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Qalubeya Drain System / Egypt
Environmental Studies on
Water Quality

Abstract

The water quality of the Bahr El-Baqar Drain system in Egypt was studied. The first section of the drain system called Qalubeya Drain starts in the northern zone of Greater Cairo were all sewage and industrial wastewater, treated or untreated is dumped into this drain. Near the city of Zagazig the Bilbeis- and Qalubeya Drain flow together to form the Bahr El-Baqar Drain. Along its way from Cairo down to Lake Manzala there are a lot of discharges like agricultural run-offs in the north eastern cultivated areas. In larger cities or villages large amounts of untreated urban municipal water are discharged into the drain. Despite of these facts the water is also used for irrigation of farmland too. In several sections of the drain the surface was completely covered by weed flourishing which provides habitats for Billharzia snails. From our study it was estimated that Lake Manzala which is an important resource of fishing in Egypt receives about 60 m^3/s of wastewater from Bahr El-Baqar Drain. In the year 2006 at twelve different sites along the Bilbeis- and Bahr El-Baqar Drain water samples were taken and analysed for sum parameters, salts, heavy metals and natural radioactivity (Part I [44]). In 2007 the water of the Qalubeya drain was analysed too in the same way taking samples at 12 different sites.

Qalubeya Kanal / Ägypten
Untersuchungen zur Wasserqualität

Zusammenfassung

Das Bahr El-Baqar Kanalsystem in Ägypten beginnt bei der Hauptstadt Kairo, führt in Richtung Nordosten und mündet kurz vor Erreichen der Mittelmeerküste in den Manzalasee. Der erste Kanalabschnitt – genannt Qalubeyakanal – beginnt in der nördlichen Zone von Greater Cairo, wo an zahlreichen Stellen Abwässer kommunaler und industrieller Herkunft – behandelt und unbehandelt – in den Kanal eingeleitet werden. In der Nähe der Stadt Zagazig fließen der Qalubeya-Kanal und der Bilbis-Kanal zusammen und bilden den Bahr El Baqar-Kanal, der weiter zum Manzalasee führt. Besonders in den landwirtschaftlich intensiv genutzten Flächen im Nordosten münden zahlreiche Feldentwässerungen in den Kanal. In den Städten und Ortschaften längs des Kanals finden sich häufig Einleitungen von ungeklärten kommunalen Abwässern. Trotzdem wird das Kanalwasser auch zur Bewässerung von landwirtschaftlichen Flächen genutzt. Es wird geschätzt, dass dem Manzalasee, der intensiv zur Fischzucht genutzt wird etwa 60 m^3 Wasser pro Sekunde zugeführt werden. Im Jahr 2006 wurden im Verlauf des Bilbis- Bahr-El-Baqar-Kanals (Teil I [44]) in 2007 im Abschnitt des Qalubeya-Kanals 12 Proben genommen und auf Summenparameter, Salze und Schwermetalle untersucht.

Preface

This water study was prepared as a contribution to the agreement between the Government of the Arab Republic of Egypt and the Government of the Federal Republic of Germany on cooperation in the field of scientific research and technological development signed 1979 and 1981. In the frame of the project ”Environmental Analytical Chemistry” between the Atomic Energy Authority (AEA), National Egyptian Radiation and Environmental Monitoring Network in Cairo and the Karlsruhe Institute of Technology, Institute for Technical Chemistry – Division of Chemical-Physical Processing (ITC-CPV) the environmental situation in Egypt is studied and characterised. On behalf of the BMBF (Federal Ministry of Education and Research) the International Bureau of BMBF linked to the Forschungszentrum Jülich as well as to the DLR Bonn assists in developing this international cooperation. The focus of the two laboratories research program is on analytical methods and their cost-effectiveness use for the identification, control and prevention of pollution to water and its subsurface resources. The research provides solutions to environmental problems by developing and promoting techniques that help to protect and improve the environment by advancing scientific information to support regulatory and policy decisions and providing the technical support and by information transfer to ensure implementations of environmental regulations and strategies at the national, state and community levels. It contributes to an international network of research institutions and the education of the involved scientists on both sides. Many of the leading scientists of AEA have been in Germany during their scientific education a fact that results in a very positive attitude towards Germany. The intensive exchange of young scientists who will be the decision makers in the near future will to help to keep up that tradition and thus contribute to strengthen democracy and economy in the Near East in the future.

Table of Contents

1 Geography and population

Egypt lies in the north–eastern corner of the African continent between latitude 22° und 32° N und longitude 25° und 35° E. The Egyptian territory is almost rectangular: in the north it is bordered by the Mediterranean Sea with a coastline of 995 kilometres. In the East Egypt is limited by a 265 km long border to Israel and the Red Sea, in the south by Sudan (1280 km) and in the west by Libya (1115km) [1]. From north to south the largest distance is about 1085 km, from west to east about 1255 km. It covers an area of about one million km^2 (land 995450 km^2, water 6000 km^2) and is about 3 times larger than to Germany. In 2004, the total cultivated land was about 3,3% of the total area. About 2,7% consist of arable land - land cultivated for crops like wheat, maize, and rice that are replanted after each harvest. The rest is used for permanent crops - land cultivated for crops like citrus that are not replanted after each harvest. The vast majority of Egypt's population inhabit the banks along the length of the Nile River (about 40,000 km^2) and the Suez Canal. Large areas of land are part of the Sahara Desert and sparsely inhabited. The total population is about 70,1 million (2004) of which about 55% is rural, with annual demographic growth estimated at 1,8%. The average population density is ~70 inhabitants/km^2, ranging from 2 inhabitants/km^2 in over 96% of the total area to 1500 inhabitants/km^2 in the Nile Valley and Delta.

2 Water supply

Besides some groundwater resources in the western desert and Sinai the river Nile is the main source of water for Egypt. The total water demand in Egypt is estimated at about 68 billion m^3/year [45]. About 55,5 billion m^3/year are supplied from Nile water according to an international agreement between Sudan and Egypt from1959. Like in the most arid North African countries the agricultural sector consumes the vast majority, around 86%. 8% is used for domestic purposes and another 6% is used for industrial production. Almost all agriculture is irrigated. The irrigation system is based on gravity and lifting. A main canal takes its water from head regulators, which are located upstream at the river Nile. The water is distributed in smaller branches with a continuous flow. Finally water is pumped from small distributaries to irrigate the fields. The total length of the network of irrigation canals is about 30000 km long. A typical irrigation canal is the Ismailia canal which leads fresh Nile water to the north eastern region of the delta. Challenging new projects such as El-Salam and Toshka agriculture project have a large impact on the distribution and use of presently available water resources. Continued population and economic growth will exert further pressure on the water resources.

With a growing population and intensified industrial and agricultural activities large amounts of untreated urban municipal, industrial wastewater and rural domestic wastes discharge into the river Nile, canals or agricultural drains which become an easy dumping site for all kinds of wastes. According to El-Gohary [2] the main industrial sectors are oil and soap, starch yeast glucose, pulp and paper, metal industry, plastic and rubber and textile and dyeing. In the irrigated areas the level of applied water is generally higher than necessary to prevent salt accumulation in the root zone of the soil. In a system of drainages (~18000km length) the excess water carrying salts and chemical residues is collected and either pumped into irrigation canals for reuse or pumped into the river Nile or into the northern lakes or the Mediterranean. Using the water twice or even three times increases the salinity especially in drains near the lakes bordering the Mediterranean Sea. Already in 1995 Ghassemi, Jakeman and Nix estimated that in Egypt about 0,9 million ha of irrigated land were damaged by salt corresponding to about 33% of the total irrigated land [3]. The mixing of drain water with clean water diffuses all kinds of constituents that still have negative environmental and health impacts. Without seasonal flushing floods, the former delta plain surface is now incapable of recycling and removing agricultural, municipal and industrial waste generated by Egypt's rapidly expanding population. The necessary expansion of the water supply services exceeds the capacity of the sewerage system. The constituents of domestic and urban inputs to water resources are pathogens, nutrients, salts, oxygen demanding materials and suspended solids. This results to an increasing pollution load to canals and drains [4] shifting the environmental problem to other regions. Typical examples are the Qalubeya drain system and the Rahawy drain (study 2009 in progress).

The capacity of the whole drain system to regenerate itself will further diminish as more water is diverted away for new irrigation and municipal projects in the Egyptian desert. In the Nile flood plain groundwater quality is very much affected by the water quality of the surface water. The groundwater is recharged from Nile water, including seepage from canals, percolation from irrigation water and leakages of the sewerage system. In 1998 about 28% of Greater Cairo's potable water supply was based on groundwater [4]. A large amount of Egypt's population gets fresh water from hand-dug wells. A general overview on the water issue in Egypt is given be Abdel-Shafy and Raouf [5]. The lack of fresh water leads to increasing reuse of wastewater. According to the law, reuse of treated wastewater is not permitted for food and fibre crops. A large share of wastewater is still not treated and a part of it is still used in an uncontrolled manner, including for the production of uncooked food crops the consumption of which poses health risks.

In 1959 the Nile Agreement between the Sudan and Egypt for full utilization of Nile waters was signed allocating Egypt 55.5 billion cubic meters of water annually — 87 percent of the Nile's flow — with Sudan getting 18.5 billion cubic meters. Today the river provides 87 percent of Egypt's water resources. Egypt, which lies at the end of the river as it flows into the Mediterranean, has the largest population — 80.24 million with a high demographic growth — among the riparian states and thus the highest demand for water. However climate change in recent years has reduced rainfall, leading to lower water flows in the Nile and jeopardizing hydraulic projects in several states like for example new dams in Ethiopia. At recent the upstream countries contest the validity of the agreement. Having recognized their common concerns and interests, the 10 Nile countries that share the rive Egypt, Sudan, Ethiopia, Uganda, Kenya, Tanzania, Burundi, Rwanda, the Democratic Republic of Congo, as well as Eritrea established in 1999 the Nile Basin Initiative (NBI) which was formally launched in February, 1999 by the water ministers. The most important issue for the 10 Nile Basin countries is to reach an agreement about sharing water. To sign such a water-sharing agreement definitely cuts the traditional quotas. In contrast Egypt's water needs will surpass its resources in the near future because of its increasing population and agriculture. One solution to raising water demand is a concept of increased water use efficiency and re –use. According to Egyptian estimates an additional amount of 20 km^3/year could be made available.

Such possibilities are:

- water use for agriculture (new irrigation techniques),
- re-use of agricultural drainage water;
- domestic water use (reduce distribution losses),
- industrial water use (recycling, new production techniques),
- improve and expand capacities for wastewater treatment,
- use of treated water (Jabal el-Asfar, northeast of Cairo),.

3 Objectives

The Food and Agriculture Organisation (FAO) of the United Nations states that in Egypt limited investment in wastewater collection and treatment infrastructure in the past has resulted in a significant shortfall in sanitary coverage and a growing surface water problem. The Ismailia Canal is the only canal for fresh water supply in the distinct area between Cairo and Ismailia. The quality of its water which was used for irrigation has been studied in 2004 [43]. The surplus of irrigation water and the discharge of raw and insufficiently treated wastes in the Nile and irrigation canals and drains degradate the fresh water resources [6]. Major problems and issues related to the use of treated sewage water in Egypt were studied by Shaalan in 2001 [7]. The Bahr El-Baqar Drain system is the main canal for waste water disposal in the distinct area between Cairo and the north eastern area of the Nile delta. Discharges of municipal and domestic wastes make the use of this water even after mixing with fresh water for irrigation risky for pubic health. Finally the drain discharges into Lake Manzala which is very important for fish production.

The main objectives of this study were to

a) summarise and provide reliable information about the water quality;
b) determine the influence of industrial, agricultural or municipal discharges;
c) estimate its influence onto the quality of surface- and groundwater;
d) establish a databases to identify changes in the near future and give a contribution to upcoming international projects like ProMed [8,9];
e) train young scientists in different analytical techniques and quality assurance;
f) enhance the sensitivity for environmental impacts of water pollutants;
g) promote the installation of a water monitoring system in Egypt;
h) support installations for the treatment of wastewater before discharging it into drains.

4 Bahr El-Baqar Drain System

The Bahr El-Baqar drain system is shown in figure 1. It consists of a main drain that starts near the city of Zagazig where it collects the effluents from two secondary drains: the Bilbeis Drain and the Qalubeya Drain. From Zagazig the Bahr El-Baqar drain transports water for about 100 km to the Ginka subbasin in the southeast sector of the Lake Manzala which is located on the north-eastern edge of the Nile Delta (Fig.1). Lake Manzala is one of the coastal lake systems of the northern Nile Delta. It is surrounded with great areas of wetlands. The fish production is high and once supplied about 30% of Egypt's total catch.

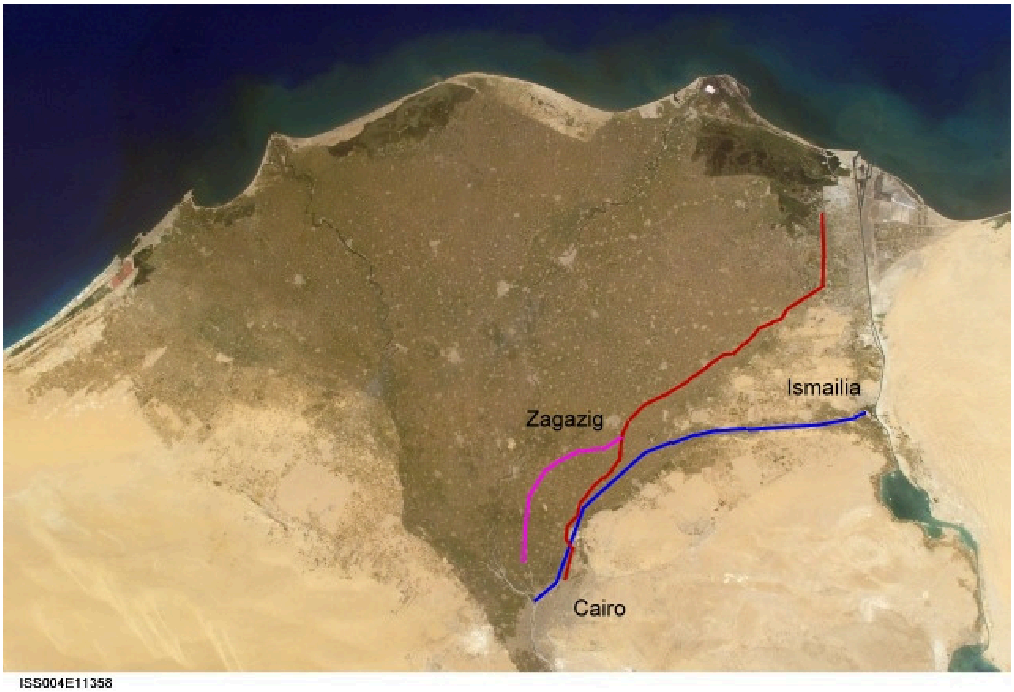

**Figure 1: River Nile delta from space, (Nasa, http://eol.jsc.nasa.gov)
Ismailia Canal (blue), Bilbeis- Bahr El Baqar Drain (red), Qalubeya Drain (pink)**

Tainted drinking water from the lake leads to enteric diseases of the population. The Bahr El-Bagar drain contributes to almost 45% of the total discharge into the lake. In turn, Lake Mazola discharges into the Mediterranean Sea. The reported significant deterioration of the water quality of the lake is due to the direct discharge of wastewater [11]. The relation between the environmental pollution and the health status of the population inhabiting the area near the lake was established by Osford at al. in 1998 [12]. The Ginka subbasin acts as a sink and as a result high levels of toxic metals were found in the sediments. In 1997 a project of engineered wetland technology started to treat 25000 m^3/day of polluted water from Bahr El-Baqar Drain [15] before the water enters Lake Manzala.

The Bahr El-Baqar drain system passes through the Qalubeya, Sharkia and Ismailia Governorates. One secondary drain called Bilbeis Drain starts near Cairo and has a total length of about 60 kilometres. All sewage and industrial wastewater, treated or untreated, from the eastern zone of Greater Cairo is dumped into this drain. The other drain called Qalubeya Drain is about 70 km long and runs parallel to the Bilbeis Drain at a distance of about 20 kilometres. It collects treated and untreated wastewater from the critical area of Shoubra El-Kheima and its large industrial area and the urban communities of the Qalubeya and Sharkia Governorates. Both drains are more like open sewers than like agricultural drains. In 1999 a study showed that the water quality parameters measured along the drain exceed the legal limits [13]. Poor sanitary drainage and rising ground-water level in the northern villages may lead to severe floods where houses submerge in feculent water spreading diseases like hepatitis or accumulating colonies of mosquitoes in the stagnant water. The risk of ground-water pollution is high. Especially in the north east the drain passes the old deltaic plain which shows a high vulnerability to pollution [16, 17].

