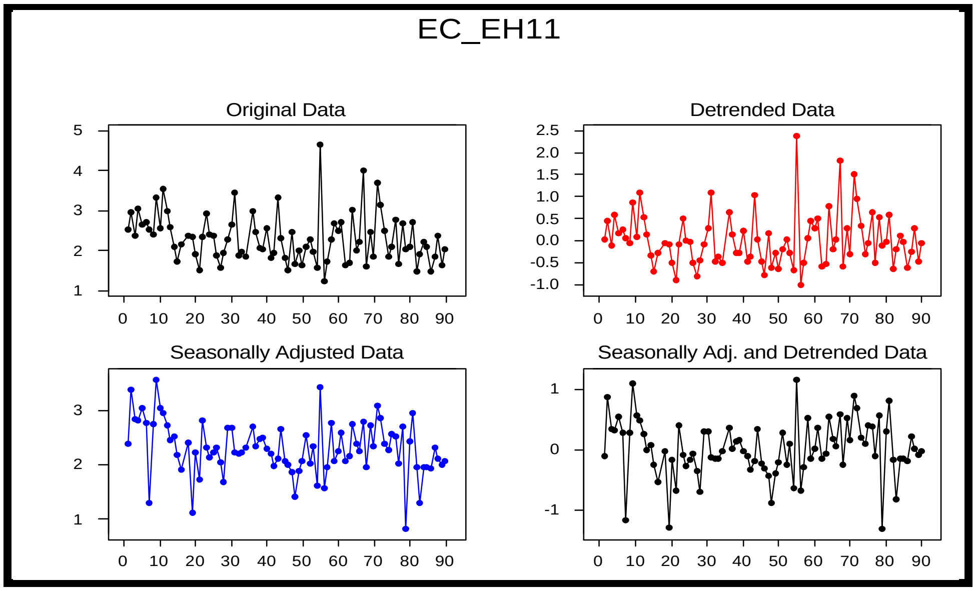




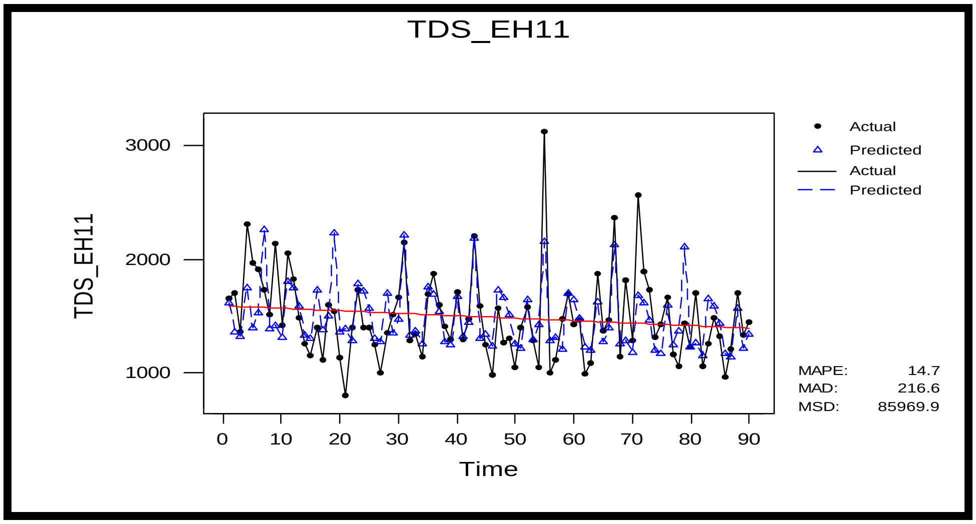
Annex 6-2A17: Timeseries decomposition for EC (dS/m) measured at the monitoring site EH11

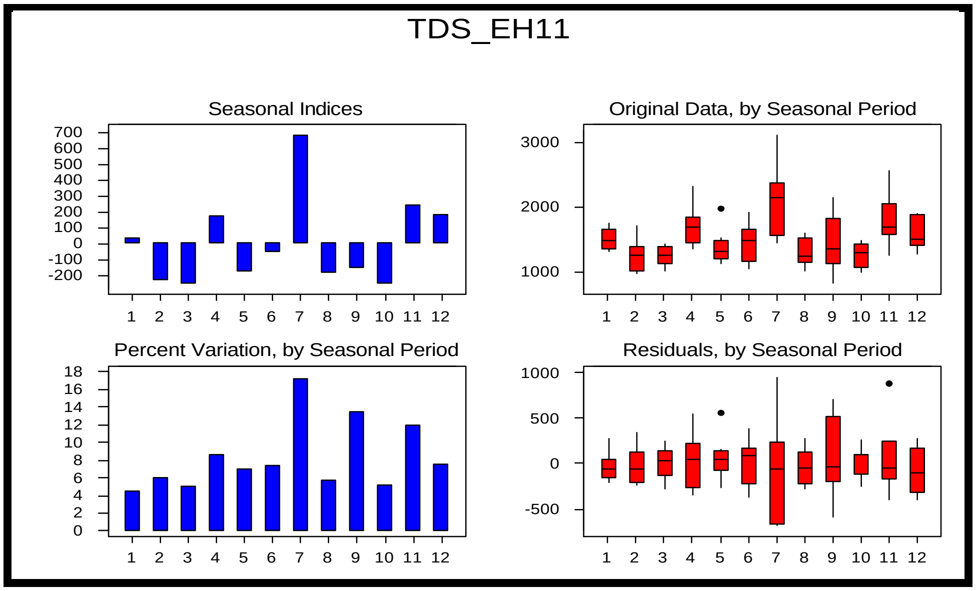


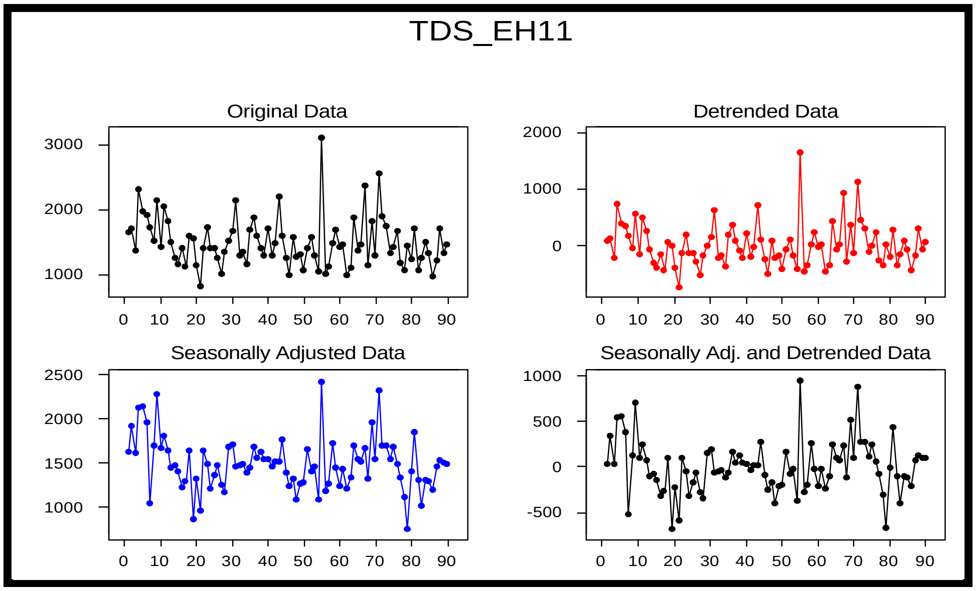




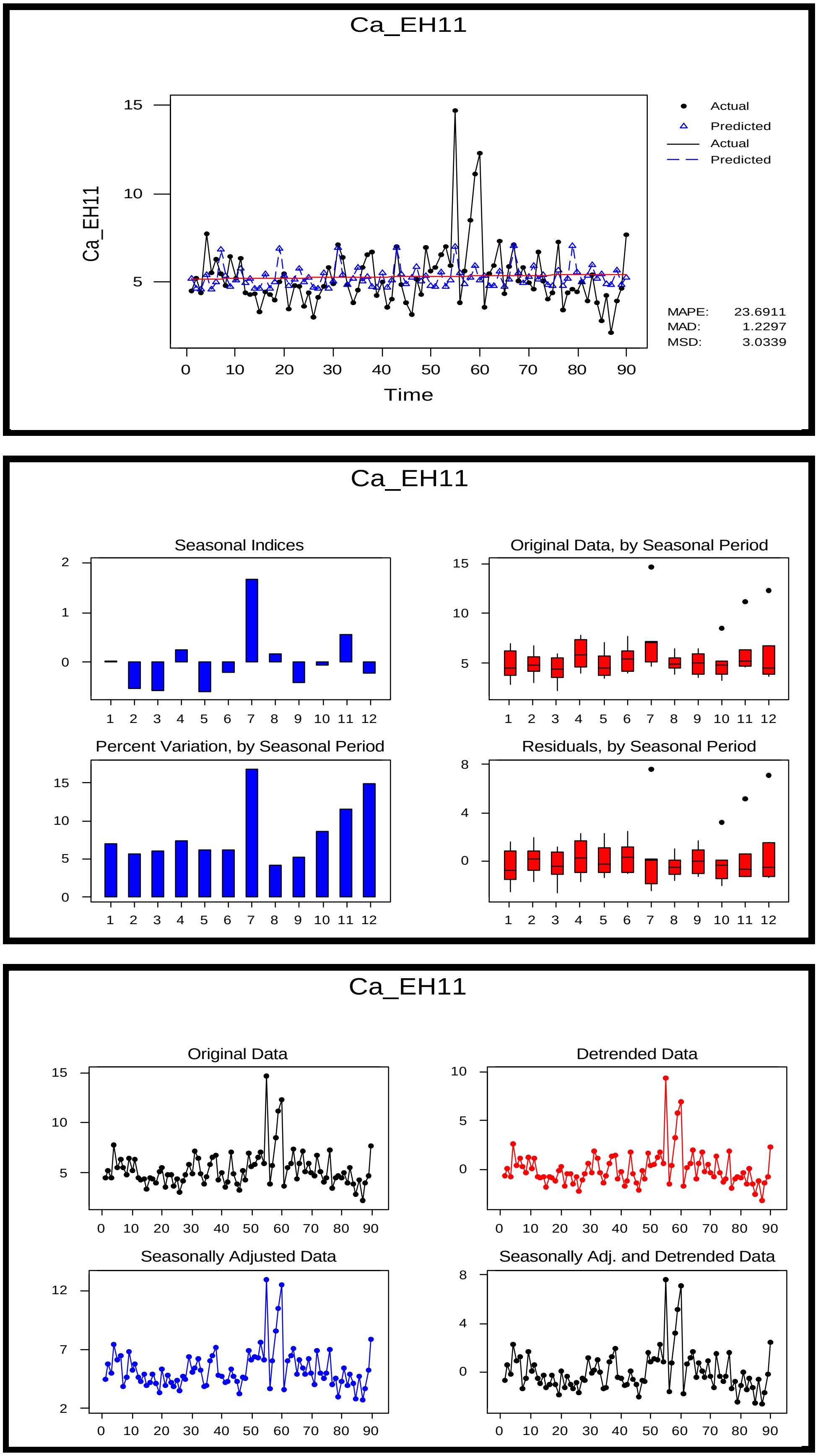
Annex 6-2A18: Timeseries decomposition for TDS (mg/l) measured at the monitoring site EH11



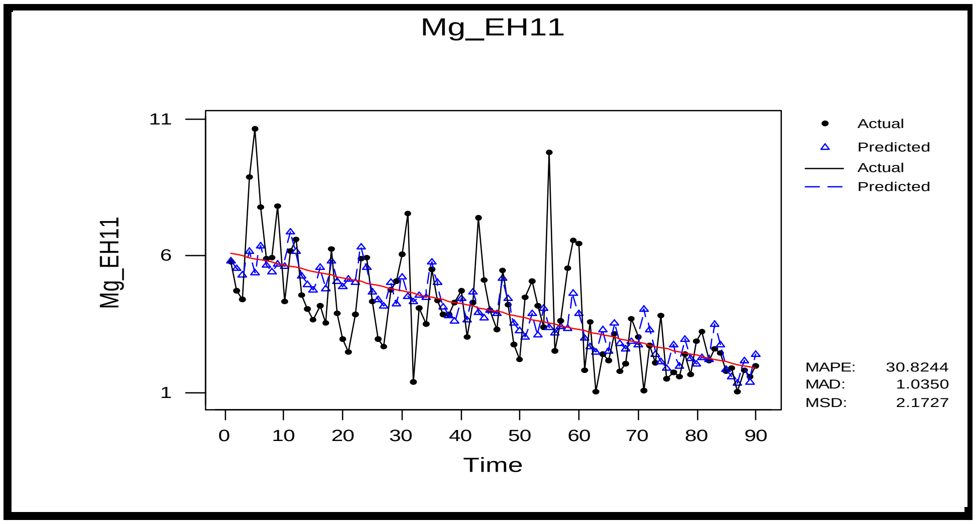


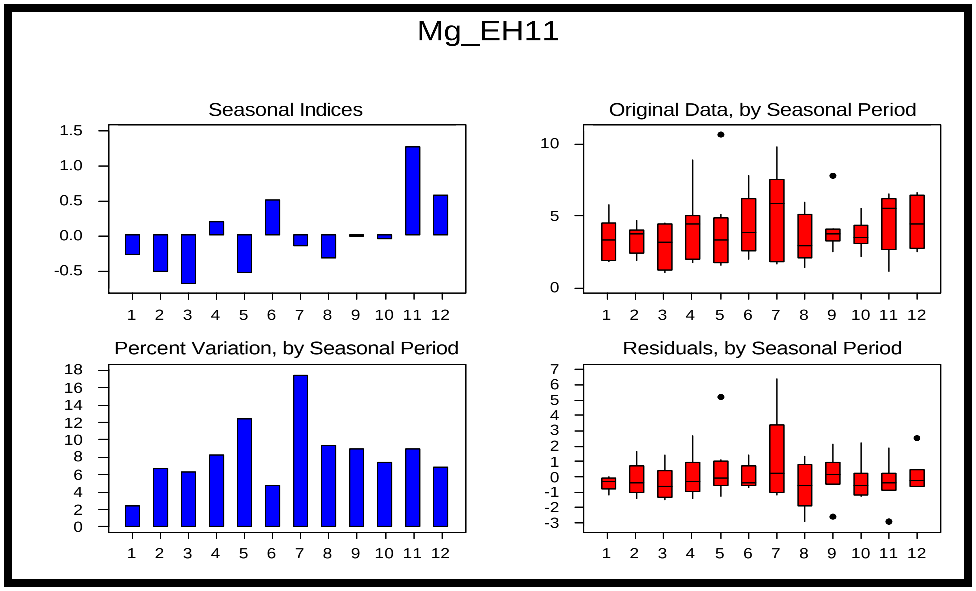


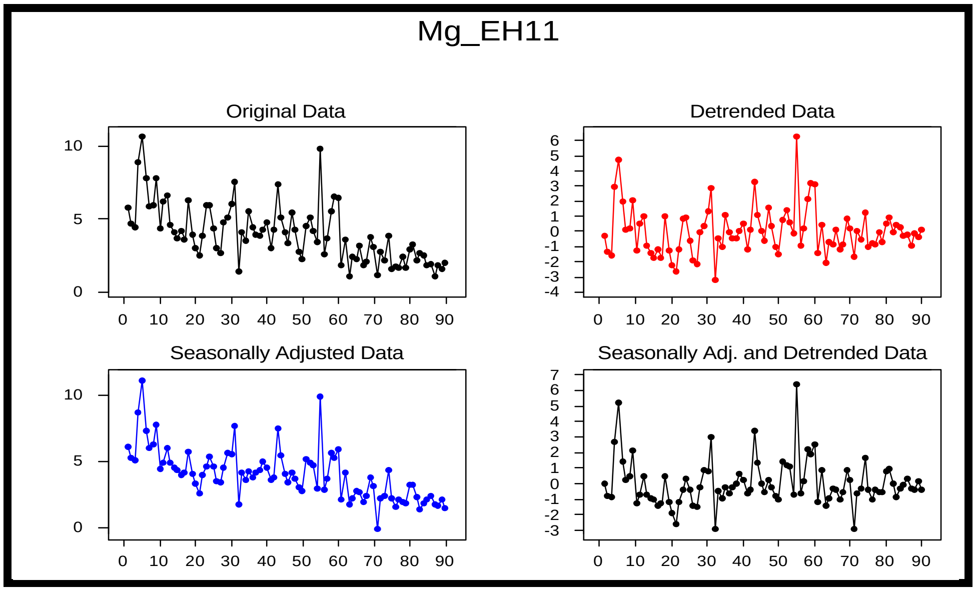
Annex 6-2A19: Timeseries decomposition for Ca (meq/l) measured at the monitoring site EH11



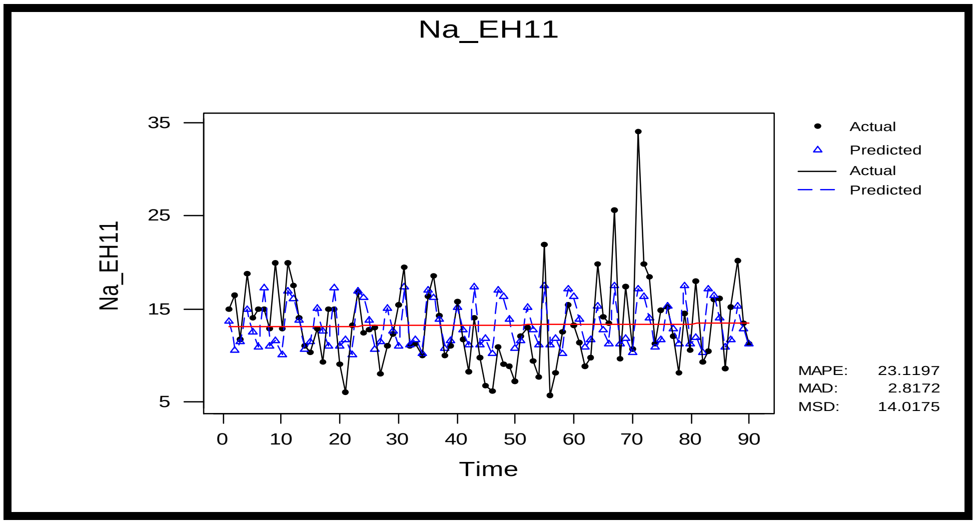
Annex 6-2A20: Timeseries decomposition for Mg (meq/l) measured at the monitoring site EH11

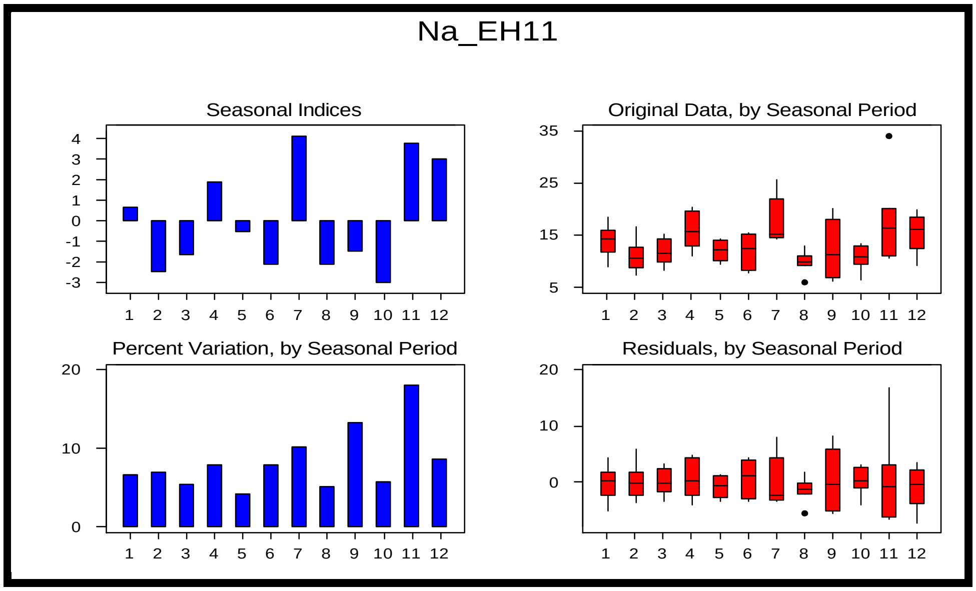


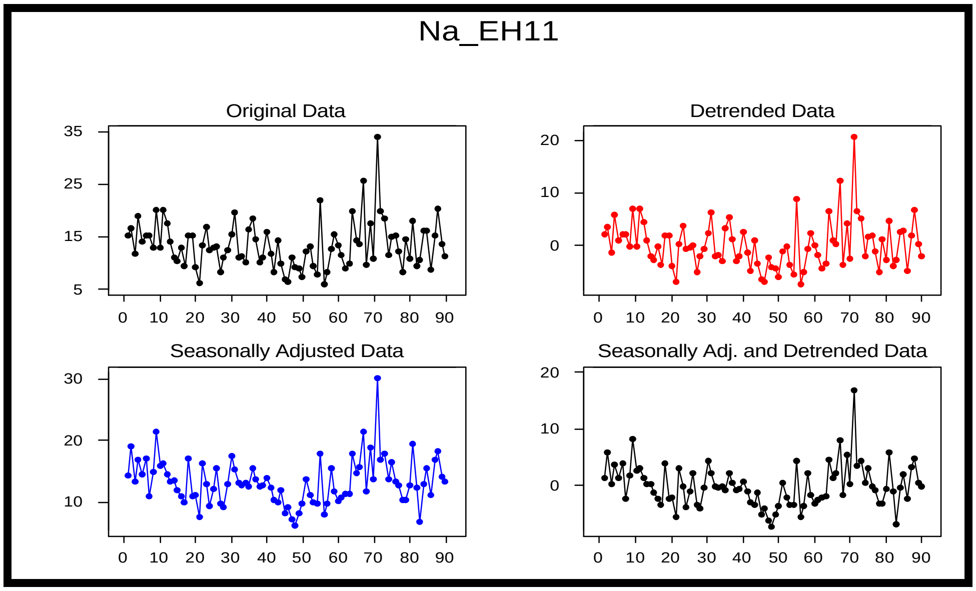




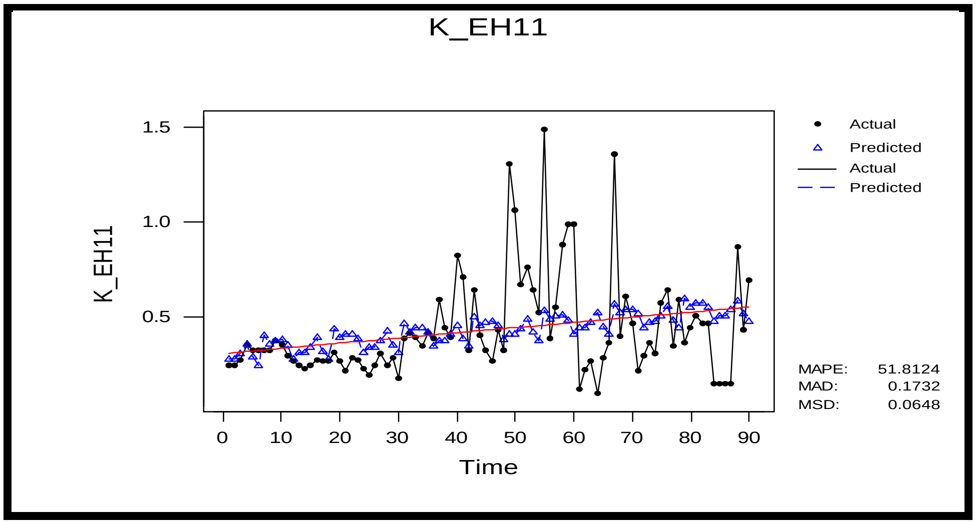
Annex 6-2A21: Timeseries decomposition for Na (meq/l) measured at the monitoring site EH11

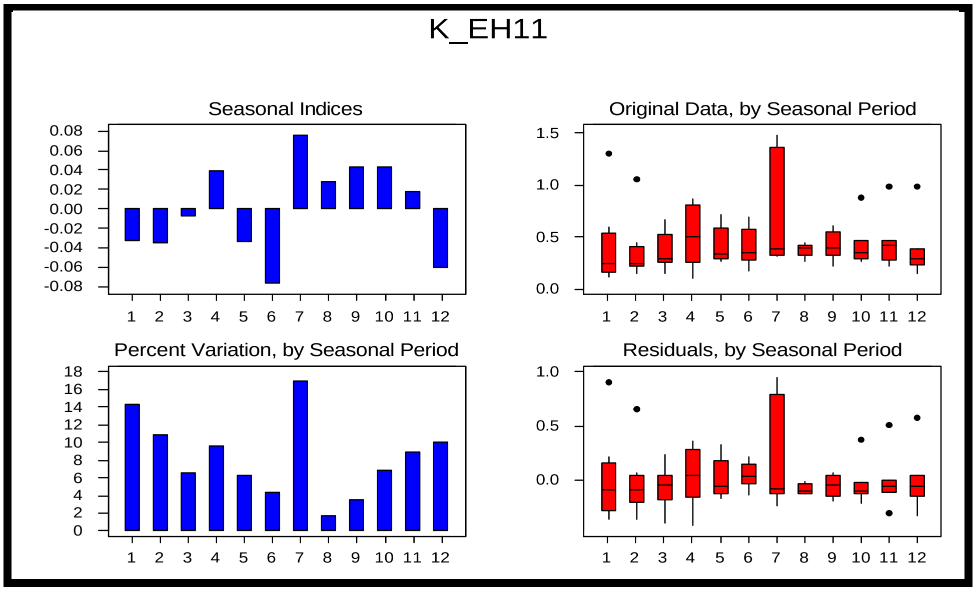


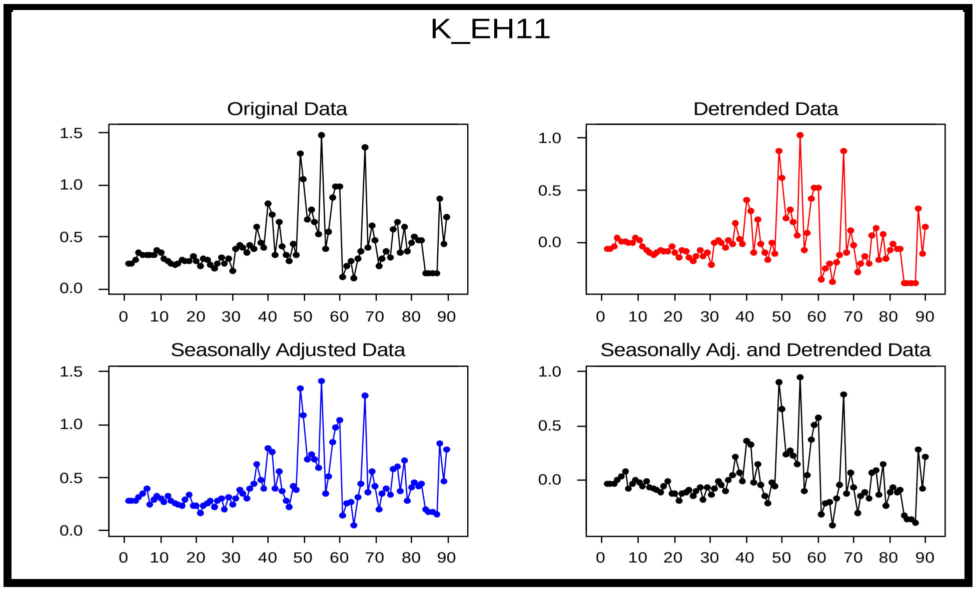




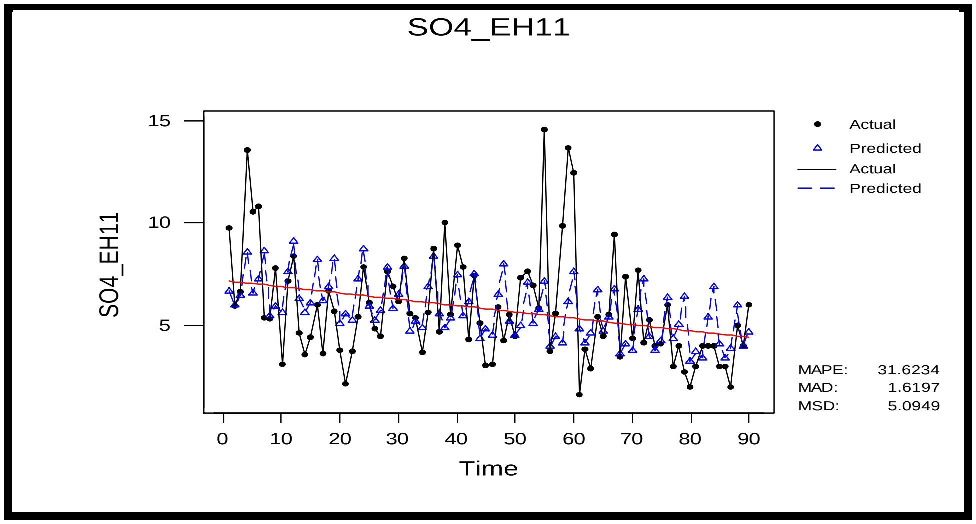
Annex 6-2A22: Timeseries decomposition for K (meq/l) measured at the monitoring site EH11

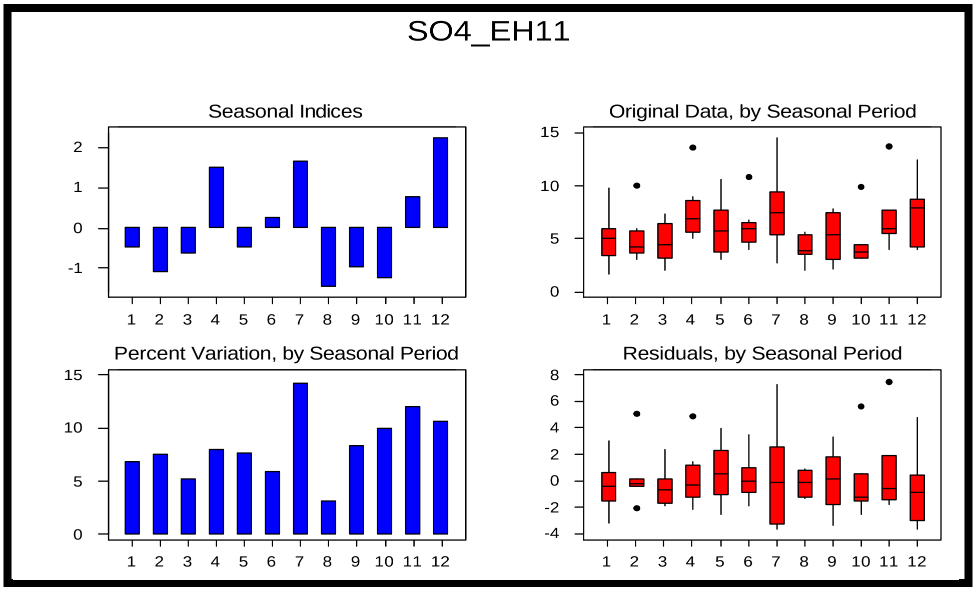


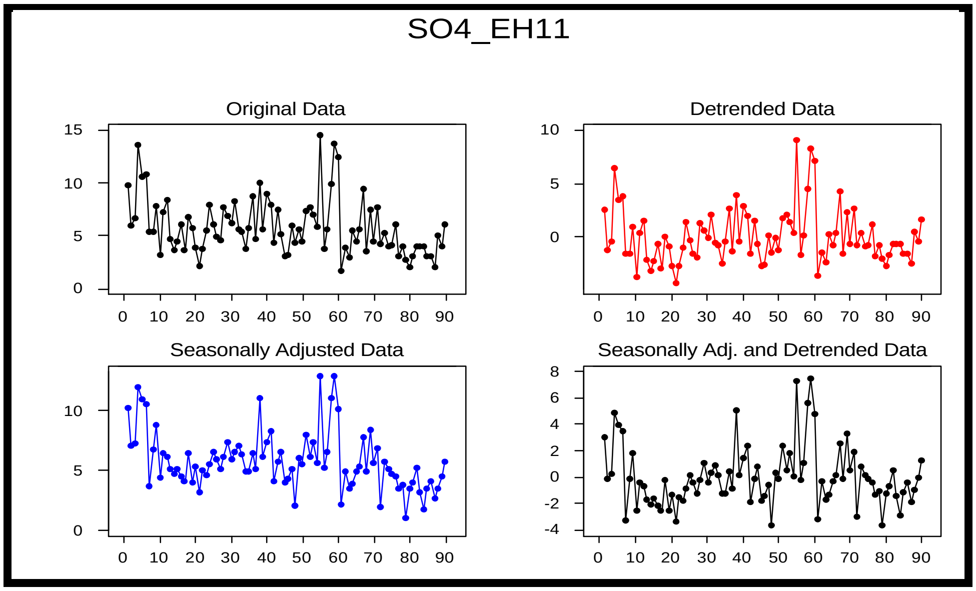




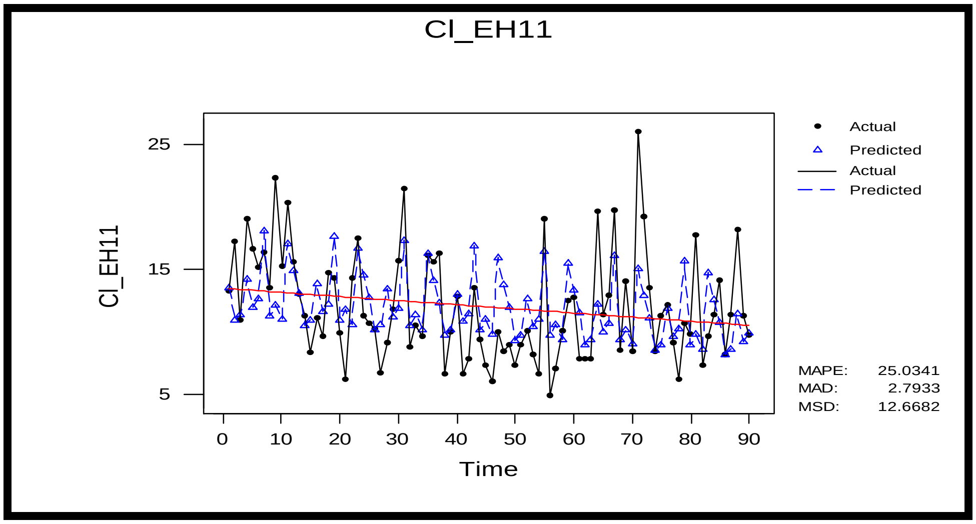
Annex 6-2A23: Timeseries decomposition for SO4 (meq/l) measured at the monitoring site EH11

