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Abstract

The inorganic chemical water quality of the Ismailia Canal / Egypt was studied in 2003 and 2004 at seventeen different sites from the main canal between Cairo and Ismailia. Additional samples were taken from selected discharges and groundwater sources. As the Ismailia Canal is fed by water from the Nile some samples were taken from the Nile near Aswan for comparative reasons too. Water samples were analysed for sum parameters, salts, heavy metals and natural radioactivity. Especially in the Greater Cairo Area due to different uncontrolled discharges pH and conductivity changed significantly when proceeding from up to downstream sites. The water temperature increased significantly during the first 20 km. The main reason was the discharge of warm water used to cool machinery in the industrial suburb of Cairo.. Iron, Zinc and Manganese were found in low concentrations. Because of dilution effects the amounts of dissolved salts were still below the German “Trinkwasserverordnung”. A higher total organic carbon level indicated the presence of organic contaminants however. The natural radioactivity level was in the normal range.

Untersuchungen zur Wasserqualität des Ismailia Kanals in Ägypten

Zusammenfassung

Die Beeinflussung der Wasserqualität des Ismailia Kanals in Ägypten durch anorganische Komponenten wurde im Jahre 2003 und 2004 untersucht. Das Wasser des Hauptkanals wurde an 17 verschiedenen Stellen zwischen Kairo und Ismailia beprobt. Zusätzlich wurden Proben von ausgewählten Einleitern und von Grundwasser gezogen. Da das Wasser des Kanals aus dem Nil gespeist wird wurden zu Vergleichszwecken Proben aus dem Nil bei Aswan genommen. Alle Wasserproben wurden auf Summenparameter, Salze, Schwermetalle und auf natürliche Radioaktivität hin untersucht. Besonders im Großraum Kairo schwankten die pH-Werte und die elektrische Leitfähigkeit infolge verschiedener unkontrollierter Einleitungen deutlich. Im Verlauf der ersten 20 Kanalkilometer stieg die Wassertemperatur im Bereich der industrialisierten Vororte von Kairo durch die Einleitung von Kühlwasser deutlich an. Eisen, Zink und Mangan waren in niederen Konzentrationen nachweisbar. Durch die Verdünnung war der Salzgehalt des Kanalwassers unter den Grenzen der deutschen Trinkwasserverordnung. Ein höherer TOC-Wert (Gesamter Organischer Kohlenstoff) wies auf eine gewisse Belastung durch organische Wasserinhaltsstoffe hin. Die natürliche Radioaktivität zeigte keinerlei Besonderheiten.

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 Forschungszentrum Karlsruhe, 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 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.

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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 when compared 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 in over 96% of the total area to 1500 inhabitants/km^2 in the Nile Valley and Delta.

Besides some groundwater resources in the western desert and Sinai the river Nile is the main source of water for Egypt. Almost all agriculture is irrigated – about 95% from Nile water. The irrigation system is based on gravity and after 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.

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 industial 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. 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 or removing agricultural, municipal and industrial waste generated by Egypt’s rapidly expanding population. The necessary expansion of the water supply services is not always fitting to the conjugate development of the sewerage system. This results to an increasing pollution load to canals and drains [3].

The capacity of the whole aquifier 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 [3]. A large amount of Egypt's population gets fresh water from hand-dug wells.

2 Objectives

As the Ismailia Canal is the only canal for water supply in the distinct area between Cairo and Ismailia its influence can be clearly identified. The main objectives are to:

a) summarize 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 databasis to identify changes in the near future and give a contribution to upcoming international projects like ProMed [4,5];
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 control system in Egypt;

3 Description of the Ismailia Canal

The Ismailia Canal was constructed in 1862 by virtue of two agreements between the Egyptian government and the Suez Canal Company for creating a navigable waterway between the Nile and the Suez Canal. Today it's water is only used for irrigation and to provide drinking water for towns along its course. The canal has its inlet from the Nile at Cairo and runs directly to the east to the town of Ismailia passing the governorates of Cairo – Kalioubeya – Sharkeya and Ismailia (Fig.1). At Ismailia it bifurcates into two arms: one to the north to supply the town of Port Said and the second to the south to the town of Suez. A short part without current directly connects the canal to the Sues Canal.