5 Actual situation

In this work the water quality of the secondary Qalubeya Drain was studied before the Bahr El-Baqar Drain originates in the region near Zagazig at the confluence with the Bilbeis drain. There the main quantity of the Qalubeya Drain discharge can be pumped into Wadi irrigation canal. The Wadi reuse pump station has stopped operation due to the bad drain water quality, resulting in a loss of about 200 Mm^3 of reuse water per year [13]. Examinations on the water of the Bilbis and Bahr El-Baqar drain have been reported in 2009 [44]. The Qalubeya Drain is 70 km long and its depth is about 1 -2 m; its width was about 34 m, near Qaha it decreased down to about 15 m. From the GPS data the total high difference along the Qalubeya drain has been estimated to be about 7 m. Near Zagazig along the left hand of the drain a good road, straight and often tree lined is running parallel. Starting at the confluence of the Bilbais- and Qalubeya drain it allowed to reach all the sampling places quickly by car. Several bridges could be used for measurements and sampling along the cross section of the drain. Only in the north western section between the villages Kar ash Shaykh Khalifah and Minya el Qamh the infrastructure was not so well developed. A long section of the drain leads through cultivated agricultural areas. Along the drain there are several discharges – industries in the region of Cairo - as well as numerous agricultural run-offs in the north eastern part, in larger cities or villages treated or untreated urban municipal waters are discharged into the drain. Saad concluded in 1997 that 58% of the total drainage water comes from agricultural drainage, 2% from industrial drainage and 40% from domestic and commercial drainage [14]. The effluents from different waste water treatment plants (WWTP) are discharged into the drain: a) near Sinhira the Sheben drain (Sampling pos. no. 78) discharges treated wastewater from the Shoubra EL Kheima waste water treatment plant. The plant with a capacity of 600 000 $m^{3/}$day is located in the north of the city of Cairo; The detailed study of the Sheben drain has been performed in autumn 2010 (to be published in 2011); b) the WWTP located at the drain between the cities of Minya el Qamh and Shalshalmun (Sampling pos. no. 77 - 73), c) WWTP in the southwest of the city of Quaha (capacity about 10.000 $m^{3/}$day) (sampling position 80) and d) the outlet of the Sandanhour drain (sampling position 73b) which contains the effluent from a WWTP located about 20 km away in the direction south – south west, about 3 km in the east of the village Mit Suhayl (capacity about 10.000 $m^{3/}$day). The water in general was muddy with a high level of suspended particles. Methane and hydrogen sulphide bubbled up to the surface. In attachment IV and tables VI examples (inflow no, 1 and 2) for such agricultural runoffs are given. They are characterised by a high conductivity caused by high levels of chloride (160 - 260 mg/L), sodium (180 - 240 mg/L) and typical compounds of fertilizers like Ammonium (20 mg/L). Despite of these facts the water was used for washing dishes and vegetables and for the irrigation of farmland too. In several sections of the drain the surface was completely covered by weed flourishing which provides habitats for Billharzia snails. From our study it was estimated that Bahr El-Baqar drain receives about 20 m^3/s +- 30% of wastewater from Qalubeya Drain. In 1999 the water flow was reported to be about 11,6 m^3/s [13]. The risk is high to contaminated drinking water, responsible for enteric diseases such as infective hepatitis and amoebic dysentery. The water pollution affects not only public health but also the economic factors related to water quality and natural resources of reusable water. Mixing the drain water with fresh water seems to be a common practice as there were several connections to fresh water irrigation canals.

6 Experimental

6.1 Sampling

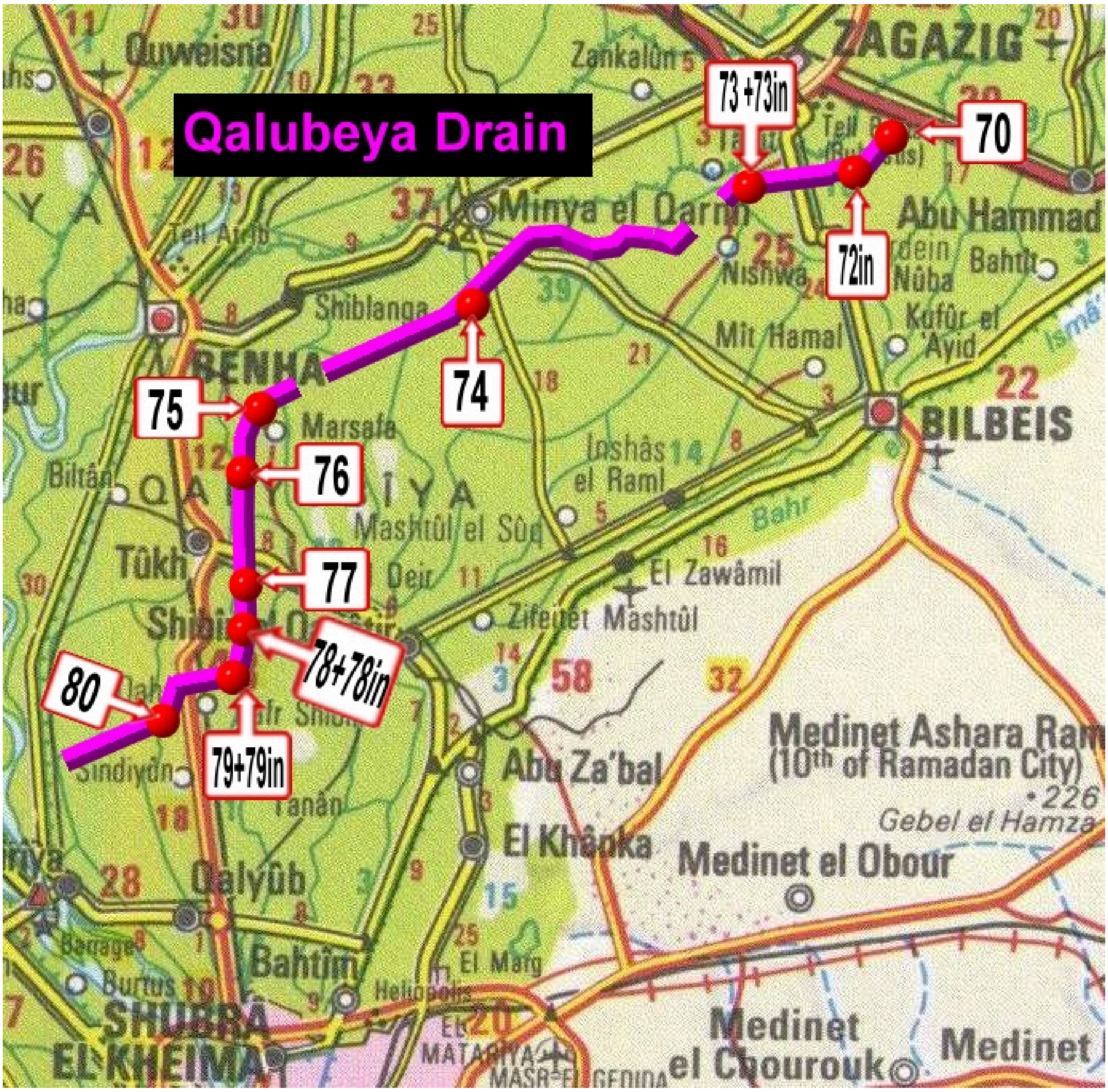

Figure 2: Sampling sites along the Qalubeya Drain

The study of the canal was performed in a sampling campaign in September 2007. The first sample (no.70) was taken in the north east of Cairo in the area of Zagazig (Fig.2) near the inflow of the Bilbeis drain. This site was chosen as starting point were the distances of all the other sampling points were related to. Totally 12 sampling sites were fixed (Fig.2), No.80 to 77 were close to Cairo to study the influence of the industry. For demonstration samples were taken additionally from agricultural discharges. Near Ezbet Fares (no.77) a groundwater sample was taken at a pumping station to check a possible influence of the drain water onto the groundwater. The detailed descriptions of all locations are given in appendix no. III. Besides the online measurement near the surface two samples of 100 ml each were taken in the middle of the canal. Several outfalls show an incomplete mixing with the main water flow over a very considerable distance from the point of entry. Before the samples were taken the homogeneity of the water was controlled by several online measurements along the cross section of the canal.

One sample was used for metal analysis; the second pure sample was used for the analysis of anions. For analysis the samples were stored in a polyethylene bottle in the dark at a temperature of 4°C. The samples were analysed in Egypt in the laboratories of the EAEA in Cairo and after transport to Germany in the laboratories of the Forschungszentrum Karlsruhe. All samples were filtrated before analysis through a 0,45µm filter (GHP-filer, Pall, Germany).

The volumetric flow was estimated from the average water velocity and the cross section of the canal. The cross section was determined from the width and the depth of the canal. Because of the coloured water it was not possible to see the ground. The water depth was measured two times. Assuming a constant depth along the width of the canal and a rising land bordering angle of about 25° the cross section was calculated. As figure 3 shows during the curse of the drain the water flow increased continuously up to ~ 20 m^3/s. Significant contributions are given by the inflows of the Sedanhour drain (inflow no. 2) and the Sheben drain (inflow no.3). The flow rate of this drain was estimated to be about 4 m^3/s (Literature 5,5 m^3/s [13]) The properties of this discharge showed a large influence onto the water of the main drain. At the end near Zagazig the flow rate of the Qalubeya drain increased to ~19 m^3/s (Literature 11,6 m^3/s in 1999 [13])

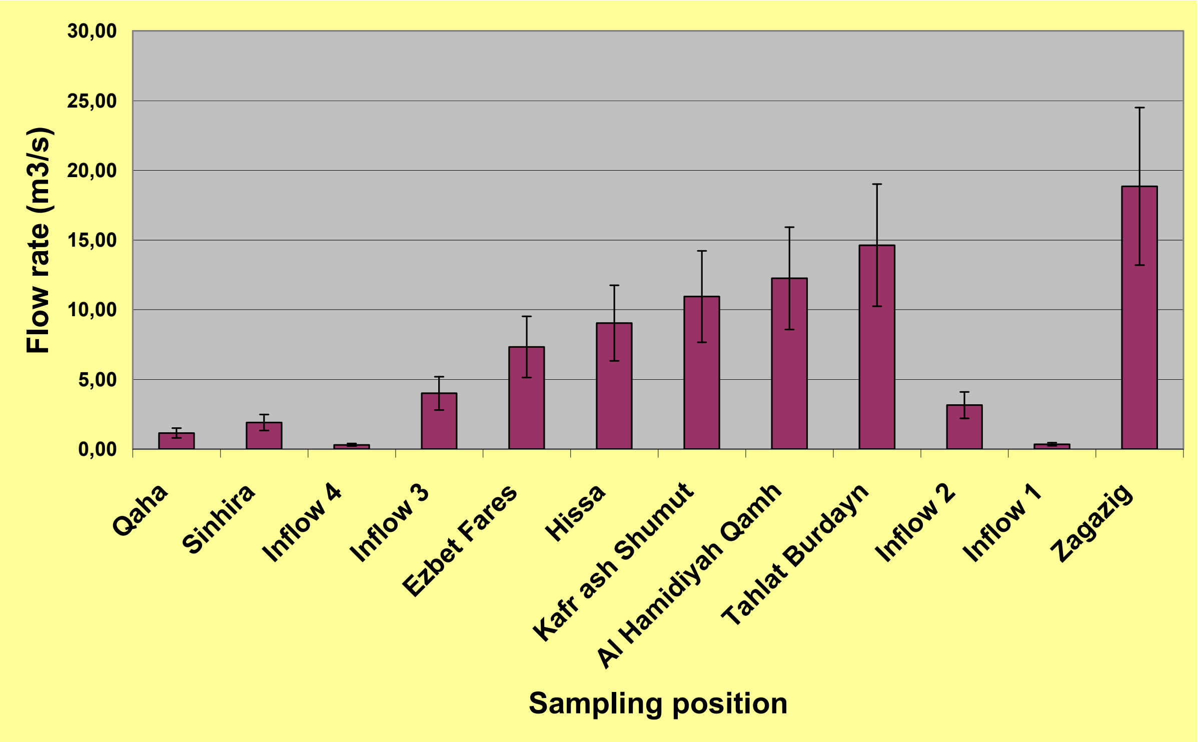

Figure 3: Water flow rate along the Qalubeya drain

6.2 Equipment

6.2.1 In situ measurements

General indicators are pH, electrical conductivity, redox potential, temperature and dissolved oxygen. These parameters were determined online and simultaneously samples were taken for detailed examination in the laboratory. For the field operations a portable multimeter model 197i from WTW (Wissenschaftliche Weilheim [18]) was used (Fig. 5) in combination with special probes for conductivity, oxygen content, pH and redox potential (Fig. 4) including a built in temperature sensor. The multi parameter instrument has a built in preamplifier and is therefore suitable in combination with depth armatures for single-parameter operation at a depth down to 100 m. Each probe had a cable length of 20 m for depth measurements. Thereby higher positions above the water level like bridges or barrages could be used. Additionally these sensors are pressure resistant up to max. 10 bars. Before their first use the sensors were calibrated and checked with corresponding standard solutions for specific conductance and pH, and the partial pressure of oxygen in water-saturated air for dissolved oxygen. In general they were kept at depth of 0.5 m until constant conditions were achieved. Error caused by instrument drift was determined by comparing the cleaned instrument readings with standard solutions. For all measurements a separate documentation of all details was done. Details of the Multi 197i and the different sensors are given in appendix I (A,B,C).

Figure 5 : Field multimeter Multi 197i (WTW – Company, Germany)

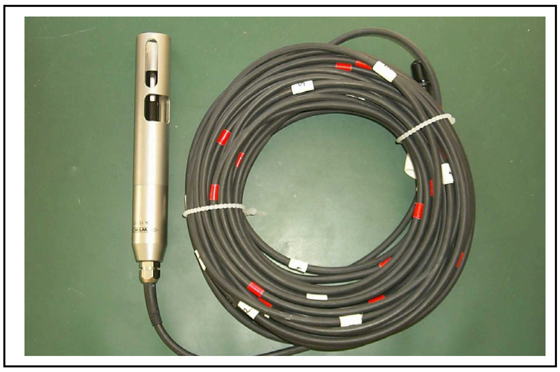

Figure 4: conductivity/temperature sensor

6.2.2 Laboratory analysis

Sum parameters

Chemical oxygen demand (COD)

The chemical oxygen demand test is used to estimate the amount of organic matter in samples. It is a measurement of the oxygen equivalent of the materials present in the sample subject to oxidation by a strong chemical oxidant - here dichromate. Typical values of COD are 500-1000 mg/l at the inlet of a waste water treatment plant and below 75 mg/l at the outlet of the plant.

UV measurements

UV measurements were made on a Perkin Elmer spectrophotometer Lambda 16 with distilled water as reference. The spectral absorption coefficient was determined as defined in DIN 38402 by the German Institute of Standardisation.

Total Carbon (TC), Total Organic Carbon (TOC) and Total Inorganic Carbon (TIC)
The TC and TIC in the samples are measured independently using a Rosemount DC-190 analyser. For details see appendix No. II. The percent TC is determined by a catalytical combustion at 680-900°C under an oxygen atmosphere where the carbon is oxidised to form CO2. For the determination of the TIC, H3PO4 (20%) is added to the sample. The carbon dioxide gas evolved by combustion of organic matter or carbonates is swept into a non-dispersive infrared spectrometer (NDIR) that measures CO2 directly. The TOC concentration is calculated by difference TOC = TC –TIC. For the calibration a blank and a potassium hydrogen phthalate solution with a TOC of 100 ppm was used.

Ion Chromatography
Ion chromatography (IC) is a popular method for ion analysis because many ions can be determined quickly with high precision simultaneously. In this study anions and cations were analysed with a single column chromatographic system (Metrohm Company, Germany). After calibration the area counts of ions were used to determine the concentration. To check the validity of the calibration to each sample sequence several standard samples were added.

Metals
Metals in the water samples were determined using ICP-OEs (Varian Liberty 150) and AAS (SeptrAA-800, Varian, Germany). Calibration standards were prepared from 1000 ppm solutions (VWR Company, Darmstadt, Germany). If necessary the samples were diluted with 0.05M HNO3.

7 Quality control

7.1 Ion balance

The ion balance describes the relation between the equivalent concentration of the different cations and anions. Larger differences indicate that important ions are missing. For its calculation the dominant cations Na^+, K^+, NH_4^+ Mg^{2+}, Ca^{2+} and the anions Cl^-, SO_4^{2-}, NO_3^- and HCO_3^- were taken into account. Fig. 6 shows the ion balance for the different sites. In general the error was found to be about ± 3% or lower. According to the literature an error of 5% to 10 % is acceptable [19, 20].

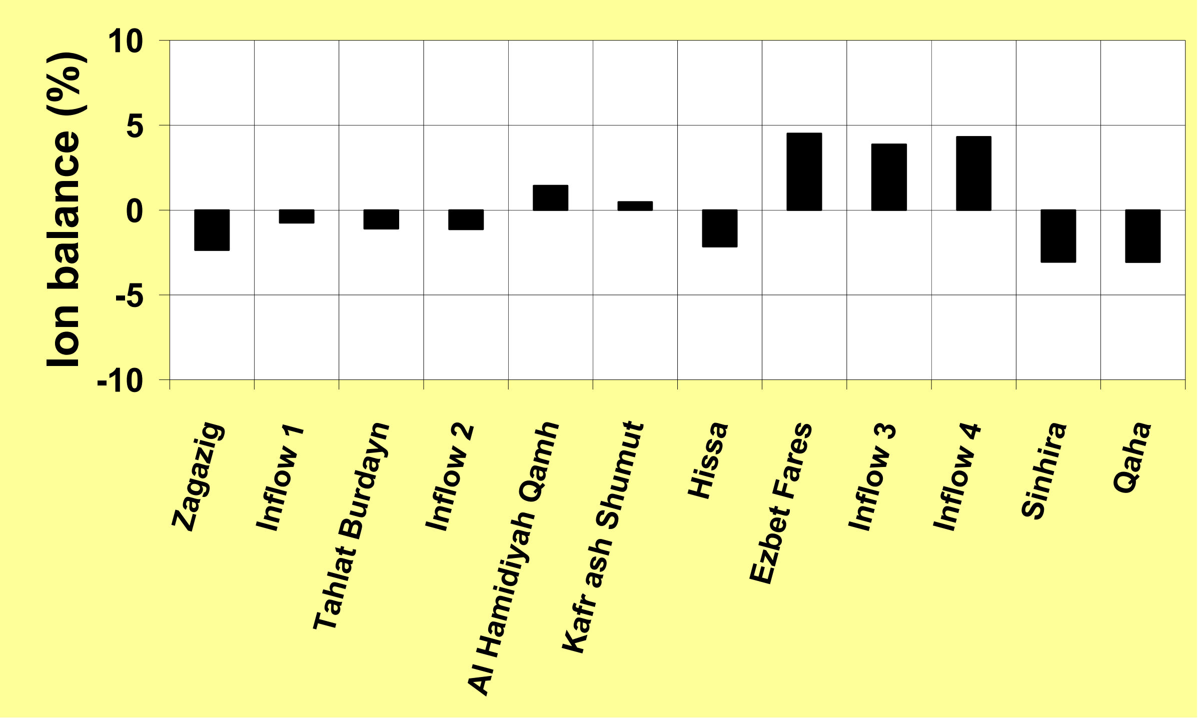

Figure 6: Ion balance for the different samples

Only the samples of Ezbet Fares and inflows 3 and 4 show a slightly higher error. The positive values indicate that the sum of the anions is slightly lower than that of the cations because anions are missing or the level of cations is too high. As no other anions were found it is supposed that the deviations are based on the hydrogen carbonate concentration which was calculated from the total inorganic carbon content. The average percentage error of the difference between the measured conductivity and the calculated conductivity [21] was -2 % with a standard deviation of +-1 % (see fig no. 12 in chapter 8.4). The critical analytical results were repeated and confirmed.