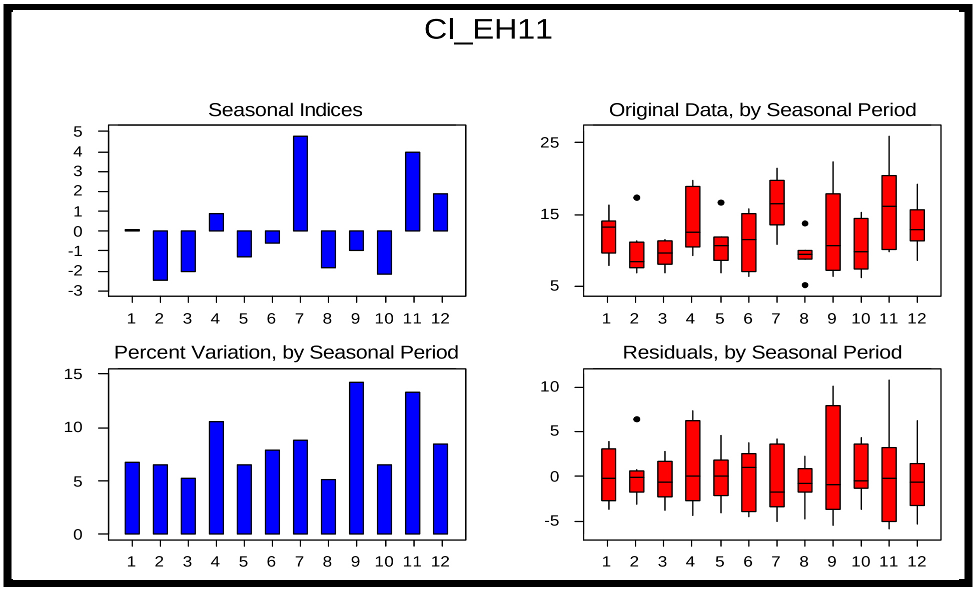


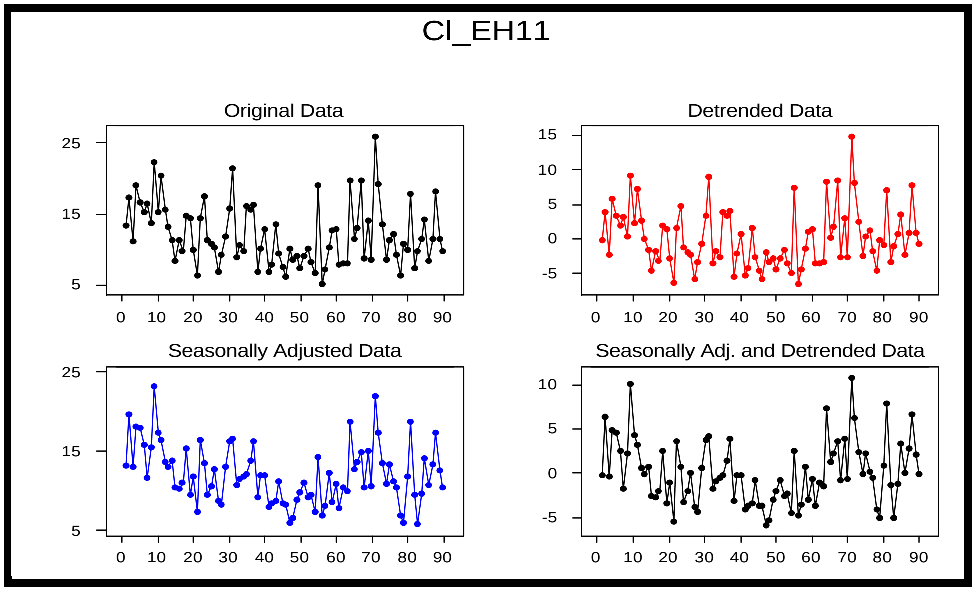




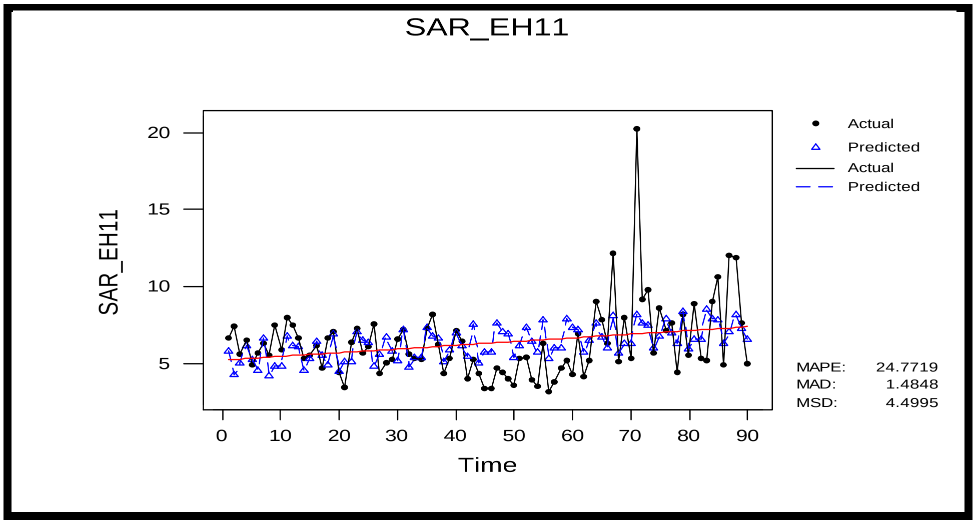
Annex 6-2A24: Timeseries decomposition for Cl (meq/l) measured at the monitoring site EH11

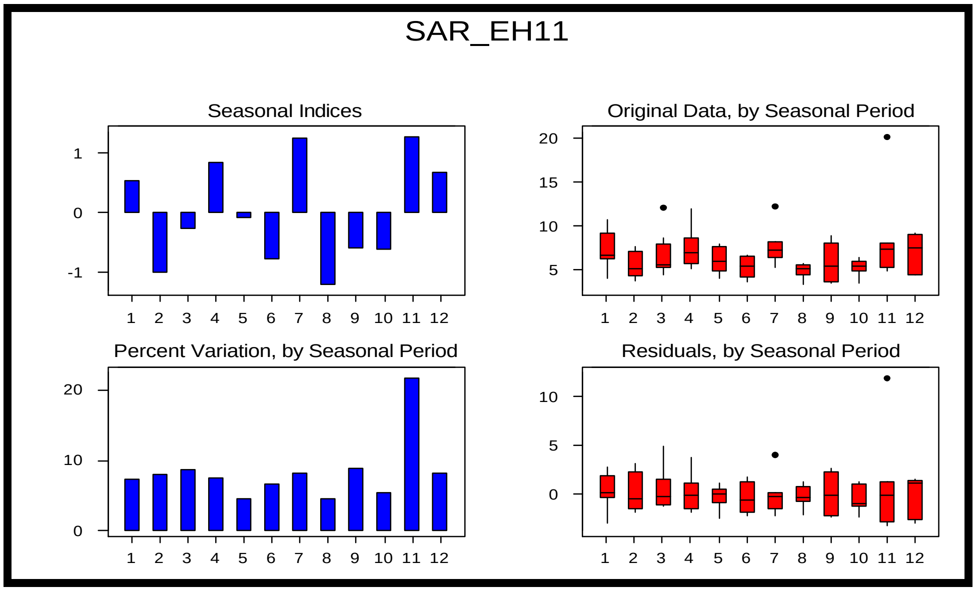


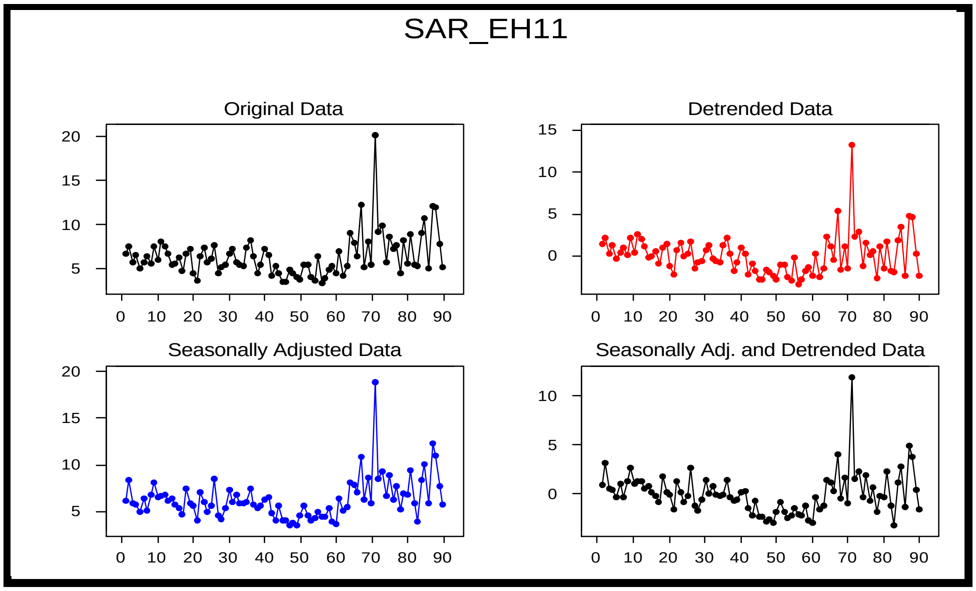




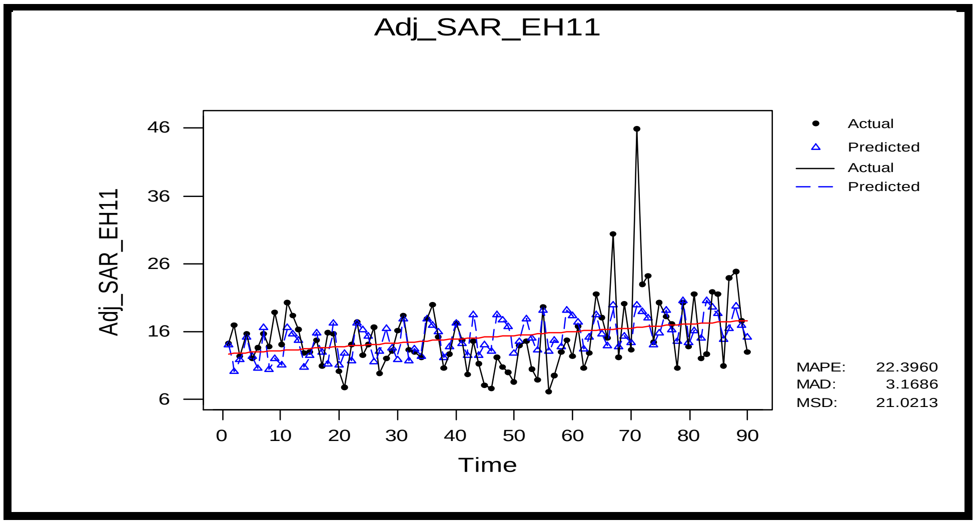
Annex 6-2A25: Timeseries decomposition for SAR calculared at the monitoring site EH11

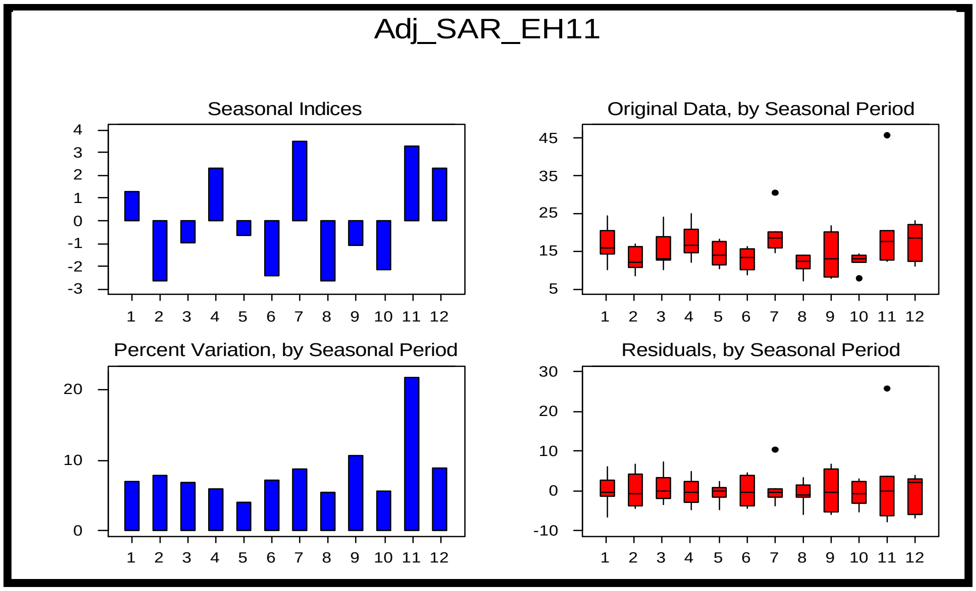


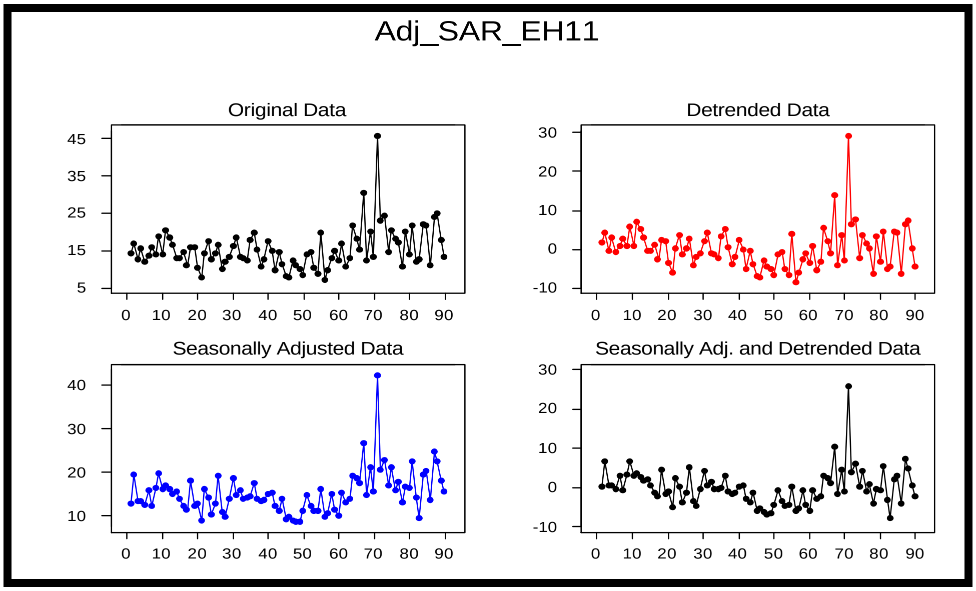




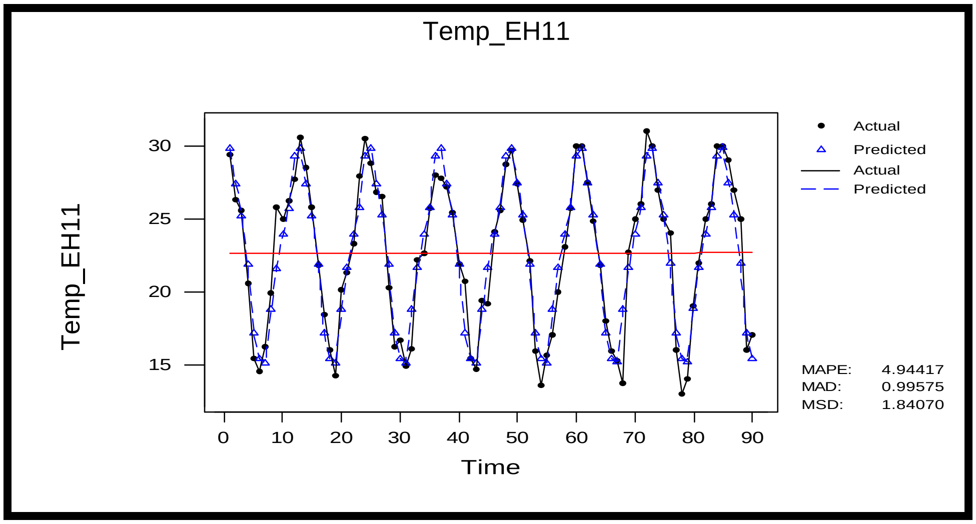
Annex 6-2A26: Timeseries decomposition for Adj._SAR calculated at the monitoring site EH11

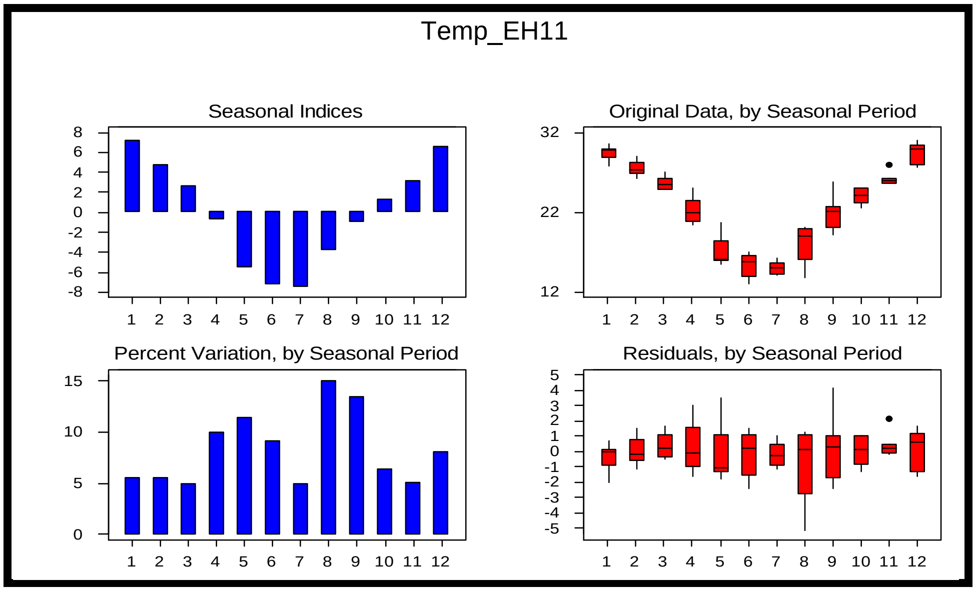


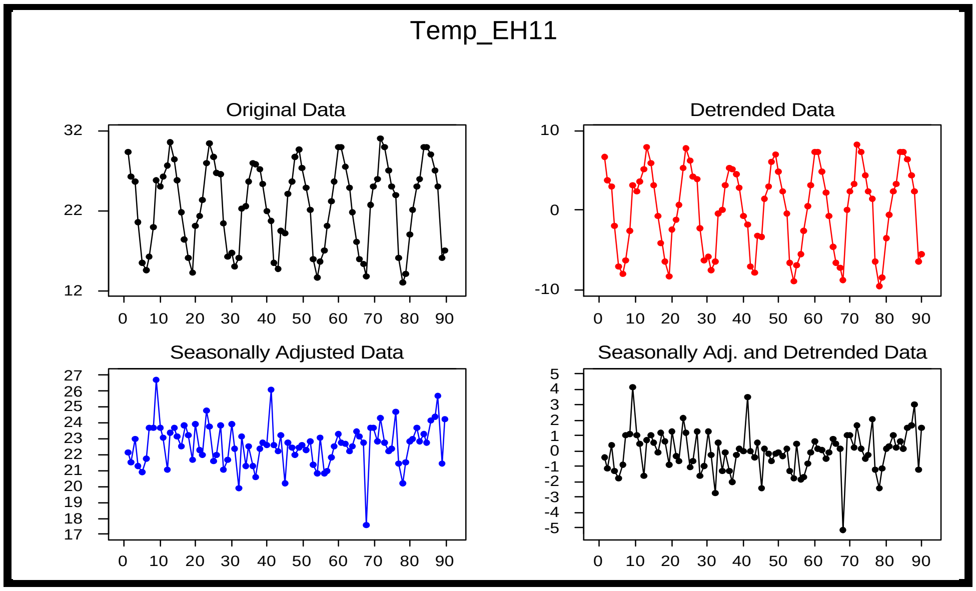




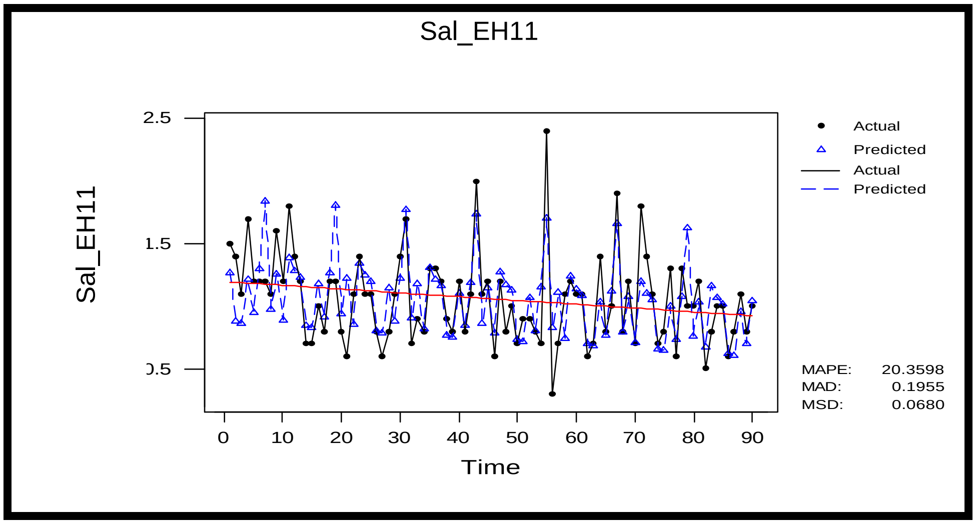
Annex 6-2A27: Timeseries decomposition for Temp (C°) measured at the monitoring site EH11

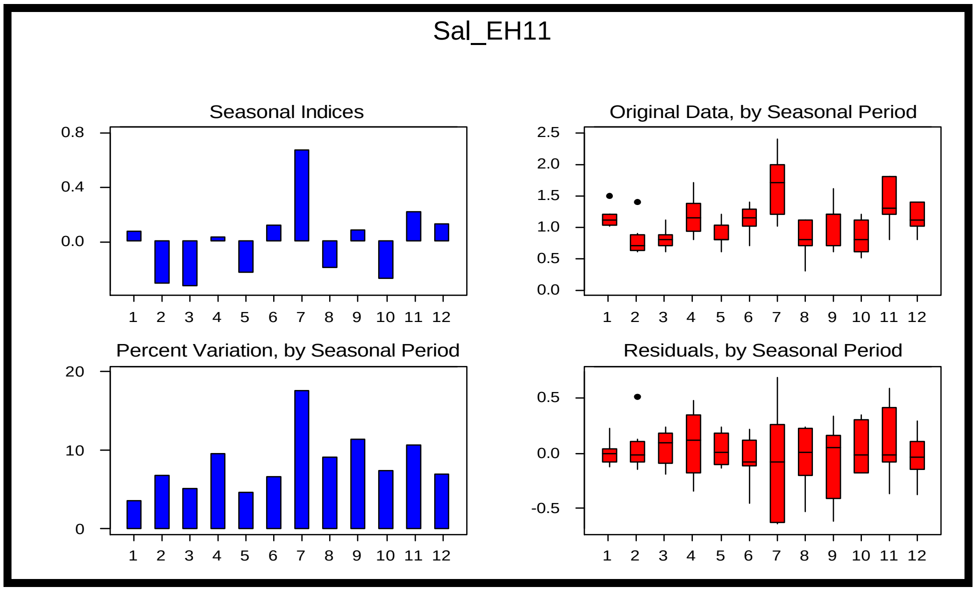


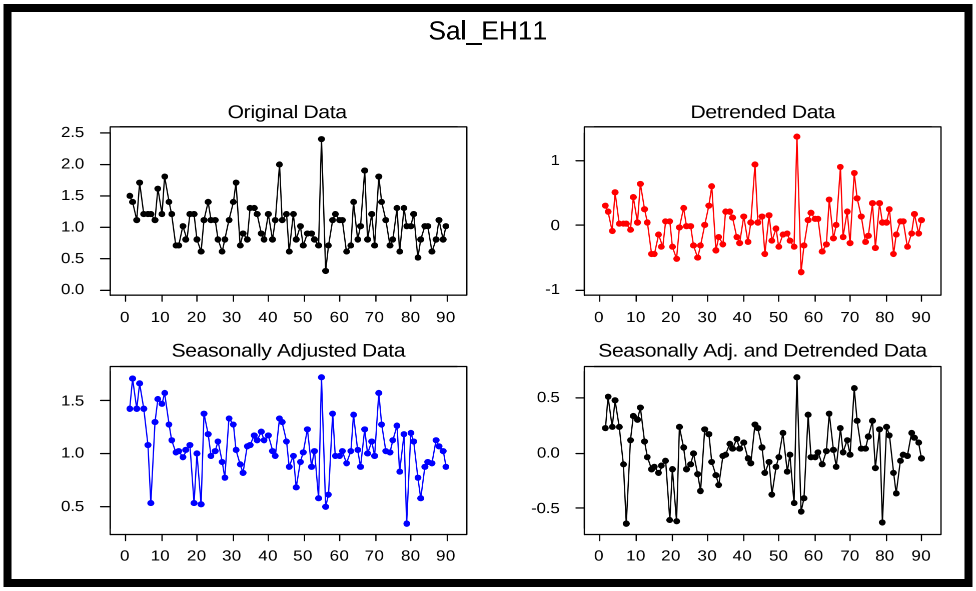




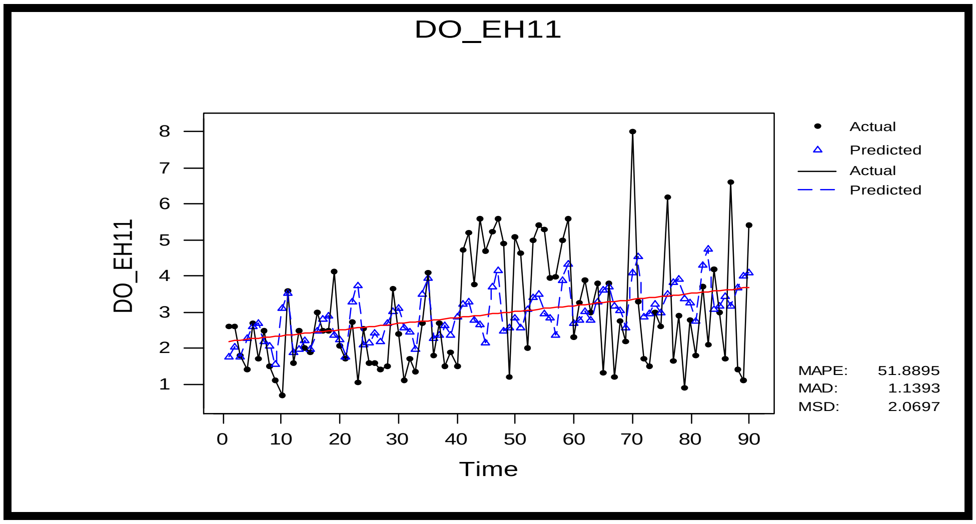
Annex 6-2A28: Timeseries decomposition for sal measured at the monitoring site EH11

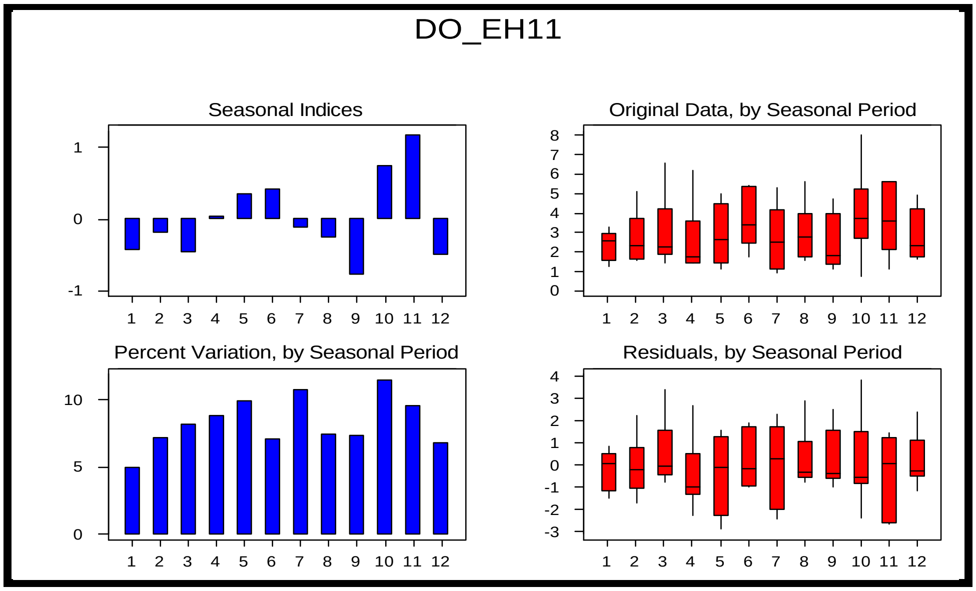


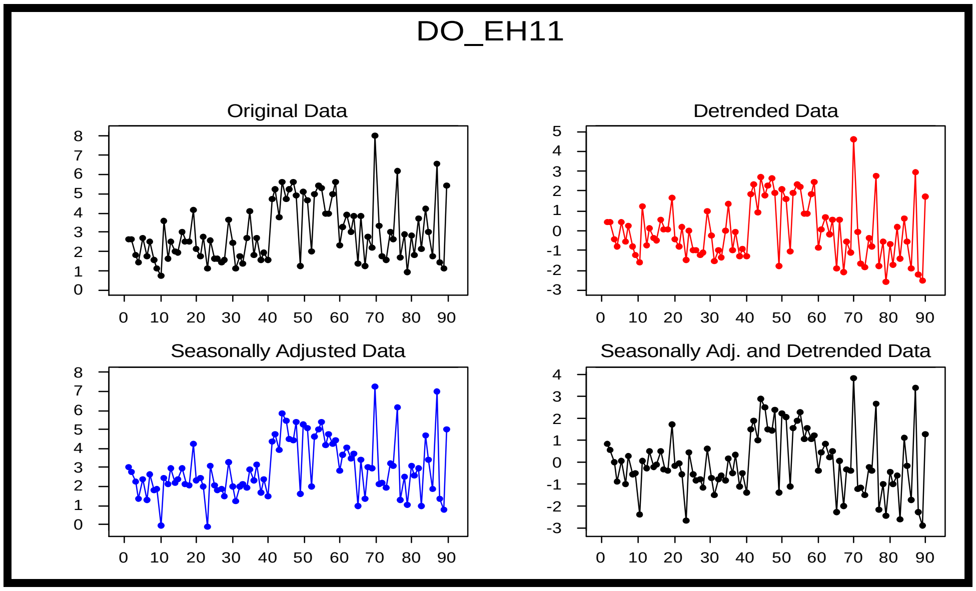




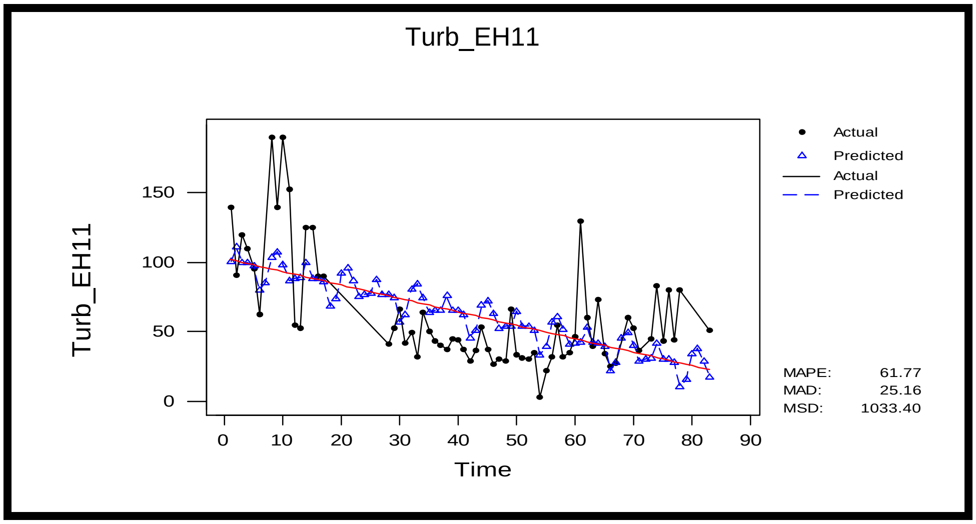
Annex 6-2A29: Timeseries decomposition for DO (mg/l) measured at the monitoring site EH11