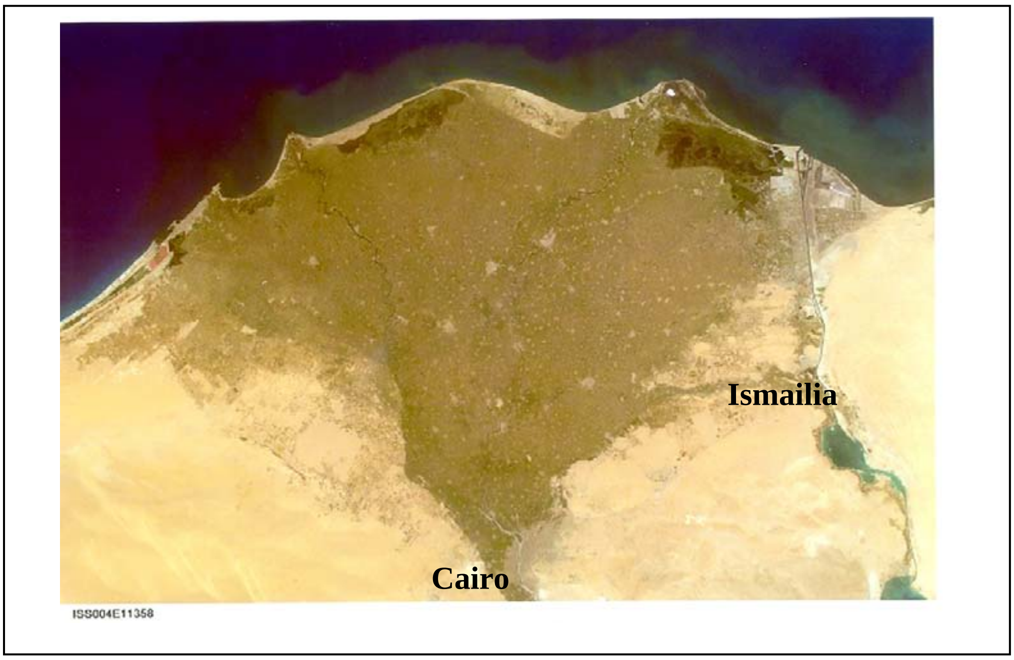

Figure 1: River Nile delta from space, (Nasa, http://eol.jsc.nasa.gov)

The canal is 128 km long its depth is about 1-3 m and its width is about 30 - 70 m. A big part leads through sandy areas. As the water level is above the surrounding land there's is a significant amount of seepage from the canal. It is reported to increase the canal's capacity from 135 m^3/s up to 440 m^3/s [6]. According to the year book of Egypt [7] widening and deepening of Al Ismailia Canal and its subordinate ditches has been done in 1995 at a sum of L.E. 15 million expected to serve around 832 thousand feddans (1 feddan = 0,4047ha). Along the canal there are several sources of pollution – industries in the region of Cairo as well as agricultural run-offs in the eastern part. For example the El-Mahsama pumping station was built to pump drainage water from the El-Mahsama Drain into the Ismailia canal. Because of pressure from the local governments, the mixing station was closed in 1994 [8]. Heavy metal concentrations in the canal water are reported to be 1.9 ppm Zn, 2.0 ppm Pb, 1.0 ppm Ni, 1.9 ppm Co, 1,9 ppm Cr and 1,2 ppm for Cd [9].

4 Actual situation in 2004

In 2004 the Ismailia canal was used for irrigation only. Feasibility studies are on the way to reactivate the shipping from Ismailia to Cairo [10]. Along the left hand of the canal a good road, straight and often tree lined is running parallel. Starting in Cairo it allows to reach all the sampling places quickly by car. Several bridges or barrages can be used for measurements and sampling along the cross section of the canal. In case of need there are numerous small ferry boats. At the beginning the canal width is about 80 m, at Ismailia it decreased to about 25 m. From the GPS data a high difference along the canal has been estimated to be about 12 m. Near Cairo the Cairo North Power Plant was under construction on the right bank of the canal. Its cooling system will influence the water temperature significantly. A new barrage and a lock near Sarikoos have been established; earthworks were not finished yet. In general the flow speed of the water is moderate (~1-2 m/s). At the most barrages the flow rate increases. There as a consequence of the turbulent flow the water is mixed and homogenised. The irrigated farmland can be seen on the space picture as a narrow swath of green extending on both sides (Fig. 2). Many center-pivot irrigation field patterns are visible in the area south of the canal. In the smaller villages along the canal its water is often used for washing purposes. There the canal boarder is often completely covered with plastics and other kinds of waste. At El Amira, Moustorod, AEA Inshas and El Ebour drinking water is directly prepared from surface water of the Ismailia canal to supply El Abour city, New Cairo and Nasr City.

Figure. 2: Curse of the Ismailia Canal from space, leading from Cairo (left) to Ismailia (right) (Nasa, http://eol.jsc.nasa.gov [11])

5 Experimental

5.1 Sampling

The study of the canal was performed in two sampling campaigns in 2003 and 2004. The second campaign took place in the period 22.03.2004 - 01.04.2004 within two days. For the examination the whole canal was subdivided into two sections: section I