7.2 Additional measurements

For the validation of the results potassium and calcium were analysed with the two independent techniques ICP and IC. The ICP measurements were also repeated in a second laboratory showing identical values within a deviation of +-8%.

7.3 Calibration

The online instruments were calibrated with standard solutions for specific conductance, pH and redox potential. For dissolved oxygen the partial pressure of oxygen in water-saturated air was determined. To avoid possible errors caused by sensor fouling the sensors were cleaned with distilled water and the standards were measured from time to time.

For the calibration of ICP, AAS and IC calibration curves were prepared by at least four different standard solutions. Each calibration level was measured four/six times. For normal analysis freshly prepared standard samples are analysed once before and once after the series of unknown samples to check the validity of the calibration. For each unknown sample three injections were made. For the evaluation the scattering of the results and the confidence limits of the calibration were taken into account [22, 23].

All experimental results are given in the appendix no.IV and no.V (table VI, VII and VIII).

8 Results and Discussion

8.1 Temperature

In all graphs the patterns of the inflows are marked individually with black crosses. The water temperature of a river or canal is very important for water quality. Many of the physical, biological and chemical characteristics are directly affected by temperature like amount of oxygen that can be dissolved in water, rate of photosynthesis by algae or larger aquatic plants, metabolic rates of aquatic organisms and sensitivity of organisms to toxic wastes, parasites and diseases. Several parts of the drain showed a very tight flora of different aquatic plants. A temperature increase of the canal water will result in an even greater plant growth resulting in an increased oxygen demand during their decomposition. As Fig.7 shows the water temperature was slightly decreasing. At the beginning the water temperature is about 24.5°C mainly caused by the discharges of the WWTP via the Sheben drain (inflow no.3). The temperatures of the agricultural drains (inflows 1, 2, 4) are lower when compared to the drain water. Along the banks of the canal there is only little native vegetation to control the water temperature through natural shading. The risk is high that in the summertime a high temperature level will reduce available oxygen in the water. Simultaneously the rate of oxygen consuming processes like photosynthesis and the decomposition of organic residues will increase.

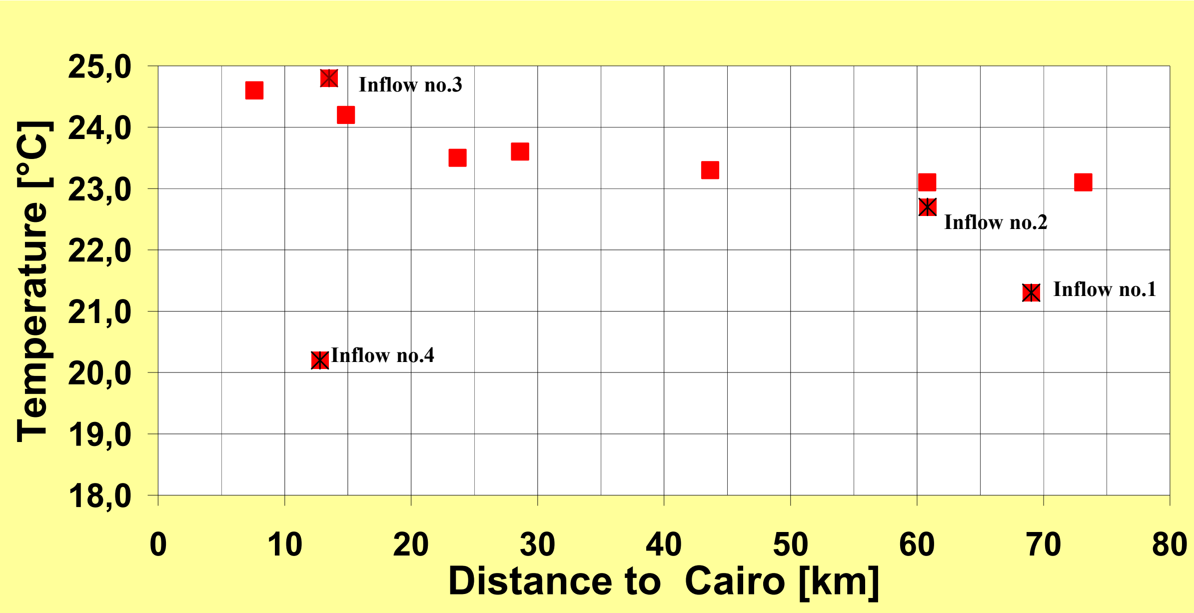

Figure 7: Temperature along the Qalubeya drain in March 2006

8.2 Dissolved oxygen (DO)

Dissolved oxygen is essential for the maintenance of healthy rivers. The presence of oxygen in water is a positive sign since most aquatic plants and animals need oxygen to survive. The DO can change during a day as a result of different photosynthesis activities. Large daily fluctuations in dissolved oxygen are characteristic of bodies of water with extensive plant growth. During dry periods, flow may be reduced and air and water temperatures are often higher. Both of these factors tend to reduce DO levels. Any oxidizable material present in a natural waterway or in an industrial wastewater will be oxidized both by biochemical (bacterial) or chemical processes. The result is that the oxygen content of the water will decrease. Basically, the reaction for biochemical oxidation may be written as:

Oxidizable material + bacteria + nutrient + O_2 ==> CO_2 + H_2O + oxidised inorganics

such as NO_3 or SO_4

Oxygen consumption by reducing chemicals such as sulphides and nitrites is typified as follows:

$$S^{--} + 2\,O_2 \implies SO_4^{--}$$
$$NO_2^{-} + 0.5\,O_2 \implies NO_3^{-}$$

Since all natural waterways contain bacteria and nutrient, almost any waste compounds introduced into such waterways will initiate such biochemical reactions

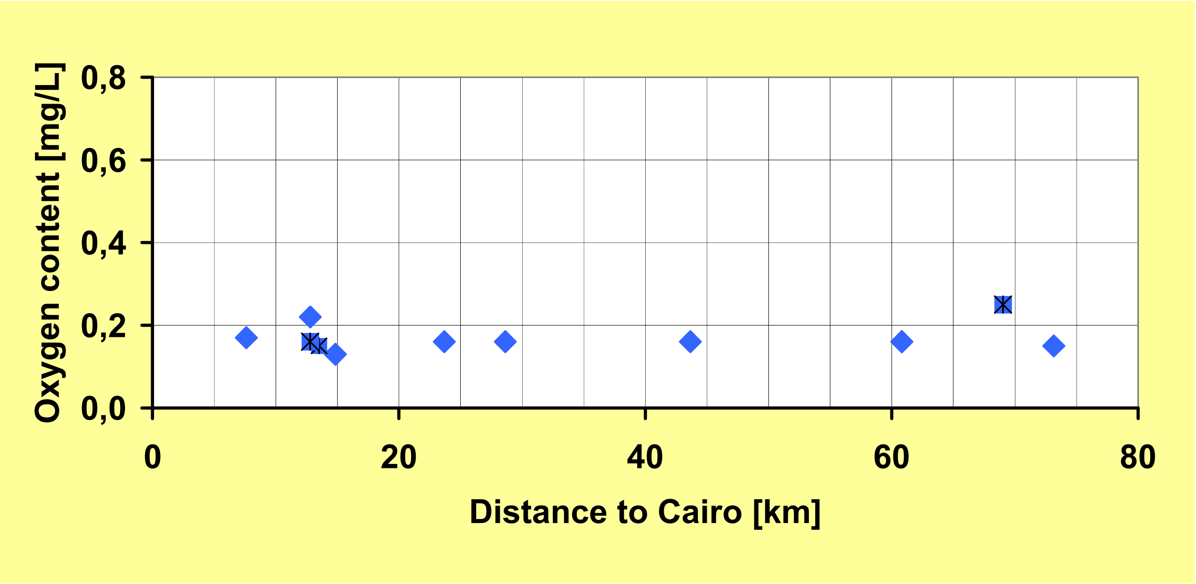

Figure 8: Dissolved oxygen along the Bar El-Baqar Drain

As Fig. 8 shows the DO level of the canal water was very low (~0.2 mg/L). No differences were found in the oxygen content between surface and bottom of the canal. Calculated in percent saturation the measured dissolved oxygen concentration was about 2% (Based on sea level, Barometric Pressure of 760 mm HG) [24, 25]. During the cleaning process of water a sufficient amount of dissolved oxygen for growth and metabolism of micro-organism has to be ensured. In general a DO concentration of 1-2 mg/l is necessary in an aeration tank. The observed oxygen level is therefore to low to keep up the self-cleaning efficiency. Consequently under these anoxic conditions there will be no self cleaning effect and no aquatic life.

8.3 pH and redox potential

The pH is important for aquatic life. Most organisms have adapted to life in a pH ranging from 6.5 up to 8.5. Runoff from agricultural, domestic and industrial areas may contain iron, aluminium, ammonia, mercury or other species. The pH of the water will determine the toxic effects, if any, of these substances. Especially acetic waters will cause heavy metals to be released into the water. Figure 9 shows the pH along the drain. The pH in general was about 7.4 slightly increasing along the course of the drain. Only right at the beginning near Cairo it was found to be a higher but later the pH was dominated by discharge no.3 . The pH was in the normal pH range recommended for irrigation water (6,0-8,5). The oxygen concentration level correlated with the measured redox potential which was extremely low (Fig. 10).

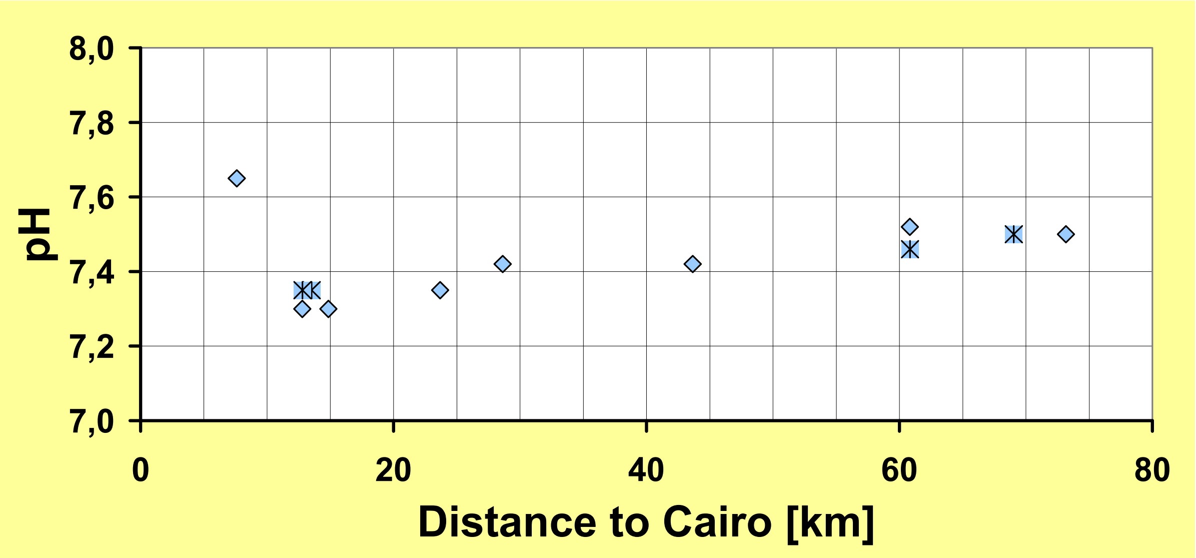

Figure 9: pH along the drain

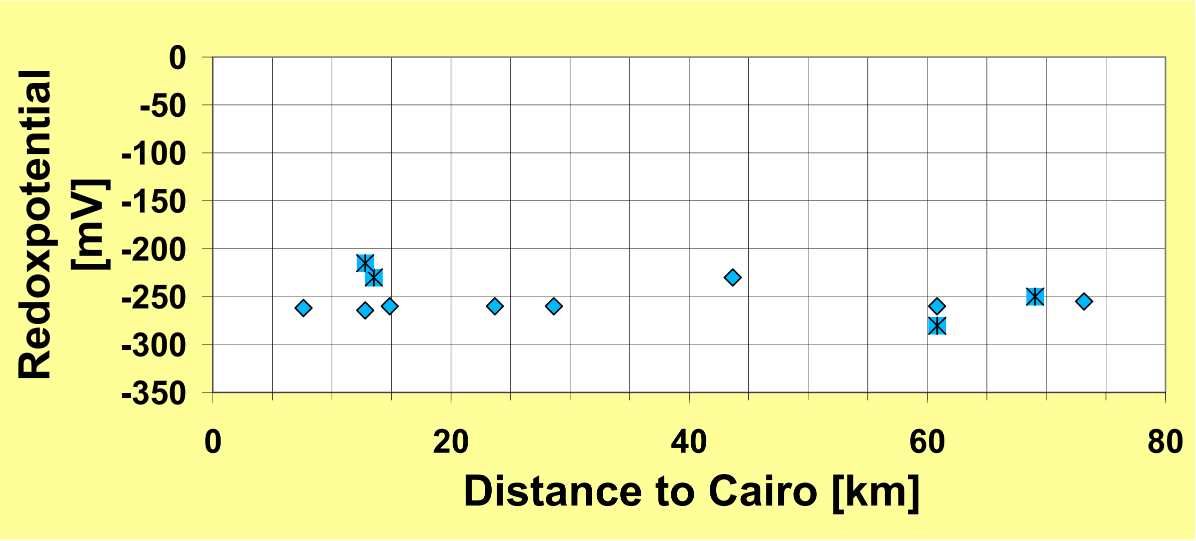

Figure 10: Redox potential (measured) along the drain

Eh and pH of surface waters are important to the regulatory processes affecting the solubility of heavy metals and their distribution among various geochemical forms. As shown in Fig. 11 the most values of the canal water were below the region that is typical for bog water. From the moderately low pH and reducing redox potential conditions it can be concluded that the relatively bio available soluble and exchangeable chemical forms of metals were favoured [26]. Even the uptake of heavy metals by plants grown on irrigated land may be influenced [27].

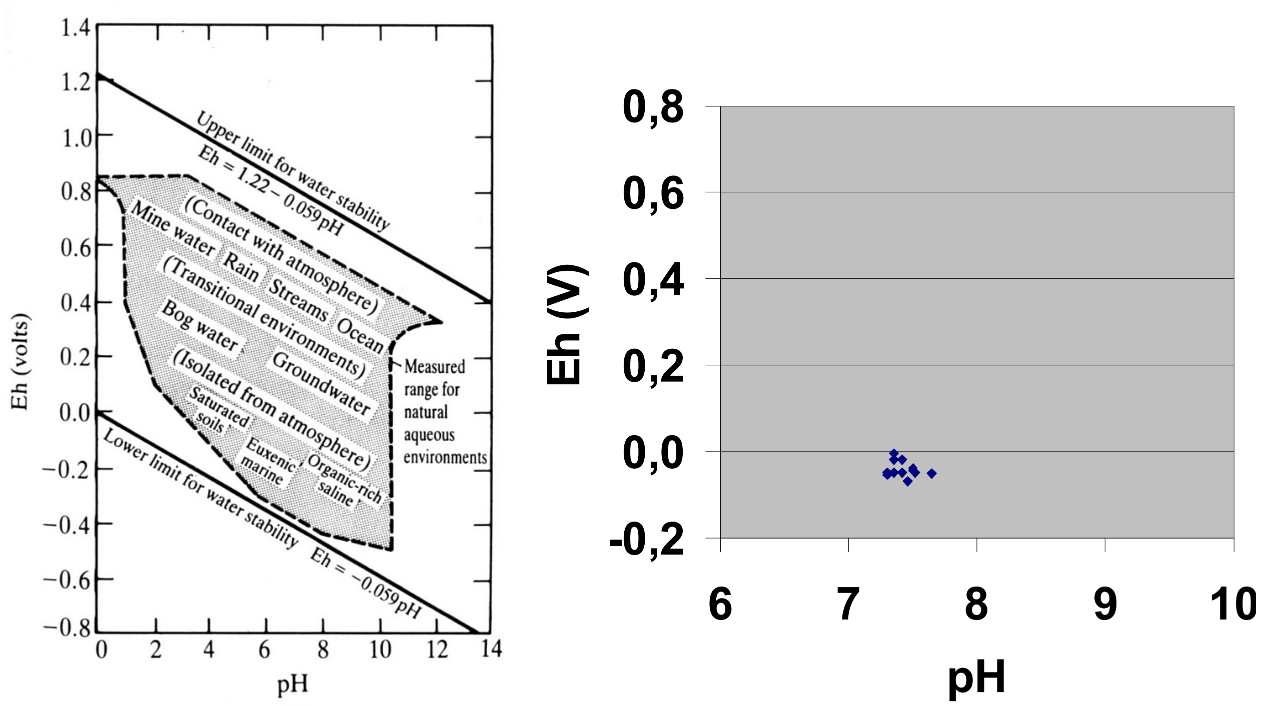

Figure 11: Eh – pH diagrams

8.4 Electrical Conductivity

The electrical conductivity along the canal is given in Fig. 13. Starting at 150 mS/m at the inflow of the Sheben drain the conductivity decreases to 110 mS/m, and remains nearly constant along the rest of the canal. The agricultural drain inflows showed a higher conductivity of 150 - 190 mS/m. According to Hölting [19] the amount of dissolved solids in the drain water remaining after evaporation at 100°C was calculated to be about 800 – 1000 mg/L by multiplying the electrical conductivity in µS/cm by a factor of 0.725. The result is about 3 times higher when compared to the fresh water of the Ismalia canal. The electrical conductivity was calculated by means of the equivalent conductivity. If according to Rossum [21] corrections are used related to the relaxion of ion-cloud effect and the electrophoric effect relative to ion mobility then the calculated conductivity was about 2% lower when compared to the online measurement (Fig. 12). According to actual evaluation of irrigation water salinity by the Food and Agriculture Organisation of the United Nations (FAO) the drain water was classified to be slightly/moderately saline [28].