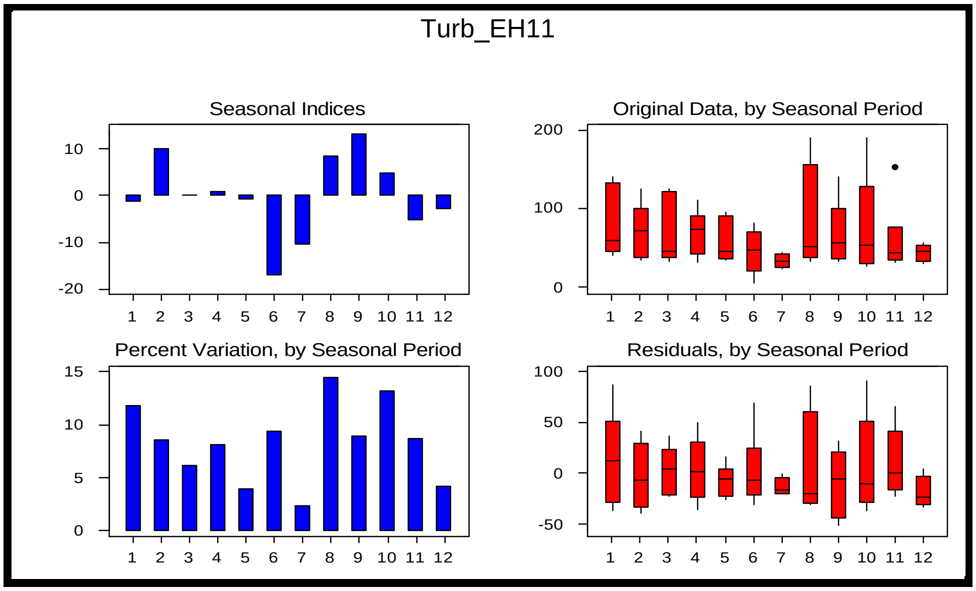


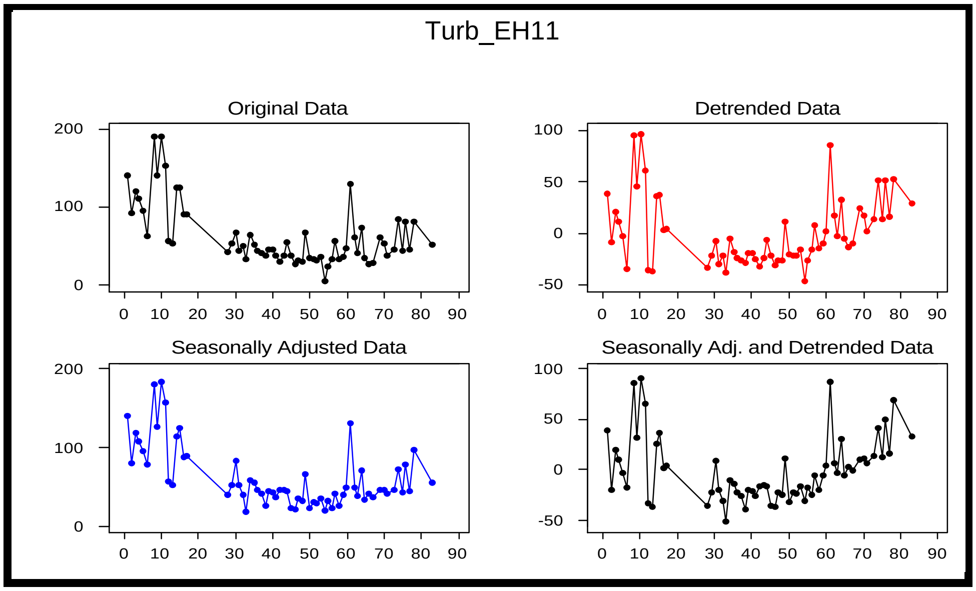




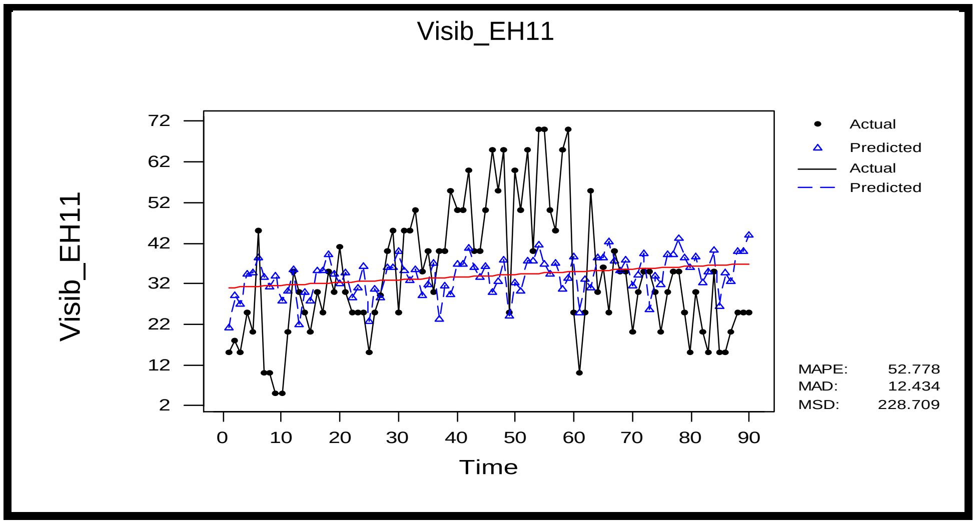
Annex 6-2A30: Timeseries decomposition for Turb (NTU) measured at the monitoring site EH11

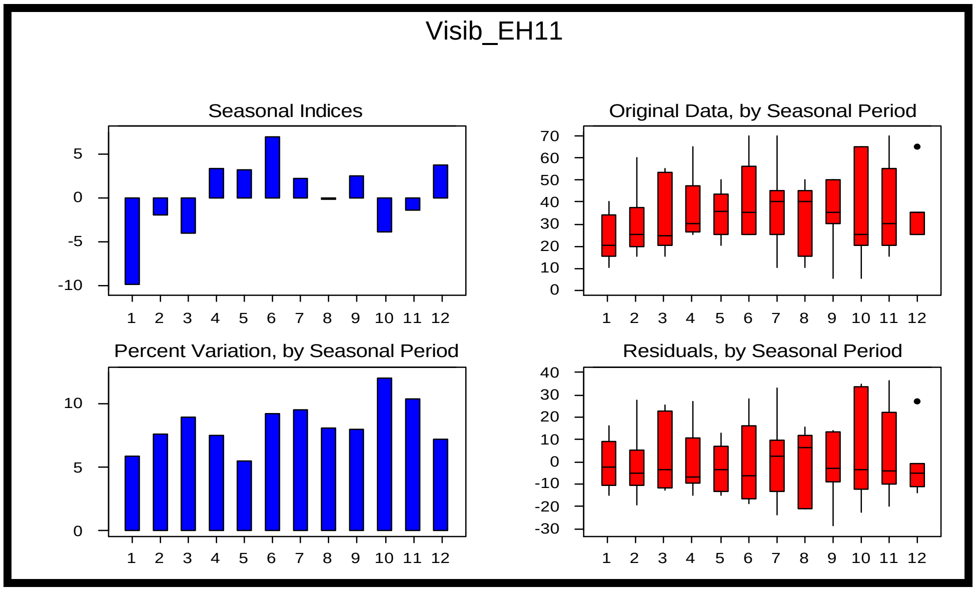


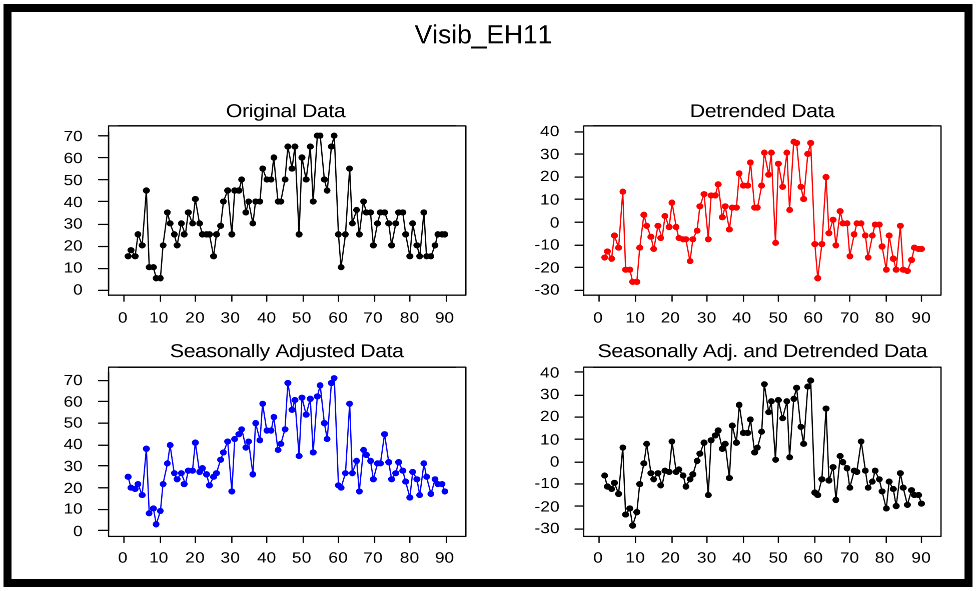




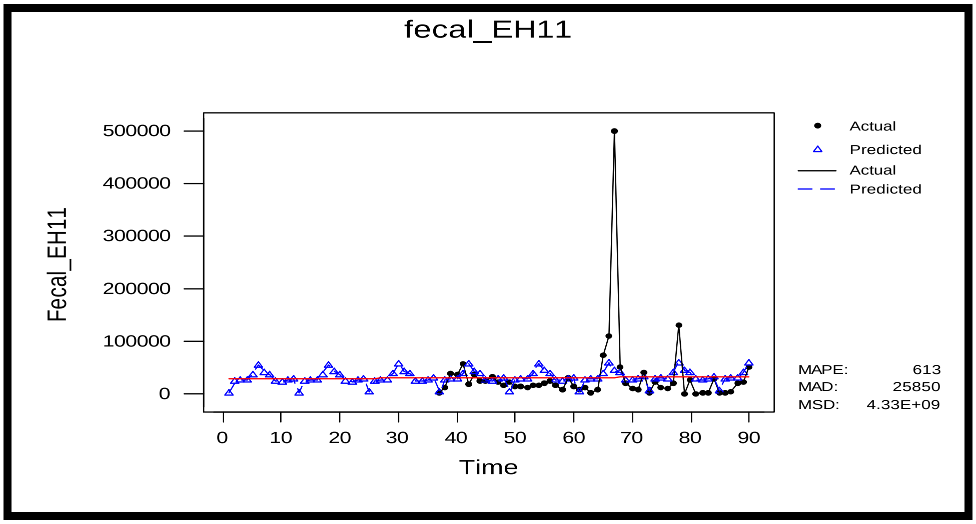
Annex 6-2A31: Timeseries decomposition for Visib (cm) measured at the monitoring site EH11

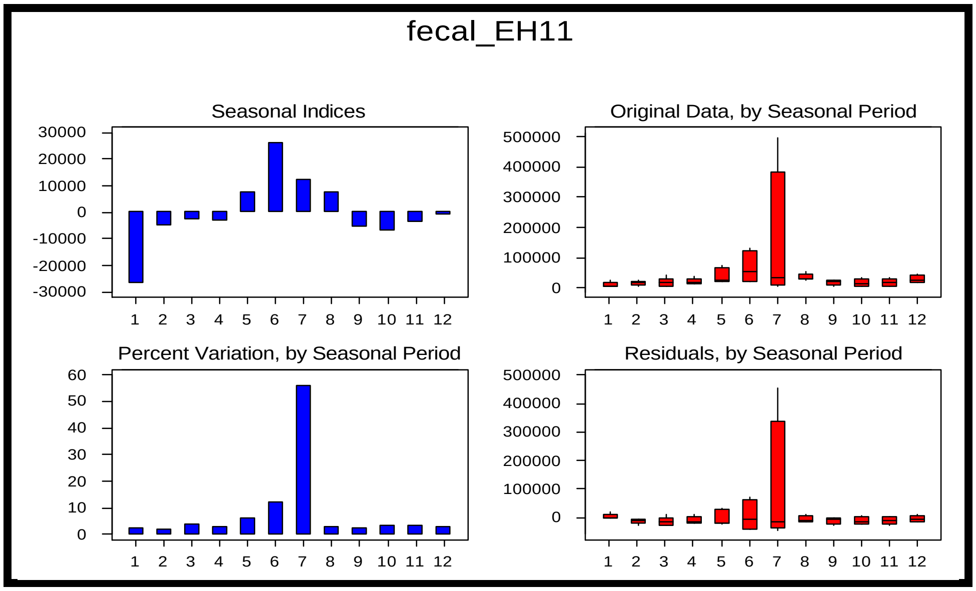


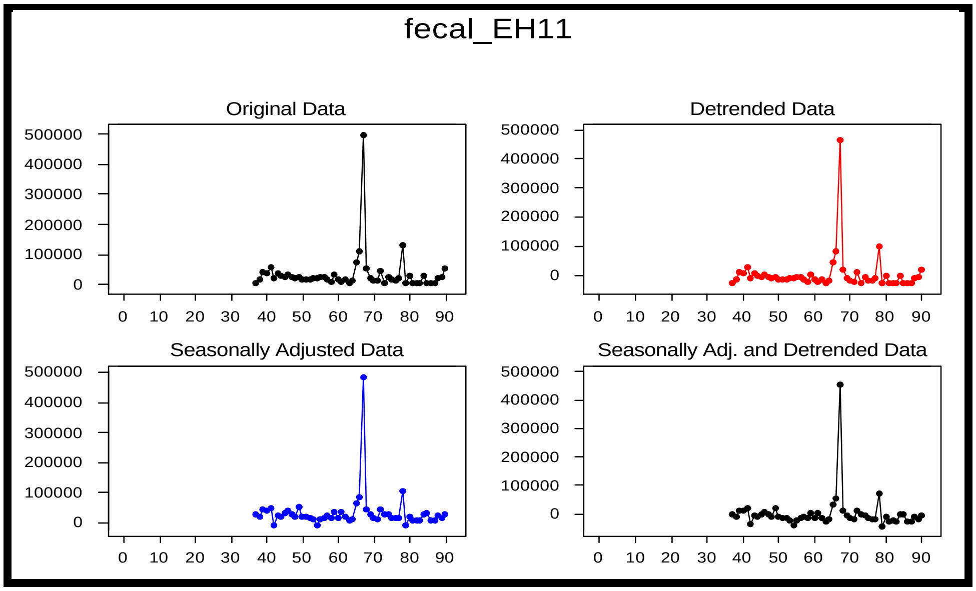




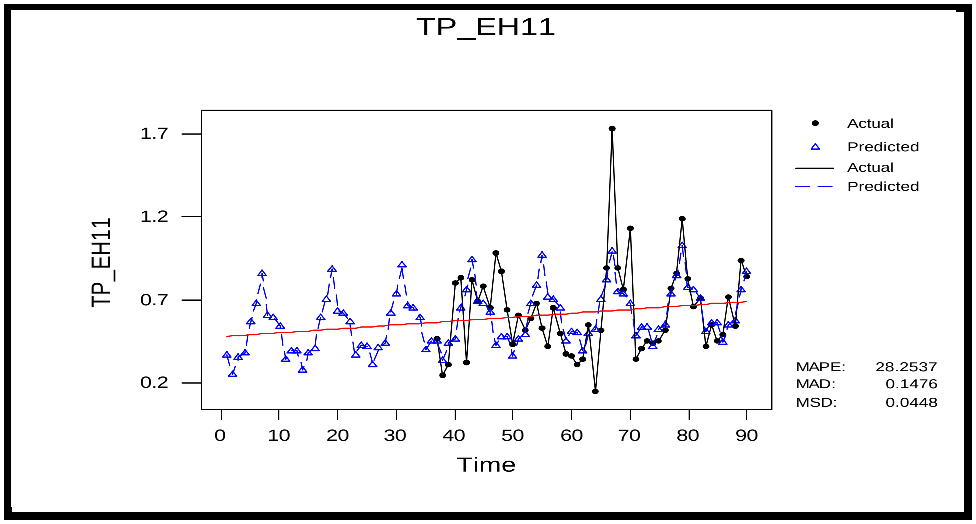
Annex 6-2A32: Timeseries decomposition for Fecal ((MPN/100ml)) measured at the monitoring site EH11

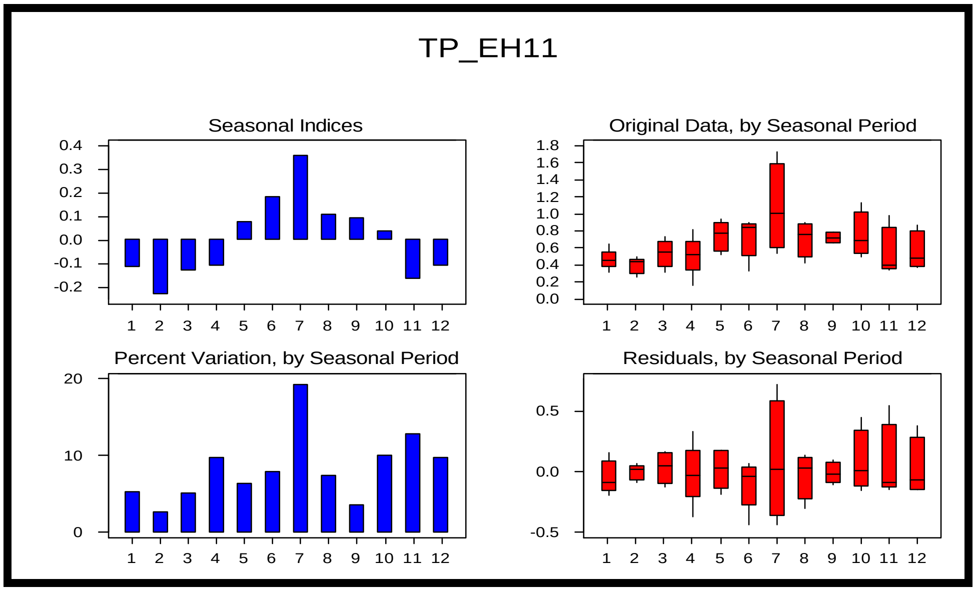


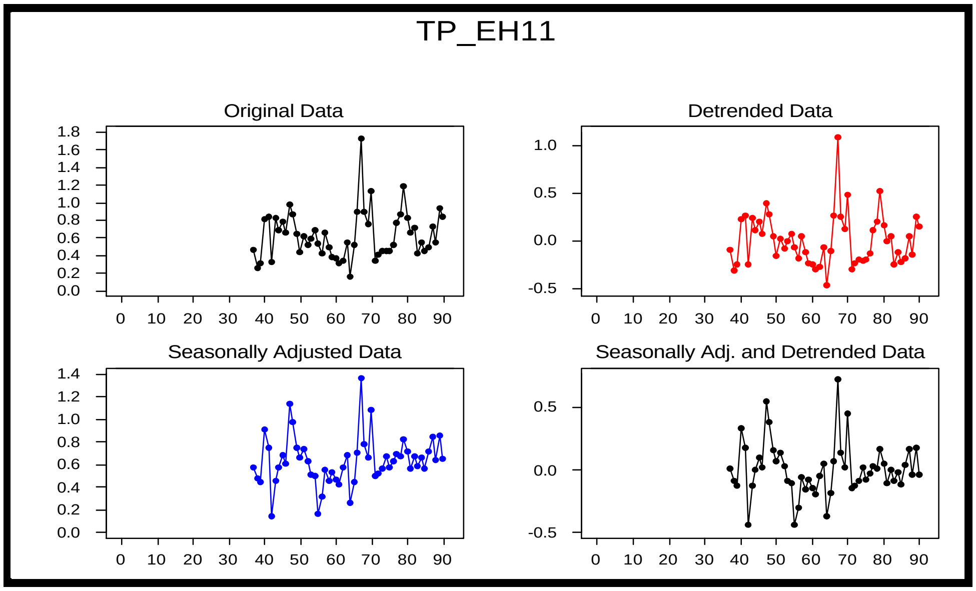




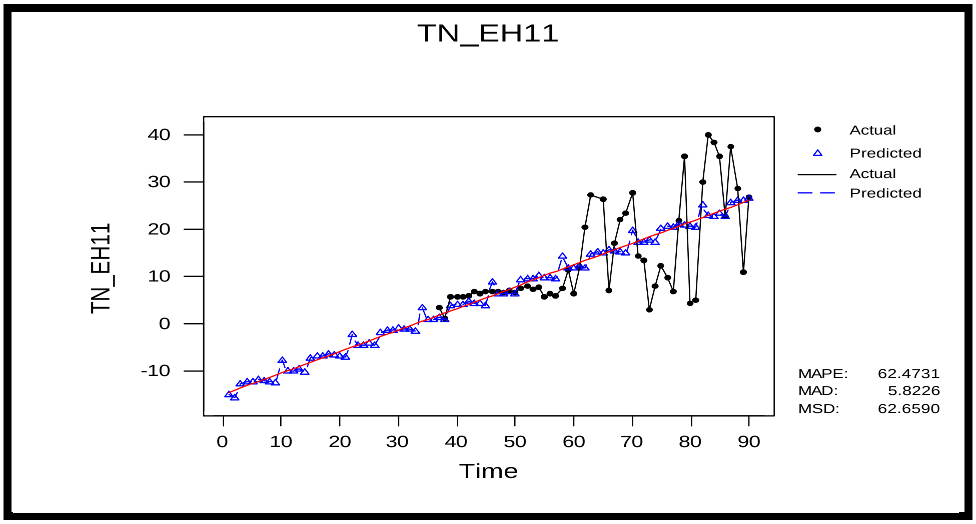
Annex 6-2A33: Timeseries decomposition for TP (mg/l) measured at the monitoring site EH11

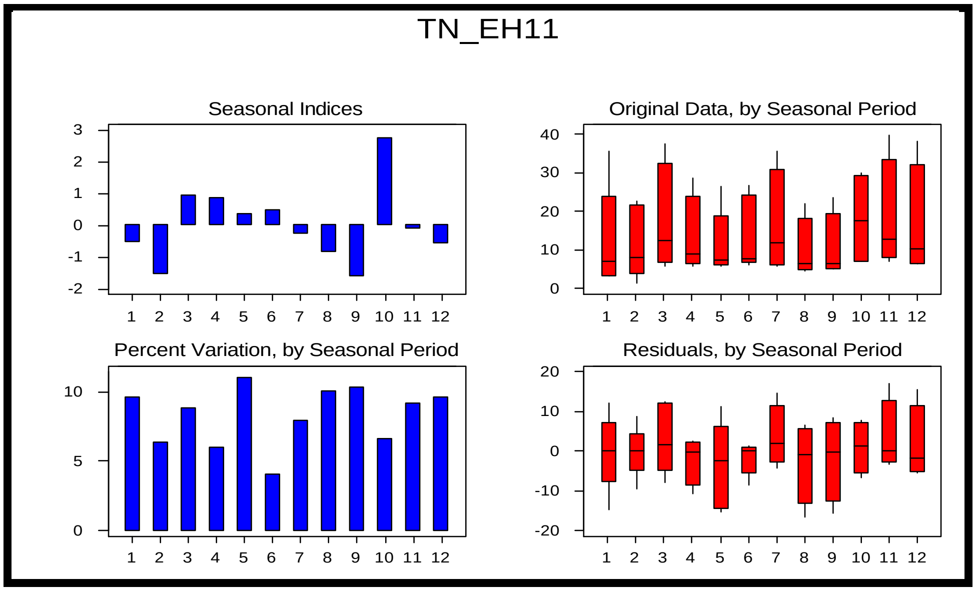


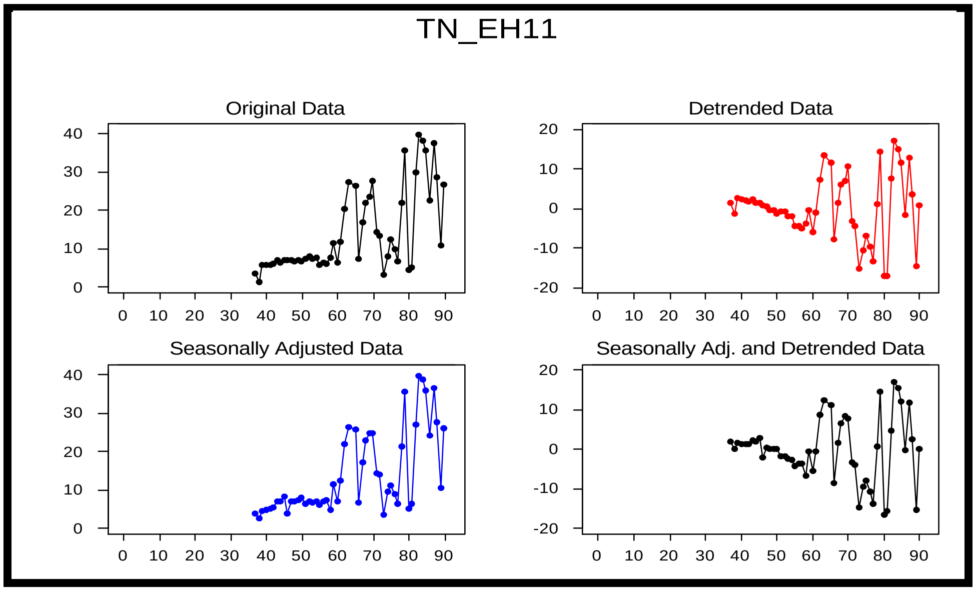




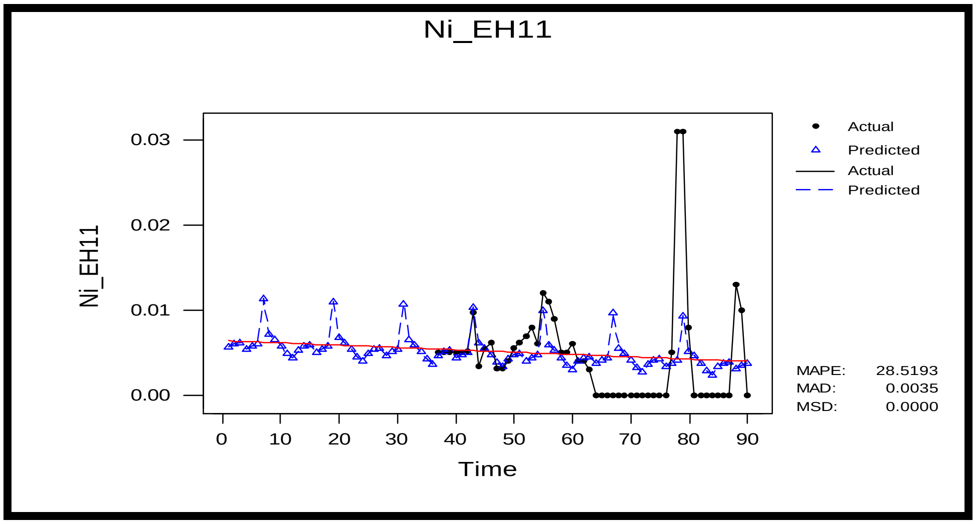
Annex 6-2A34: Timeseries decomposition for TN (mg/l) measured at the monitoring site EH11