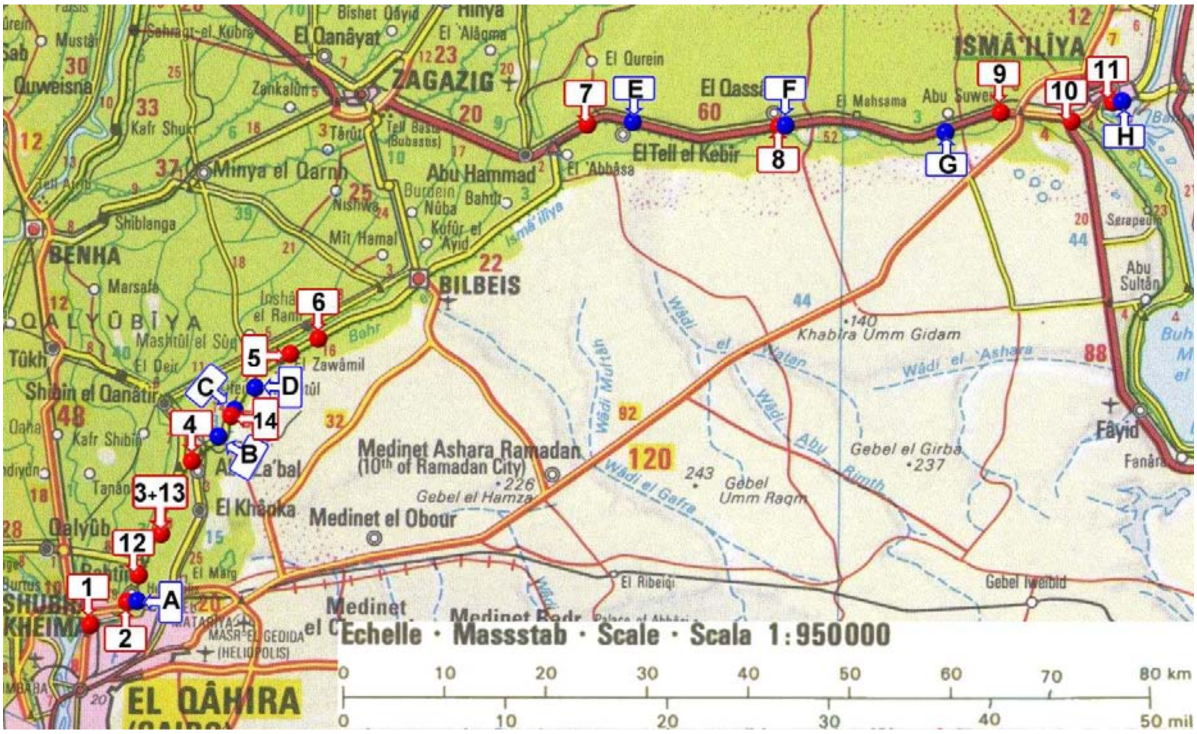

Figure 3: Sampling sites on the Ismailia Canal (blue letters: samples for radioactivity study)

leading from Cairo to El Tell El Kebir (position No. 7) and section II from El Tell El Kebir to Ismailia. Totally 17 sampling sites were fixed (Fig.3), No.1 to 6 were close to Cairo to study the influence of the industry. Site No.12 represents 3 examples of wastewater or cooling water discharges very close to each other (No.12a, 12b, 12c). At the new barrage at canal km 12,7 two samples were taken to study its mixing influence; sample No. 3a before and sample No. 3b at the downstream end of the lock. At the same site a groundwater sample was taken at a pumping station (No.13). At the barrage near El Tell El Kebir two samples were taken to study daily fluctuations (samples No.7a, 7b). The detailed description of each position is 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. Before the samples were taken the homogeneity of the water was controlled by several online measurements along the cross section of the canal. Especially in the industrial area near Cairo (sample No.12) the waste outlet shows an incomplete mixing with the main water flow over a very considerable distance from the point of entry. One sample was acidified with nitrogen acid for metal analysis; the second pure sample was used for the analysis of anions. To analyse the suspended solid phase from one factory inlet at position No. 12 additionally a 500 mL sample was taken in a polyethylene container. Until they were analysed the samples were stored in the dark at a temperature of 4°C. Additionally 8 samples were taken in Mai 2004 to determine the natural radioactivity (positions A – H). 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, Institut für Technische Chemie (ITC-CPV). All samples were filtrated before analysis through a 0,45µm filter (GHP-filer, Pall, Germany). For comparison reasons four additional water samples were taken from the river Nile at Aswan.

5.2 Equipment

5.2.1 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 (Wissenschaftlicher Werke Weilheim [12]) was used (Fig. 4) in combination with special probes for conductivity, oxygen content, pH and redox potential (Fig. 5) including a built in temperature sensor. The multi parameter instrument has a built in preamplifier and is therefore

Figure 4: Field multimeter Multi 197i (WTW – Company, Germany)

Figure 5: conductivity/temperature sensor

suitable in combination with depth armatures for single-parameter operation at depth down to 100 m. Each probe had a cable length of 20m 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 bar. 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).

5.2.2 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.
In all canal water samples the COD was lower than 25 mg/L.

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 CO_2. For the determination of the TIC, H_3PO_4 (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 CO_2 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. For detailed results of the standard measurements see appendix II, table No.V.

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 (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 HNO_3.

6 Quality control

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, Mg and Ca and the anions chloride, sulphate and hydrogen carbonate were taken into account. Fig. 6 shows the ion balance for the different sites. In general the error is 5% or lower. According to Hölting [13] up to concentrations of 2 mval an error of 5% is acceptable. The positive values indicate that the sum of the cations is slightly higher than that of the anions. The average percentage error of the difference between the measured conductivity and the calculated conductivity [14] was +1,2 per cent with a standard deviation of 1,0 per cent. 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. A higher concentration would compensate both differences.