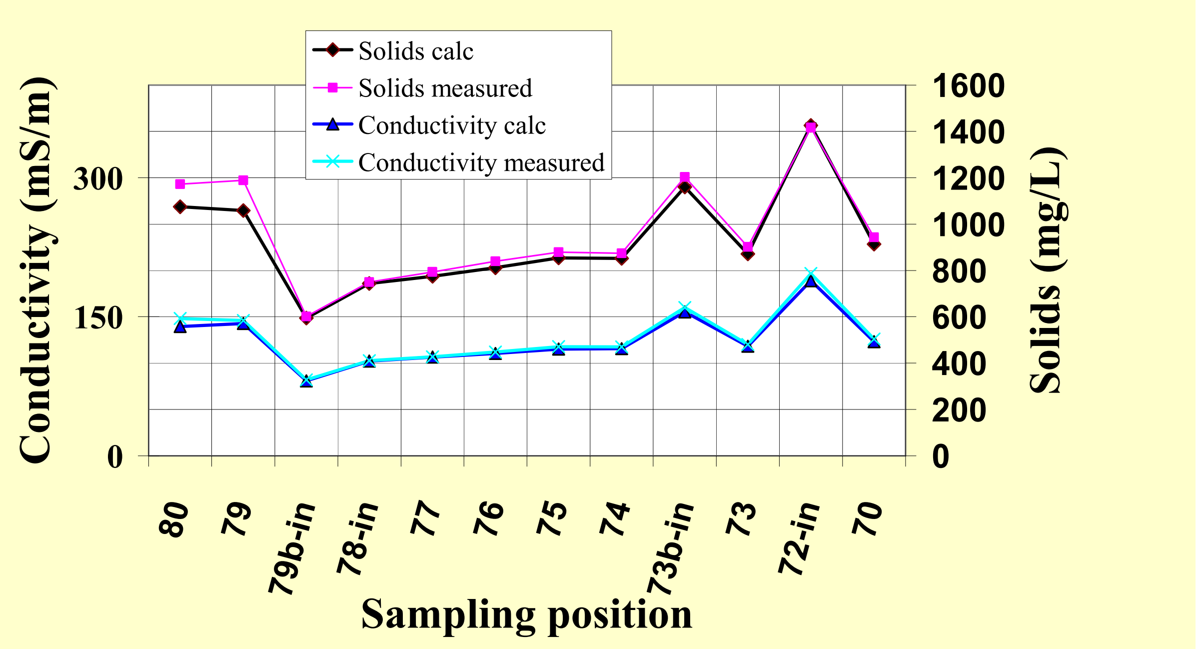

Figure 12 Calculated and measured electrical conductivity and solids content along the drain.

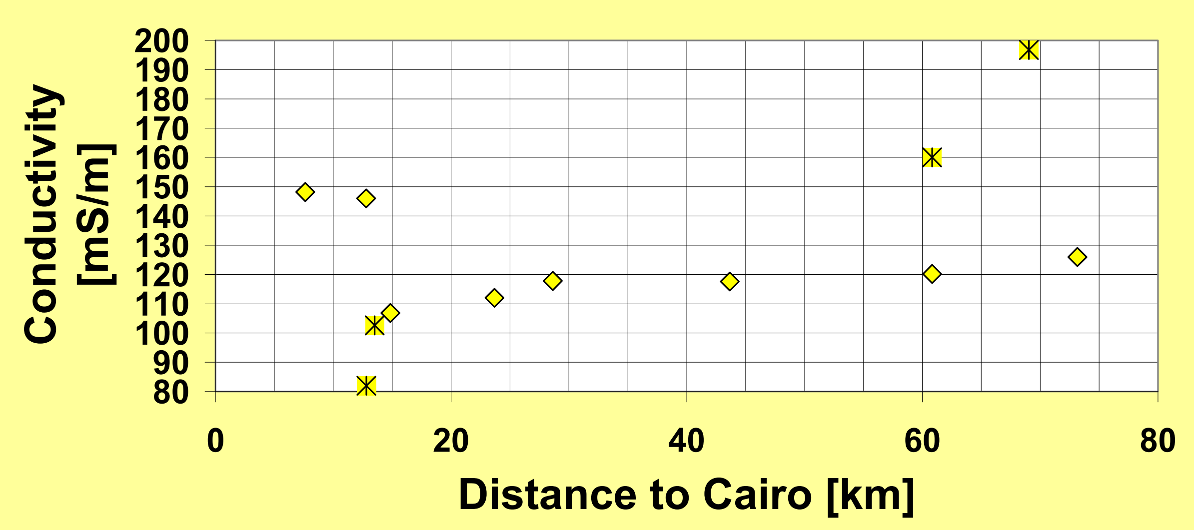

Figure 13: Electrical conductivity along the drain

8.5 TC, TOC, TIC and SAC

The measured TIC given in Fig. 14 shows no significant change along the canal. After 12 km the initial value of 130 mg/L drops down to ~80 mg/L caused by the discharge of the Sheben drain. The average of about 10 mg/L calculated for TOC is about five times higher when compared to clean water (1-2 mg/L) indicating a slight organic pollution The TIC was used to calculate the amount of hydrogen carbonate (HCO_3^-). Additionally to the TOC the spectral absorption coefficients at 254/200 nm (SAC 254 / SAC 200) were measured against distilled water (Fig. 15). In general for the determination of organic components the SAC 254 can be used [29]. The SAC 254 remained constant at a level of about 0,25 cm^{-1}. In this work the SAC 200 is considered too as a sum parameter for all components absorbing in the range of ultraviolet radiation. The SAC 200 started on a level of about 2,2 cm^{-1} near Qaha decreasing down to ~1,5 cm^{-1} at the inflow of the Sheben drain.

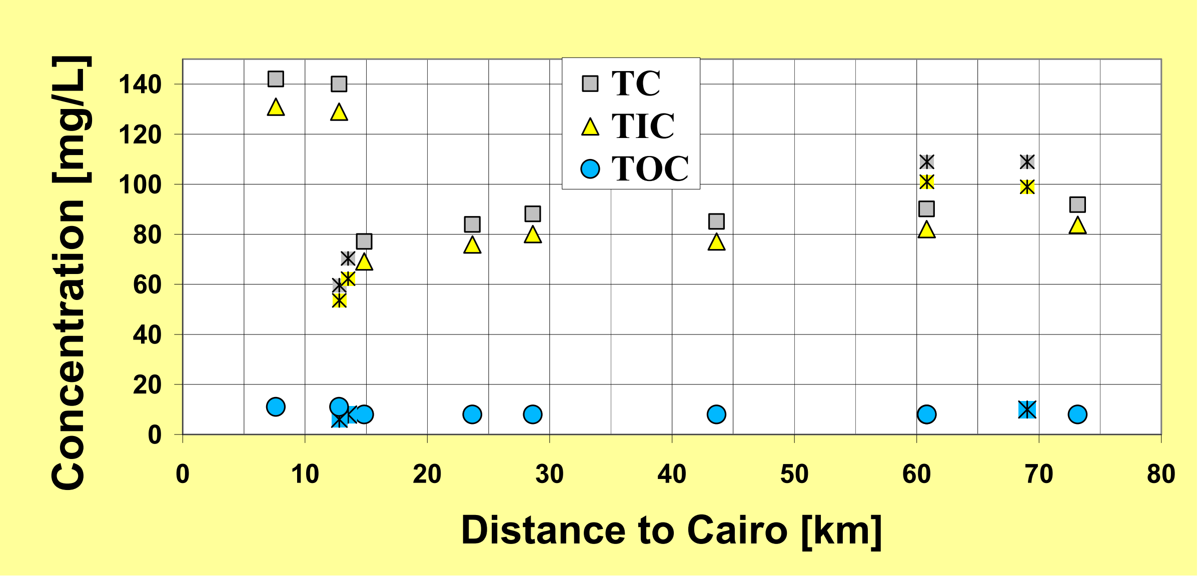

Figure 14: TC, TIC measured, (TOC calculated by difference TC-TIC).

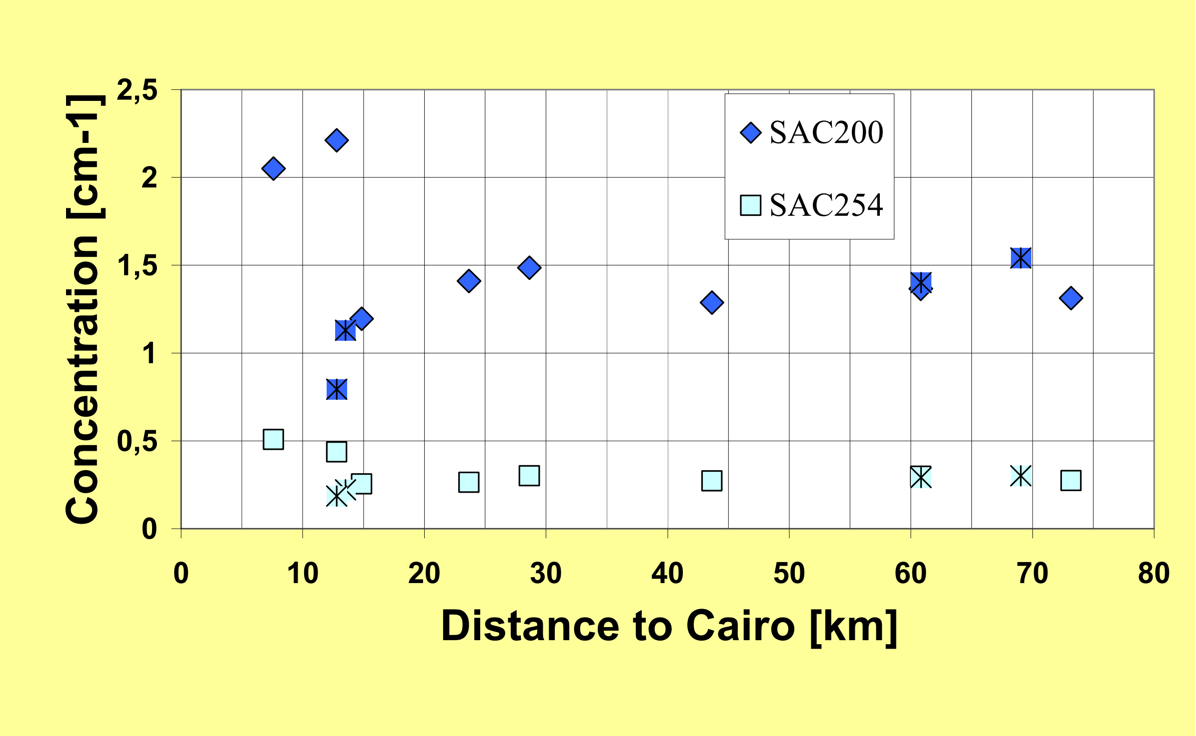

Figure 15: SAC 254 and SAC 200

8.6 Chemical oxygen demand (COD)

The chemical oxygen demand indicates the amount of oxygen required to oxidise the organic and inorganic matter in wastewater. The higher the COD of waste water, the more oxygen the discharges demand from water bodies. In practice, it is usually expressed in milligrams O_2 per litre. A chemical oxidising agent is added to the sample and its consumption is subsequently measured. In addition to the organic compounds, other compounds like nitrites, bromides, iodides, metal ions and sulphur compounds present in the sample can also be oxidised and have an influence on the result. Typical values are in the range from 5 to 20 mg/L for open watercourses, for domestic and municipal waste water 20 to 100 mg/L (after biological cleaning) and 300 to 1000 mg/L (without cleaning). The COD along the drain is shown in figure 16. At the beginning of the drain the water showed a COD of 80 mg/L. There the initial main water stream is caused by the discharge of large water purification plants in the north of Cairo. Due to several discharges along the drain the COD is reduced to 50 mg/L. Based on the molecular mass ratio between oxygen and carbon the theoretical correlation factor between COD and TOC is 2,67. In real samples the factor is found between 3 and 4. All samples from the drain show correlation factors in the range 3.4 to 7.4 indicating that a certain amount of non-carbon compounds are also oxidised during the COD determination. Such high values are especially found in industrial discharges like from mineral oil- sugar- or chemical industry.

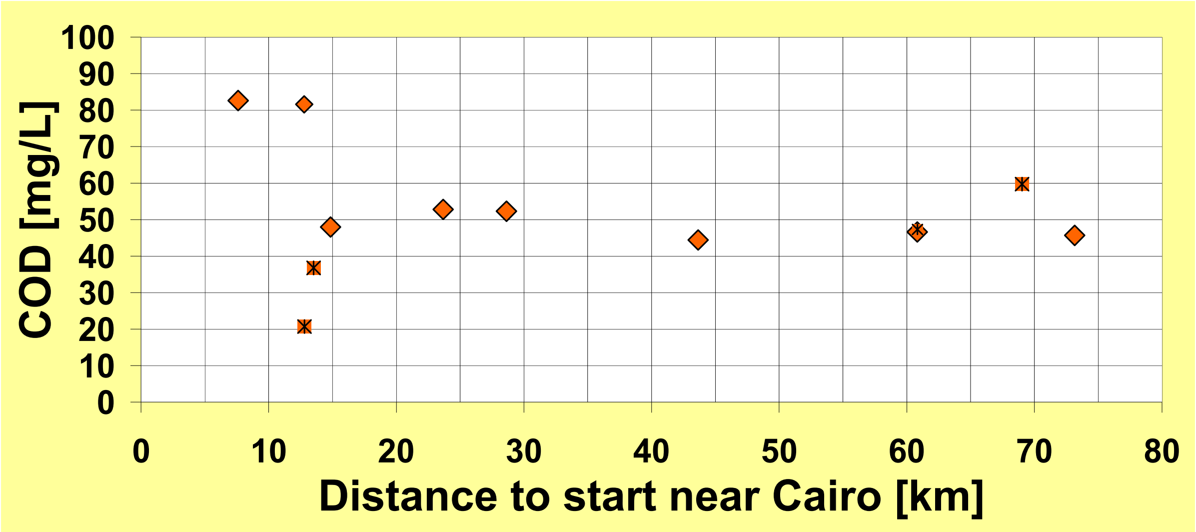

Figure 16: **Chemical oxygen demand**

8.7 Adsorbable organic halogens

Adsorbable organic halogens (AOX) are used as an indicator for halogenated substances [30]. Moreover, AOX determination is a relatively easy technique. Because AOX is an analytical parameter and represents a wide range of substances, differing not only in their chemical structure but also in their toxicological profile, a description of relevant toxicological endpoints cannot be given. AOX was in the range of 30-50 µg Cl/L, indicating a certain level or halogenated organic compounds (Fig.17). A possible source of AOX is the paper industry if these industries were using old technologies consuming large amounts of chlorine and if discharging directly into waterways or to water treatment plants with pore efficiency. Additionally the high levels of added chlorine to the raw water may led to increased concentration of organochlorinated compounds.