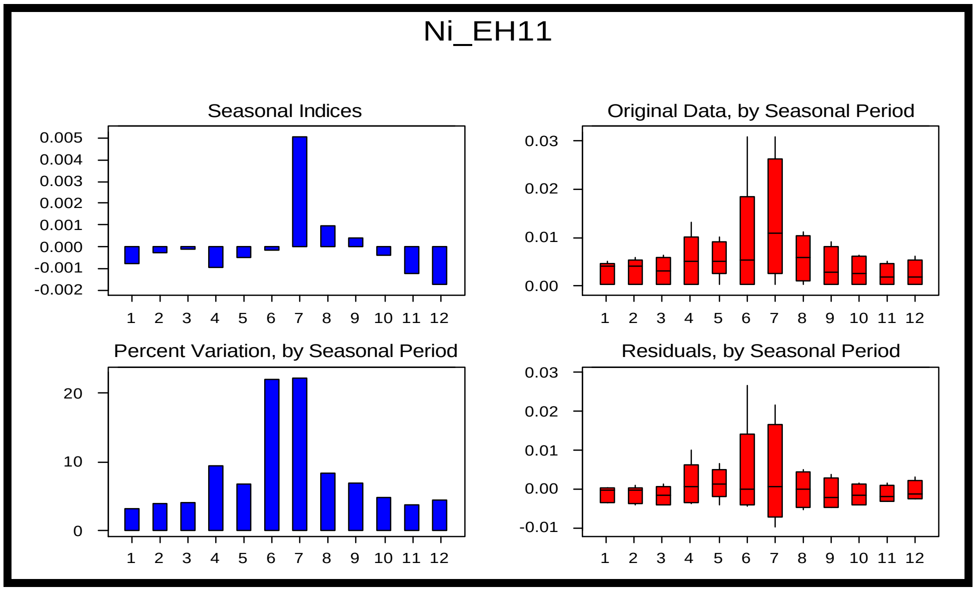


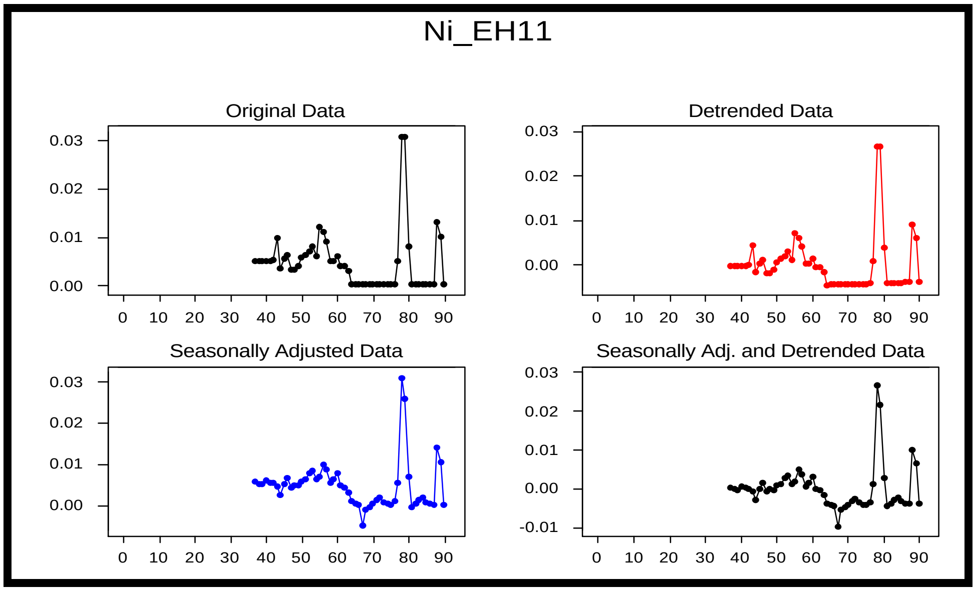




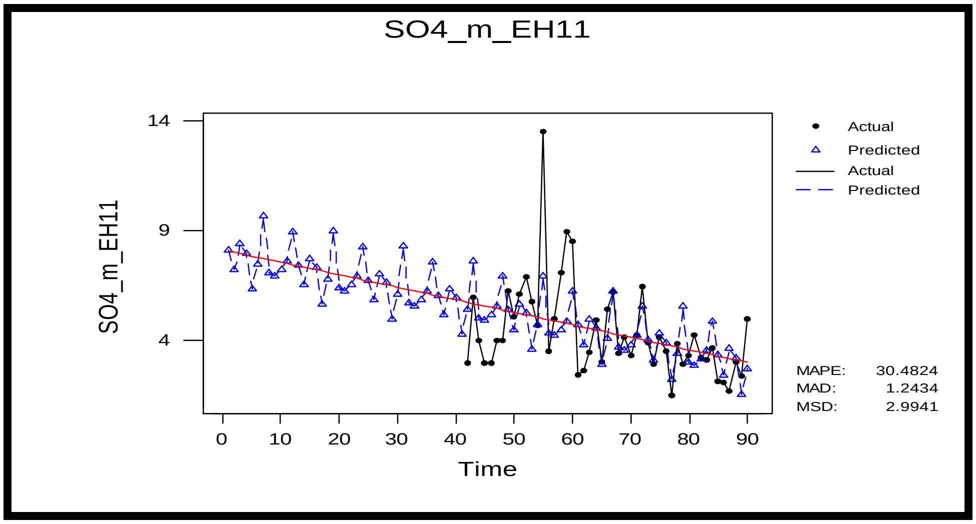
Annex 6-2A35: Timeseries decomposition for Ni (mg/l) measured at the monitoring site EH11

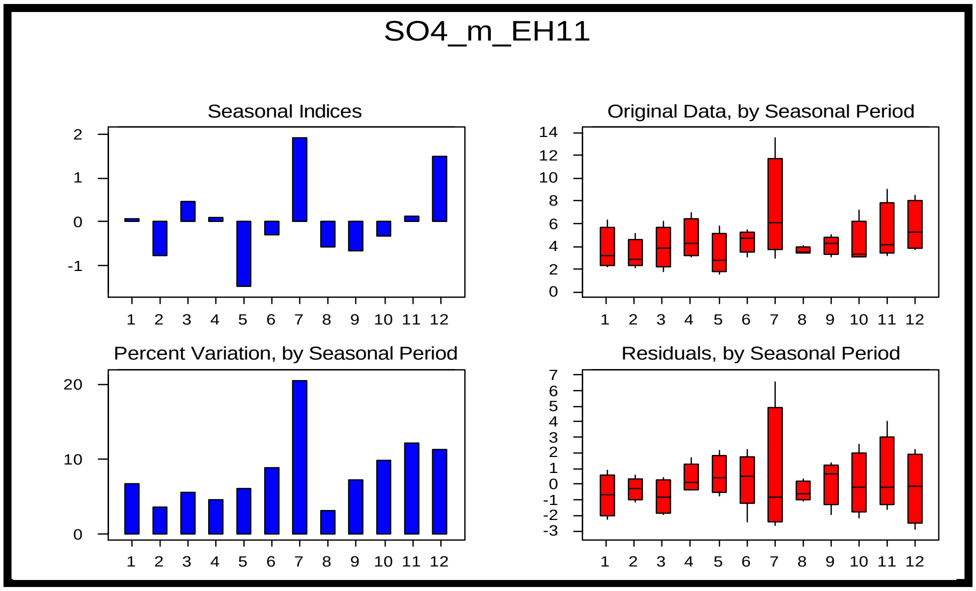


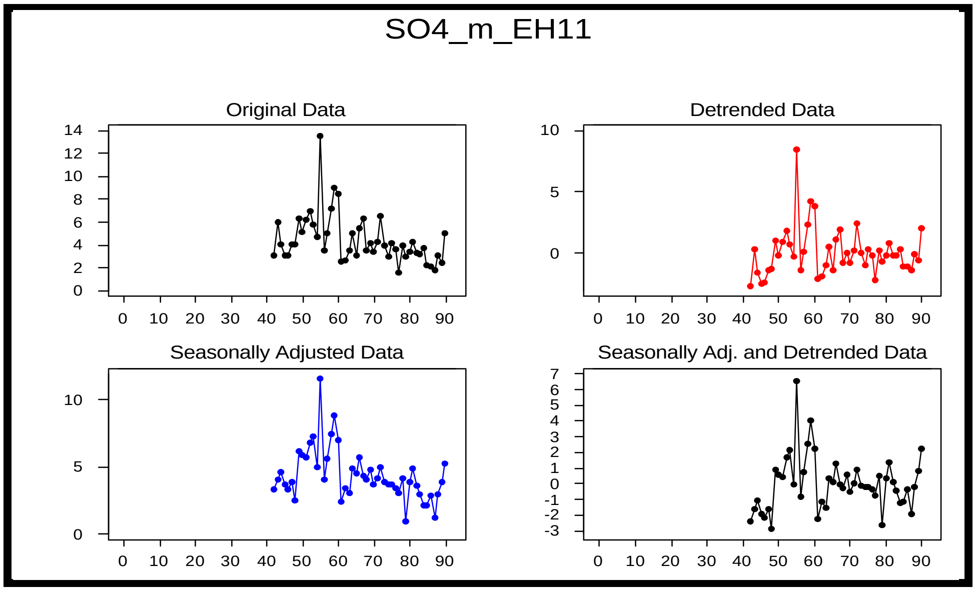




Annex 6-2A36: Timeseries decomposition for SO4_m (meq/l) measured at the monitoring site EH11



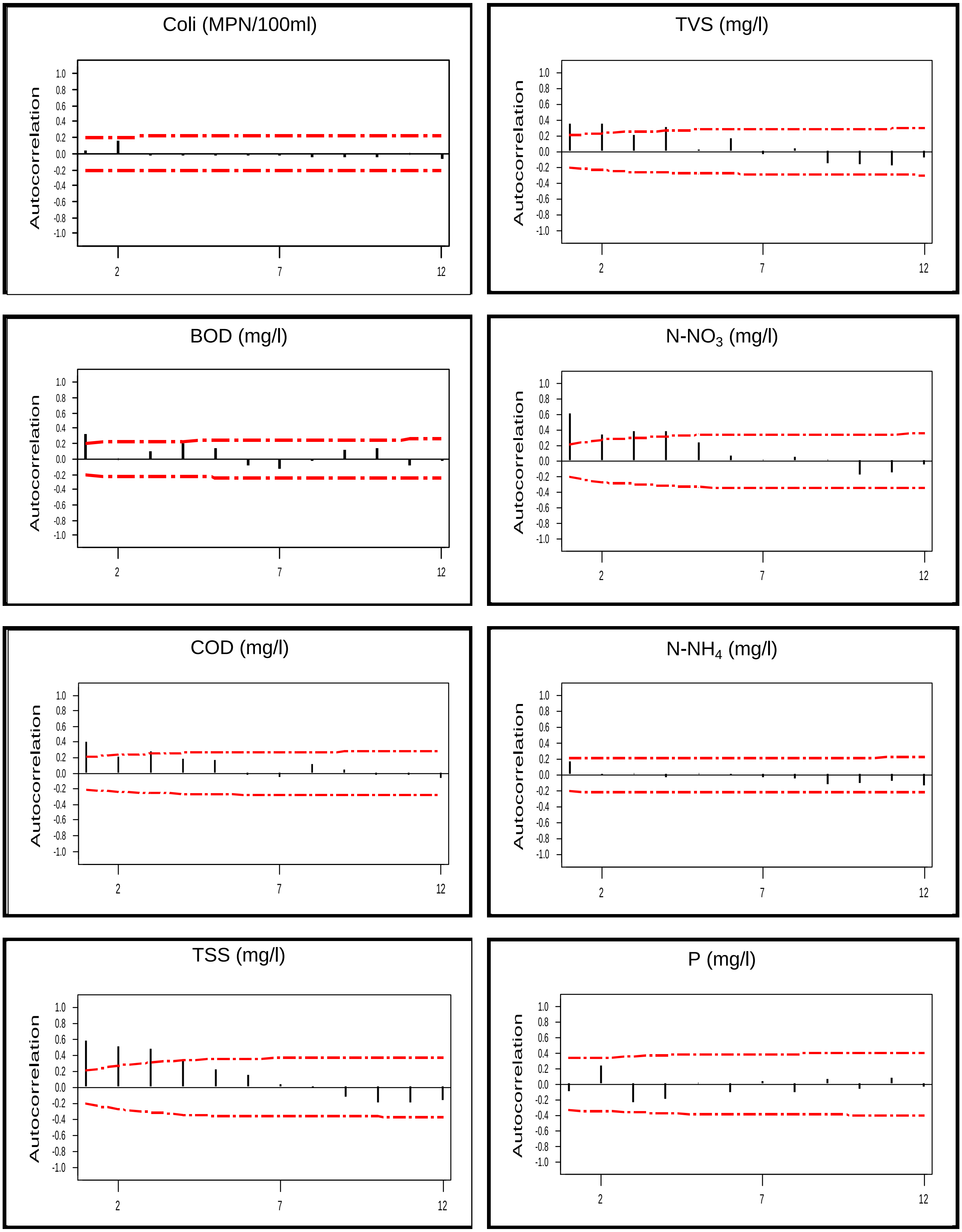




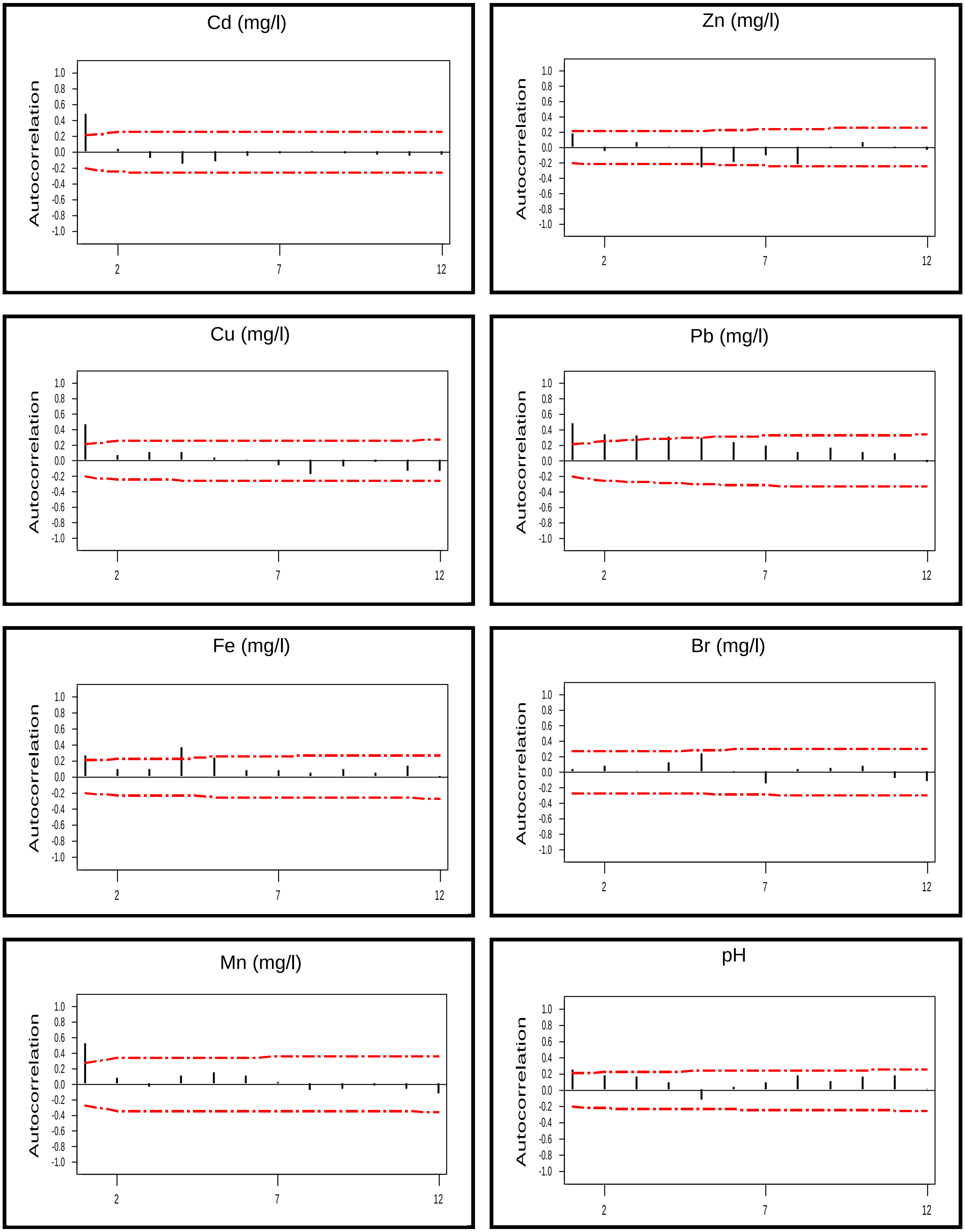
ANNEX 6-3

THE CORRELOGRAMS FOR DE-TRENDED AND DE-SEASONALISED WQ MEASUREMENTS FOR THE MONITORING SITE BAHR HADUS BRIDGE (EH11)

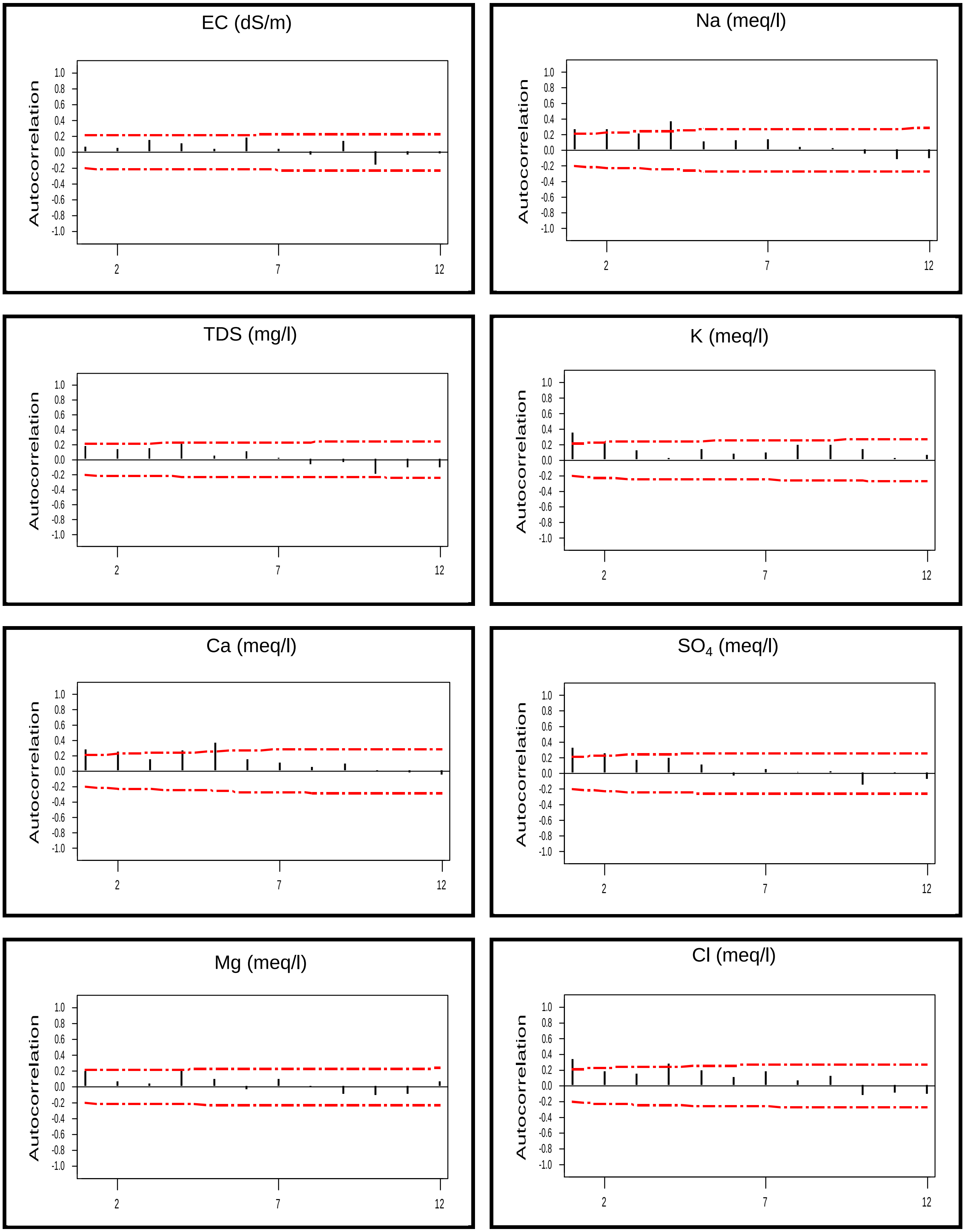
Annex 6-3A1: The Correlograms for de-trended and de-seasonalised WQ measurements for the monitoring site EH11



Annex 6-3A2: The Correlograms for de-trended and de-seasonalised WQ measurements for the monitoring site EH11

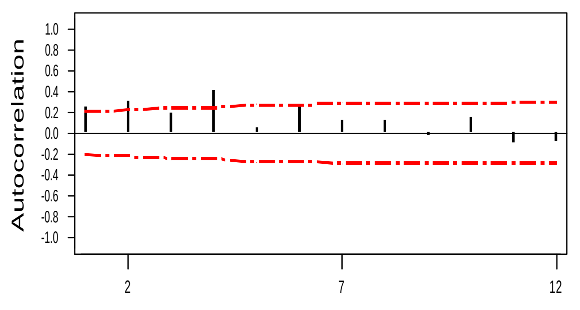


Annex 6-3A3: The Correlograms for de-trended and de-seasonalised WQ measurements for the monitoring site EH11

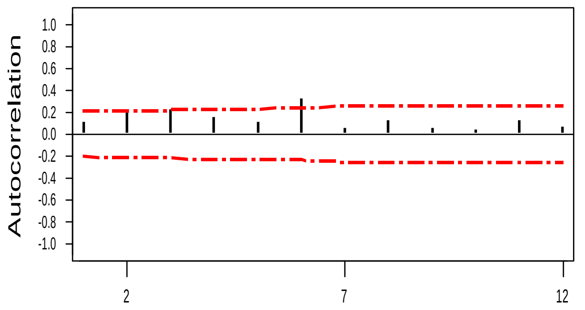


Annex 6-3A4: The Correlograms for de-trended and de-seasonalised WQ measurements for the monitoring site EH11

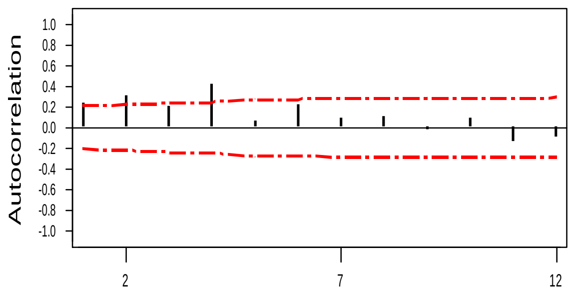
SAR



DO (mg/l)



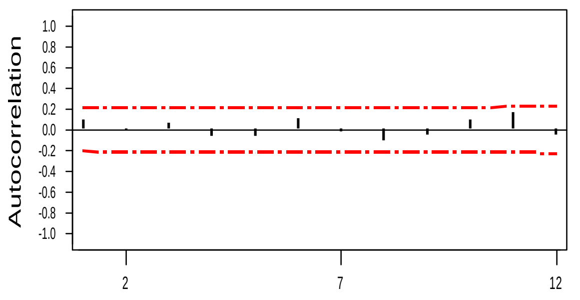
Adj._SAR



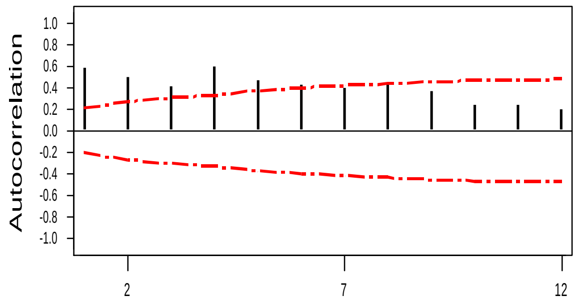
Turb (NTU)

Not available due to many missing values

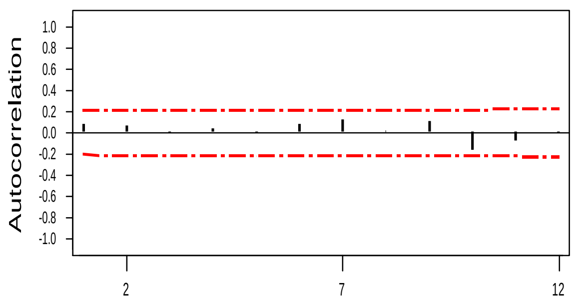
Temp (C^o)



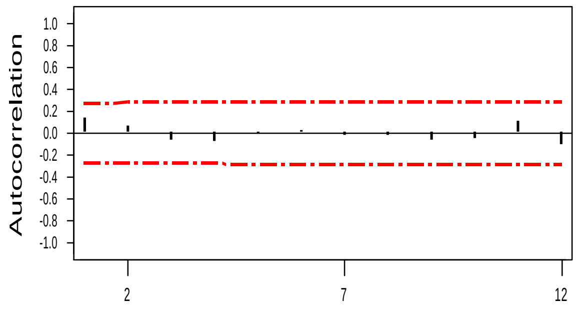
Visib (cm)



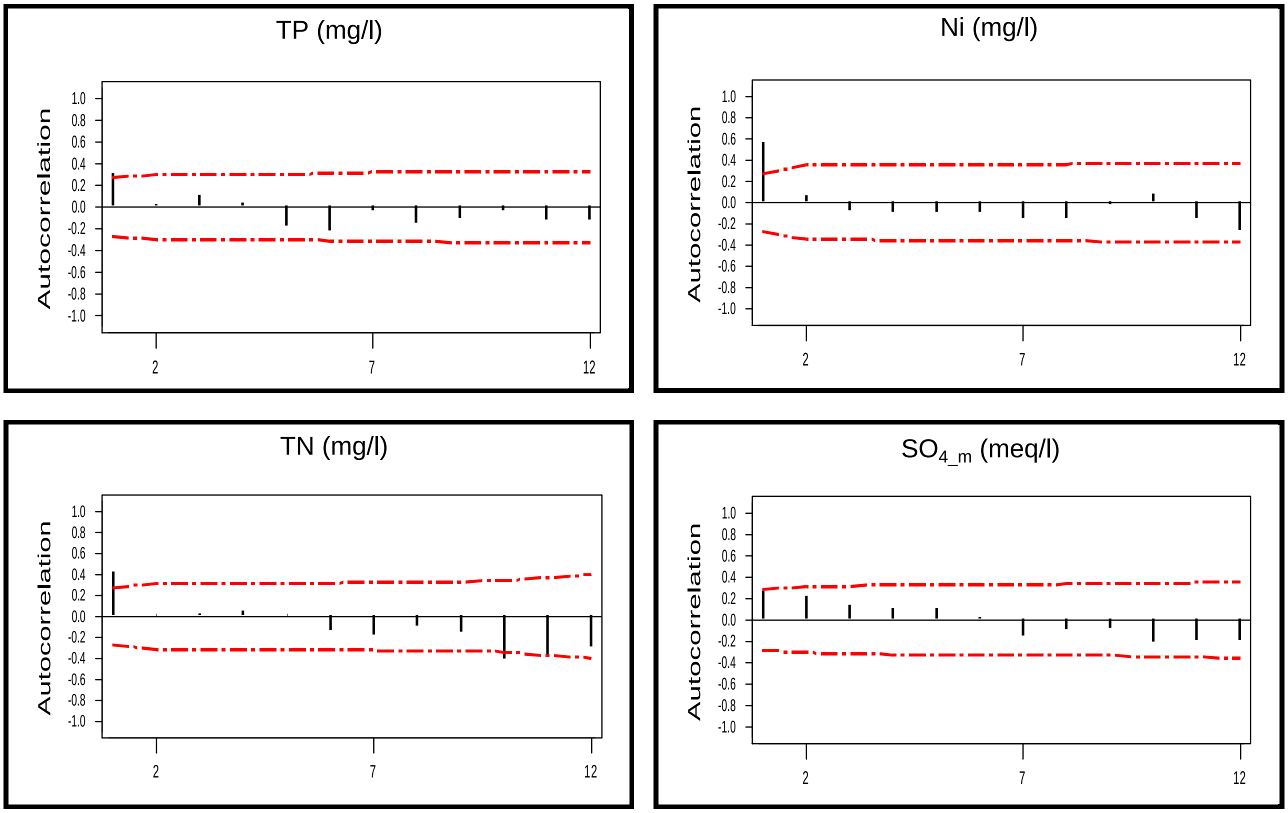
Sal



Fecal ((MPN/100 ml))



Annex 6-3A5: The Correlograms for de-trended and de-seasonalised WQ measurements for the monitoring site EH11



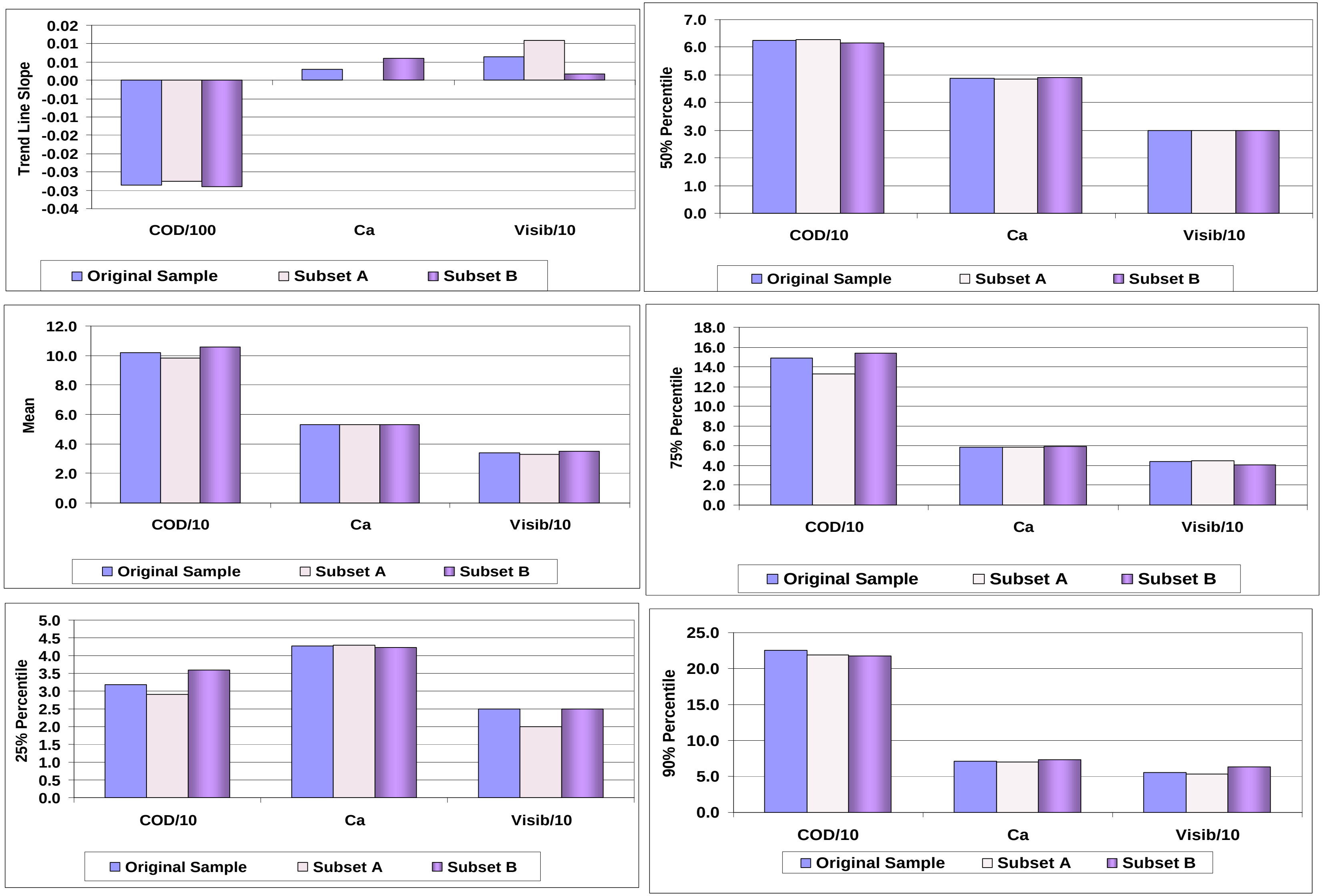
ANNEX 6- 4

PRE-SELECTED STATISTICS AND VISUAL ASSESSMENT FOR THE WQPs IN PARAMETER GROUP 1 (N* ≤ 4)

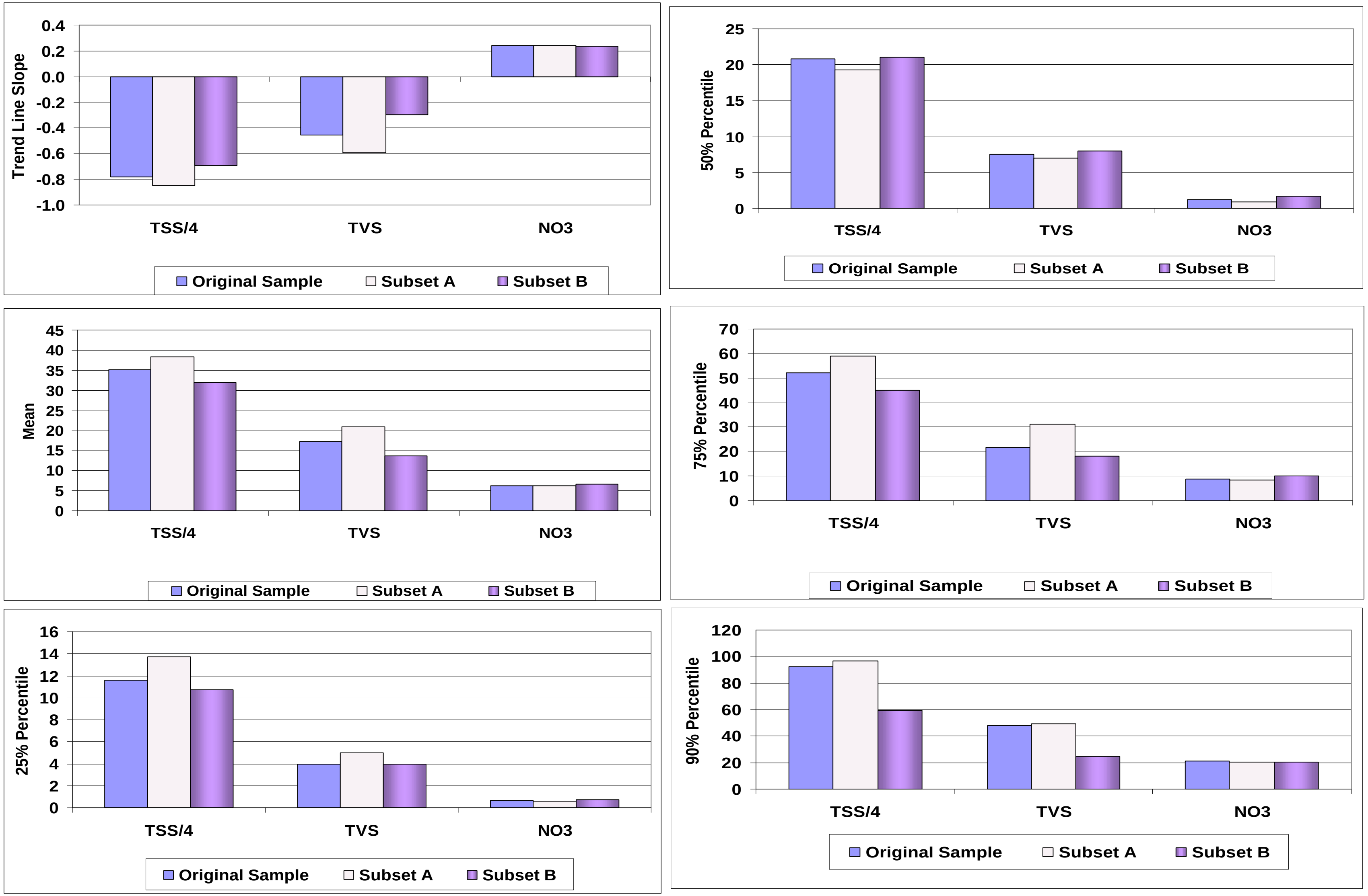
ANNEX 6-4A: PRE-SELECTED STATISTICS AND VISUAL ASSESSMENT FOR THE WQPs IN PARAMETER GROUP 1 (N* ≤ 4) ASSUMING SAMPLING FREQUENCY AS 6 SAMPLES PER YEAR