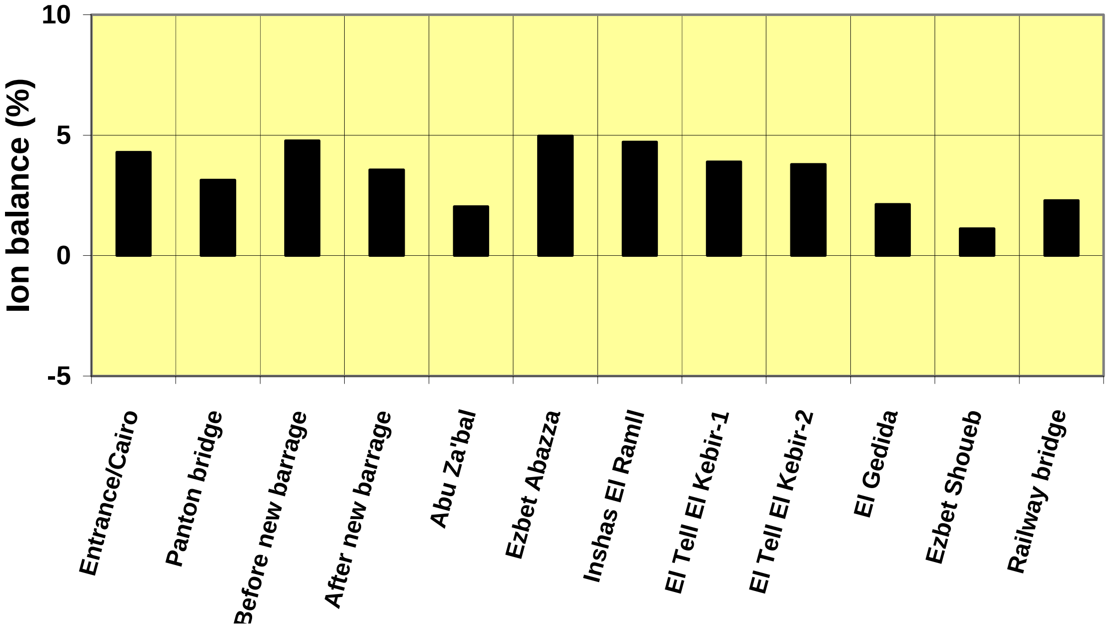

Figure 6: Ion balance for the different samples

Additional measurements

For the validation of the results potassium and calcium were analysed with the two independent techniques ICP and IC showing identical values within +-7%.

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 [15, 16]. All the results are given in the appendix No.V in table VI, VII and VIII.

7 Results and Discussion

7.1 Temperature

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 Ismailia canal showed a very tight flora of different aquatic plants. A temperature increase of the Ismailia 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 increased significantly during the first 20 km. The main reason was the discharge of warm water used to cool machinery in the industrial suburb of Cairo. An example is given by sampling site 12c about 7 km from the beginning of the canal. The discharge water has a temperature of 30°C compared to 19,9°C of the canal water. In the near future the new Cairo North Power Plant will raise the water temperature level too. At canal km 37 the temperature increased and remained nearly constant along the rest of the canal due to the shallow water of the canal. 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.