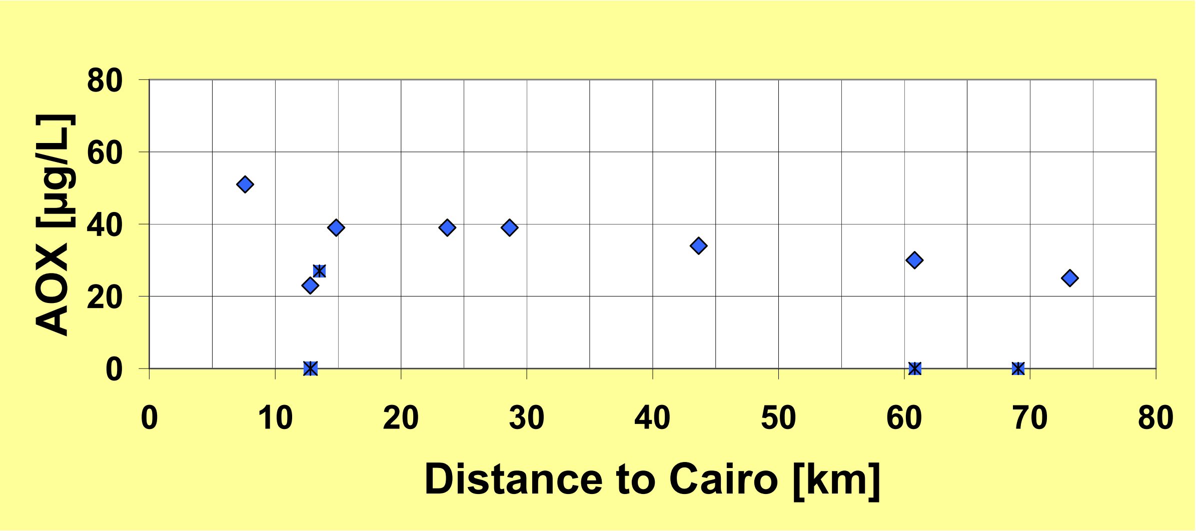

Figure 17: Adsorbable organic halogens

8.8 Anions

The dominant anions in the canal water are hydrogen carbonate (HCO_3^-), chloride (Cl^-) , sulphate and (SO_4^{2-}) As the volume of the samples was too small to determine the content of hydrogen carbonate (HCO_3^-) directly the TIC content was used for its calculation. These parameters were analysed in the laboratories about 10 days after sampling. Because of the uncontrolled access of oxygen the amount of nitrate and nitride was not reproducible. Under

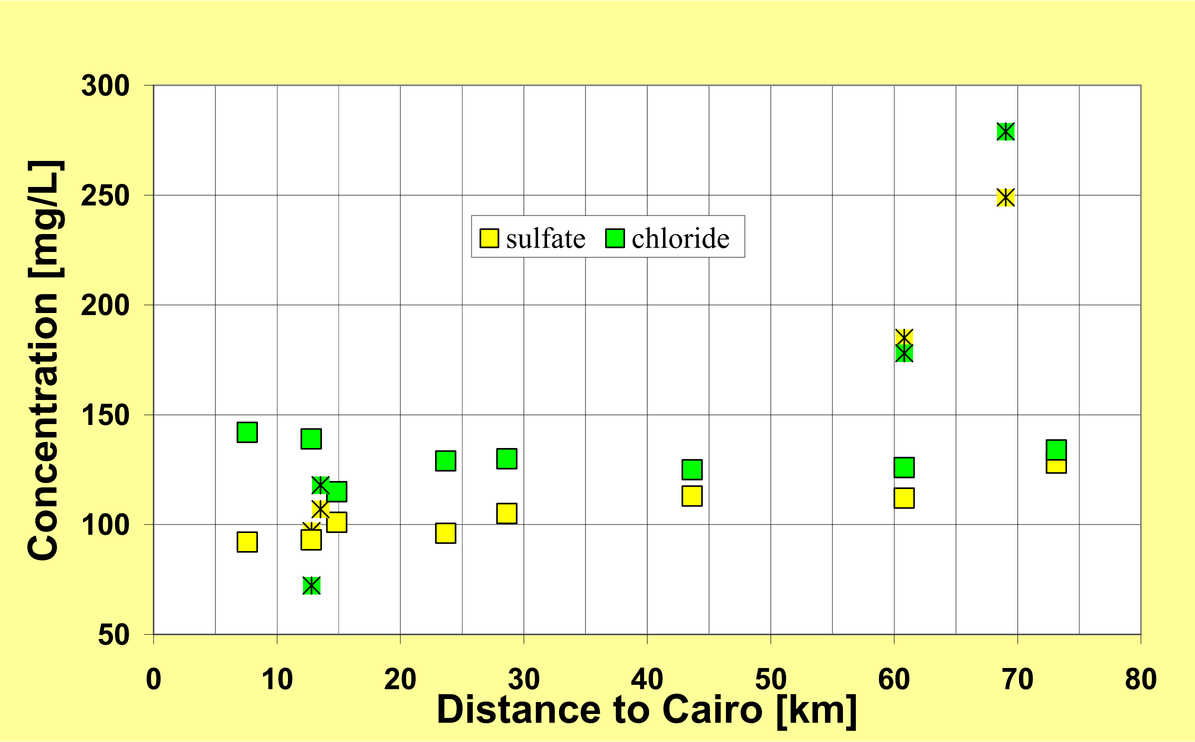

Figure 18 Chloride and sulphate concentrations.

the observed Eh – pH conditions hydrogen carbonate is the dominating species in the system H_2CO_3 - HCO_3^- - CO_3^{2-}. The mean HCO_3^- concentration of the canal water has been calculated and found to be in the range of about 350 - 670 mg/L. The chloride and concentrations were nearly constant at ~140 mg/L (Fig 18). Only the agricultural drains at km 61 and 69 showed significantly higher values. The sulphate level increased from ~90 mg/L up to ~130.

8.9 Cations

8.9.1 Alkali- and Alkaline-earth metals

The concentrations of Sodium, Potassium, Magnesium and Calcium determined by ICP along the course of the canal are given in figure 19. Except of the first 12 km of the drain the concentrations were found to be constant along the whole drain at a concentration level of about 25 mg/L for magnesium and potassium and about 60 mg/L for Calcium The sodium level slightly increased along the drain. The reasons are numerous agricultural run offs with a high potassium level as shown by the inflows at km 62 and 69 along the drain. At the beginning of the drain the concentrations were found to be significantly higher. The normal concentration for natural waters is about 0-3 mg/L. Sodium in the household is derived from foodstuffs, cooking additions and numerous chemicals which utilise the high solubility of sodium salts. The most significant source of sodium is from laundry detergents, particularly the standard, non concentrated powders which use various sodium salts as active ingredients and as fillers. The fillers provide no worthwhile contribution to the wash but may provide up to 40% of the sodium salts in the domestic waste water. The actual German "Trinkwasserverordnung" sets limits only for sodium at 200 mg/L. For potassium, magnesium and calcium there is no actual limit fixed. The limits of the old regulation for potassium and magnesium (50mg /L) have been cancelled. The fresh Nile water which enters the region via the

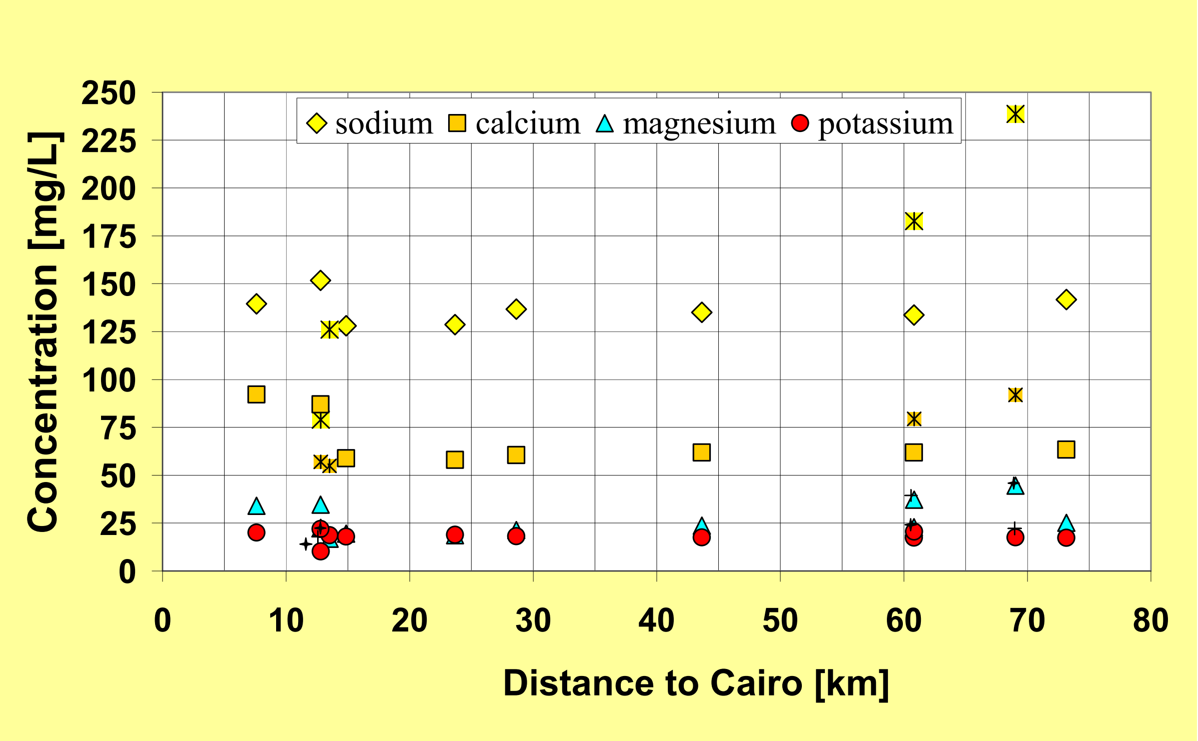

Figure 19 Concentrations of Sodium, Potassium, Magnesium and Calcium.

Ismailia Canal showed a concentration level (mg/L) of sodium (30), potassium (7), calcium (32) and magnesium (12) [43].

The ratio of K+/Na+ is in the normal range of ~0.1. The Mg^{2+}/Ca^{2+} ratio was found to be slightly above the normal range (0.1 –0.4). The $(K^+ + Na^+)/Cl-$ was about 2 times higher than the normal level (1.0) (Fig,20).

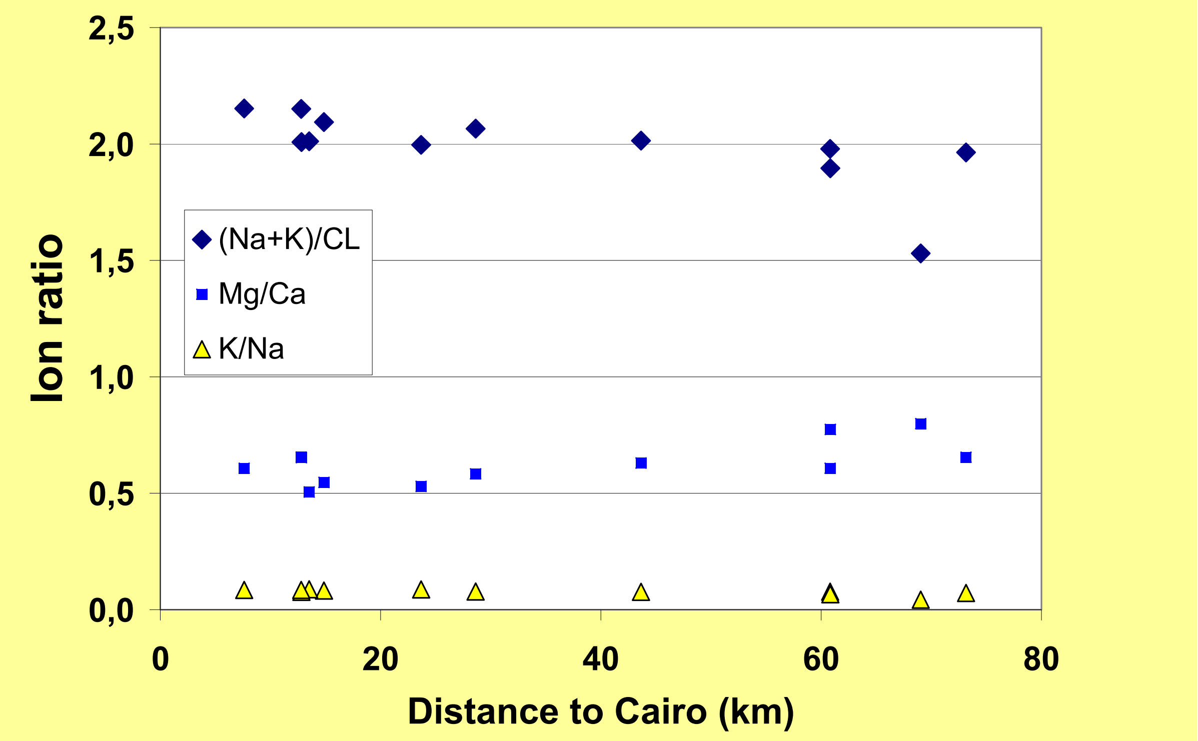

Figure 20: Ion ratios in the drain water

From these concentrations the Sodium Adsorption Ratio (SAR) index that expresses the relative activity of sodium ions in the exchange reactions with the soil was calculated (see chapter 8). This ration measures the relative concentration of sodium to calcium and Magnesium. SAR is defined by the following equation:

$$SAR = [CNa] / [\sqrt{(CCa + CMg)/2}]$$

(C): ion concentrations in mol/m^3

The dominant ions of the drain water are shown in the Schöller Diagram (Fig. 21) [32] in comparison to those of the water of the Ismailia Canal (dotted line in black) which is the main water supply for that area. Significant deviations were found in the Chlorine and Sodium concentration level.

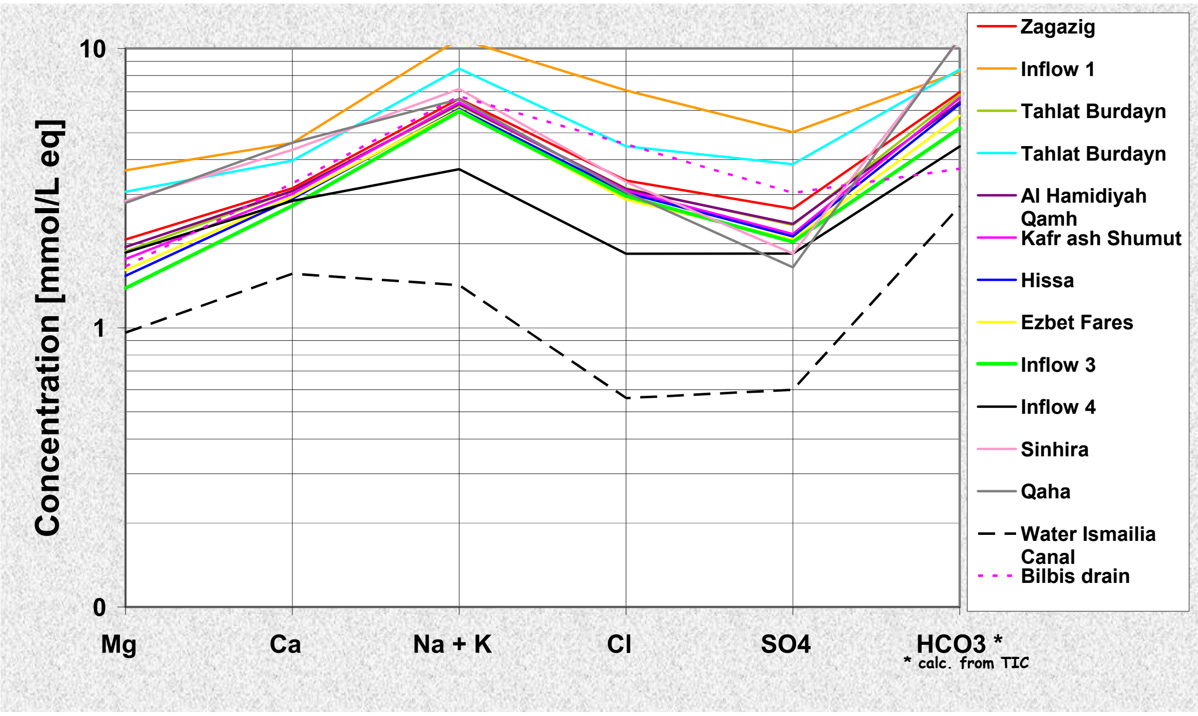

Figure 21: Schöller-Diagram of the water samples

8.9.2 Ammonia

Ammonia is environmentally hazardous both because of its toxicity to fish and because of its ease of oxidation, enabling it to deplete dissolved oxygen rapidly. It is the initial product of the decay of nitrogenous organic wastes, and the breakdown of animal and vegetable wastes. These are the principal sources of ammonia in river water. Sewage effluent from treatment plants is a major source of ammonia in water, and the diurnal fluctuations of the sewage plants' effluents can give rise to fluctuating ammonia concentrations downstream of their discharges. Agricultural diffuse sources of ammonia have some correlation with irrigation schedules but are otherwise difficult to characterise. The ammoniacal nitrogen concentrations in the Bahr El-Bagar draining system during 1996-97 were reported to be about 20-25 mg/L [11]. As figure 22 demonstrates the NH_4-N level was found to be nearly constant at ~10-14 mg/L along drain. In 2006 the level of ammonia of the Qalubeya drain near the junction with the Bilbeis drain has been about two times higher [44].