ANNEX 6-4B: PRE-SELECTED STATISTICS AND VISUAL ASSESSMENT FOR THE WQPs IN PARAMETER GROUP 1 (N* ≤ 4) ASSUMING SAMPLING FREQUENCY AS 4 SAMPLES PER YEAR

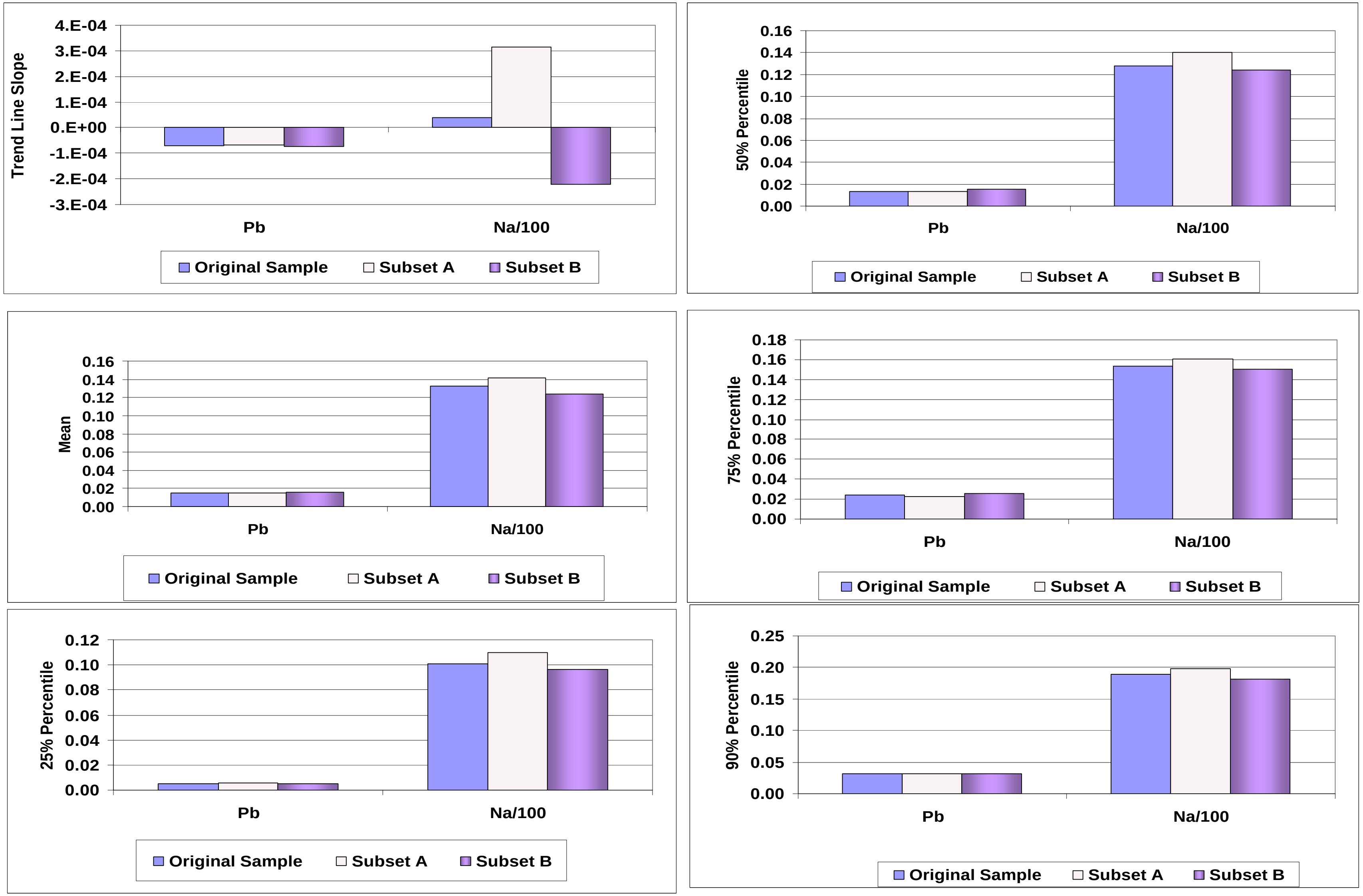
Annex 6-4A1: Pre-selected statistics for the WQPs in parameter group 1 (n* ≤ 4) assuming sampling frequency as 6 samples per year



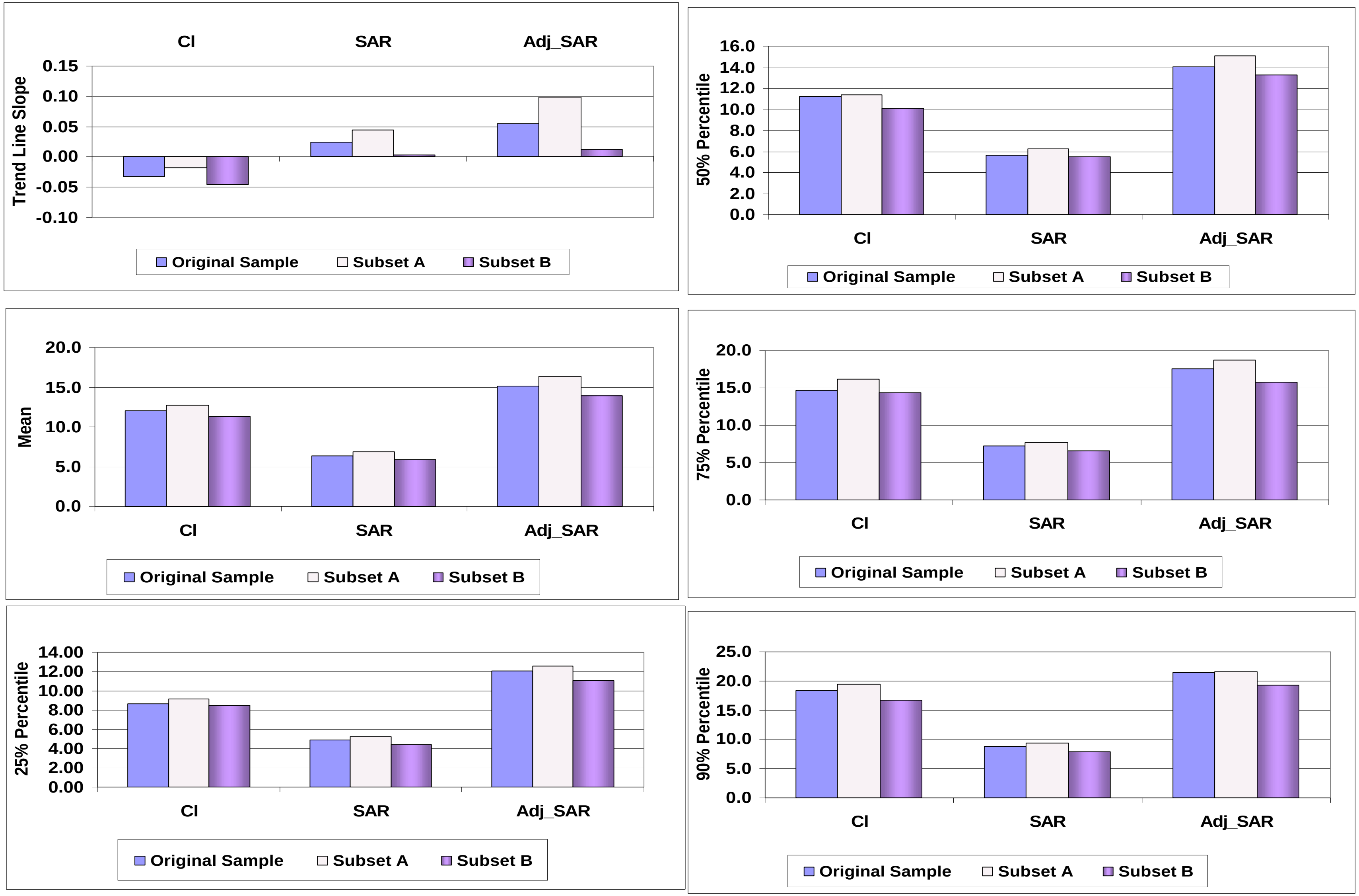
Annex 6-4A2: Pre-selected statistics for the WQPs in parameter group 1 (n* ≤ 4) assuming sampling frequency as 6 samples per year



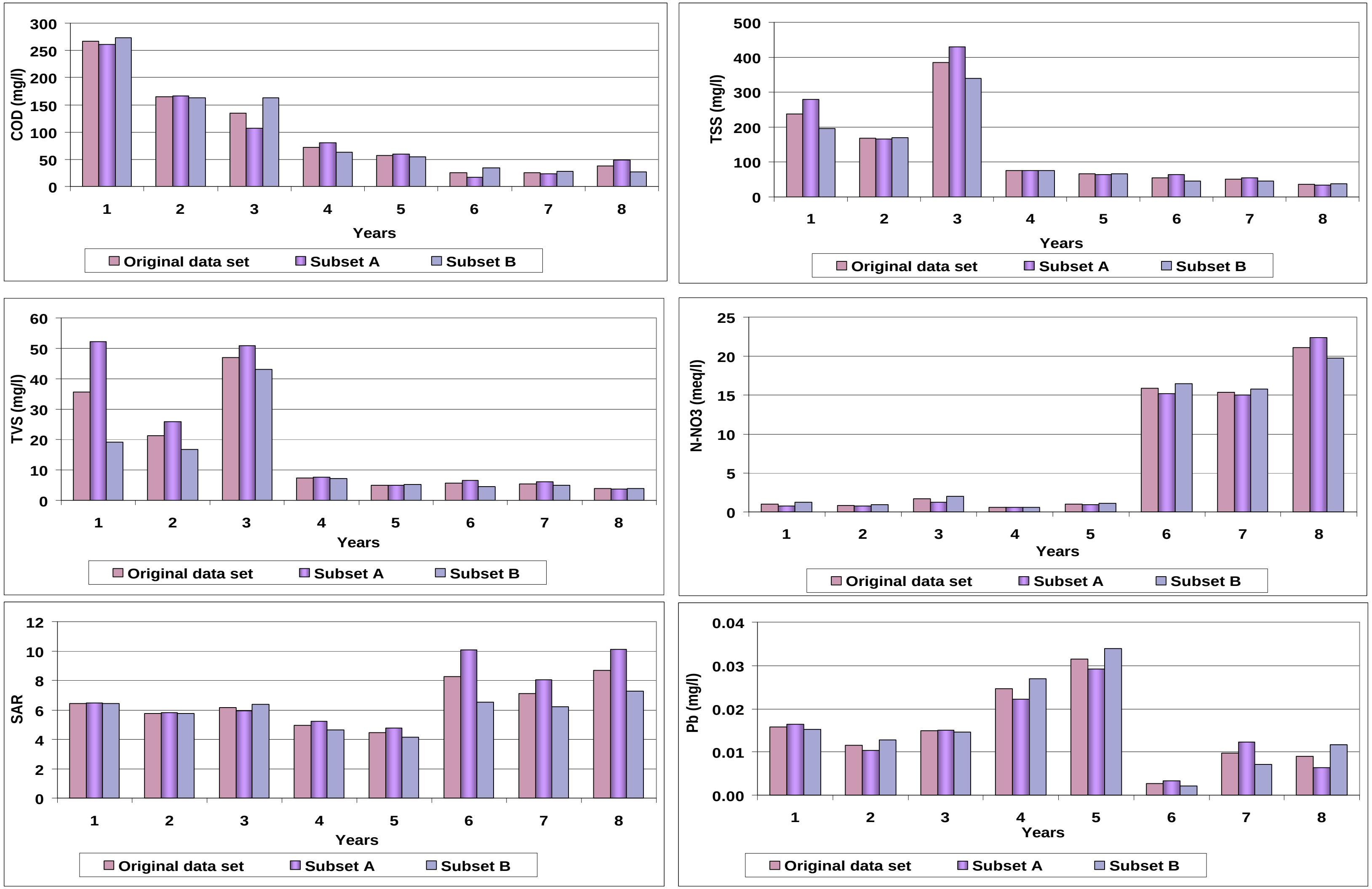
Annex 6-4A3: Pre-selected statistics for the WQPs in parameter group 1 (n* ≤ 4) assuming sampling frequency as 6 samples per year



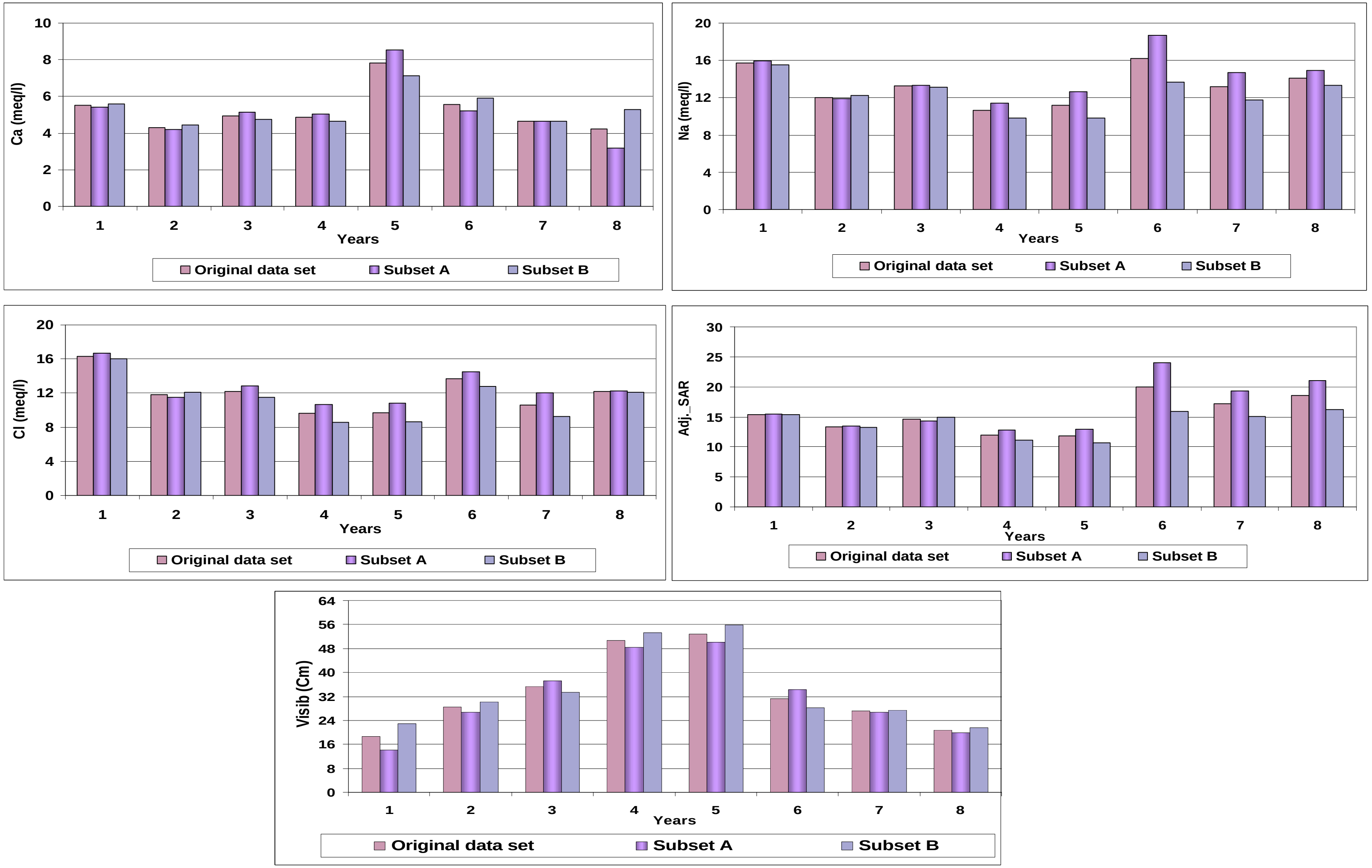
Annex 6-4A4: Pre-selected statistics for the WQPs in parameter group 1 (n* ≤ 4) assuming sampling frequency as 6 samples per year



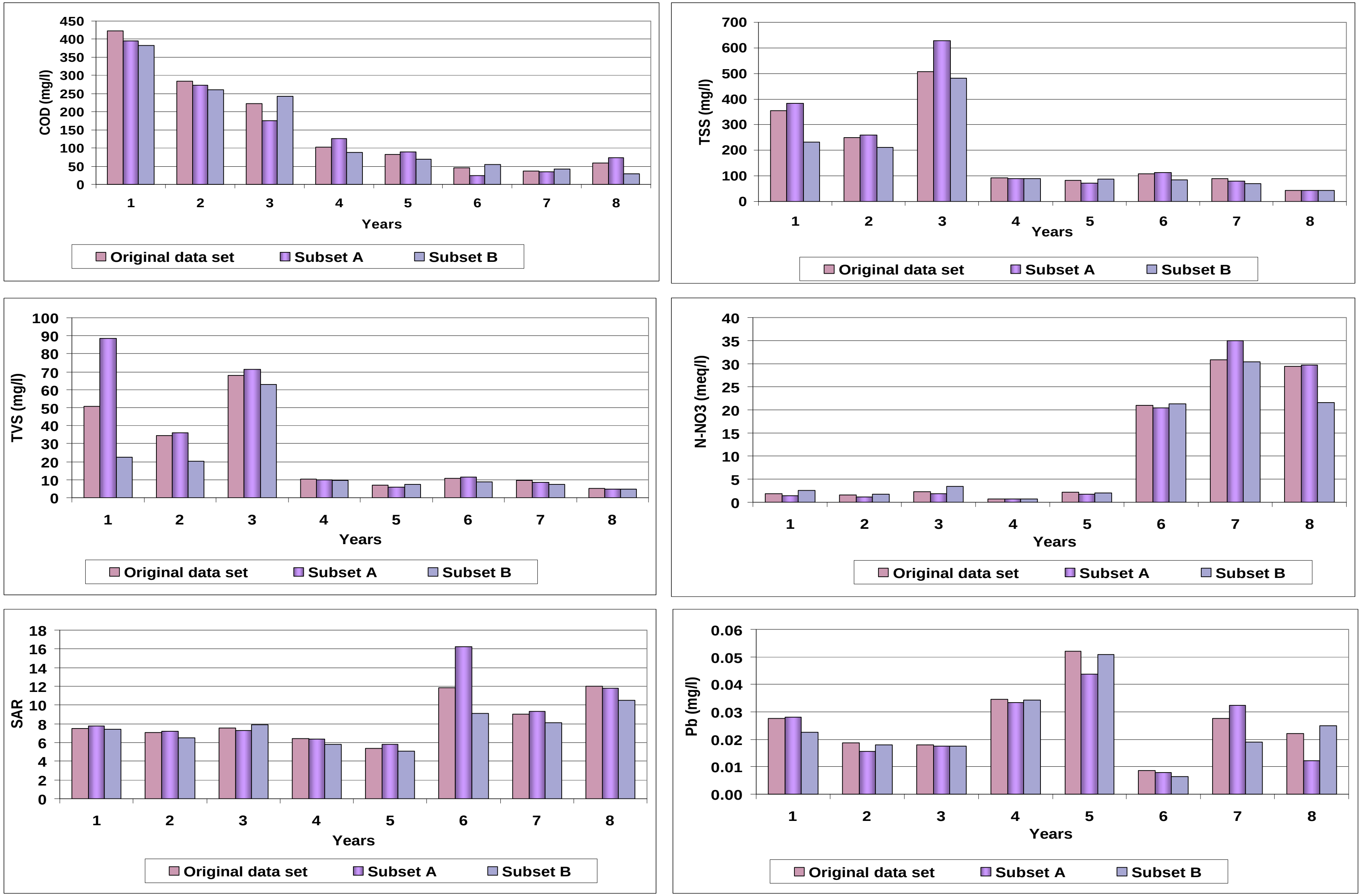
Annex 6-4A5: Yearly averages for the WQPs in parameter group 1 (n* $\leq$ 4) assuming sampling frequency as 6 samples per year.



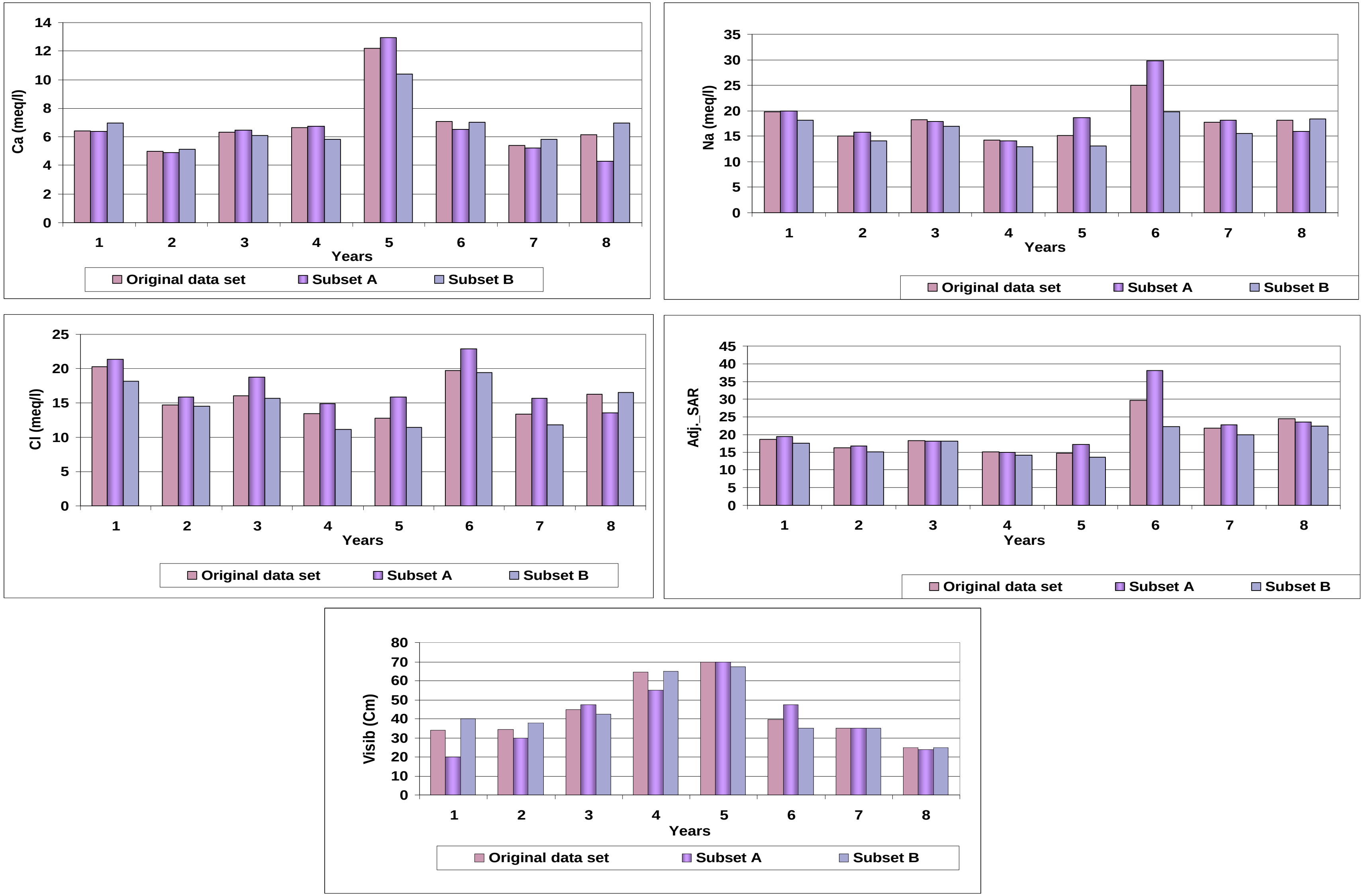
Annex 6-4A6: Yearly averages for the WQPs in parameter group 1 (n* ≤ 4) assuming sampling frequency as 6 samples per year.



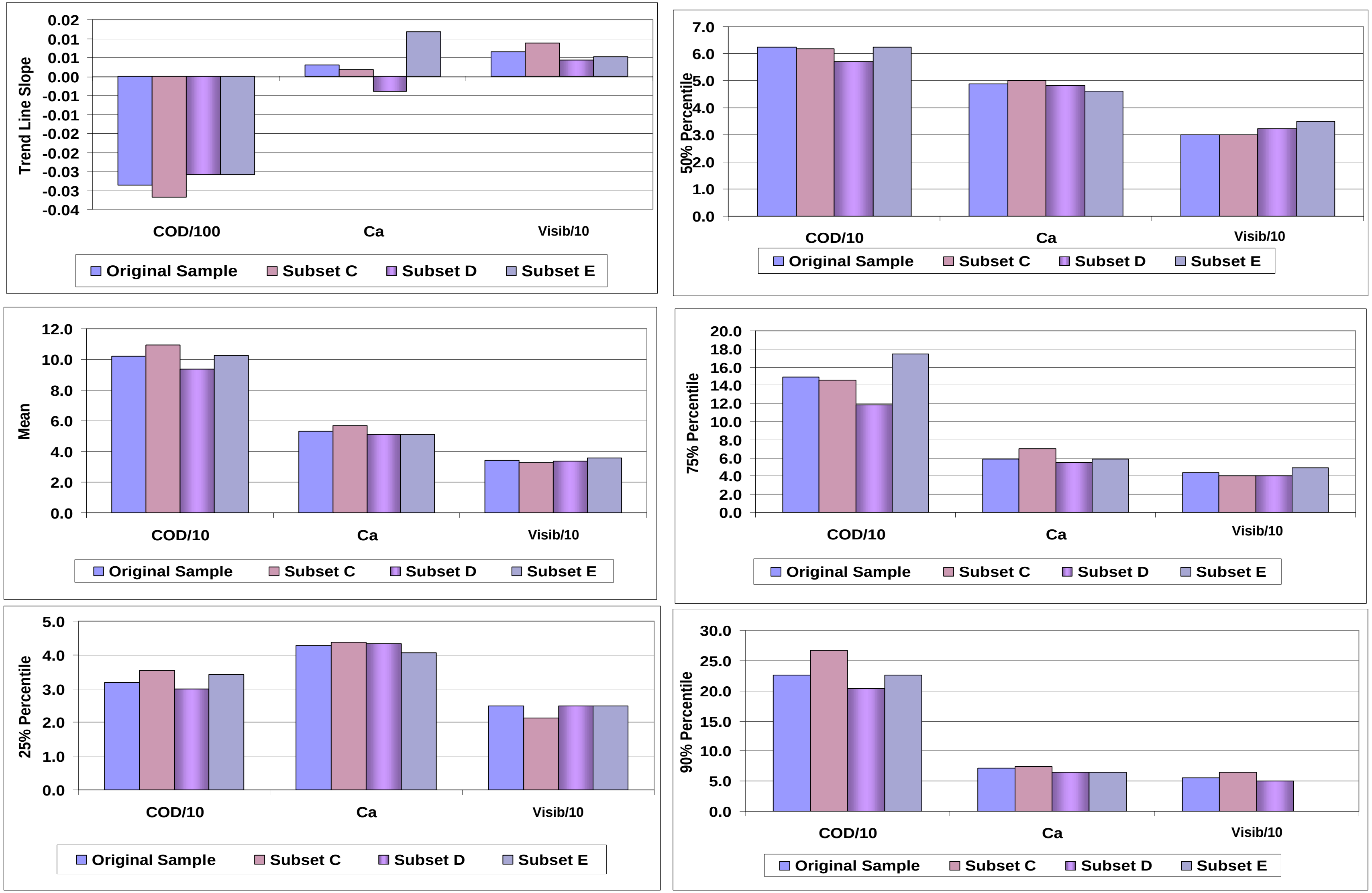
Annex 6-4A7: 90% Yearly percentiles for the WQPs in parameter group 1 (n* ≤ 4) assuming sampling frequency as 6 samples per year.



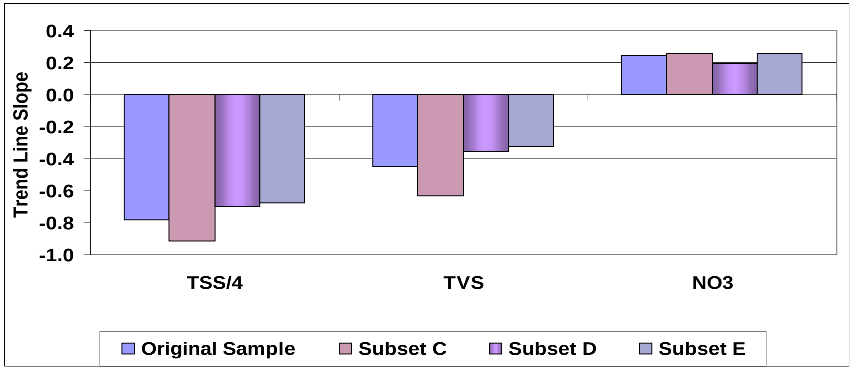
Annex 6-4A8: 90% Yearly percentiles for the WQPs in parameter group 1 (n* ≤ 4) assuming sampling frequency as 6 samples per year.

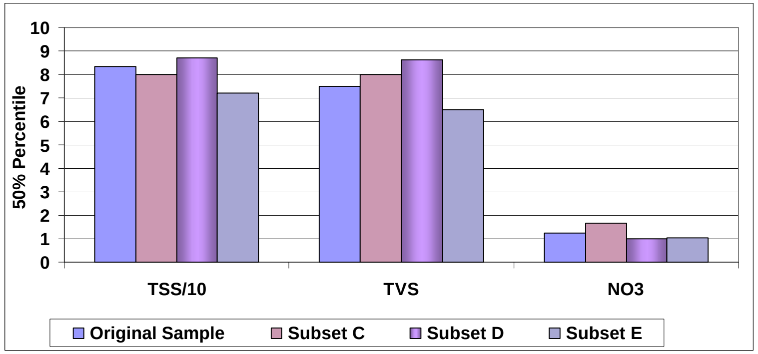


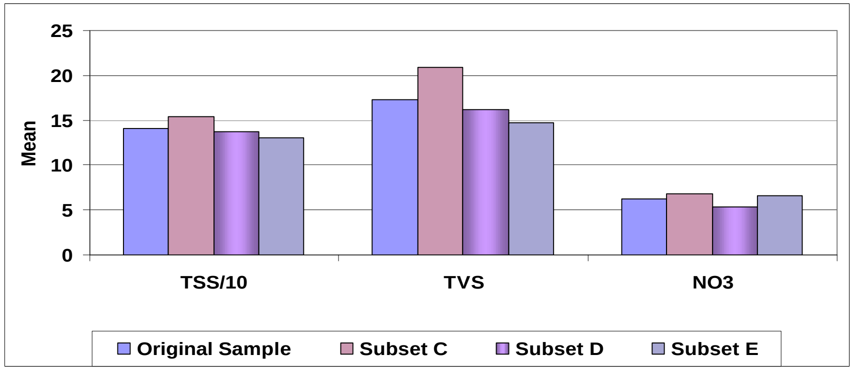
Annex 7-4B1: Pre-selected statistics for the WQPs in parameter group 1 (n* < 4) assuming sampling frequency as 4 samples per year.