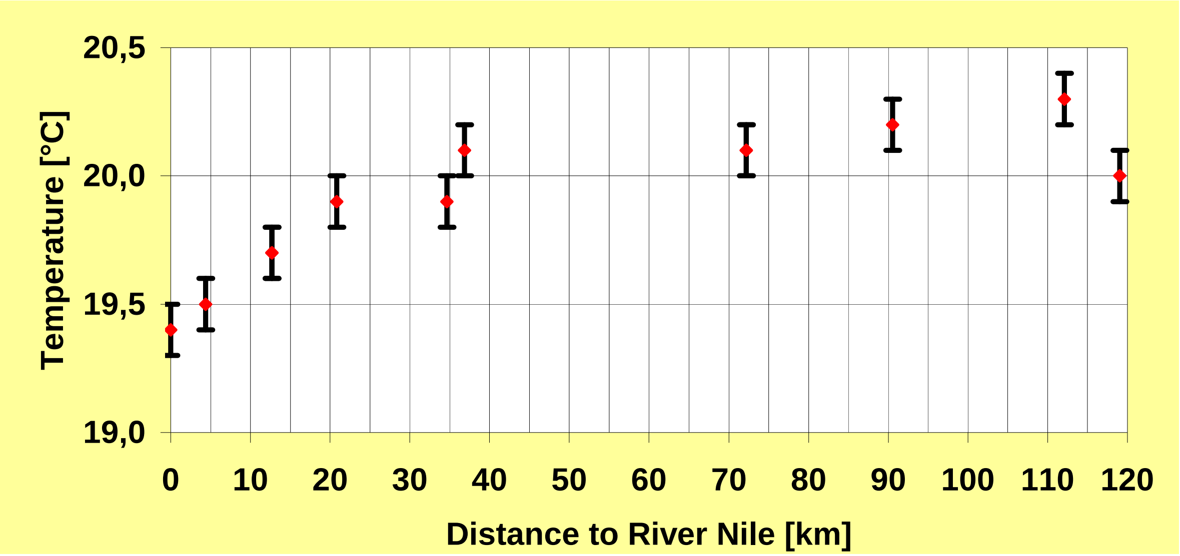

Figure 7: Temperature along the Ismailia canal in March 2004

7.2 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. As Fig. 8 shows the DO level of the Ismailia canal was higher than 8 mg/L. In the region of Cairo during the first 12 km the DO decreases because of different wastewaters, which enter the canal as sewage, urban runoff and industrial sources (see site No 12c: 4.9 mg/L). Waves and tumbling water at the new barrage at km 12 (site 3a and 3b) mix the canal water with air and raise the oxygen level up to 8,9 mg/L. Calculated in percent saturation the measured dissolved oxygen concentration varies from 92 up to 102% (Based on sea level, Barometric Pressure of 760 mm HG) [17, 18]. No differences were found in the oxygen content between surface and bottom of the canal. Only in the last section of the canal without water flow the dissolved oxygen was low near to the ground.

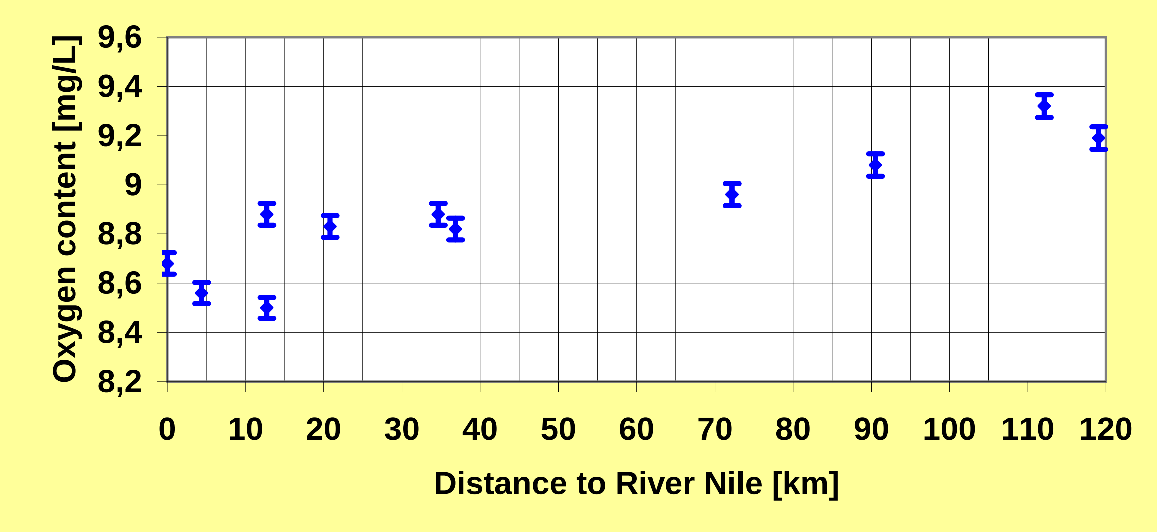

Figure. 8: Dissolved oxygen along the Ismailia canal in March 2004

7.3 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

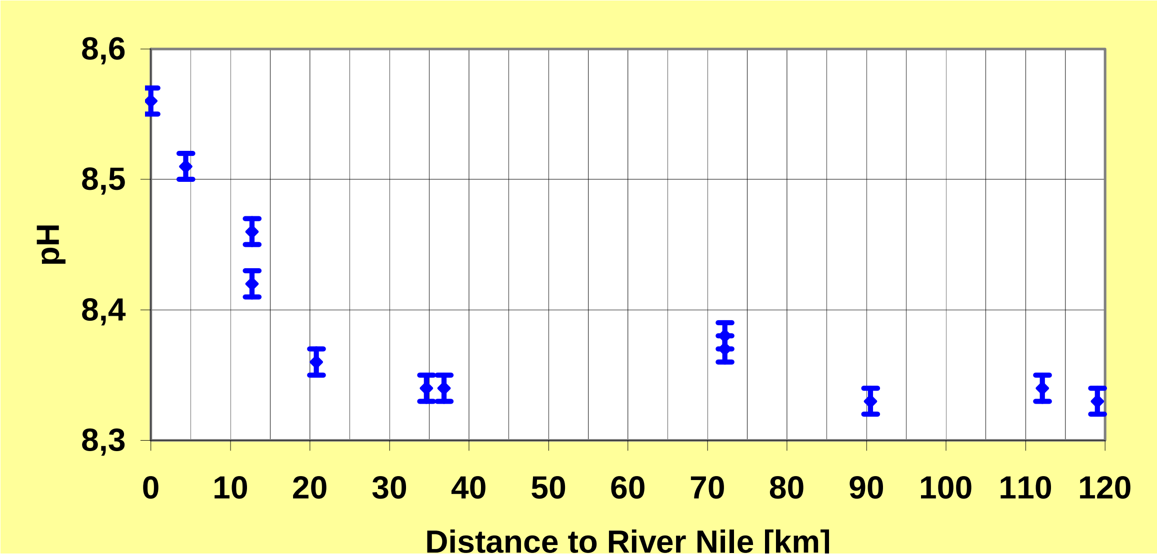

Figure 9: pH along the Ismailia canal

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 Ismailia canal. The pH during the first 25 km decreased from 8,56 to 8,33 – supposed to several discharges (see site No. 12a, pH =4,9 at km 6,9). At the barrage at 12 km from the canal inlet the different water streams are mixed, resulting in a lower pH when compared to the pH before. In the further part of the canal the pH was stable at about 8.33. The measured redox potential was in the normal range (Fig. 10).