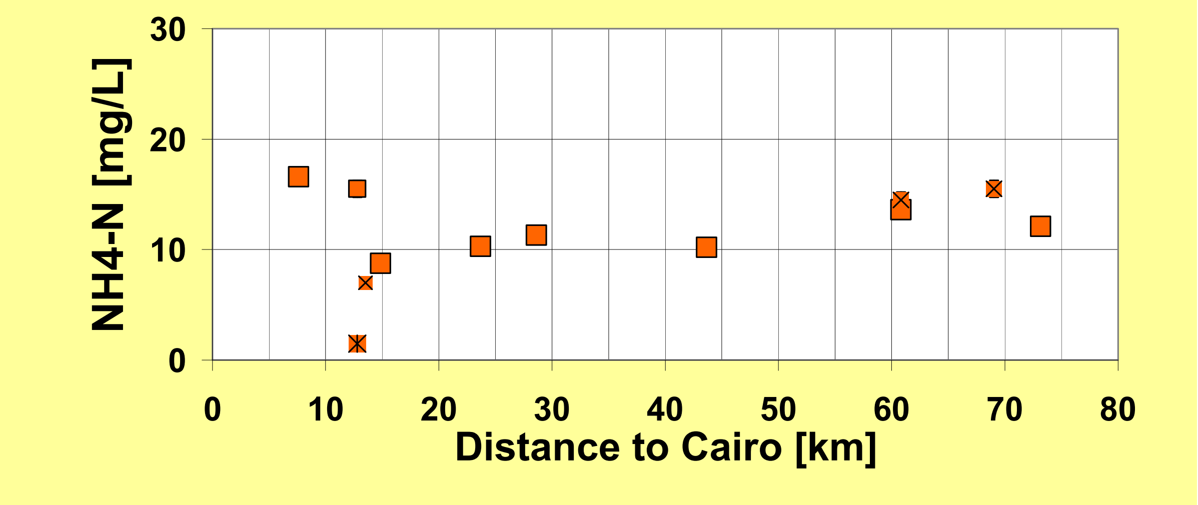

Figure 22: **NH_4-N concentrations**

8.9.3 Phosphorus, boron, aluminium, silicon and heavy metals

Boron, Aluminium, Silicon and the heavy metals were analysed using AAS or ICP technology. Several elements were studied additionally, but their concentrations in the drain water were found to be below the detection limit (brackets in mg/L): Cr(0,01), Ni(0,01), Pb(0,01), Cu(0,01), Cd(0,01), Co(0,01), Sn(0,03),Tl(0,01, Zn(0,01), Sb (0,02)). Consequently these concentrations were below the recommended maximum concentrations of trace elements in irrigation water [33]. The observed concentrations are illustrated in Fig.23. Except from the beginning of the drain all concentration profiles remain constant. Very low concentration levels were found for Aluminium and Iron. After the first 10 kilometres their concentration increased up to 0,2 mg/L and 0,4 mg/L respectively – the concentration of silica decreased from 16 mg/L down to about 10 mg/L. Boron can be toxic at very low concentration levels. A Boron concentration less than 1mg/L is essential for plant development, but higher levels can cause problems in sensitive plants. Most plants exhibit toxicity problems when the concentration of boron exceeds 2mg/L. The main source of anthropogenic boron comes from domestic effluents where products such as perborate are used as bleaching agent (i.e. boron can be found in urban wastewater at concentration levels as high as 5 mg/L in dry countries and concentrated sewage) with an average level of 1 mg/L. According to guidelines for interpretation of water quality [33] there will be no restriction on the use for irrigation at concentrations lower than 0.3 mg/L boron. The actual Boron level found in the drain was about 0,27 mg/L.

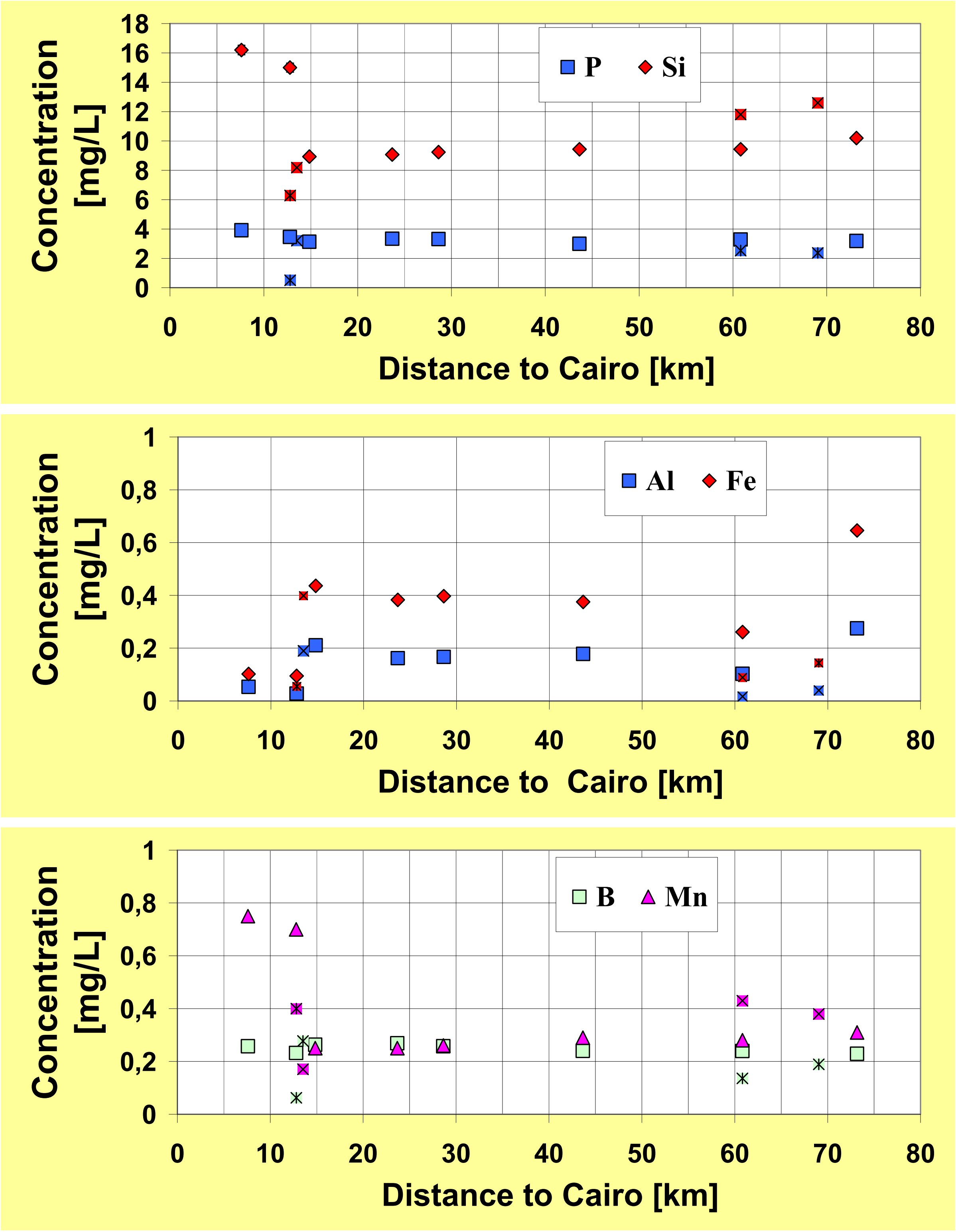

Figure 23: Concentrations of P, Si – Al, Fe – B, Mn along the drain

9 Water use for irrigation

When the drain water is used for irrigation two types of salt problems exist which are very different: those associated with the total salinity and those associated with sodium. Within this report no details on irrigation problems will be discussed. (For further detailed information see [33] or general information available at the world wide web).

9.1 Salinity

Water with high salinity is toxic to plants and poses a salinity hazard. High concentrations of salt in the soil can result in a "physiological" drought condition. Salts accumulate in the root zone to such an extend that the crops are no longer able to extract sufficient water from the soil solution even though the field appears to have plenty of moisture. Yield reductions occur and the plants show symptoms similar in appearance to those of drought. In extreme cases crusting seed beds and temporary saturation of the surface soil appear. Water salinity is usually measured by the TDS (total dissolved solids) or the EC (electric conductivity). The amount of TDS of the drain water varies from 800 up to 1200 mg/L and the EC was about 1,05 to 1,5 dS/m. According to the literature [34] the drain water has a medium salinity level with a slight to moderate hazard risk. When the salinity level is bigger than the threshold, the crop yield reduces linearly as salinity (EC) increases. For rice the EC threshold is 4,8 dS/m for sand and 1,6 dS/m for clay based soil. Further thresholds are given in appendix VI, table IX. In the case of a loamy soil the EC (~1,5 dS/m) of the water of the drain is below the limits for several products.

9.2 Water infiltration rate

An infiltration problem related to water quality occurs when the normal infiltration rate for the applied water is reduced. The most common water quality factors which influence the normal infiltration rate are the salinity of the water (total quantity of salts in the water) and its sodium content relative to the calcium and magnesium content. High salinity water will increase infiltration. Low salinity water or a water with a high sodium to calcium ratio will decrease infiltration. Both factors may operate at the same time. Irrigation water containing large amounts of sodium is of special concern due to sodium's effects on the soil and poses a sodium hazard. Sodium hazard is usually expressed in terms of SAR or the sodium adsorption ratio. SAR is calculated from the ratio of sodium to calcium and magnesium. The latter two ions are important since they tend to counter the effects of sodium. Continued use of water having a high SAR leads to a breakdown in the physical structure of the soil. This is because sodium when present in the soil in exchangeable form replaces calcium and magnesium adsorbed on the soil clays and causes dispersion of soil particles. The soil then becomes hard and compact when dry and increasingly impervious to water penetration. Fine textured soils, especially those high in clay, are most subject to this action whereas sandy soils may not get damage as easy as other heavier soils. This problem is also related with the salinity rate. At a given SAR the infiltration rate increases as salinity increases or the other way around. Therefore the SAR and EC should be used in combination to evaluate potential problems. According to literature after the discharge of the Sheben drain the drain water can be classified as slight to moderate reduction in the rate of infiltration. Towards the end of the drain the situation improves to still no reduction in rate of infiltration and still no affect on crop water availability

(Fig.24, table I). The situation may change quickly to a slight to moderate restriction on use in dry periods with high temperatures when agricultural drains raise the sodium level and a high water evaporation rate leads to higher salt concentration.

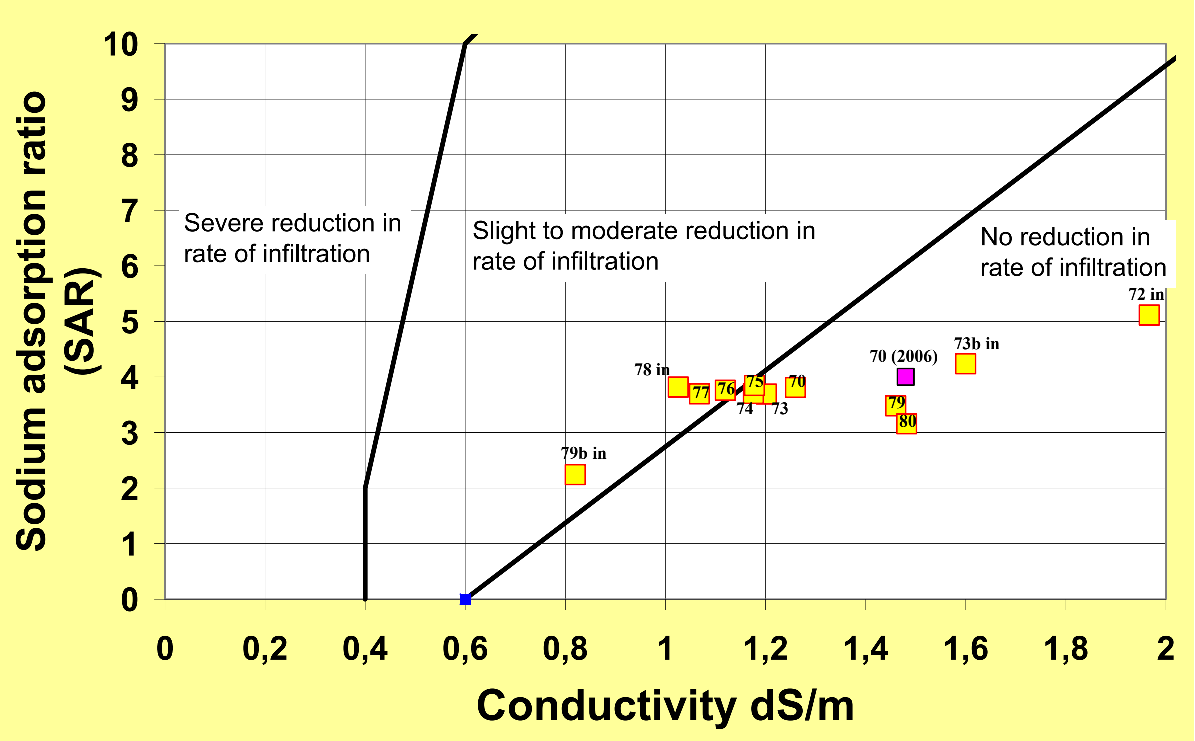

Figure 24: Relative rate of water infiltration as affected by salinity and sodium adsorption ratio [35] (sample 70 was measured in 2006 too)

Table 1: Guidelines for interpretation of water quality [36]

Potential Irrigation Problem				Units	Degree of Restriction on Use		
					None	Slight to Moderate	Severe
Salinity*(affects crop water availability)*[1]							
	EC_w			dS/m	< 0.7	0.7 – 3.0	> 3.0
	(or)						
	TDS			mg/l	< 450	450 – 2000	> 2000
Infiltration*(affects infiltration rate of water into the soil. Evaluate using EC_w and SAR together)*[2]							
SAR	= 0 – 3	and EC_w	=		> 0.7	0.7 – 0.2	< 0.2
	= 3 – 6		=		> 1.2	1.2 – 0.3	< 0.3
	= 6 – 12		=		> 1.9	1.9 – 0.5	< 0.5
	= 12 – 20		=		> 2.9	2.9 – 1.3	< 1.3
	= 20 – 40		=		> 5.0	5.0 – 2.9	< 2.9

1 ECw means electrical conductivity, a measure of the water salinity, reported in deciSiemens per metre at 25°C (dS/m). TDS means total dissolved solids, reported in milligrams per litre (mg/l).

2 SAR means sodium adsorption ratio. SAR is sometimes reported by the symbol RNa. See Figure1 for the SAR calculation procedure. At a given SAR, infiltration rate increases as water salinity increases. Evaluate the potential infiltration problem by SAR as modified by ECw. Adapted from Rhoades 1977, and Oster and Schroer 1979

or weeks) is normally required before accumulation reaches toxic concentration. Symptoms usually appear as a burn or drying of tissue at the outer edges of the leaf and as severity increases, the symptoms progress inward between the veins towards the centre of the leaf. Special guidelines for interpretation of water quality are given in table II. According to the concentration levels found (Na ~ 140mg/L, Cl ~ 130 mg/L, B 0,25 mg/L, Total Nitrogen 1-3 mg/L, HCO_3^- ~ 6,0 me/L, pH ~ 7,4) a slight to moderate restriction on the drain water use for surface irrigation of sensitive crops is recommended.

Based on more detailed guidelines which were given by Ayers and Westcot (appendix VI, table X, [42]) the concentrations of nitrogen species like ammonium and nitrate, phosphate-phosphorus and potassium are outside the limits for irrigation water.

Table 2 Guidelines for interpretation of water quality [36]

Potential Irrigation Problem	Units	Degree of Restriction on Use		
		None	**Slight to Moderate**	**Severe**
Specific Ion Toxicity *(affects sensitive crops)*				
Sodium (Na)[1]				
surface irrigation	SAR	< 3	3 – 9	> 9
sprinkler irrigation	mg/l	< 70	> 70	
Chloride (Cl)[1]				
surface irrigation	mg/l	< 140	140 – 350	> 350
sprinkler irrigation	mg/l	< 140	> 140	
Boron (B)	mg/l	< 0.7	0.7 – 3.0	> 3.0
Trace Elements (see appendix VI, table VIII)				
Miscellaneous Effects *(affects susceptible crops)*				
Nitrogen (NO_3 - N)[2]	mg/l	< 5	5 – 30	> 30
Bicarbonate (HCO_3)				
(overhead sprinkling only)	me/l	< 1.5	1.5 – 8.5	> 8.5
pH		**Normal Range 6.5 – 8.4**		

1 For surface irrigation, most tree crops and woody plants are sensitive to sodium and chloride; use the values shown. Most annual crops are not sensitive; use the salinity tolerance tables for chloride tolerance of selected fruit crops. With overhead sprinkler irrigation and low humidity (< 30 percent), sodium and chloride may be absorbed through the leaves of sensitive crops.

2 NO_3 -N means nitrate nitrogen reported in terms of elemental nitrogen (NH_4 -N and Organic-N should be included when wastewater is being tested).

9.3 Miscellaneous

Further risks are unsightly deposits on fruit or foliage which reduce the markability of the products. In some areas there might be a risk of fouling or corrosion of equipment increasing costs for maintenance and repairs.

9.4 Pathogens

There are several health hazards associated with the use of wastewater: the rural health and safety problem for those working on the land or living on a near land where the water is being used, the risk that contaminated products from the wastewater use may subsequently infect humans or animals through consumption or handling of the foodstuff. Finally there is the domestic user of irrigation water to whom irrigation water constitutes the primary water source for daily domestic needs. For the drain system the level of pathogenic organisms similar to those in the original human excreta is supposed to be high. There may be several types of pathogens like viruses, bacteria, protozoa and helminths. The type and amount of pathogens present in the drain water were determined within this study during autumn 2006 at 3 locations along the drain system: at the beginning and the end of the drain as well as at the inflow of the Sheben drain. To prevent disease several questions have to be solved: what types of pathogens are likely to be present in the wastewater? How many and what types of pathogens reach the field or crop?

E-Coli

By testing for coliforms, especially the well known Escherichia coli, which is a thermo tolerant coliform, one can determine if the water has probably been exposed to fecal contamination; bacterial water analysis is a routine check to make sure that the concentration of potentially pathogenic bacteria in drinking water is sufficiently low to say it is safe for human consumption at a reasonable level of confidence. The presence of E. coli in water is a strong indication of recent sewage or animal waste contamination [37]. Analysis is usually performed using culture, biochemical and sometimes optical methods. Specific pathogens can be quickly detected (where suspected) using molecular biology. In drinking water sampling the Colilert culture method is common. A reagent is added to water samples of a uniform amount. These are cultivated on a nutrient tray that is sealed and incubated at 22ºC and 37ºC for 24 hours. Bacteria reproduces to form a colony and each one can be counted easily because they become fluorescent in the reagent. Prior to this method, each sample would be cultivated on a single nutrient pad such as Agar and the colonies were then painstakingly counted under a microscope.