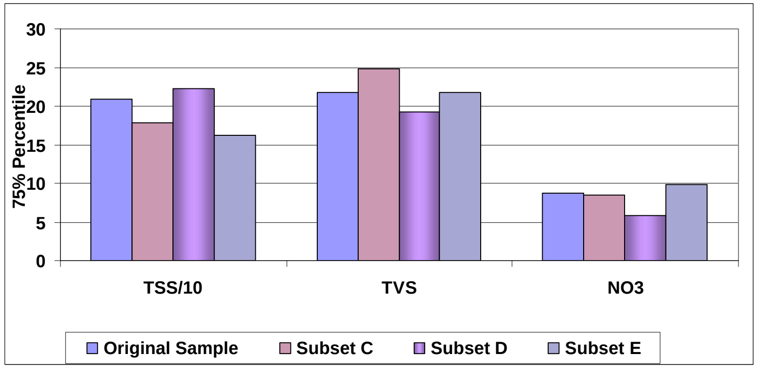


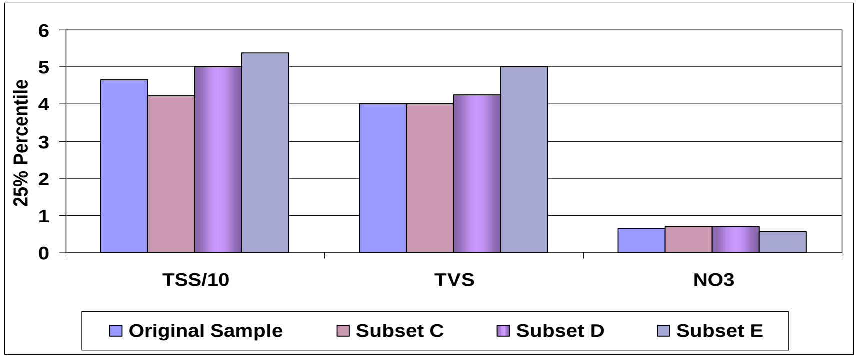
Annex 6-4B2: Pre-selected statistics for the WQPs in parameter group 1 (n* ≤ 4) assuming sampling frequency as 4 samples per year.

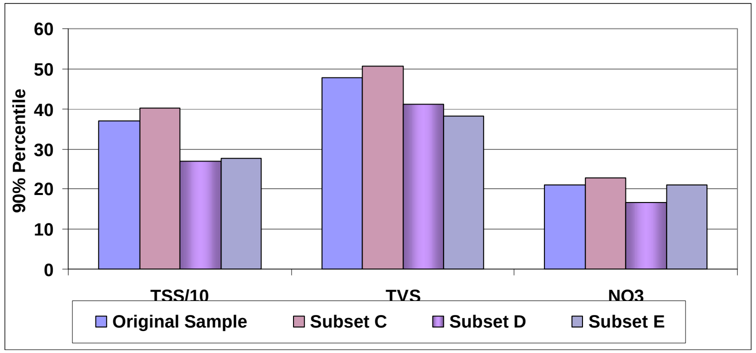




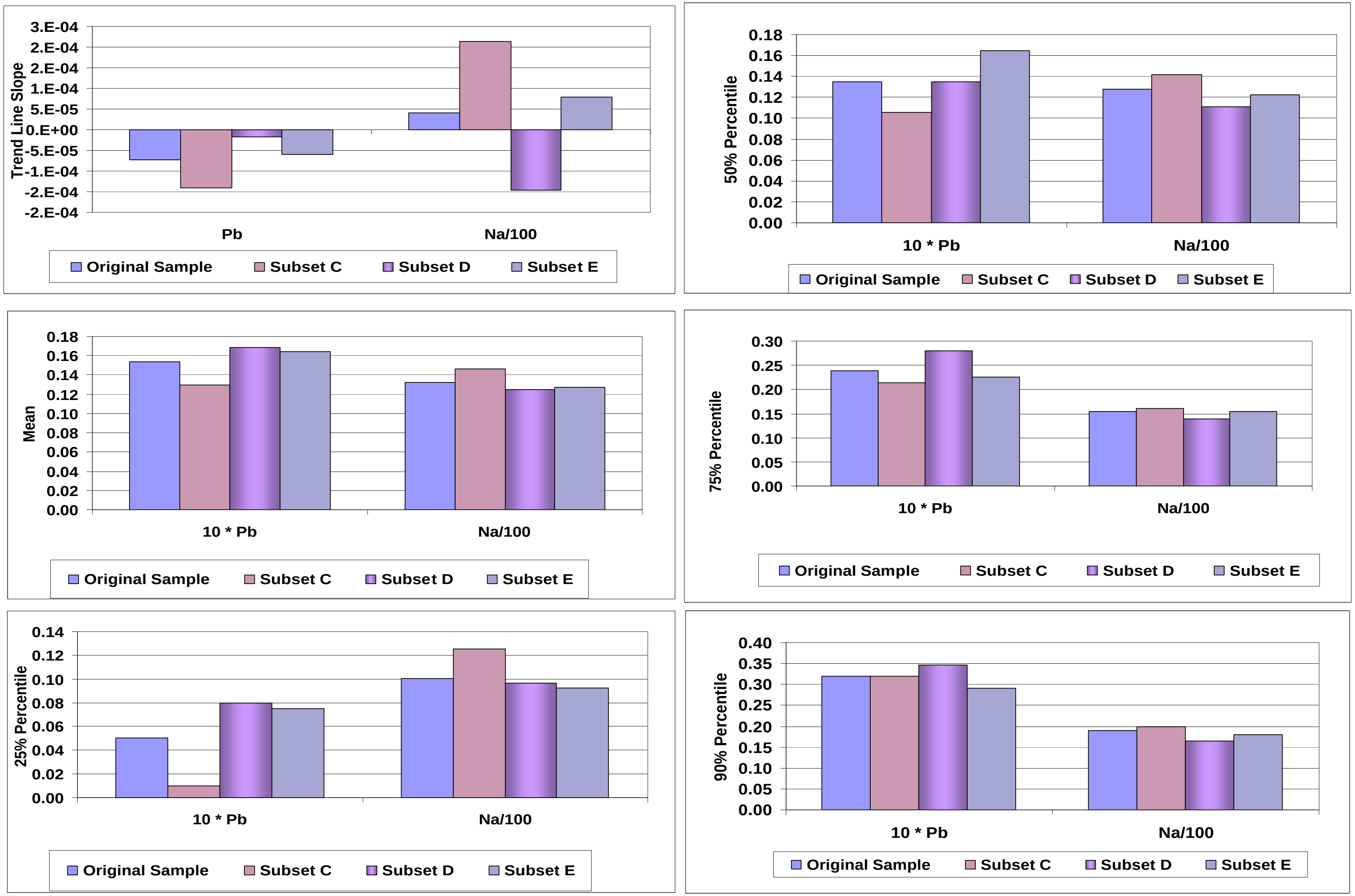




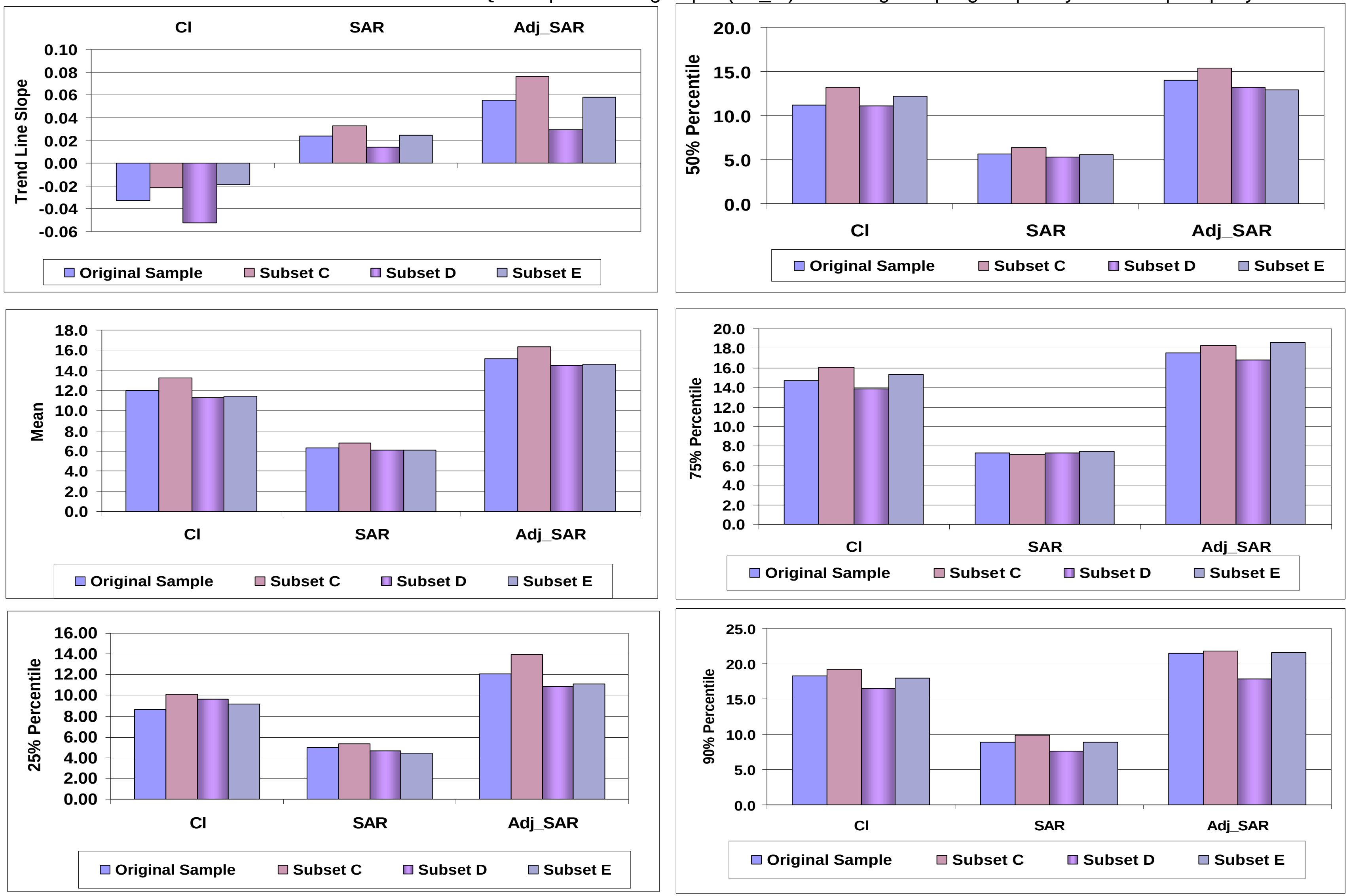




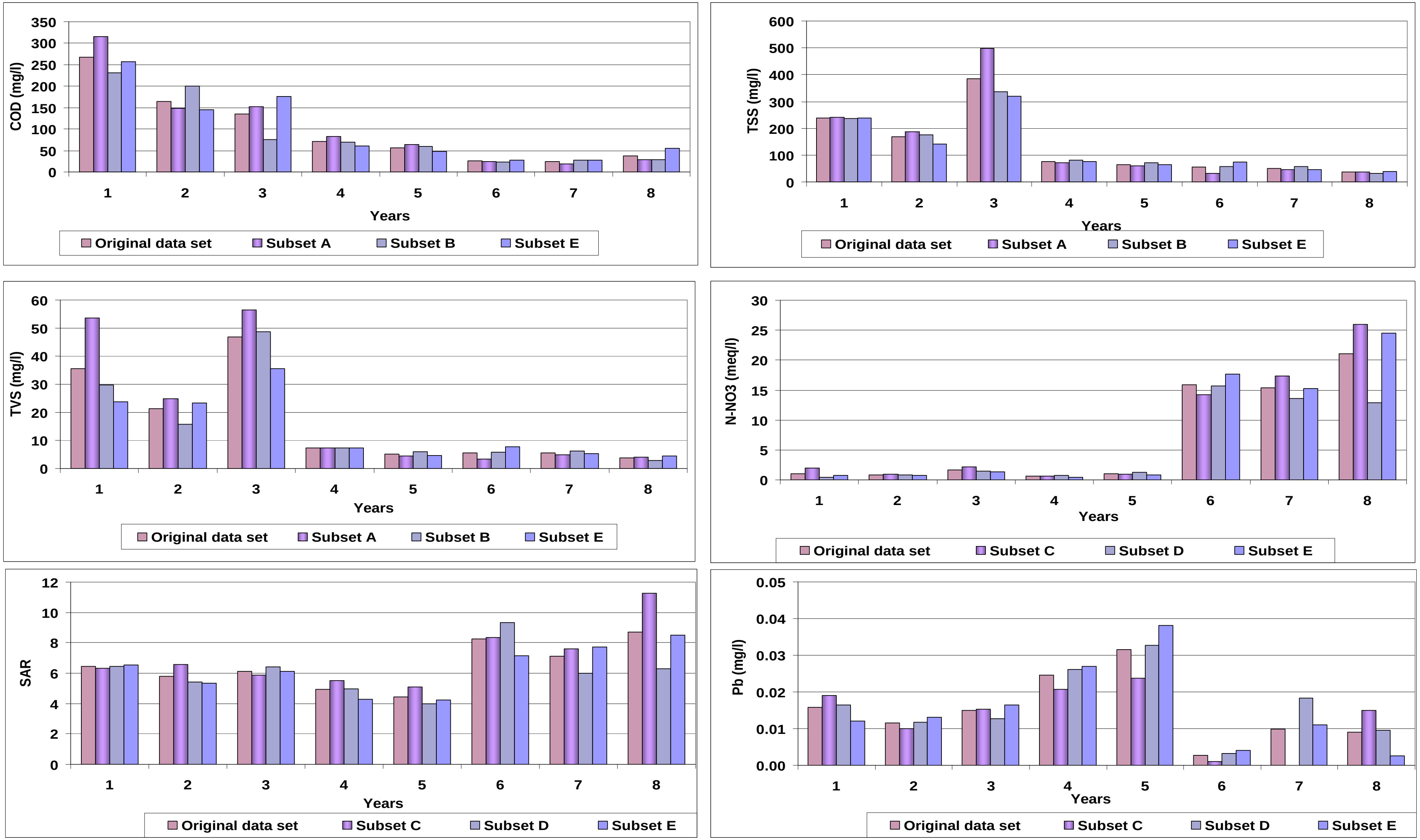
Annex 6-4B3: Pre-selected statistics for the WQPs in parameter group 1 (n* ≤ 4) assuming sampling frequency as 4 samples per year.



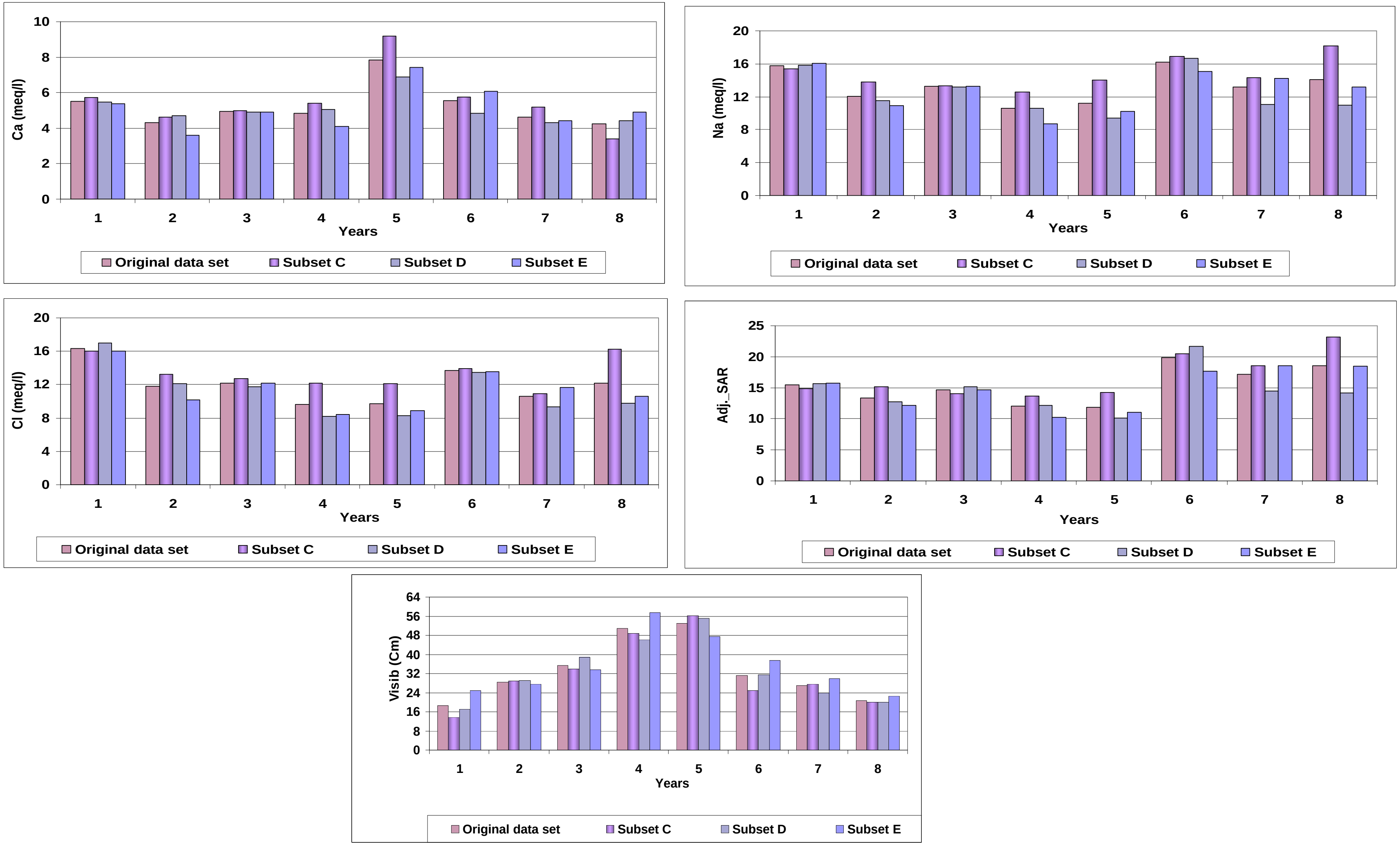
Annex 6-4B4: Pre-selected statistics for the WQPs in parameter group 1 (n* < 4) assuming sampling frequency as 4 samples per year.



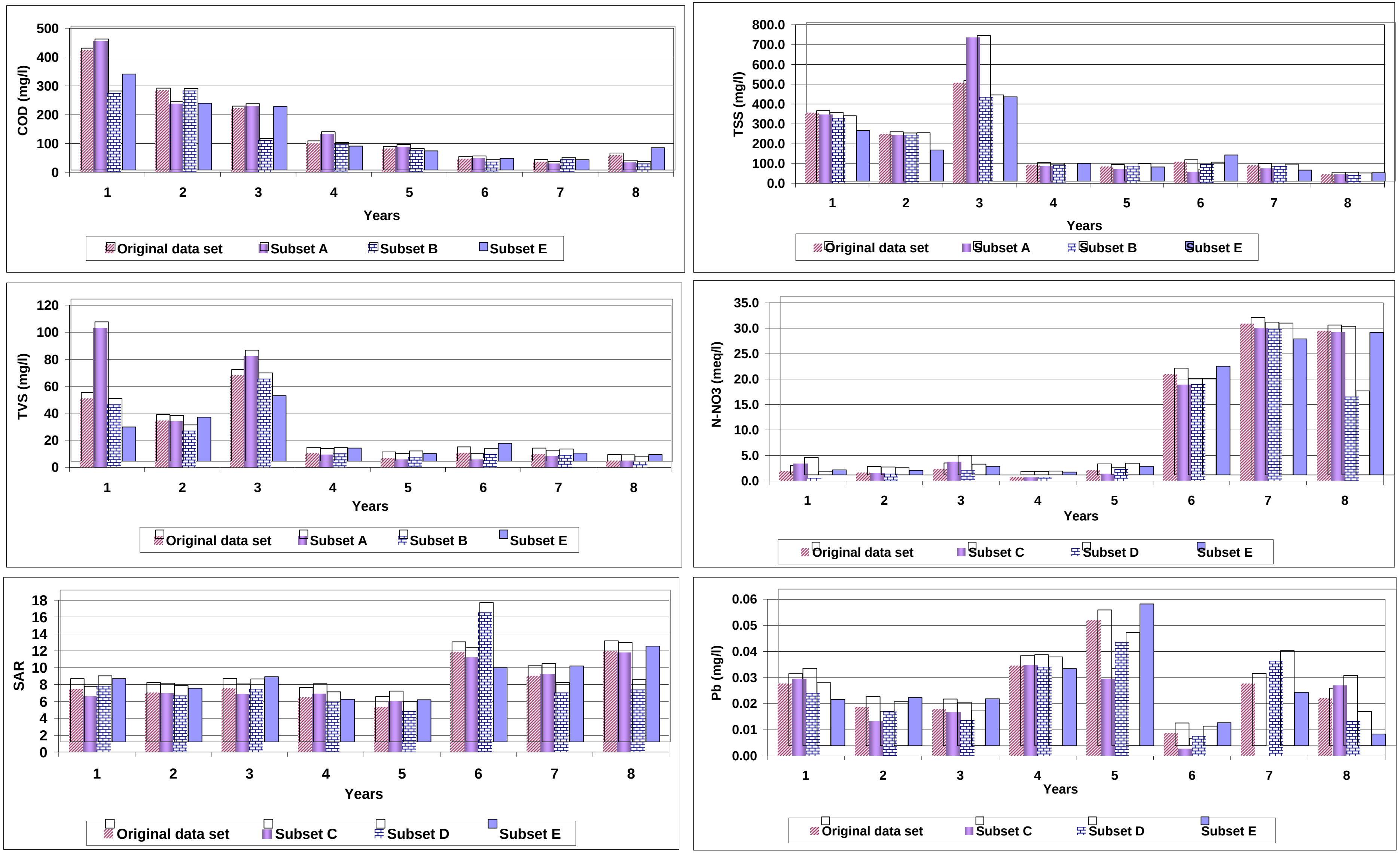
Annex 6-4B5: Yearly averages for the WQPs in parameter group 1 (n* ≤ 4) assuming sampling frequency as 4 samples per year



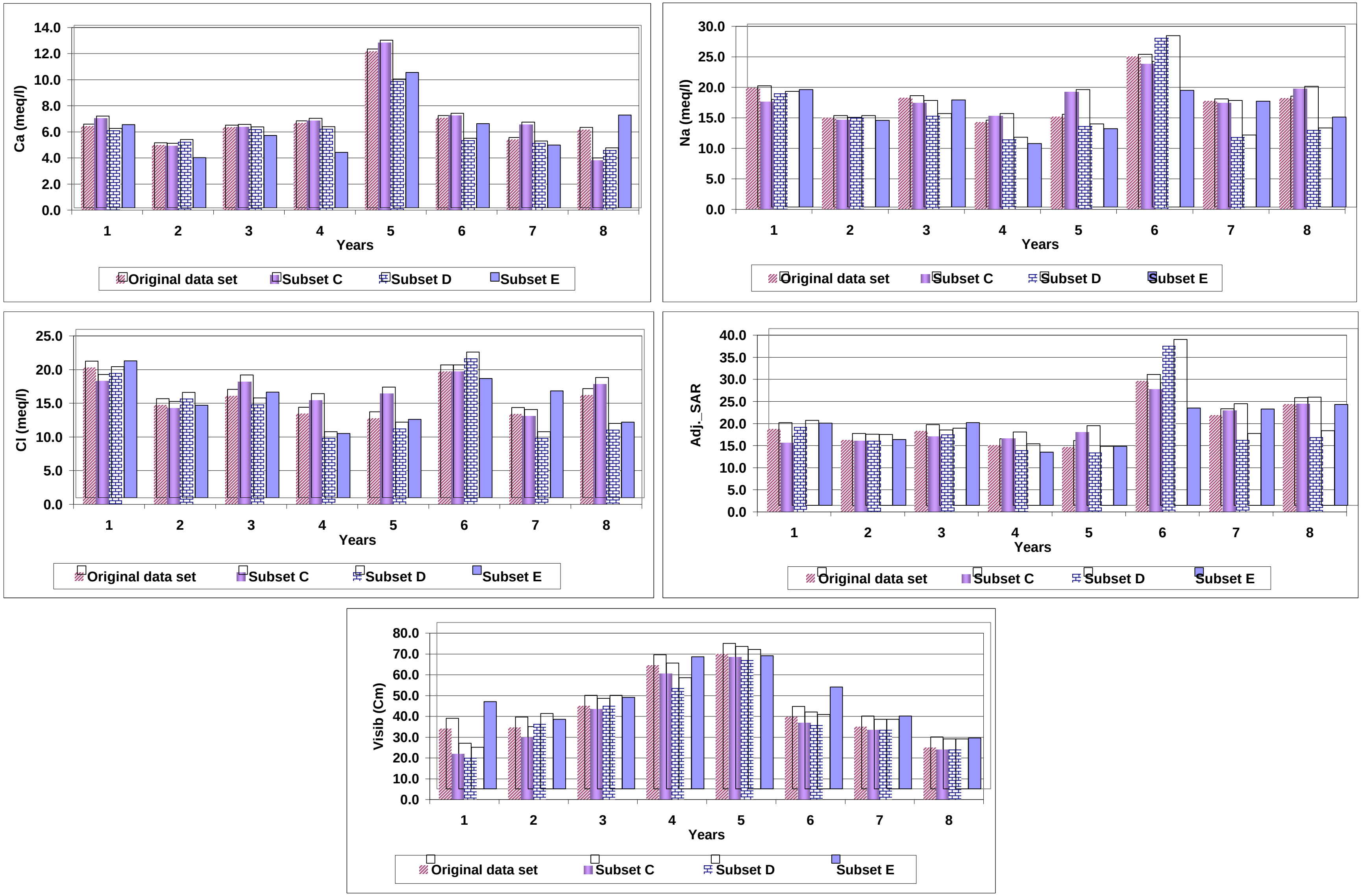
Annex 6-4B6: Yearly averages for the WQPs in parameter group 1 (n* ≤ 4) assuming sampling frequency as 4 samples per year



Annex 6-4B7: Yearly averages for the WQPs in parameter group 1 (n* ≤ 4) assuming sampling frequency as 4 samples per year



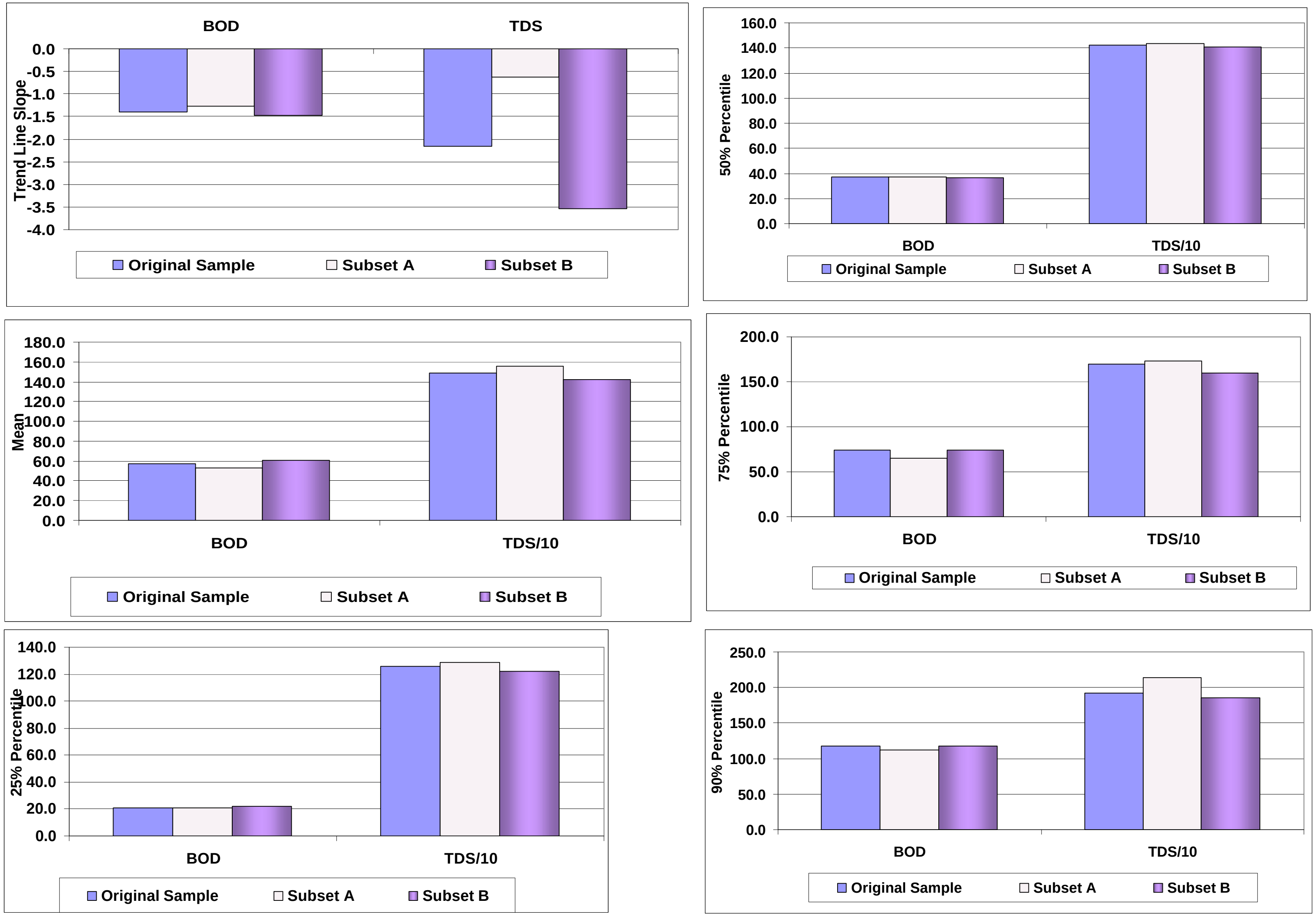
Annex 6-4B8: Yearly averages for the WQPs in parameter group 1 (n* ≤ 4) assuming sampling frequency as 4 samples per year.