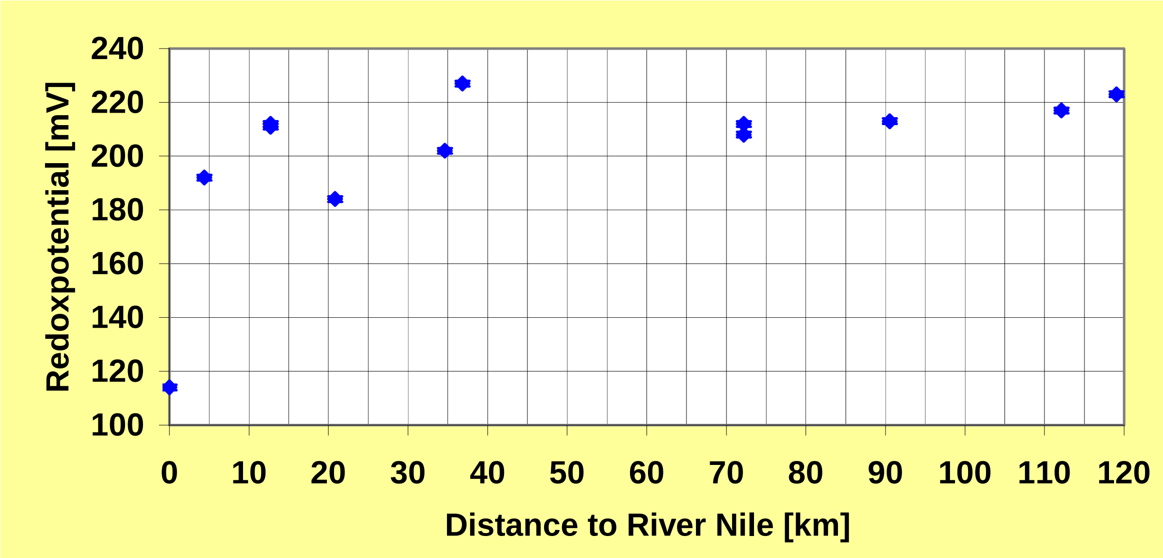

Figure 10: Redoxpotential (measured) along the canal

Eh and pH conditions are important influences on the mobility of heavy metals. As shown in Fig. 11 the most values of the canal water were in the region typical for streams. Only the first site (sample No. 1) at the canal entrance differed a little bit.