Coliform bodies

The total number of colonies is called the Total Viable Count (TVC). The unit of measurement is cfu/ml (or colony forming units per millilitre). Typically three indicator bacteria are chosen; non-specific coliforms, E. Coli and Pseudomonas Aeruginosa. Coliforms (and especially E. Coli) could suggest the possibility of fecal matter contamination of a water supply. Guidelines for evaluation are available in the literature [38,36].

It is also recognized that using faecal coliforms alone as the only indicator presents a risk. A disadvantage to the faecal coliform measurement is that faecal coliforms occur in both human and animal sources of pollution and detection does not tell whether the water contamination is of human or animal origin.

Enterococcus spp

In 2004 in the state of Hawaii Enterococcus spp took the place of fecal coliform as it is believed to provide a higher correlation with many of the human pathogens found in city sewage.

Pseudomonas aeruginosa

The presence of Pseudomonas may indicate that the water is not as clean as it should be, although it may still be potable if the levels are sufficiently low and prompt action is taken.

Clostridium.perfringens

It is reported that food contaminated with a high level of Clostridium.perfringens (mainly type A) may lead to severe diseases within 8 to 12 hours [46].

The WHO bacterial guideline for unrestricted irrigation use is described as less than or equal to 1000 faecal coliforms per 100 ml measured as a geometric mean of the samples taken.

Table 3 Micro organisms identified

Sampling position		80	78 inflow	70
Escherichia coli	in 100mL	1986000	1790000	31000
Enterococcus spp	in100 mL	155000	94000	8000
Pseudomonas aeruginosa	in 100mL	1000	2000	30000
Clostridium perfringens	in 100mL	22000	26000	33000
Total coliforms (TC)	in 100 mL	2500000	8660000	206000

The results of the microbiological analysis demonstrate high bacteria counts (Tab.3). The level of the pathogens studied is high above of all quality standards and the WHO guidelines [47]. Consequently the drain water can't be used in any way. The orders of magnitude in which the various bacteria groups are found in the inflow of the Sheben drain indicate a poor efficiency of the corresponding waste water treatment plant. The increase of Pseudomonas aeruginosa and Clostridium perfringens along the drain may be caused by the numerous agricultural runoffs because these species may by multiplied there under appropriate conditions [48, 49]. During this study the bacteriological evaluation has been analysed only partially for selected places without repeating sampling. Further research is required in order to determine the full health risks.

10 Groundwater

Table 4 Main salt components of drain-, canal- and groundwater

Parameter	unit	Bahr EL Baqar drain	Ismailia canal	Ground water	Qalubeya drain
Chloride	Mg/L	158	17	79	110
Sulphate	Mg/L	140	29	172	100
Hydrogen carbonate	Mg/L	303	169	453	401
Calcium	Mg/L	67	31	74	60
Magnesium	Mg/L	22	12	42	19
Potassium	Mg/L	24	7	6	19
Sodium	Mg/L	137	29	71	130
Conductivity	mS/m	135	38	n.a.	110

As the groundwater resources are supported by the surface water, the risk of groundwater pollution by seepage water from the drain is high. For that reason near Ezbet Fares (sampling site no. 77) a groundwater sample was taken from a small well the water of which was used for irrigation. The local distance to the Qalubeya drain was about 80 m. The results of the groundwater analysis are summarised in table 4 (for details see appendix V, tab. VIII; sample No. 13). The sample shows a higher level of hydrogen carbonate, sulphate and calcium whereas the concentrations of chloride and sodium are lower. Chemical oxygen demand, total organic carbon and the spectral absorption coefficients are quite low indicating a very low level of organic compounds. It seems that the water has taken up minerals from the underground and that there was ne seepage water from the drain passing the underground. Yet the result is only one spotlight and should be confirmed by additional analysis of groundwater samples.

11 Summary

Agricultural drainage reuse will be an important source of the irrigation in the Delta. The continuous expansion of irrigated fields has resulted in an increasing summer water shortage especially in the East Delta were the Ismailia canal is the most important freshwater source. The reuse of drainage water or special use of treated waste water could provide a valuable contribution to water supply over the East Delta. However the Qalubeya drain system is threatened by the contamination of municipal and industrial discharge of untreated wastewater. Many agricultural branch drains waters fall into the drain and consequently loose their reusability.

Additionally to the study on the Bar El Baqar study in 2006 [44] a preliminary assessment of the Qalubeya drain water was performed on water samples taken along the course of the drain. Analysis of various chemical parameters including sum parameters, concentrations of anions and cations and were performed. Microbiological analysis were performed too. In general the result is similar to that of the Bar El Baqar study:

The observed amount of dissolved oxygen is too low to keep up the self-cleaning efficiency. The comparison with the measurement in 2006 near Zagazig shows that the concentrations of all ions (except that of sulphate) in the drain water are lower, whereas COD and TOC are in the same range. This may be caused by the higher flow rate which increased from ~14 up to 20 m^3/s. In contrast to the measurement in March 2006 the pH-value of the drain water is in the range from 7,3 to 7,7 and the activity the micro-organism needed for the cleaning process will not cease. However due to a very low oxygen content and a very low redox potential the canal is unable to clean itself and break down pollutants. Not all pollutants are biodegradable and the risk is high that contaminants will concentrate downstream on the irrigated land, in fishes or at least in the Mediterranean Sea. The heavy metals attach themselves to silt particles and hence the pollutants are focussed on the fields. When the drain water is used for irrigation two types of salt problems exist which are very different: those associated with the total salinity and those associated with sodium. The results indicate that for the salinity and water infiltration rate a light to moderate restriction on use is recommended.

However the impact of canal water on adjacent soil and groundwater systems is great. According to Fatma [4] in Greater Cairo the vulnerability of groundwater to pollution from the surface varies from moderate to high. Preliminary results indicate that seepage water from the drain has entered the ground water.

Several sewerage discharges of partially treated or untreated water from the Cairo Area and other cities and towns along the drain are problematic. It seems that the daily water usage far exceeds the capacity of the sewerage system and of the existing waste water treatment plants. The dilution of the discharged volumes by the canal water may reduce the possible negative consequences. For the drain the level pathogenic organisms similar to those in the original human excreta is supposed to be very high. There were several types of pathogens like viruses, bacteria, protozoa and helminths. The type and amount of pathogens present in the drainwater were determined within this study be on a very high level. As a consequence the water of the drain can’t be used for any kind of irrigation. How many and what types of pathogens reach the field or crop? It seems that without a complete treatment of the discharged waters it is not possible to use of the drain water for irrigation purposes. From the legislative point of view the situation is quite clear. A comparison with the situation in 1996-97 (Tab. V) shows that the situation has moderately changed. The chemical oxygen demand (COD) and the Ammonia level decreased significantly but the amount of dissolved oxygen is still very low. The concentrations still exceed the legal limits. It should be mentioned that in certain areas several laws, ministerial resolutions and local guidelines exist. Law 48/1982 addresses the protection of the Nile and related fresh waterways from pollution. It prohibits the discharge into the Nile River, irrigation canals, drains, lakes and groundwater without a licence issued by the Ministry of Water Resources and Irrigation [39]. Law No 124/1983 generally prohibits to dispose any industrial wastes, insecticides, and other poisonous and radioactive materials in the Egyptian waters. In chapter 3 of The Environmental law No.4 of 1994 the protection of water environments including pollution caused by wastewater is addressed. Ministerial Resolution No. 1909 (2001) concerns the conditions and measures necessary for the exportation of fish and marine products to the European Union.

Table 3 **Water quality parameters of Bahr Baqar drain during 1996-97 [11]** n.a.= not available

Parameter	unit	Bilbeis drain beginning	Qalubeya drain beginning	Bahr Baqar beginning	Law 48 permits	This study
DO	Mg/L	0,1	0,1	0,1	5	0,2
TC	MPN/100mL	4,0E+08	1,0E+09	4,0E+08	5,0E+03	2,5E+06
BOD	Mg/L	206	198	169	10	n.a.
COD	Mg/L	388	386	336	15	50
NH4-N	Mg/L	27	22	20	0,5	11
P	Mg/L	3,2	2,8	2,6	1	3

12 Outlook

The study of the water quality based on only two campaigns is incomplete because it illustrates the situation only like a temporary spotlight. For detailed results it would be necessary to study the organic and biological situation too and to perform chemical analysis all over the year like it is done for example in Germany in the frame of the River Rhine program. On the other hand this report identifies several problems and raises the sensitivity for pollution. In the future the monitoring of the water quality should be extended in time and parameters in a very close cooperation with the partners from the Egyptian side to

- identify permanently all kinds of pollution from all sources;
- accelerate their reduction;
- reduce the risk of accidents and spillages;
- improve hydrological and other conditions of the water.

Complementary the heavy metals in the sediments of the canal should be studied too. The quality of the incoming water from the Ismalia Canal onto the area between Cairo and Ismailia is only one aspect of the general hydrological situation. The next step will be the study of the several other drainages which collect the excess water from the irrigation to lead it into Lake Manzala and into the Mediterranean Sea.

Step by step a water-monitoring network like that for radioactivity has to be built up where the technological and scientific support and the training of the staff should be supported by the German side. Training programmes in basic water pollution control awareness are needed. Although university educated engineers are expected to be capable in the basic aspects of water analysis they often lack practical experience, especially where financial resources are extremely limited. Seminars and symposiums are excellent for drawing attention to problems. In addition continuous workshop-type training is needed for all operating personal.

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14 Appendix

I) Properties of the Multi 197i and the sensors

A) Conductivity

Measuring range and resolution

variable:	measuring range:	resolution:
χ [□S/cm]	0 ... 1999	1
χ [mS/cm]	0,00 ... 19,99 0,0 ... 199,0 0 ... 500	0,01 0,1 1
SAL	0 ... 70,0 acc. IOT-Table	0,1
T [°C]	-5,0 ... + 105 °C	0,1

Accuracies

variable:	accuracy (+/- 1 Digit):	
	accuracy:	*temperature:*
χ [□S/cm] /[mS/cm]:	+/- 0,5%	0°C ... 35°C EN 27 888;
T [°C]:	+/- 0,5%	35°C ... 50°C extended nLF-function from WTW-measurements
Salinity:	*accuracy:*	*temperature:*
	+/- 0,1	5°C ... 25°C
(range 0,0 ... 42,0)	+/- 0,2	25°C ... 30°C
T [°C]:	+/- 0,1	

Conductivity depth armature TA 197 LF

Measuring range:	10 □S/cm – 2 S/cm
Cell constant:	0,475 cm^{-1} +/- 1,5%
Temperature:	Thermistor: Integrated NTC (30kΩ25°C) range: -5 ... +60°C accuracy: +/- 0,2 K
Number of electrodes:	4
Material:	Graphite

B) Dissolved oxygen

Measuring range and resolution

Variable	14.1 measuring range	resolution
concentration [mg/L]:	0 ... 19,99 0 ... 90,0	0,01 0,1
saturation [%]:	0 ... 199,9 0 ... 600	0,1 1
T[°C]:	0 ... 50,0	0,1

Accuracies

variable	(+/- 1 Digit)
concentration [mg/L]:	+/- 0,5% of measured value at ambient temperature 5°C ... 30°C
saturation [%]:	+/- 0,5% of measured value when measuring in the range of+/- 10 K near the calibration temperature
T [°C]:	+/- 0,1

Oxygen depth armature TA 197 Oxi

Measuring principle:	Membrane covered galvanic sensor
Temperature compensation:	automatic via IMT compensation
measuring range:	0 – 50mg/L O_2
Temperature range:	0°C – 50°C
Velocity of approach:	> 3 cm/s 10% accuracy 10 cm/s 5% accuracy 18 cm/s 1% accuracy
Zero signal:	< 0,1% from saturation
oxygen consumption:	0,008 mg / (h*mg/L)

C) pH and Oxidation Reduction Potential

variable:	measuring range:	resolution:	accuracy (+/- 1 Digit):
pH	-2.00 ... +19,99	0,01	+/- 0,01*
U [mV]	-1999 ... +1999	1	+/- 1
T[°C]	-5,0 ... + 105,0	0,1	+/- 0,1

Sensors in combination with depth armature TA 197 pH

Temperature measurement	Integrated NTC (30 kΩ/25°C)
pH-electrode SensoLyt GDA:	Range of pH: 0 .... 14 temperature range: 0 ... 60°C reference electrolyte: Gel electrolyte, AgCl-free, ceramic diaphragm storage: 3M KCl
redox electrode SensoLyt PtA:	temperature range: 0 ... 60°C reference electrolyte: Polymer-solid electrolyte, AgCl-free 2 hole diaphragms shunt conductant element: AG/AgCl measuring electrode: Platinum storage: 3M KCl

Voltage of the polymer reference system U_{REF} with regard to the standard hydrogen Electrode. To determine the redox voltage U_H, add the chart value of the reference system to the measured voltage U_{MEAS} with regard to the standard hydrogen electrode U_{REF} (see DIN 38404 part 6).

$U_H = U_{MEAS} + U_{REF}$

Table 4 Voltage of the polymer reference system

T(°C)	**U_{REF} (mV)**	**T(°C)**	**U_{REF}(mV)**	**T(°C)**	**U_{REF}(mV)**
0	+224	25	+207	50	+188
5	+221	30	+203	55	+184
10	+217	35	+200	60	+180
15	+214	40	+196		
20	+211	45	+192		

II) Properties of the Rosemount DC-190 analyser

Measuring range:	0,2 ppm C – 50.000 ppm C 0,08 µg C – 160 µg C
accuracy:	+/- 2 % or +/- 0,1 ppm C or +/- 0,04 mg C
gas:	99,990 % O_2 < 1 ppm CO_2 und CO < 1 ppm KW at 30 psig (2,1 bar)
Sample volume:	Autosampler: 100 µL particles up to: 0,5 mm diameter
detector:	Non-dispersive infrared detector (NDIR)

Results of standard measurements thrice repeated

Standard:			
TC:	101,1 ppm	+/-	1,9 ppm
TIC:	0,504 ppm	+/-	0,05 ppm
TOC:	101 ppm	+/-	2 ppm
Blank:			
TC:	1,7 ppm	+/-	0,5 ppm
TIC:	0,4 ppm	+/-	0,2 ppm
TOC:	1,3 ppm	+/-	0,7 ppm

III) Sampling sites

6.1.1 Site No. 70 “Safet El Kanter - Road bridge to Zagazir“

Distance to Cairo:	73,16	km			
Time and date:	9:30		6.	November	2007
Weather:	Sunny, foggy				
Canal width:	18	m	**Canal depth**	~2	m
Flow velocity (estimated)	1,0	m/s	**Rate of flow:** ~18,9 m^3/s		

Remarks:

GPS-data:

N:	30	°	33	'	40,38	"
E:	31	°	36	'	7,02	"
HAMSL			m			

6.1.2 Site No. 72 inflow 1 near “El Sharakoua“

Distance to Cairo:	69,04	km			
Time and date:	10:00		6.	November	2007
Weather:	Sunny, foggy				
Canal width:	12	m	**Canal depth**	0,3	m
Flow velocity (estimated)	0,2	m/s	**Rate of flow:** ~ 0,4 m^3/s		

Remarks:

GPS-data:

N:	30	°	32	'	29,4	"
E:	31	°	34	'	38,82	"
HAMSL			m			

6.1.3 Site No. 73 near "Tahlat Burdayn"

Distance to River Cairo:	60,82	km			
Time and date:	10:30		6.	November	2007
Weather:	Sunny				
Canal width:	18	m	**Canal depth**	2,1	m
Flow velocity (estimated)	0,8	m/s	**Rate of flow:** ~14,6 m^3/s		

Remarks:

GPS-data:

N:	30	°	31	'	29,4	"
E:	31	°	29	'	33,12	"
HAMSL			m			

6.1.3 Site No. 73 inflow 2 (Sedanhour drain) near “Tahlat Burdayn”

Distance to River Cairo:	60,82	km			
Time and date:	10:30		6.	November	2007
Weather:	Sunny				
Canal width:	15	m	**Canal depth**	0,8	m
Flow velocity (estimated)	0,4	m/s	**Rate of flow:** ~3,2 m^3/s		
Remarks:			**GPS-data:**		

N:	30	°	31	'	29,4	"
E:	31	°	29	'	33,12	"
HAMSL			m			

6.1.4 Site No. 74 “Al Hamidiyah Quamh“

Distance to Cairo:	43,65	km			
Time and date:	11:30		6.	November	2007
Weather:	Sunny, hazy				
Canal width:	19	m	**Canal depth**	1,5	m
Flow velocity (estimated)	0,7	m/s	**Rate of flow:** ~12,3 m^3/s		

Remarks:

Toter Fisch treibt am rechten Gewässerrand

GPS-data:

N:	30	°	29	'	11,58	"
E:	31	°	20	'	59,76	"
HAMSL			m			

6.1.5 Site No. 75 “Kafr ash Shumut“

Distance to Cairo	28,63	km			
Time and date:	12:15		6	November	2007
Weather:	Sunny, hazy				
Canal width:	13	m	**Canal depth**	1,3	m
Flow velocity (estimated)	1,2	m/s	**Rate of flow:** ~11 m^3/s		
Remarks:			**GPS-data:**		

N:	30	°	25	'	41,04	"
E:	31	°	14	'	7,26	"
HAMSL			m			

6.1.6 Site No. 76 “Hissa“

Distance to Cairo:	23,68	km			
Time and date:	12:45		6.	November	2007
Weather:	Foggy				
Canal width:	18	m	**Canal depth**	1,8	m
Flow velocity (estimated)	0,5	m/s	**Rate of flow:** ~9 m^3/s		