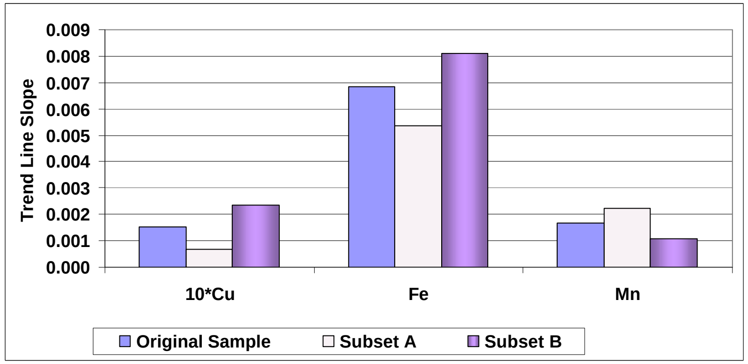
ANNEX 6-5

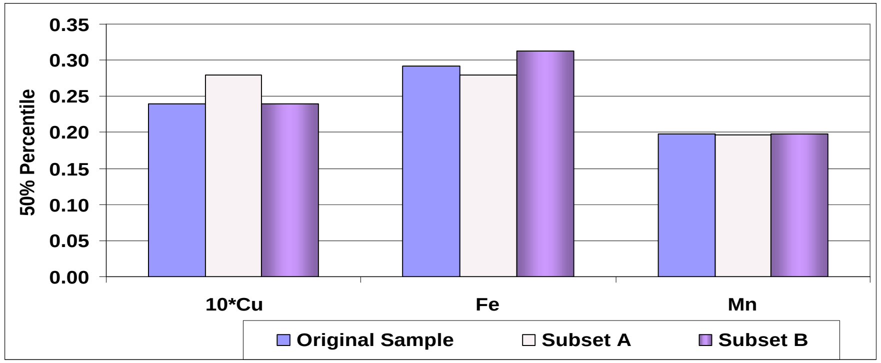
PRE-SELECTED STATISTICS AND VISUAL ASSESSMENT FOR THE WQPs IN PARAMETER GROUP 2 (4 < N* ≤ 6) ASSUMING SAMPLING FREQUENCY AS 6 SAMPLES PER YEAR

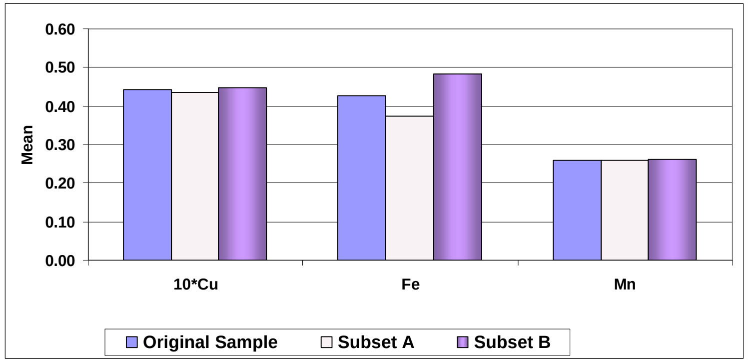
Annex 6-5A1: Pre-selected statistics for the WQPs in parameter group 2 (4 > n* ≤ 6) assuming sampling frequency as 6 samples per year

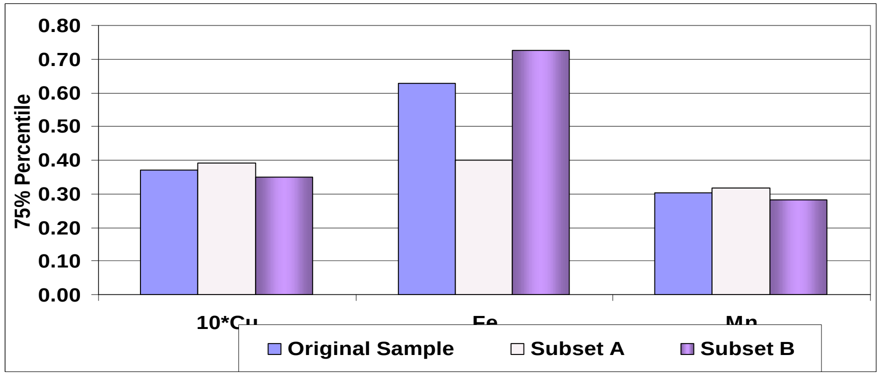


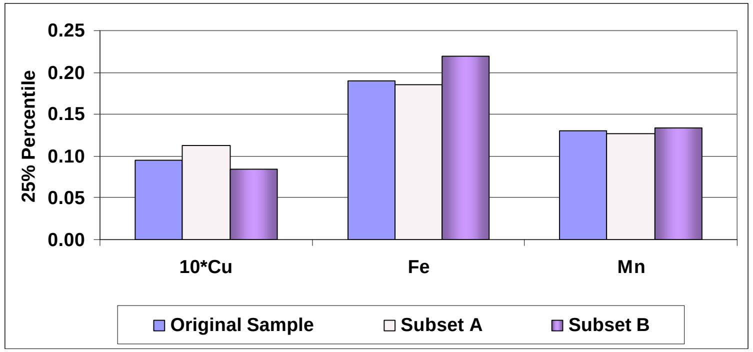
Annex 6-5A2: Pre-selected statistics for the WQPs in parameter group 2 ($4 > n^* \leq 6$) assuming sampling frequency as 6 samples per year

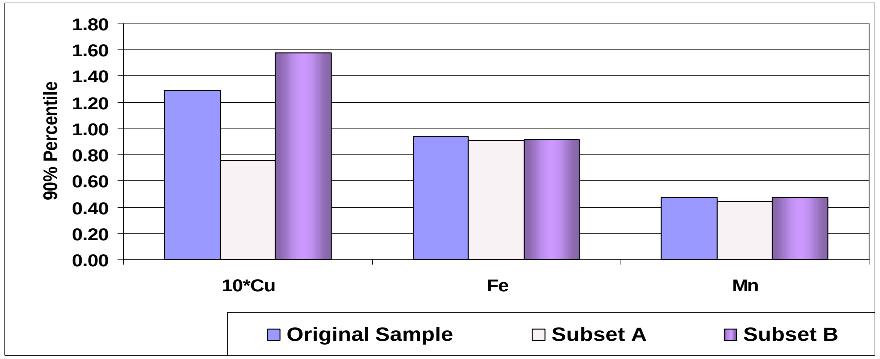




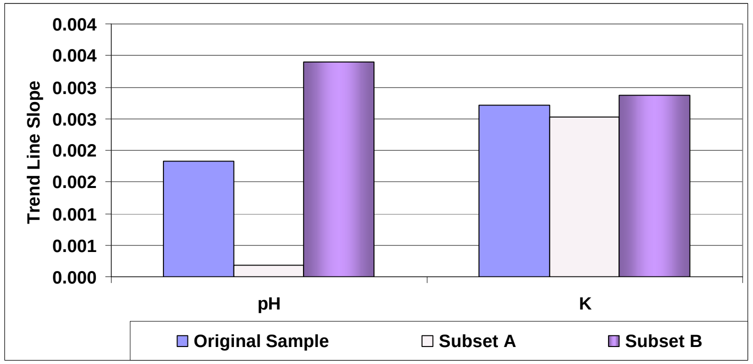


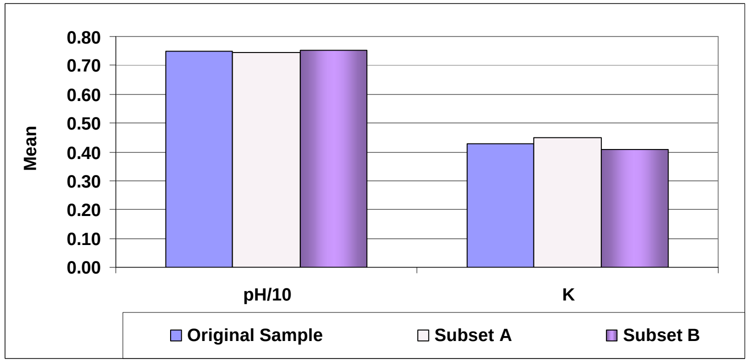


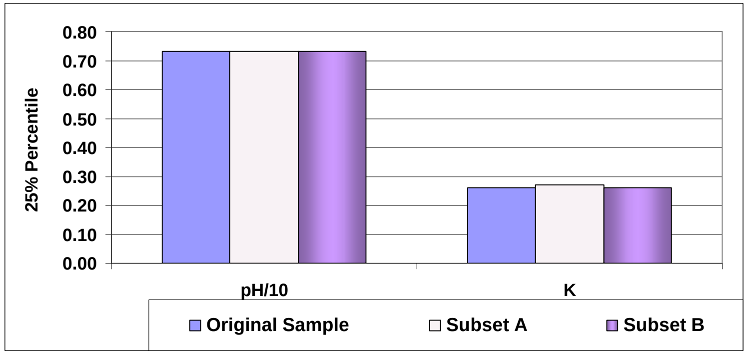


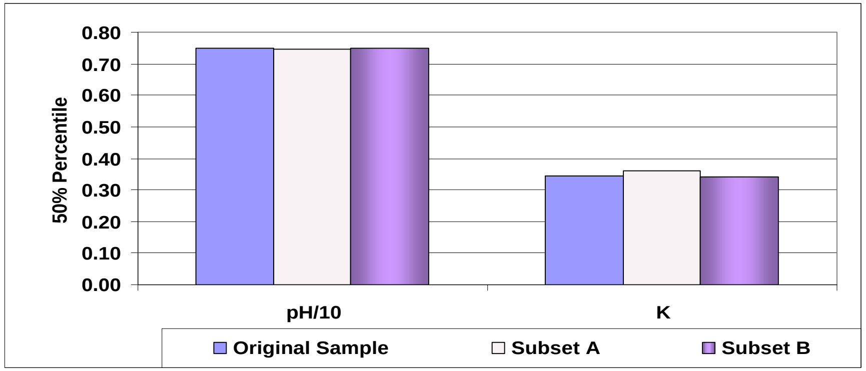


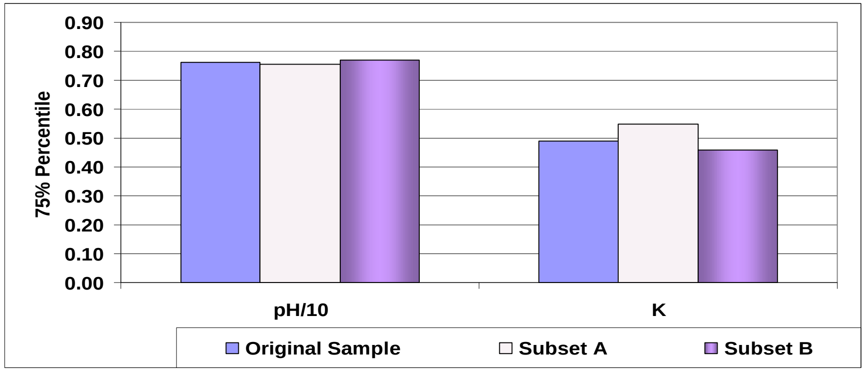
Annex 6-5A3: Pre-selected statistics for the WQPs in parameter group 2 (4 > n* ≤ 6) assuming sampling frequency as 6 samples per year.

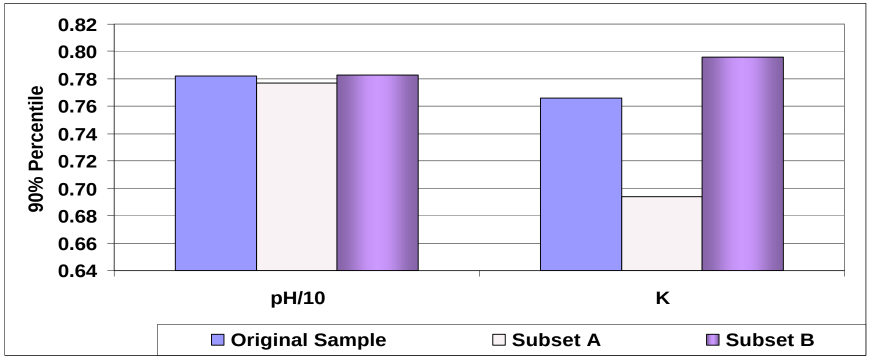




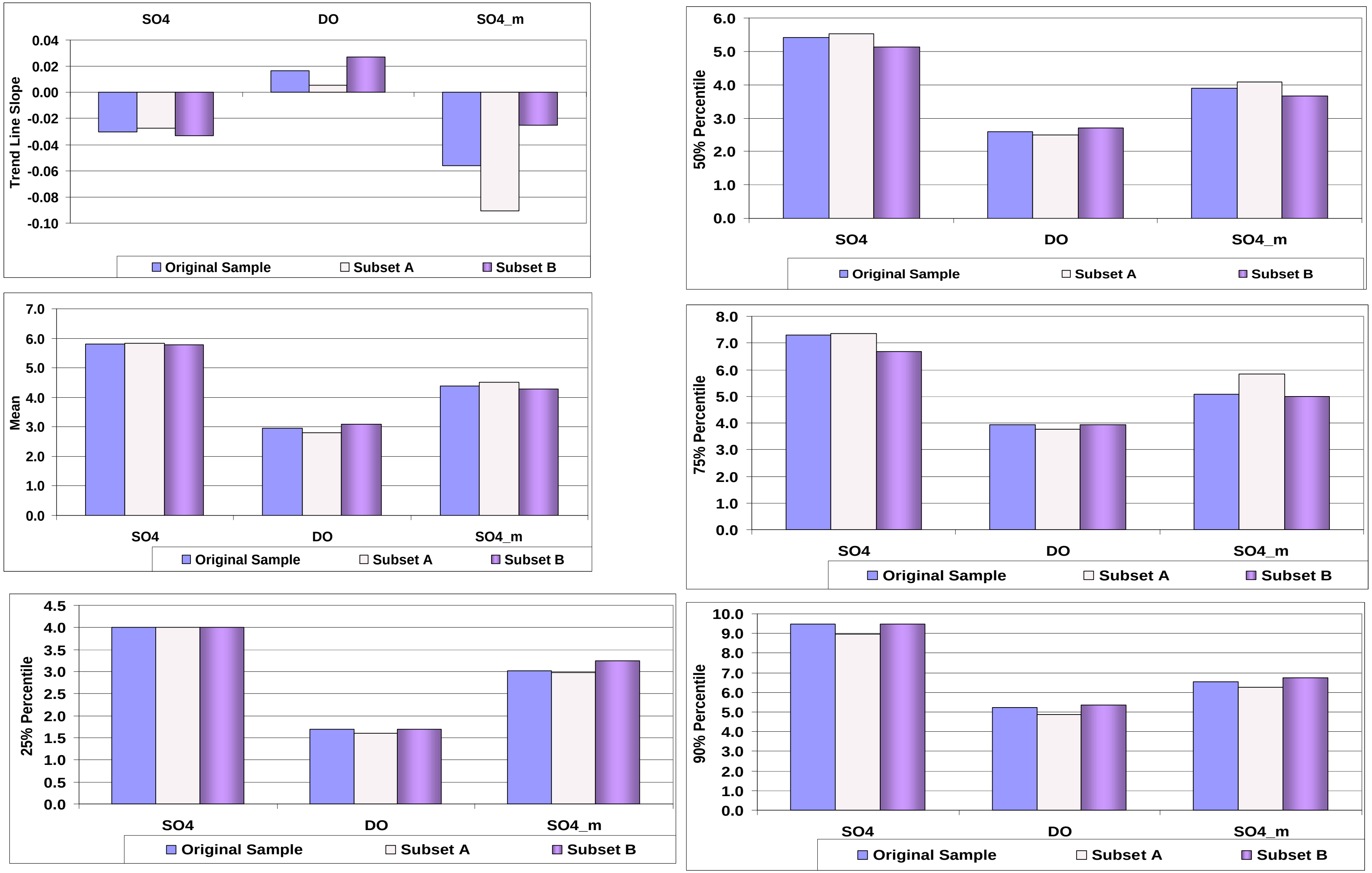




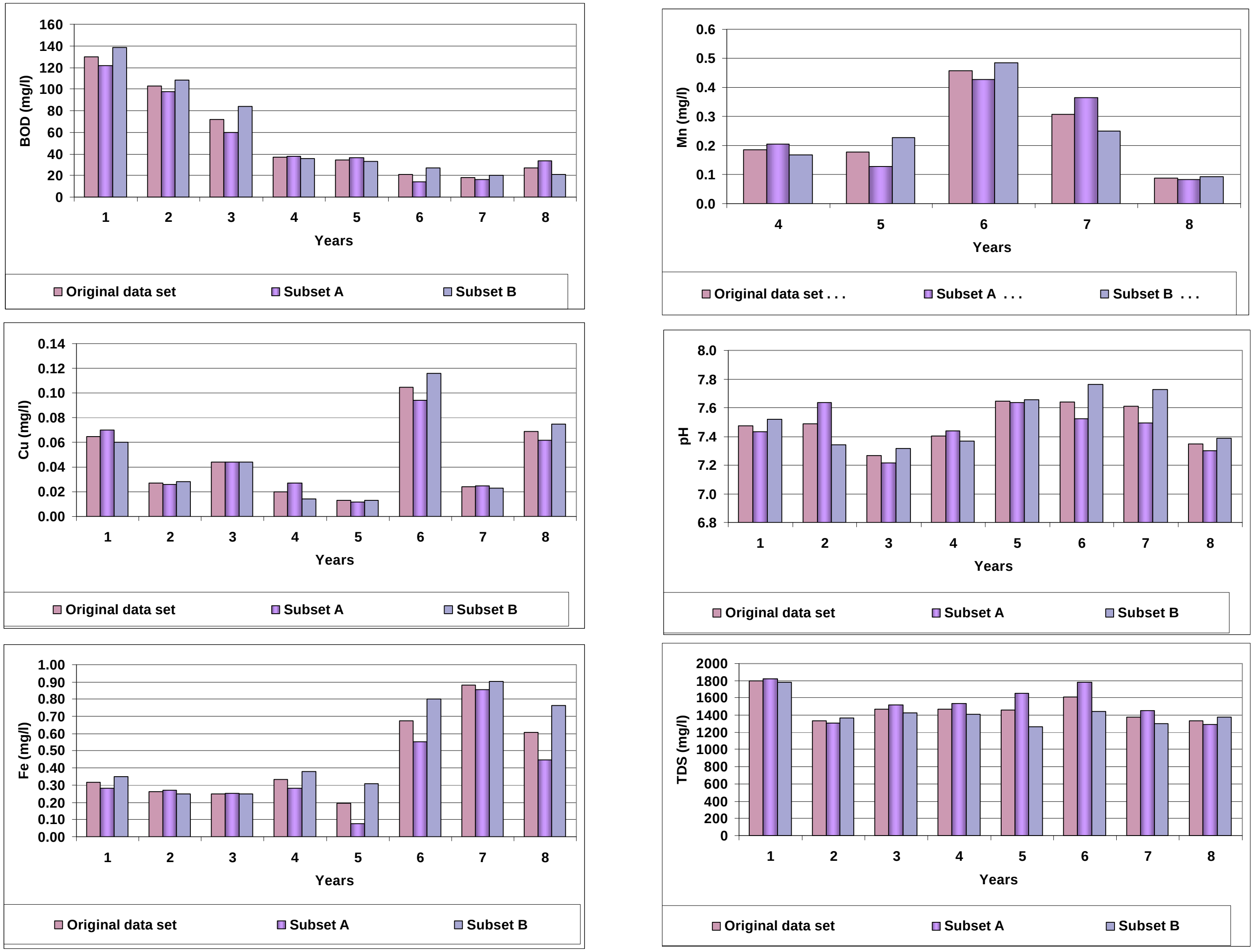




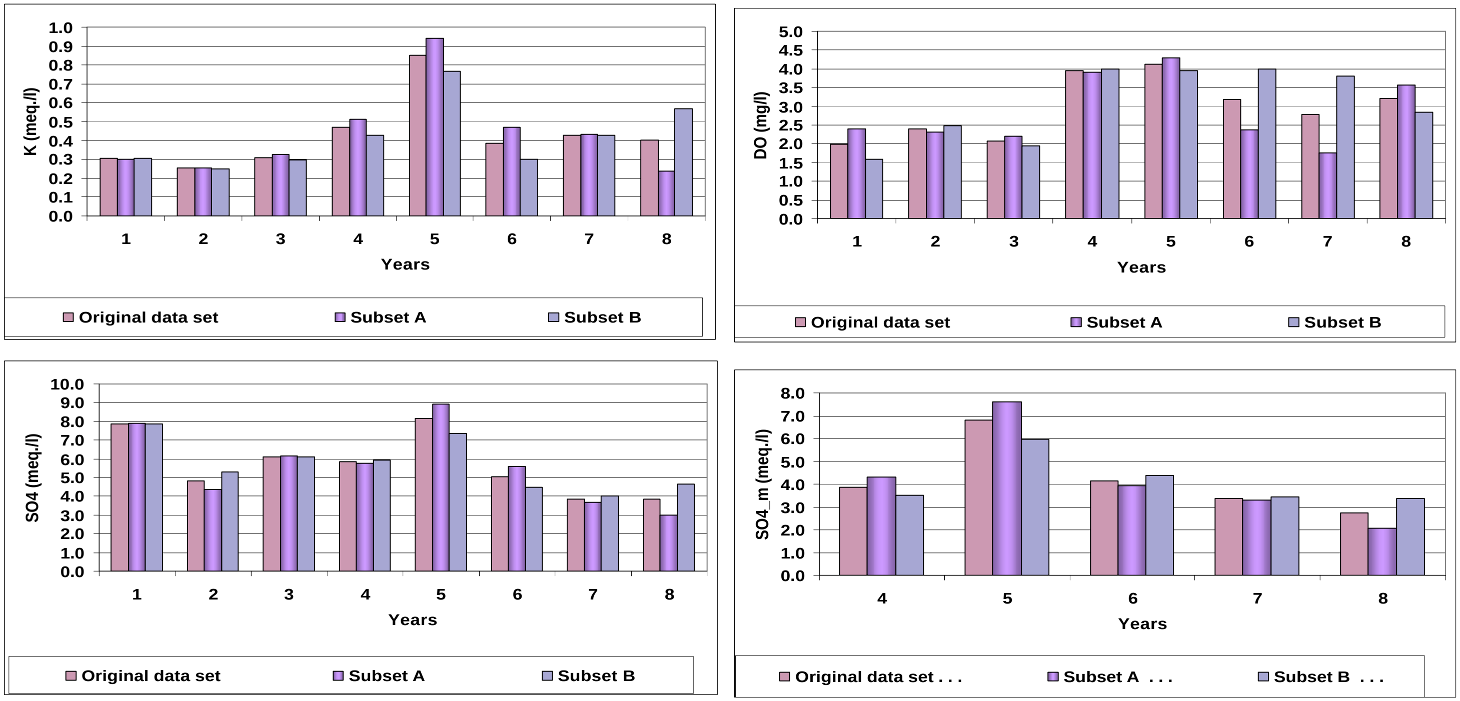
Annex 6-5A4: Pre-selected statistics for the WQPs in parameter group 2 (4 > n* ≤ 6) assuming sampling frequency as 6 samples per year



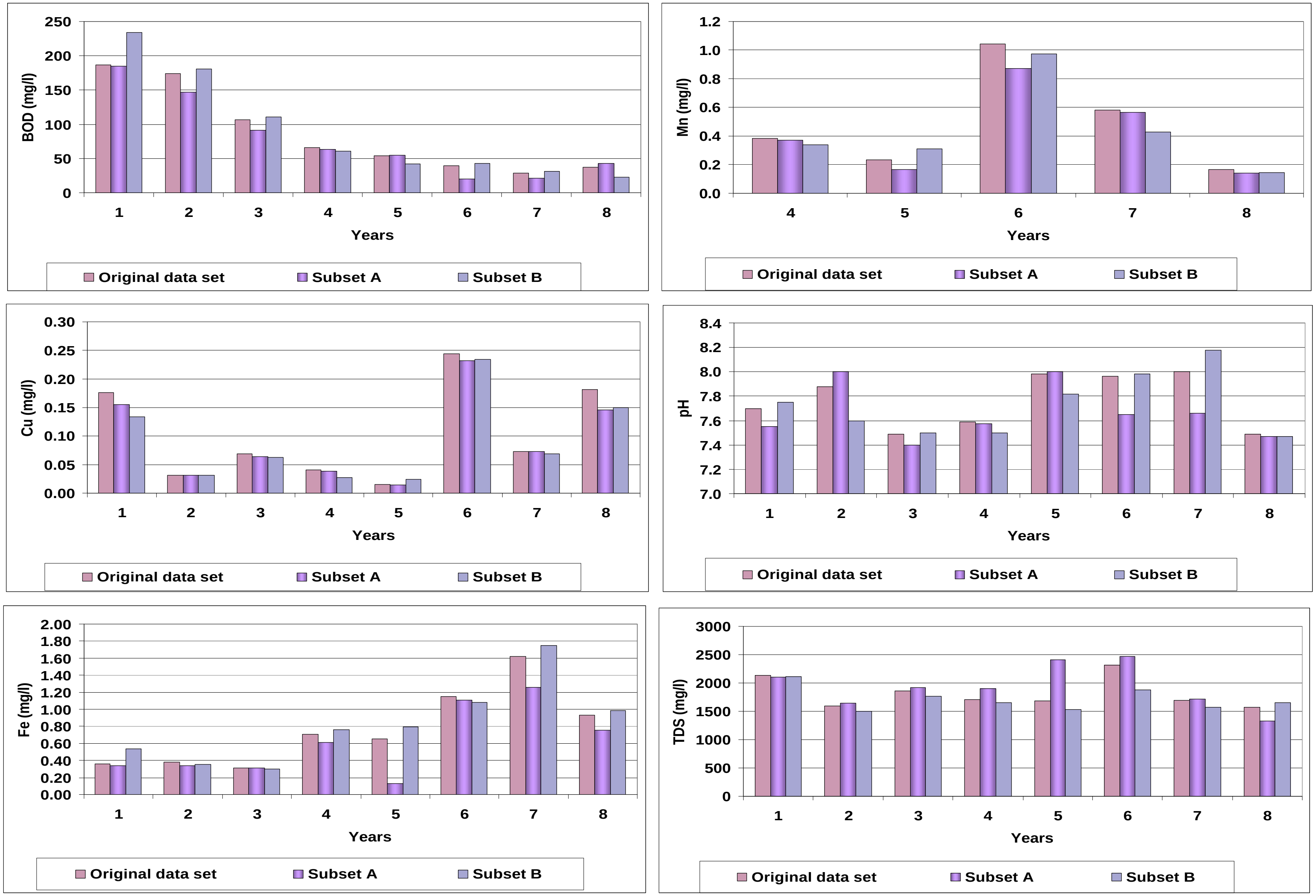
Annex 6-5A5: Yearly averages for the WQPs in parameter group 2 (4 > n* ≤ 6) assuming sampling frequency as 6 samples per year



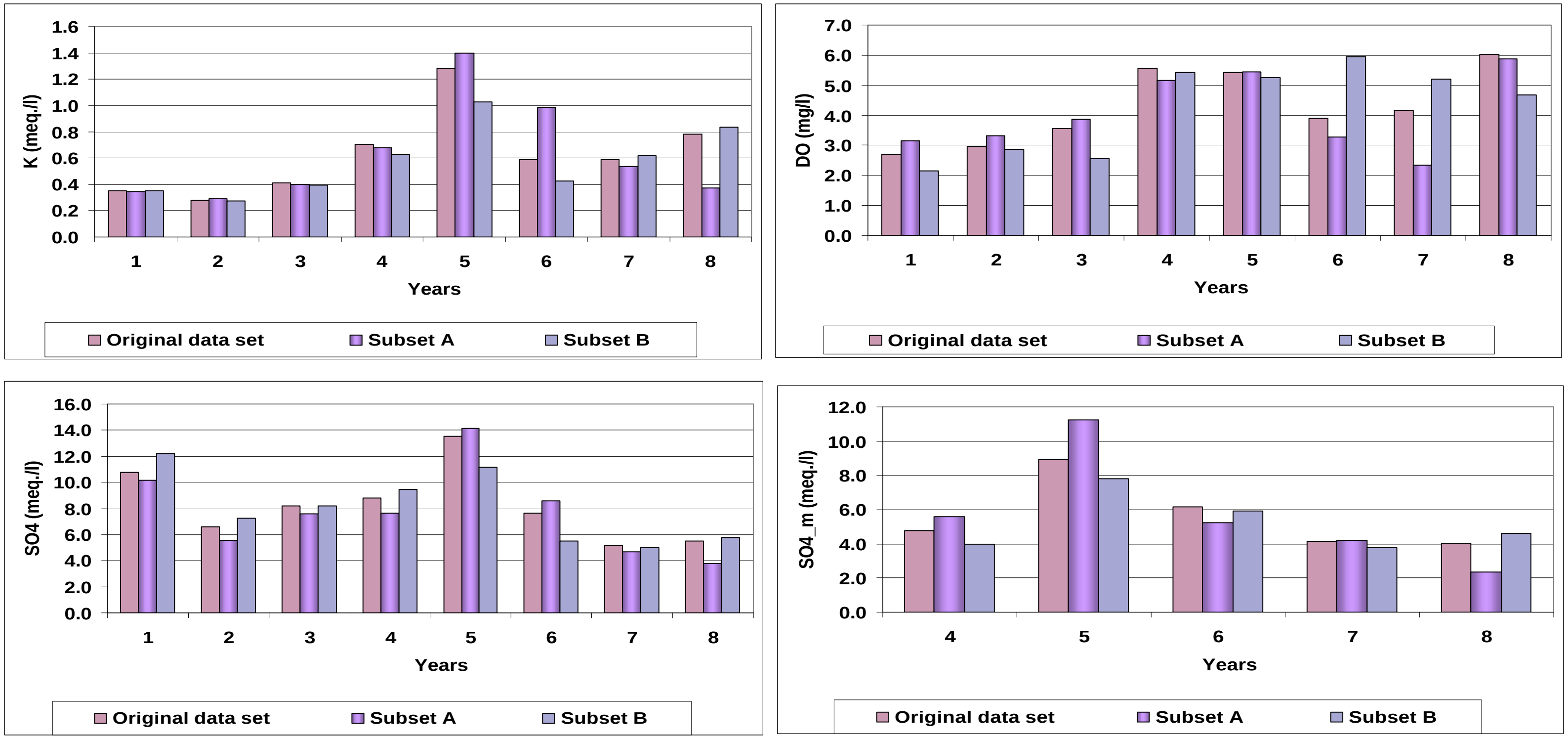
Annex 6-5A6: Yearly averages for the WQPs in parameter group 2 (4 > n* ≤ 6) assuming sampling frequency as 6 samples per year



Annex 6-5A7: 90 %Yearly percentiles for the WQPs in parameter group 2 (4 > n* ≤ 6) assuming sampling frequency as 6 samples per year.



Annex 6-5A8: 90 %Yearly percentiles for the WQPs in parameter group 2 (4 > n* ≤ 6) assuming sampling frequency as 6 samples per year.



ANNEX 6-6

STATISTICAL ASSESSMENT FOR THE WQPs IN PARAMETER GROUP 1 (N* ≤ 4)

ANNEX 6-6A: STATISTICAL ASSESSMENT FOR THE WQPs IN PARAMETER GROUP 1 (N* ≤ 4) ASSUMING SAMPLING FREQUENCY AS 6 SAMPLES PER YEAR

ANNEX 6-6B: STATISTICAL ASSESSMENT FOR THE WQPs IN PARAMETER GROUP 1 (N* ≤ 4) ASSUMING SAMPLING FREQUENCY AS 4 SAMPLES PER YEAR

Annex 6-6A1: The output results for normality tests applied for the yearly averages obtained from the original data set (12 sample/year) and data subsets A and B (6 sample/year).

Parameters	Data group	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
COD	Original Data	0.248	8	0.159	0.850	8	0.099
	Subset A	0.201	8	0.200	0.874	8	0.216
	Subset B	0.288	8	0.049	0.821	8	0.055
TSS	Original Data	0.307	8	0.026	0.799	8	0.036
	Subset A	0.315	8	0.019	0.785	8	0.025
	Subset B	0.294	8	0.040	0.806	8	0.041
TVS	Original Data	0.332	8	0.010	0.773	8	0.018
	Subset A	0.343	8	0.006	0.740	8	0.010
	Subset B	0.298	8	0.035	0.729	8	0.010
N-NO$_3$	Original Data	0.363	8	0.003	0.739	8	0.010
	Subset A	0.369	8	0.002	0.739	8	0.010
	Subset B	0.356	8	0.004	0.735	8	0.010
Pb	Original Data	0.213	8	0.200	0.941	8	0.593
	Subset A	0.152	8	0.200	0.973	8	0.905
	Subset B	0.265	8	0.103	0.927	8	0.473
Ca	Original Data	0.265	8	0.104	0.795	8	0.033
	Subset A	0.307	8	0.025	0.840	8	0.083
	Subset B	0.222	8	0.200	0.872	8	0.205
Na	Original Data	0.140	8	0.200	0.951	8	0.688
	Subset A	0.138	8	0.200	0.941	8	0.588
	Subset B	0.156	8	0.200	0.943	8	0.614
Cl	Original Data	0.216	8	0.200	0.916	8	0.419
	Subset A	0.207	8	0.200	0.890	8	0.293
	Subset B	0.176	8	0.200	0.909	8	0.387
SAR	Original Data	0.135	8	0.200	0.961	8	0.794
	Subset A	0.230	8	0.200	0.867	8	0.181
	Subset B	0.233	8	0.200	0.903	8	0.356
Adj_SAR	Original Data	0.122	8	0.200	0.944	8	0.620
	Subset A	0.234	8	0.200	0.862	8	0.156
	Subset B	0.285	8	0.054	0.851	8	0.101
Visib	Original Data	0.182	8	0.200	0.896	8	0.323
	Subset A	0.167	8	0.200	0.950	8	0.682
	Subset B	0.275	8	0.077	0.813	8	0.046

Large significance values (>.05) indicate normality.

Annex 6-6A21: Analysis of variance (ANOVA) output results for the yearly averages for the WQPs in parameter group 1 (n* $\leq$ 4) assuming sampling frequency as 6 samples per year.