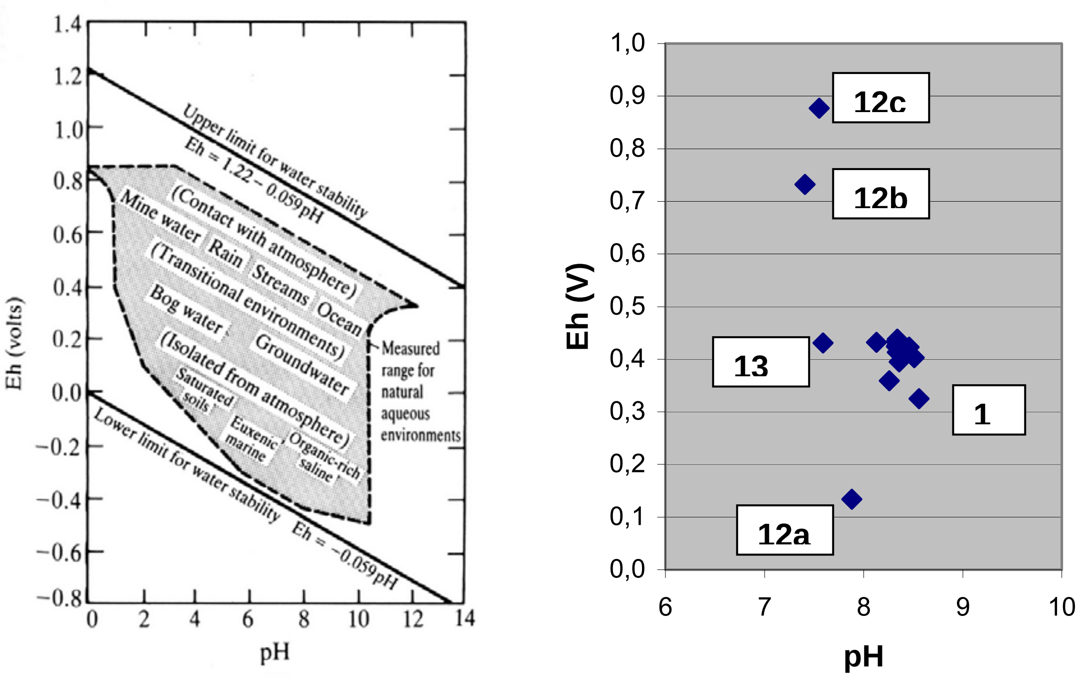

Figure 11: Eh – pH diagrams

The groundwater discharge (sample No. 13) showed the same Eh but differs slightly in pH. The special properties of the discharged process waters (sample No.12a, 12b, 12c) are clearly indicated. From the Eh-pH conditions it can be concluded that most of the heavy metals will exist as species with a very low solubility in water [19]. As soon as they enter the canal they will precipitate and be fixed to silt or other suspended particles.

7.4 Electrical Conductivity

The electrical conductivity along the canal is given in Fig. 12. Starting at 36.8 mS/m along the first 35 kilometres the conductivity increases up to 38 mS/m and remains nearly constant along the rest of the canal. According to Hölting [13] the amount of dissolved solids remaining at 100°C can be estimated to be about 260 - 280 mg/L by multiplying the electrical conductivity in µS/cm by a factor of 0.725. The electrical conductivity calculated by means of the equivalent conductivity in general is about 8% lower. If according to Rossum [14] corrections are used related to the relaxion of ion-cloud effect and the electrophoric effect relative to ion mobility then the calculated conductivity is only about 1.5% higher.

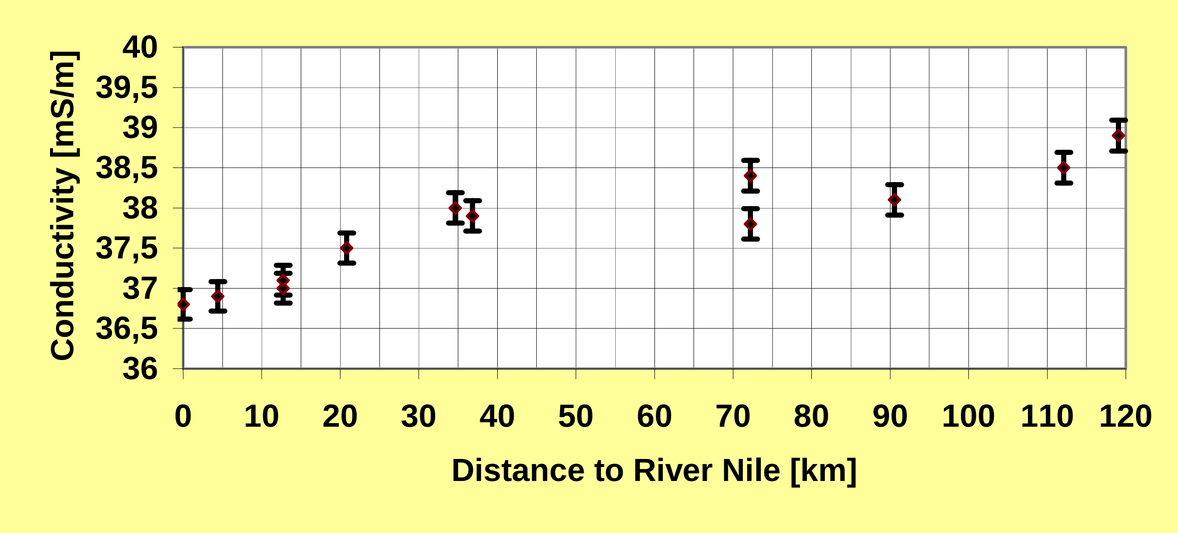

Figure 12: Electrical conductivity along the canal

7.5 TC, TOC, TIC and SAC

The measured TC and TIC given in Fig. 13 show no significant change along the canal. 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 pollution already present in the Nile water entering the canal. 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. 14). In general for the determination of organic components the SAC 254 can be used [20]. In this work the SAC 200 is considered too as a sum parameter for all components absorbing in the range of ultraviolet radiation. In contrast to the TOC the SAC decreased during the first 10 km of the canal. After the new barrage at km 12 the SAC 254 remained constant at a level of about 4 m^{-1}. The mixing of the canal water at the barrage showed no significant change of the SAC 254. In contrast the SAC 200 increased after mixing. This indicates that the industrial water discharges at km 6 which have a higher SAC200 than the canal water were not mixed completely with the canal water before it passes the barrage. At canal km 35 the TOC as well as the SAC 200 went up indicating a discharge of municipal waste water.