Remarks:
Lot of discharges

GPS-data:

N:	31	°	33	'	40,44	"
E:	31	°	13	'	28,14	"
HAMSL			m			

6.1.7 Site No. 77 “Ezbet Fares“

Distance to Cairo:	14,85	km			
Time and date:	13:15		6.	November	2007
Weather:	Sunny				
Canal width:	17	m	**Canal depth**	1,0	m
Flow velocity (estimated)	0,5	m/s	**Rate of flow:** ~7,3 m^3/s		

Remarks:

Lot of waste on both banks

GPS-data:

N:	30	°	19	'	30,18	"
E:	31	°	13	'	33,48	"
HAMSL			m			

6.1.8 Site No. 78 Inflow 3 (Sheben drain from WWTP Shoubra EL Kheima)

Distance to Cairo:	13,52	km			
Time and date:	13:30		6.	November	2007
Weather:	sunny				
Canal width:	9.	m	**Canal depth**	1,4	m
Flow velocity (estimated)	0,9	m/s	**Rate of flow:** 4,0. m^3/s		

Remarks:

GPS-data:

N:	30	°	18	'	54,0	"
E:	31	°	13	'	49,26	"
HAMSL			m			

6.1.9 Site No. 79b inflow 4

Distance to Cairo:	12,8	Km			
Time and date:	9:15		8	March	2006
Weather:	Sunny, hazy				
Canal width:	~ 2	m	**Canal depth**	0,5	m
Flow velocity (estimated)	0,6	m/s	**Rate of flow:** ~0,3 m^3/s		

Remarks:

discharge of wastewater

GPS-data:

N:	30	°	18	'	34,36	"
E:	31	°	13	'	40,86	"
HAMSL			m			

6.1.10 Site No. 79 “Sinhira”

Distance to Cairo:	12,8	km			
Time and date:	13:45		6.	November	2007
Weather:	sunny				
Canal width:	13	m	**Canal depth**	~ 1,75	m
Flow velocity (estimated)	0,2	m/s	**Rate of flow:** ~1,9 m^3/s		

Remarks:

GPS-data:

N:	30	°	18	'	34,86	"
E:	31	°	13	'	40,86	"
HAMSL			m			

6.1.11 Site No. 80 “Qaha “

Distance to Cairo:	7,6	km			
Time and date:	3014		6	November	2007
Weather:	Sunny, hazy				
Canal width		m	**Canal depth**	1	m
Flow velocity (estimated)	0,4	m/s	**Rate of flow:** 3,9 m^3/s		

Remarks:

HAMSL = High Above Mean Sea Level

GPS-data:

N:	30	°	17	'	9,36	"
E:	31	°	11	'	20,64	"
HAMSL:			m			

IV. Bahr El-Baqar Drain system – Water samples - Experimental Results

Table VI. Online measurements

Location		**Safet**	**Inflow 1**	**Tahlat Burdayn**	**Inflow 2**	**Al Hamidiyah**	**Kafr ash**	**Hissa**	**Ezbet Fares**	**Inflow 3**	**Inflow 4**	**Sinhira**	**Qaha**
		El Kanter				**Quamh**	**Shumut**						
Position-No.		**70**	**72-in**	**73**	**73b-in**	**74**	**75**	**76**	**77**	**78-in**	**79b-in**	**79**	**80**
Distance	Km	73,16	69,04	60,82	60,83	43,65	28,63	23,68	14,85	13,52	12,8	12,79	7,61
Online data:	**Unit:**												
Conductivity	mS/m	126	196,7	120,2	160	117,6	117,8	112	106,8	102,6	82	146	148,2
Temperature	°C	23,1	21	21	21	21	21	20	20	19	19	19	19
Oxygen	mg/L	0,15	0,15	0,15	0,13	0,15	0,14	0,08	0,15	0,1	0,14	0,15	0,13
Oxygen	%	2	1,6	1,6	1,2	1,6	1,5	1	1,6	1	1,5	1,6	1,2
pH	--------------	7,5	1,8	3,5	4,6	4,4	4,6	3	5,2	4	3,7	3,5	3,6
Redoxpotential MEAS	mV	-255	-25	-6	60	64	-31	-50	29	-61	-49	-30	-35
Redoxpotential H (MEAS+REF)	V	-0,044	-0,039	-0,049	-0,0694	-0,019	-0,049	-0,049	-0,049	-0,019	-0,004	-0,0535	-0,051
U REF	mV	211	211	211	211	211	211	211	211	211	211	211	211

IV. Bahr El-Baqar Drain system – Water samples - Experimental Results

Table VII. Laboratory results

Location		**Safet**	**Inflow 1**	**Thalat**	**Inflow 2**	**Al Hami-diyah**	**Kafr ash**	**Hissa**	**Ezbez**	**Inflow 3**	**Inflow 4**	**Sinhira**	**Qaha**
		El Kanter		**Burdayn**		**Quamh**	**Shumut**		**Fares**				
Position-No.		**70**	**72-in**	**73**	**73b-in**	**74**	**75**	**76**	**77**	**78-in**	**79b-in**	**79**	**80**
Distance to Nile	Km	**73,16**	**69,04**	**60,82**	**60,83**	**43,65**	**28,63**	**23,68**	**14,85**	**13,52**	**12,8**	**12,79**	**7,61**
	-												
TC	mg/L	91,8	109	90,1	109	85,1	88,1	83,9	77,1	70,3	59,6	140	142
TIC	mg/L	83,8	99	82,1	101	77,1	80,1	75,9	69,1	62,3	53,6	129	131
TOC	mg/L	8	10	8	8	8	8	8	8	8	6	11	11
SAK 254	A/cm^{-1}	0,2736	0,3009	0,2982	0,2905	0,271	0,3011	0,2632	0,2543	0,2202	0,1855	0,4367	0,5081
SAK 200	A/cm-1	1,3133	1,5416	1,3661	1,4014	1,2863	1,4853	1,4104	1,1956	1,1291	0,7939	2,2113	2,0502
CSB	mg/L	45,7	59,7	46,6	47,3	44,4	52,3	52,8	48	36,8	81,6	20,7	82,6
AOX	ug/L	25	<20	30	<20	34	39	39	39	27	23	<20	51
Chloride (IC)	mg/L	134,0	265,0	126,0	178,0	125,0	120,0	118,5	108,5	97,7	65,3	128,5	125,2
Sulphate (IC)	mg/L	128,0	241,0	112,0	185,0	113,0	104,0	102,0	99,5	97,5	88,5	88,5	79,0
Hydrogencarbonate	mg/L	432,7	511,2	424,0	521,6	398,1	413,6	391,9	356,8	321,7	276,8	666,2	676,5
Nitrate-N	mg/L	<0,23	<0,23	<0,23	<0,23	<0,23	<0,23	<0,23	<0,23	<0,23	<0,23	0,3	0,3
Calcium	mg/L	63	92	62	79	62	61	58	59	55	57	87	92
Magnesium	mg/L	25	45	23	37	24	21	19	20	17	23	35	34
Potassium	mg/L	17	18	17	21	18	18	19	18	19	10	22	20
Sodium	mg/L	142	239	134	183	135	137	129	128	126	79	152	140
Manganese (ICP)	mg/L	0,31	0,38	0,28	0,43	0,29	0,26	0,25	0,25	0,17	0,40	0,70	0,75
Iron (ICP)	mg/L	0,5	<0,25	0,22	<0,25	0,31	0,32	0,37	0,36	0,37	0,23	<0,25	0,29
Zinc (ICP)	mg/L	<0,15	0,3	<0,15	<0,15	<0,15	<0,15	0,35	<0,15	<0,15	<0,15	<0,15	<0,15
Aluminium (AAS)	µg/L	178	56	74	22	128	116	128	150	141	24	16,6	31
Boron (ICP)	mg/L	0,22	0,21	0,23	0	0,22	0,27	0,25	0,26	0,26		0,21	0,22
Phosphorus(ICP)	mg/L	3,18	2,37	3,28	2,53	2,99	3,31	3,34	3,13	3,21	0,507	3,46	3,91
Silica (ICP)	mg/L	10,2	12,6	9,4	11,8	9,4	9,2	9,1	8,9	8,2	6,3	15,0	16,2
NH4	mg/L	15,56	19,93	17,49	18,64	13,11	14,53	13,24	11,26	9,01	1,92	19,93	21,34

V. Bahr El-Baqar Drain system – discharged water

Table VIII: discharged water

Location		**Discharge**	**Ground water**	**Drain average**
Sample-no		**73b-in**	**77b**	**70 - 77**
Distance to Cairo	km	60,8	14,85	
Online data	**Unit**			
Conductivity	mS/m	160	n.d.	110
Temperature	°C	23,3	18,5	24,2
Oxygen	mg/L	0,16	n.d.	0,16
Oxygen	%	1,8	n.d.	1,8
pH		7,46	n.d.	7,4
Redoxpotential MEAS	mV	-280	n.d.	-250
U REF	mV	211		211
Redoxpotential	V	-0,07	n.d.	-0,04
Laboratory	-			
data	-			
TC	mg/L	109	89,1	90
TIC	mg/L	101	97,8	80
TOC	mg/L	8	1,25	10
COD	mg/L	47,3	<5,0	50
SAK 254	A/cm^{-1}	0,29	0,094	0,25
SAK 200	A/cm^{-1}	1,41	0,603	1,4
Chloride (IC)	mg/L	158	79,1	140
Sulphate (IC)	mg/L	185	171,8	120
Nitrate	mg/L	n.d.	n.d.	n.d.
Calcium	mg/L	79	74	60
Ammonium-N	mg/L	14,5	0,7	11
Magnesium	mg/L	39	42	25
Potassium	mg/L	21	6,2	20
Sodium	mg/L	174	70,5	130
Phosphorus	mg/L	2,53	n.d.	3
Manganese (ICP)	mg/L	0,43	n.d.	0,3
Iron (ICP)	mg/L	0,09	n.d.	0,4
Zinc (ICP)	mg/L	n.d.	n.d.	n.d.
Aluminium (AAS)	µg/L	22	<2,0	200
Boron (ICP)	mg/L	0,14	<2,0	0,25
Silicon (ICP)	mg/L	11,8	14,1	9

1) AAS; n.d.= not detected

VI Parameters for irrigation water

Table: IX Salinity threshold for different crops and soils [41]

common name	**Average root zone salinity threshold (EC_{se})**		**EC threshold for crops**		
			sand	**loam**	**clay**
Field Crop					
- Cotton	7.7 (+)		12.1	6.9	4.0
- Wheat	6		9.4	5.3	3.1
-Sunflower	5.5		7.5	4.3	2.5
- Rice	3		4.8	2.7	1.6
- Corn grain sweet	1.7		3.2	1.8	1.1
- Sugar cane	1.7 (-)		4.3	2.5	1.4
Fruits					
-Olive	4 (+)		5.1	2.9	1.7
- Peach	3.2		4.7	2.7	1.6
- Grapefruit	1.8		3.0	1.7	1.0
- Orange	1.7		2.9	1.7	1.0
- Grape	1.5		3.3	1.9	1.1
- Apple	1 (-)		2.0	1.2	0.7
Vegetables					
- Zucchini	4.7 (+)		7.3	4.2	2.4
- Broccoli	2.8		4.9	2.8	1.6
- Pea	2.5		3.2	1.8	1.1
- Tomato	2.3		3.5	2.0	1.2
- Potato	1.7		3.2	1.8	1.1
- Onion	1.2 (-)		2.3	1.3	0.8

Table X Water parameters for irrigation water [42]

LABORATORY DETERMINATIONS NEEDED TO EVALUATE COMMON IRRIGATION WATER QUALITY PROBLEMS				
Water parameter	**Symbol**	**Unit**[1]	**irrigation water**	
SALINITY			**Usual range**	**This work**
Salt Content				
Electrical Conductivity	EC_w	dS/m	0 – 3	1,1 – 1,4
(or)				
Total Dissolved Solids	TDS	mg/l	0 – 2000	200-1700
Cations and Anions				
Calcium	Ca^{++}	me/l	0 – 20	3 - 5
Magnesium	Mg^{++}	me/l	0 – 5	1 - 3
Sodium	Na^{+}	me/l	0 – 40	3 - 7
Carbonate	CO^{--}_3	me/l	0 – .1	n.d.
Bicarbonate	HCO_3^-	me/l	0 – 10	3 - 8
Chloride	Cl^-	me/l	0 – 30	2 - 5
Sulphate	SO_4^{--}	me/l	0 – 20	2 - 4
NUTRIENTS[2]				
Nitrate-Nitrogen	NO_3-N	mg/l	0 – 10	**7 - 16**
Ammonium-Nitrogen	NH_4-N	mg/l	0 – 5	**6 - 20**
Phosphate-Phosphorus	PO_4-P	mg/l	0 – 2	**1,0 – 4,0**
Potassium	K^+	mg/l	0 – 2	**12 - 25**
MISCELLANEOUS				
Boron	B	mg/l	0 – 2	**0,1 – 0,3**
Acid/Basicity	pH	1–14	6.0 – 8.5	**3,5 – 4,7**
Sodium Adsorption Ratio[3]	SAR	(me/l)[1], [2]	0 – 15	2,2 – 4,3

1) dS/m = deciSiemens/metre in S.I. units (equivalent to 1 mmho/cm = 1 millimmho/centimetre)
mg/l = milligram per litre □ parts per million (ppm).
me/l = milliequivalent per litre (mg/l ÷ equivalent weight = me/l); in SI units, 1 me/l= 1 millimol/litre adjusted for electron charge.
2) NO_3 -N means the laboratory will analyse for NO_3 but will report the NO_3 in terms of chemically equivalent nitrogen. Similarly, for NH_4-N, the laboratory will analyse for NH4 but report in terms of chemically equivalent elemental nitrogen. The total nitrogen available to the plant will be the sum of the equivalent elemental nitrogen. The same reporting method is used for phosphorus.
3) SAR is calculated from the Na, Ca and Mg reported in me/l (see chapters 7.7 and 8).

Table VIII Water parameters for irrigation water [42]

RECOMMENDED MAXIMUM CONCENTRATIONS OF TRACE ELEMENTS IN IRRIGATION WATER[1]		
Element	**Recommended Maximum Concentration[2] (mg/l)**	**Remarks**
Al(aluminium)	5.0	Can cause non-productivity in acid soils (pH < 5.5), but more alkaline soils at pH > 7.0 will precipitate the ion and eliminate any toxicity.
As (arsenic)	0.10	Toxicity to plants varies widely, ranging from 12 mg/l for Sudan grass to less than 0.05 mg/l for rice.
Be (beryllium)	0.10	Toxicity to plants varies widely, ranging from 5 mg/l for kale to 0.5 mg/l for bush beans.
Cd (cadmium)	0.01	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans.
Co (cobalt)	0.05	Toxic to tomato plants at 0.1 mg/l in nutrient solution. Tends to be inactivated by neutral and alkaline soils.
Cr (chromium)	0.10	Not generally recognized as an essential growth element. Con-servative limits recommended due to lack of knowledge on its toxicity to plants.
Cu (copper)	0.20	Toxic to a number of plants at 0.1 to 1.0 mg/l in nutrient solutions.
F (fluoride)	1.0	Inactivated by neutral and alkaline soils.
Fe (iron)	5.0	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum. Overhead sprinkling may result in unsightly deposits on plants, equipment and buildings.
Li (lithium)	2.5	Tolerated by most crops up to 5 mg/l; mobile in soil. Toxic to citrus at low concentrations (<0.075 mg/l). Acts similarly to boron.
Mn (manganese)	0.20	Toxic to a number of crops at a few-tenths to a few mg/l, but usually only in acid soils.
Mo (molybdenum)	0.01	Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum.
Ni (nickel)	0.20	Toxic to a number of plants at 0.5 mg/l to 1.0 mg/l; reduced toxicity at neutral or alkaline pH.
Pd (lead)	5.0	Can inhibit plant cell growth at very high concentrations.

Se (selenium)	0.02	Toxic to plants at concentrations as low as 0.025 mg/l and toxic to livestock if forage is grown in soils with relatively high levels of added selenium. An essential element to animals but in very low concentrations.
Sn (tin)		
Ti (titanium)	----	Effectively excluded by plants; specific tolerance unknown.
W (tungsten)		
V (vanadium)	0.10	Toxic to many plants at relatively low concentrations.
Zn (zinc)	2.0	Toxic to many plants at widely varying concentrations; reduced toxicity at pH > 6.0 and in fine textured or organic soils.

The water quality of the Bahr El-Baqar Drain system in Egypt was studied. The first section of the drain system called Qalubeya Drain starts in the northern zone of Greater Cairo were all sewage and industrial wastewater, treated or untreated is dumped into this drain. Near the city of Zagazig the Bilbeis- and Qalubeya Drain flow together to form the Bahr El-Baqar Drain. Along its way from Cairo down to Lake Manzala there are a lot of discharges like agricultural run-offs in the north eastern cultivated areas. In larger cities or villages large amounts of untreated urban municipal water are discharged into the drain. Despite of these facts the water is also used for irrigation of farmland too. In several sections of the drain the surface was completely covered by weed flourishing which provides habitats for Billharzia snails. From our study it was estimated that Lake Manzala which is an important resource of fishing in Egypt receives about 60 m^3/s of wastewater from Bahr El-Baqar Drain. In the year 2006 at twelve different sites along the Bilbeis- and Bahr El-Baqar Drain water samples were taken and analysed for sum parameters, salts, heavy metals and natural radioactivity (Part I [44]). In 2007 the water of the Qalubeya drain was analysed too in the same way taking samples at 12 different sites.

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