Parameters		Sum of Squares	df	Mean Square	F	Sig.
COD	Between Groups	105.884	2	52.942	0.007	0.993
	Within Groups	155808.384	21	7419.447		
	Total	155914.268	23			
TSS	Between Groups	2237.562	2	1118.781	0.073	0.930
	Within Groups	323917.468	21	15424.641		
	Total	326155.030	23			
TVS	Between Groups	177.040	2	88.520	0.298	0.745
	Within Groups	6233.675	21	296.842		
	Total	6410.715	23			
N-NO_3	Between Groups	0.047	2	0.023	0.000	1.000
	Within Groups	1583.639	21	75.411		
	Total	1583.686	23			
Pb	Between Groups	0.000	2	0.000	0.030	0.971
	Within Groups	0.002	21	0.000		
	Total	0.002	23			
Ca	Between Groups	0.063	2	0.031	0.021	0.979
	Within Groups	31.591	21	1.504		
	Total	31.653	23			
Na	Between Groups	12.622	2	6.311	1.391	0.271
	Within Groups	95.301	21	4.538		
	Total	107.923	23			
Cl	Between Groups	6.739	2	3.369	0.653	0.531
	Within Groups	108.359	21	5.160		
	Total	115.098	23			
SAR	Between Groups	5.216	2	2.608	1.003	0.384
	Within Groups	54.626	21	2.601		
	Total	59.842	23			
Adj_SAR	Between Groups	27.087	2	13.544	1.293	0.295
	Within Groups	219.999	21	10.476		
	Total	247.086	23			
Visib	Between Groups	15.327	2	7.664	0.046	0.955
	Within Groups	3490.311	21	166.205		
	Total	3505.638	23			

Large significance values (>.05) indicate no group differences.

Annex 6-6A22: Output results for the Test of Homogeneity of Variances

Parameters	Levene Statistic	df1	df2	Sig.
COD	0.15	2.00	21.00	0.87
TSS	0.28	2.00	21.00	0.76
TVS	1.58	2.00	21.00	0.23
$N-NO_3$	0.02	2.00	21.00	0.98
Pb	0.07	2.00	21.00	0.93
Ca	0.15	2.00	21.00	0.86
Na	0.23	2.00	21.00	0.80
Cl	0.20	2.00	21.00	0.82
SAR	2.94	2.00	21.00	0.07
Adj_SAR	3.00	2.00	21.00	0.07
Visib	0.01	2.00	21.00	0.99

The significance values exceed .05, suggesting that the variances are equal and the assumption are justified.

Annex 6-6A23: Kruskal Wallis tests results for the yearly averages for the WQPs in parameter group 1 ($n^* \leq 4$) assuming sampling frequency as 6 samples per year.

	Chi-Square	df	Asymp. Sig.
COD	0.02	2.00	0.99
TSS	0.06	2.00	0.97
TVS	0.68	2.00	0.71
$N-NO_3$	0.42	2.00	0.81
Pb	0.02	2.00	0.99
Ca	0.40	2.00	0.82
Na	2.11	2.00	0.35
Cl	1.45	2.00	0.49
SAR	0.86	2.00	0.65
Adj_SAR	1.14	2.00	0.57
Visib	0.29	2.00	0.87

Large significance values (>.05) indicate no group differences.

Annex 6-6A3: The output results for normality tests applied for the the yearly 90% percentiles obtained from the original data set (12 sample/year), data subsets A and B (6 sample/year)

Parameters	Data group	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
COD	Original Data	0.280	8	0.064	0.842	8	0.086
	Subset A	0.196	8	0.200	0.888	8	0.281
	Subset B	0.299	8	0.034	0.833	8	0.072
TSS	Original Data	0.319	8	0.016	0.819	8	0.051
	Subset A	0.303	8	0.030	0.799	8	0.036
	Subset B	0.316	8	0.018	0.771	8	0.017
TVS	Original Data	0.345	8	0.006	0.797	8	0.035
	Subset A	0.334	8	0.009	0.767	8	0.016
	Subset B	0.292	8	0.043	0.687	8	0.010
N-NO$_3$	Original Data	0.371	8	0.002	0.732	8	0.010
	Subset A	0.371	8	0.002	0.743	8	0.010
	Subset B	0.347	8	0.005	0.773	8	0.018
Pb	Original Data	0.203	8	0.200	0.935	8	0.533
	Subset A	0.196	8	0.200	0.947	8	0.647
	Subset B	0.227	8	0.200	0.908	8	0.380
Ca	Original Data	0.344	8	0.006	0.706	8	0.010
	Subset A	0.362	8	0.003	0.729	8	0.010
	Subset B	0.321	8	0.015	0.797	8	0.034
Na	Original Data	0.212	8	0.200	0.885	8	0.267
	Subset A	0.279	8	0.066	0.781	8	0.022
	Subset B	0.155	8	0.200	0.932	8	0.503
Cl	Original Data	0.198	8	0.200	0.880	8	0.243
	Subset A	0.297	8	0.036	0.886	8	0.274
	Subset B	0.207	8	0.200	0.921	8	0.445
SAR	Original Data	0.256	8	0.130	0.884	8	0.265
	Subset A	0.260	8	0.119	0.834	8	0.074
	Subset B	0.128	8	0.200	0.984	8	0.979
Adj_SAR	Original Data	0.213	8	0.200	0.907	8	0.377
	Subset A	0.264	8	0.108	0.776	8	0.019
	Subset B	0.164	8	0.200	0.918	8	0.433
Visib	Original Data	0.221	8	0.200	0.870	8	0.194
	Subset A	0.147	8	0.200	0.957	8	0.751
	Subset B	0.277	8	0.072	0.856	8	0.123

Large significance values (>.05) indicate normality.

Annex 6-6A41: Analysis of variance (ANOVA) output results for the 90% yearly percentiles for the WQPs in parameter group 1 (n* ≤ 4) assuming sampling frequency as 6 samples per year

Parameters		Sum of Squares	df	Mean Square	F	Sig.
COD	Between Groups	500.181	2	250.091	0.014	0.986
	Within Groups	372293.730	21	17728.273		
	Total	372793.911	23			
TSS	Between Groups	8850.698	2	4425.349	0.147	0.864
	Within Groups	632874.964	21	30136.903		
	Total	641725.662	23			
TVS	Between Groups	535.758	2	267.879	0.397	0.678
	Within Groups	14182.276	21	675.346		
	Total	14718.034	23			
$N\text{-}NO_3$	Between Groups	4.781	2	2.390	0.013	0.987
	Within Groups	3744.040	21	178.288		
	Total	3748.820	23			
Pb	Between Groups	0.000	2	0.000	0.073	0.930
	Within Groups	0.004	21	0.000		
	Total	0.004	23			
Ca	Between Groups	0.206	2	0.103	0.021	0.979
	Within Groups	103.468	21	4.927		
	Total	103.674	23			
Na	Between Groups	30.352	2	15.176	1.079	0.358
	Within Groups	295.292	21	14.062		
	Total	325.644	23			
Cl	Between Groups	25.885	2	12.943	1.328	0.286
	Within Groups	204.600	21	9.743		
	Total	230.485	23			
SAR	Between Groups	7.934	2	3.967	0.561	0.579
	Within Groups	148.580	21	7.075		
	Total	156.514	23			
Adj_SAR	Between Groups	47.107	2	23.553	0.759	0.480
	Within Groups	651.494	21	31.024		
	Total	698.601	23			
Visib	Between Groups	29.463	2	14.732	0.058	0.944
	Within Groups	5323.315	21	253.491		
	Total	5352.778	23			

Large significance values (>.05) indicate no group differences.

Annex 6-6A42: Output results for the Test of Homogeneity of Variances

Parameters	Levene Statistic	df1	df2	Sig.
COD	0.13	2.00	21.00	0.88
TSS	0.62	2.00	21.00	0.55
TVS	2.08	2.00	21.00	0.15
N-NO_3	0.47	2.00	21.00	0.63
Pb	0.07	2.00	21.00	0.94
Ca	0.19	2.00	21.00	0.83
Na	0.24	2.00	21.00	0.79
Cl	0.23	2.00	21.00	0.80
SAR	1.36	2.00	21.00	0.28
Adj_SAR	0.91	2.00	21.00	0.42
Visib	0.17	2.00	21.00	0.84

The significance values exceed .05, suggesting that the variances are equal and the assumption are justified.

Annex 6-6A43: Kruskal Wallis tests results for the 90% yearly percentiles for the WQPs in parameter group 1 ($n^* \leq 4$) assuming sampling frequency as 6 samples per year

	Chi-Square	df	Asymp. Sig.
COD	0.16	2.00	0.93
TSS	0.45	2.00	0.80
TVS	0.50	2.00	0.78
N-NO_3	0.56	2.00	0.76
Pb	0.32	2.00	0.85
Ca	0.40	2.00	0.82
Na	2.13	2.00	0.34
Cl	2.02	2.00	0.37
SAR	0.31	2.00	0.85
Adj_SAR	1.04	2.00	0.59
Visib	0.17	2.00	0.92

Large significance values (>.05) indicate no group differences.

Annex 6-6B1: The output results for normality tests applied for the yearly averages obtained from the original data set (12 sample/year) and data subsets C, D and E (4 sample/year)

Parameters	Data group	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
COD	Original Data	0.248	8	0.159	0.850	8	0.099
	Subset C	0.211	8	0.200	0.830	8	0.068
	Subset D	0.318	8	0.017	0.785	8	0.026
	Subset E	0.305	8	0.027	0.838	8	0.081
TSS	Original Data	0.307	8	0.026	0.799	8	0.036
	Subset C	0.304	8	0.029	0.755	8	0.012
	Subset D	0.303	8	0.029	0.839	8	0.081
	Subset E	0.310	8	0.023	0.811	8	0.045
TVS	Original Data	0.332	8	0.010	0.773	8	0.018
	Subset C	0.333	8	0.009	0.731	8	0.010
	Subset D	0.314	8	0.020	0.762	8	0.014
	Subset E	0.327	8	0.012	0.798	8	0.035
$N\text{-}NO_3$	Original Data	0.363	8	0.003	0.739	8	0.010
	Subset C	0.350	8	0.005	0.776	8	0.019
	Subset D	0.366	8	0.002	0.730	8	0.010
	Subset E	0.365	8	0.002	0.751	8	0.011
Pb	Original Data	0.213	8	0.200	0.941	8	0.593
	Subset C	0.211	8	0.200	0.910	8	0.390
	Subset D	0.170	8	0.200	0.964	8	0.820
	Subset E	0.217	8	0.200	0.904	8	0.363
Ca	Original Data	0.265	8	0.104	0.795	8	0.033
	Subset C	0.324	8	0.013	0.830	8	0.068
	Subset D	0.260	8	0.118	0.816	8	0.048
	Subset E	0.184	8	0.200	0.945	8	0.634
Na	Original Data	0.140	8	0.200	0.951	8	0.688
	Subset C	0.225	8	0.200	0.927	8	0.473
	Subset D	0.262	8	0.113	0.881	8	0.246
	Subset E	0.194	8	0.200	0.959	8	0.765
Cl	Original Data	0.216	8	0.200	0.916	8	0.419
	Subset C	0.169	8	0.200	0.918	8	0.430
	Subset D	0.185	8	0.200	0.910	8	0.391
	Subset E	0.137	8	0.200	0.955	8	0.732
SAR	Original Data	0.135	8	0.200	0.961	8	0.794
	Subset C	0.224	8	0.200	0.872	8	0.203
	Subset D	0.284	8	0.057	0.897	8	0.328
	Subset E	0.145	8	0.200	0.953	8	0.705
Adj_SAR	Original Data	0.122	8	0.200	0.944	8	0.620
	Subset C	0.301	8	0.031	0.838	8	0.080
	Subset D	0.241	8	0.190	0.899	8	0.339
	Subset E	0.178	8	0.200	0.901	8	0.345
Visib	Original Data	0.182	8	0.200	0.896	8	0.323
	Subset C	0.207	8	0.200	0.929	8	0.484
	Subset D	0.160	8	0.200	0.951	8	0.694
	Subset E	0.179	8	0.200	0.907	8	0.378

Large significance values (>.05) indicate normality.

Annex 6-6B21: Analysis of variance (ANOVA) output results for the yearly averages for the WQPs in parameter group 1 ($n^* \leq 4$) assuming sampling frequency as 4 samples per year.

Parameters		Sum of Squares	df	Mean Square	F	Sig.
COD	Between Groups	877.869	3	292.623	0.038	0.990
	Within Groups	215989.024	28	7713.894		
	Total	216866.893	31			
TSS	Between Groups	2026.339	3	675.446	0.043	0.988
	Within Groups	444145.347	28	15862.334		
	Total	446171.686	31			
TVS	Between Groups	149.105	3	49.702	0.167	0.918
	Within Groups	8348.192	28	298.150		
	Total	8497.297	31			
N-NO$_3$	Between Groups	21.864	3	7.288	0.093	0.963
	Within Groups	2201.617	28	78.629		
	Total	2223.481	31			
Pb	Between Groups	0.000	3	0.000	0.157	0.924
	Within Groups	0.003	28	0.000		
	Total	0.003	31			
Ca	Between Groups	1.036	3	0.345	0.222	0.880
	Within Groups	43.546	28	1.555		
	Total	44.582	31			
Na	Between Groups	27.398	3	9.133	1.764	0.177
	Within Groups	144.965	28	5.177		
	Total	172.364	31			
Cl	Between Groups	23.453	3	7.818	1.309	0.291
	Within Groups	167.277	28	5.974		
	Total	190.730	31			
SAR	Between Groups	4.445	3	1.482	0.532	0.664
	Within Groups	77.919	28	2.783		
	Total	82.364	31			
Adj_SAR	Between Groups	23.965	3	7.988	0.722	0.548
	Within Groups	309.980	28	11.071		
	Total	333.946	31			
Visib	Between Groups	49.536	3	16.512	0.096	0.961
	Within Groups	4791.380	28	171.121		
	Total	4840.917	31			

Large significance values (>.05) indicate no group differences.

Annex 6-6B22: Output results for the Test of Homogeneity of Variances

Parameters	Levene Statistic	df1	df2	Sig.
COD	0.10	3.00	28.00	0.96
TSS	0.52	3.00	28.00	0.67
TVS	1.51	3.00	28.00	0.23
N-NO_3	0.98	3.00	28.00	0.42
Pb	0.20	3.00	28.00	0.90
Ca	0.40	3.00	28.00	0.75
Na	0.62	3.00	28.00	0.61
Cl	0.63	3.00	28.00	0.60
SAR	0.33	3.00	28.00	0.81
Adj_SAR	0.29	3.00	28.00	0.83
Visib	0.08	3.00	28.00	0.97

The significance values exceed .05, suggesting that the variances are equal and the assumption are justified.

Annex 6-6B23: Kruskal Wallis tests results for the yearly averages for the WQPs in parameter group 1 ($n^* \leq 4$) assuming sampling frequency as 4 samples per year

	Chi-Square	df	Asymp. Sig.
COD	0.03	3.00	1.00
TSS	0.16	3.00	0.98
TVS	0.18	3.00	0.98
N-NO_3	0.86	3.00	0.83
Pb	0.34	3.00	0.95
Ca	1.05	3.00	0.79
Na	5.05	3.00	0.17
Cl	4.85	3.00	0.18
SAR	1.13	3.00	0.77
Adj_SAR	1.60	3.00	0.66
Visib	0.50	3.00	0.92

Large significance values (>.05) indicate no group differences.

Annex 8-6B3: The output results for normality tests applied for the the yearly 90% percentiles obtained from the original data set (12 sample/year) and data subsets C, D and E (4 sample/year)

Parameters	Data group	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
COD	Original Data	0.280	8	0.064	0.842	8	0.086
	Subset C	0.192	8	0.200	0.851	8	0.100
	Subset D	0.284	8	0.056	0.786	8	0.026
	Subset E	0.309	8	0.023	0.840	8	0.083
TSS	Original Data	0.319	8	0.016	0.819	8	0.051
	Subset C	0.319	8	0.016	0.731	8	0.010
	Subset D	0.340	8	0.007	0.822	8	0.055
	Subset E	0.237	8	0.200	0.830	8	0.068
TVS	Original Data	0.345	8	0.006	0.797	8	0.035
	Subset C	0.340	8	0.007	0.730	8	0.010
	Subset D	0.333	8	0.009	0.792	8	0.030
	Subset E	0.248	8	0.159	0.844	8	0.090
$N-NO_3$	Original Data	0.371	8	0.002	0.732	8	0.010
	Subset C	0.342	8	0.007	0.761	8	0.014
	Subset D	0.352	8	0.004	0.776	8	0.019
	Subset E	0.375	8	0.001	0.716	8	0.010
Pb	Original Data	0.203	8	0.200	0.935	8	0.533
	Subset C	0.223	8	0.200	0.909	8	0.385
	Subset D	0.198	8	0.200	0.929	8	0.487
	Subset E	0.275	8	0.075	0.849	8	0.097
Ca	Original Data	0.344	8	0.006	0.706	8	0.010
	Subset C	0.331	8	0.010	0.811	8	0.045
	Subset D	0.343	8	0.006	0.747	8	0.010
	Subset E	0.186	8	0.200	0.898	8	0.331
Na	Original Data	0.212	8	0.200	0.885	8	0.267
	Subset C	0.200	8	0.200	0.920	8	0.440
	Subset D	0.293	8	0.041	0.784	8	0.024
	Subset E	0.200	8	0.200	0.934	8	0.521
Cl	Original Data	0.198	8	0.200	0.880	8	0.243
	Subset C	0.198	8	0.200	0.956	8	0.740
	Subset D	0.243	8	0.182	0.883	8	0.256
	Subset E	0.157	8	0.200	0.971	8	0.891
SAR	Original Data	0.256	8	0.130	0.884	8	0.265
	Subset C	0.334	8	0.009	0.818	8	0.050
	Subset D	0.390	8	0.001	0.678	8	0.010
	Subset E	0.132	8	0.200	0.948	8	0.657
Adj_SAR	Original Data	0.213	8	0.200	0.907	8	0.377
	Subset C	0.277	8	0.071	0.846	8	0.092
	Subset D	0.356	8	0.004	0.646	8	0.010
	Subset E	0.190	8	0.200	0.906	8	0.371
Visib	Original Data	0.221	8	0.200	0.870	8	0.194
	Subset C	0.193	8	0.200	0.904	8	0.361
	Subset D	0.206	8	0.200	0.952	8	0.705
	Subset E	0.163	8	0.200	0.938	8	0.560

Large significance values (>.05) indicate normality.

Annex 6-6B41: Analysis of variance (ANOVA) output results for the 90% yearly percentiles for the WQPs in parameter group 1 (n* ≤ 4) assuming sampling frequency as 4 samples per year

Parameters		Sum of Squares	df	Mean Square	F	Sig.
COD	Between Groups	8320.935	3	2773.645	0.174	0.913
	Within Groups	445604.231	28	15914.437		
	Total	453925.166	31			
TSS	Between Groups	12545.939	3	4181.980	0.138	0.937
	Within Groups	850053.688	28	30359.060		
	Total	862599.627	31			
TVS	Between Groups	749.651	3	249.884	0.349	0.790
	Within Groups	20048.582	28	716.021		
	Total	20798.233	31			
$N\text{-}NO_3$	Between Groups	24.575	3	8.192	0.052	0.984
	Within Groups	4417.021	28	157.751		
	Total	4441.597	31			
Pb	Between Groups	0.000	3	0.000	0.380	0.768
	Within Groups	0.005	28	0.000		
	Total	0.005	31			
Ca	Between Groups	5.667	3	1.889	0.397	0.756
	Within Groups	133.156	28	4.756		
	Total	138.823	31			
Na	Between Groups	42.045	3	14.015	0.932	0.438
	Within Groups	421.206	28	15.043		
	Total	463.251	31			
Cl	Between Groups	33.017	3	11.006	0.940	0.434
	Within Groups	327.660	28	11.702		
	Total	360.677	31			
SAR	Between Groups	2.601	3	0.867	0.122	0.947
	Within Groups	199.576	28	7.128		
	Total	202.177	31			
Adj_SAR	Between Groups	18.309	3	6.103	0.194	0.899
	Within Groups	879.436	28	31.408		
	Total	897.745	31			
Visib	Between Groups	154.596	3	51.532	0.213	0.886
	Within Groups	6765.713	28	241.633		
	Total	6920.309	31			

Large significance values (>.05) indicate no group differences.

Annex 6-6B42: Output results for the Test of Homogeneity of Variances

Parameters	Levene Statistic	df1	df2	Sig.
COD	0.52	3.00	28.00	0.67
TSS	0.95	3.00	28.00	0.43
TVS	2.52	3.00	28.00	0.08
N-NO_3	0.44	3.00	28.00	0.73
Pb	0.08	3.00	28.00	0.97
Ca	0.18	3.00	28.00	0.91
Na	0.75	3.00	28.00	0.53
Cl	1.86	3.00	28.00	0.16
SAR	0.13	3.00	28.00	0.94
Adj_SAR	0.19	3.00	28.00	0.90
Visib	0.11	3.00	28.00	0.95

The significance values exceed .05, suggesting that the variances are equal and the assumption are justified.

Annex 6-6B43: Kruskal Wallis tests results for the 90% yearly percentiles for the WQPs in parameter group 1 ($n^* \leq 4$) assuming sampling frequency as 4 samples per year.

	Chi-Square	df	Asymp. Sig.
COD	0.39	3.00	0.94
TSS	0.83	3.00	0.84
TVS	0.53	3.00	0.91
N-NO_3	1.00	3.00	0.80
Pb	1.06	3.00	0.79
Ca	2.69	3.00	0.44
Na	4.88	3.00	0.18
Cl	2.86	3.00	0.41
SAR	0.94	3.00	0.82
Adj_SAR	1.30	3.00	0.73
Visib	1.03	3.00	0.79

Large significance values (>.05) indicate no group differences.

ANNEX 6-7

STATISTICAL ASSESSMENT FOR THE WQPs IN PARAMETER GROUP 2 ($4 < N^* \leq 6$) ASSUMING SAMPLING FREQUENCY AS 6 SAMPLES PER YEAR

Annex 6-7A1: The output results for normality tests applied for the yearly averages obtained from the original data set (12 sample/year) and data subsets A and B (6 sample/year)

Parameters	Data group	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
BOD	Original Data	0.205	5	0.200	0.856	5	0.267
	Subset A	0.294	5	0.182	0.742	5	0.038
	Subset B	0.216	5	0.200	0.849	5	0.243
Cu	Original Data	0.313	5	0.124	0.822	5	0.153
	Subset A	0.296	5	0.175	0.870	5	0.313
	Subset B	0.311	5	0.128	0.785	5	0.076
Fe	Original Data	0.198	5	0.200	0.932	5	0.540
	Subset A	0.155	5	0.200	0.986	5	0.951
	Subset B	0.290	5	0.197	0.804	5	0.097
Mn	Original Data	0.255	5	0.200	0.931	5	0.535
	Subset A	0.196	5	0.200	0.864	5	0.291
	Subset B	0.284	5	0.200	0.921	5	0.480
pH	Original Data	0.310	5	0.131	0.741	5	0.036
	Subset A	0.166	5	0.200	0.994	5	0.990
	Subset B	0.258	5	0.200	0.761	5	0.049
TDS	Original Data	0.224	5	0.200	0.944	5	0.628
	Subset A	0.122	5	0.200	0.978	5	0.896
	Subset B	0.188	5	0.200	0.907	5	0.434
K	Original Data	0.378	5	0.019	0.720	5	0.023
	Subset A	0.309	5	0.135	0.922	5	0.485
	Subset B	0.253	5	0.200	0.938	5	0.587
SO_4	Original Data	0.200	5	0.200	0.857	5	0.267
	Subset A	0.239	5	0.200	0.917	5	0.467
	Subset B	0.277	5	0.200	0.880	5	0.345
DO	Original Data	0.268	5	0.200	0.867	5	0.301
	Subset A	0.242	5	0.200	0.876	5	0.331
	Subset B	0.365	5	0.028	0.688	5	0.011
SO_{4_m}	Original Data	0.306	5	0.141	0.881	5	0.347
	Subset A	0.285	5	0.200	0.927	5	0.498
	Subset B	0.315	5	0.116	0.769	5	0.058

Large significance values (>.05) indicate normality.

Annex 6-7B1: Analysis of variance (ANOVA) output results for the yearly averages for the WQPs in parameter group 2 (4 < n* ≤ 6) assuming sampling frequency as 6 samples per year

Parameters		Sum of Squares	df	Mean Square	F	Sig.
BOD	Between Groups	158.13	2	79.065	0.044	0.957
	Within Groups	37373.37	21	1779.684		
	Total	37531.50	23			
Cu	Between Groups	0.00	2	0.000	0.007	0.993
	Within Groups	0.02	21	0.001		
	Total	0.02	23			
Fe	Between Groups	0.06	2	0.030	0.468	0.633
	Within Groups	1.36	21	0.065		
	Total	1.42	23			
Mn	Between Groups	0.00	2	0.000	0.001	0.999
	Within Groups	0.26	12	0.022		
	Total	0.26	14			
pH	Between Groups	0.01	2	0.005	0.189	0.829
	Within Groups	0.52	21	0.025		
	Total	0.53	23			
TDS	Between Groups	61347.36	2	30673.679	1.033	0.373
	Within Groups	623513.73	21	29691.130		
	Total	684861.09	23			
K	Between Groups	0.00	2	0.001	0.014	0.986
	Within Groups	0.82	21	0.039		
	Total	0.82	23			
SO4	Between Groups	0.01	2	0.005	0.002	0.998
	Within Groups	61.16	21	2.912		
	Total	61.17	23			
DO	Between Groups	0.21	2	0.104	0.125	0.883
	Within Groups	17.50	21	0.833		
	Total	17.71	23			
SO_{4_m}	Between Groups	0.04	2	0.020	0.008	0.992
	Within Groups	31.64	12	2.636		
	Total	31.68	14			

Large significance values (>.05) indicate no group differences.

Annex 6-7B2: Output results for the Test of Homogeneity of Variances

Parameters	Levene Statistic	df1	df2	Sig.
BOD	0.35	2.00	21.00	0.71
Cu	0.18	2.00	21.00	0.83
Fe	0.58	2.00	21.00	0.57
Mn	0.13	2.00	12.00	0.88
pH	0.84	2.00	21.00	0.44
TDS	0.59	2.00	21.00	0.56
K	0.16	2.00	21.00	0.85
SO_4	0.36	2.00	21.00	0.70
DO	0.65	2.00	21.00	0.53
SO_{4_m}	0.34	2.00	12.00	0.72

The significance values exceed .05, suggesting that the variances are equal and the assumption are justified.

Annex 6-7B3: Kruskal Wallis tests results for the yearly averages for the WQPs in parameter group 2 ($4 < n^* \leq 6$) assuming sampling frequency as 6 samples per year

	Chi-Square	df	Asymp. Sig.
BOD	0.02	2.00	0.99
Cu	0.01	2.00	1.00
Fe	0.67	2.00	0.72
Mn	0.08	2.00	0.96
pH	0.32	2.00	0.85
TDS	2.71	2.00	0.26
K	0.09	2.00	0.95
SO_4	0.01	2.00	0.99
DO	0.42	2.00	0.81
SO_{4_m}	0.14	2.00	0.93

Large significance values (>.05) indicate no group differences.

Annex 6-7C1: The output results for normality tests applied for the the yearly 90% percentiles obtained from the original data set (12 sample/year), data subsets A and B (6 sample/year)

Parameters	Data group	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
BOD	Original Data	0.245	5	0.200	0.930	5	0.523
	Subset A	0.239	5	0.200	0.830	5	0.178
	Subset B	0.219	5	0.200	0.960	5	0.757
Cu	Original Data	0.250	5	0.200	0.861	5	0.282
	Subset A	0.224	5	0.200	0.898	5	0.404
	Subset B	0.241	5	0.200	0.839	5	0.211
Fe	Original Data	0.183	5	0.200	0.884	5	0.358
	Subset A	0.175	5	0.200	0.938	5	0.582
	Subset B	0.293	5	0.187	0.827	5	0.169
Mn	Original Data	0.208	5	0.200	0.884	5	0.359
	Subset A	0.202	5	0.200	0.876	5	0.330
	Subset B	0.314	5	0.121	0.868	5	0.306
pH	Original Data	0.342	5	0.056	0.725	5	0.027
	Subset A	0.321	5	0.101	0.904	5	0.425
	Subset B	0.227	5	0.200	0.865	5	0.295
TDS	Original Data	0.421	5	0.004	0.742	5	0.037
	Subset A	0.222	5	0.200	0.883	5	0.355
	Subset B	0.313	5	0.123	0.888	5	0.370
K	Original Data	0.313	5	0.124	0.782	5	0.073
	Subset A	0.214	5	0.200	0.924	5	0.491
	Subset B	0.231	5	0.200	0.955	5	0.713
SO4	Original Data	0.221	5	0.200	0.875	5	0.327
	Subset A	0.222	5	0.200	0.906	5	0.429
	Subset B	0.317	5	0.113	0.795	5	0.087
DO	Original Data	0.271	5	0.200	0.832	5	0.186
	Subset A	0.286	5	0.200	0.837	5	0.202
	Subset B	0.211	5	0.200	0.992	5	0.984
SO_{4_m}	Original Data	0.254	5	0.200	0.829	5	0.177
	Subset A	0.316	5	0.115	0.905	5	0.427
	Subset B	0.245	5	0.200	0.861	5	0.281

Large significance values (>.05) indicate normality.

Annex 6-7D1: Analysis of variance (ANOVA) output results for the 90% yearly percentiles for the WQPs in parameter group 2 ($4 < n^* \leq 6$) assuming sampling frequency as 6 samples per year

Parameters		Sum of Squares	df	Mean Square	F	Sig.
BOD	Between Groups	636.74	2	318.372	0.070	0.932
	Within Groups	95294.20	21	4537.819		
	Total	95930.94	23			
Cu	Between Groups	0.00	2	0.000	0.054	0.948
	Within Groups	0.13	21	0.006		
	Total	0.13	23			
Fe	Between Groups	0.20	2	0.098	0.497	0.615
	Within Groups	4.14	21	0.197		
	Total	4.33	23			
Mn	Between Groups	0.01	2	0.005	0.043	0.958
	Within Groups	1.26	12	0.105		
	Total	1.27	14			
pH	Between Groups	0.04	2	0.020	0.364	0.699
	Within Groups	1.16	21	0.055		
	Total	1.20	23			
TDS	Between Groups	204296.31	2	102148.157	1.163	0.332
	Within Groups	1844542.67	21	87835.365		
	Total	2048838.98	23			
K	Between Groups	0.02	2	0.008	0.076	0.927
	Within Groups	2.22	21	0.106		
	Total	2.24	23			
SO_4	Between Groups	1.10	2	0.551	0.064	0.939
	Within Groups	182.24	21	8.678		
	Total	183.34	23			
DO	Between Groups	0.24	2	0.121	0.067	0.936
	Within Groups	37.90	21	1.805		
	Total	38.14	23			
SO_{4_m}	Between Groups	0.70	2	0.351	0.058	0.944
	Within Groups	72.58	12	6.048		
	Total	73.28	14			

Large significance values (>.05) indicate no group differences.

Annex 6-7D2: Output results for the Test of Homogeneity of Variances

Parameters	Levene Statistic	df1	df2	Sig.
BOD	0.49	2.00	21.00	0.62
Cu	0.25	2.00	21.00	0.78
Fe	0.02	2.00	21.00	0.98
Mn	0.10	2.00	12.00	0.91
pH	0.22	2.00	21.00	0.80
TDS	1.27	2.00	21.00	0.30
K	0.47	2.00	21.00	0.63
SO_4	0.06	2.00	21.00	0.94
DO	0.54	2.00	21.00	0.59
SO_{4_m}	0.47	2.00	12.00	0.64

The significance values exceed .05, suggesting that the variances are equal and the assumption are justified.

Annex 6-7D3: Kruskal Wallis tests results for the 90% yearly percentiles for the WQPs in parameter group 2 ($4 < n^* \leq 6$) assuming sampling frequency as 6 samples per year.

Parameters	Chi-Square	df	Asymp. Sig.
BOD	0.06	2.00	0.97
Cu	0.47	2.00	0.79
Fe	1.12	2.00	0.57
Mn	0.26	2.00	0.88
pH	0.53	2.00	0.77
TDS	2.66	2.00	0.26
K	0.08	2.00	0.96
SO_4	0.28	2.00	0.87
DO	0.26	2.00	0.88
SO_{4_m}	0.26	2.00	0.88

Large significance values (>.05) indicate no group differences.