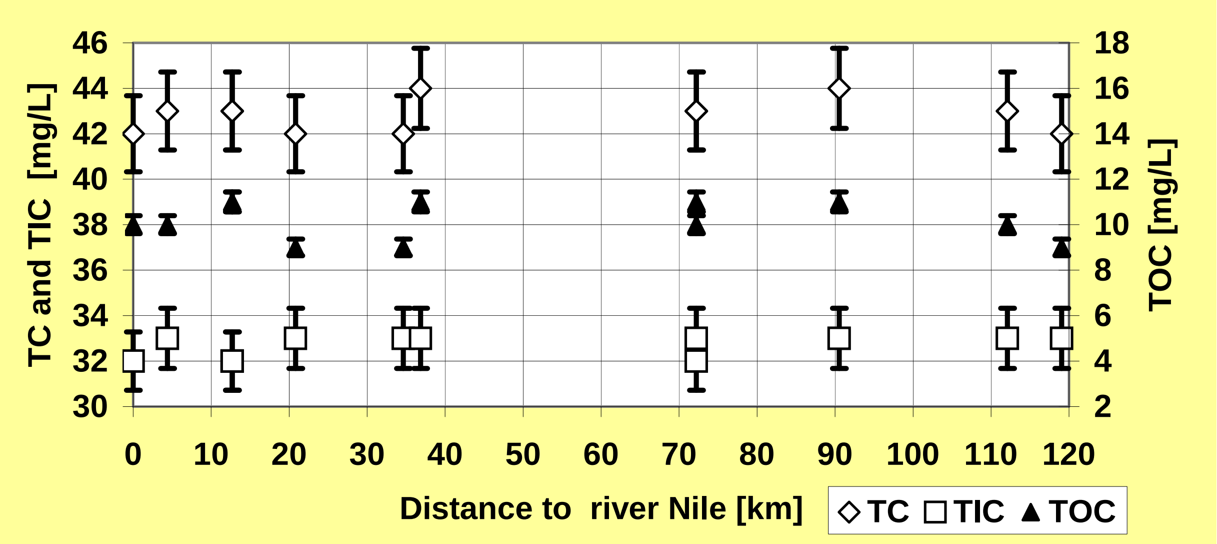

Figure 13: TC, TIC measured, TOC calculated by difference TC-TIC.

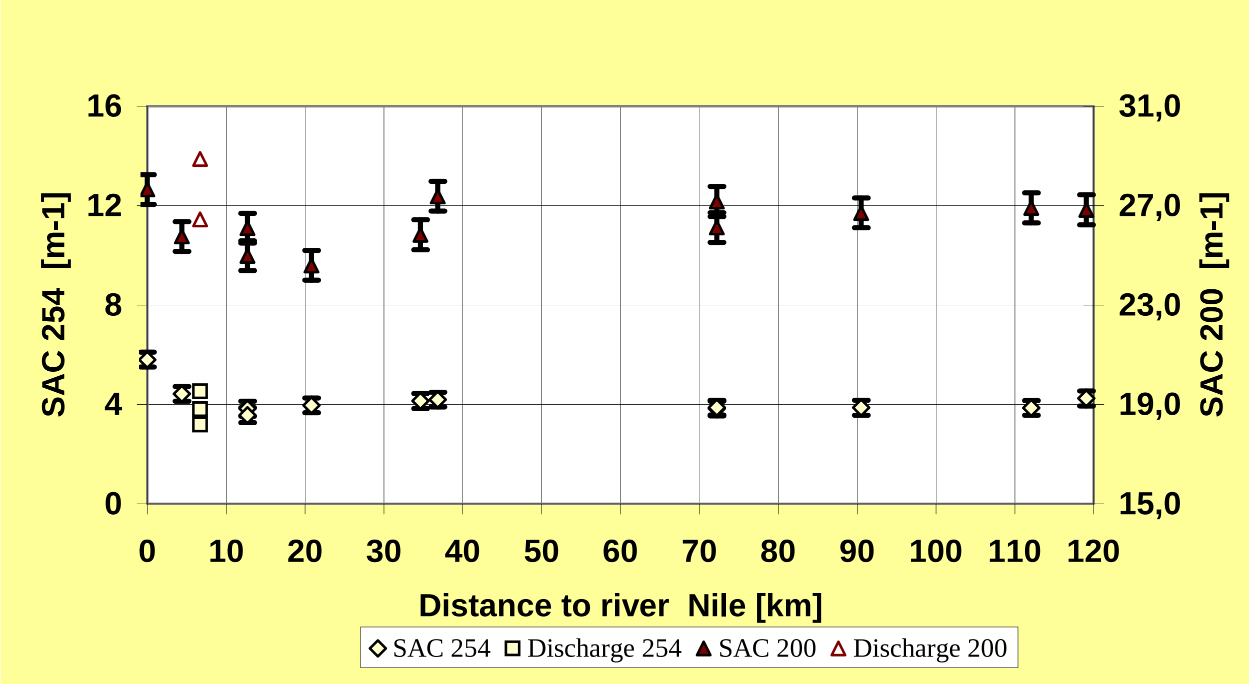

Figure 14: **The spectral absorption coefficients at 254/200 nm (SAC 254 / SAC 200)**

7.6 Anions

The dominant anions in the canal water are Hydrogen carbonate (HCO_3^-), Chloride (Cl^-) and Sulphate (SO_4^{2-}). Nitrate was found in all samples at concentration level below the quantification limit (0,2 mg/L). 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 calculation. Under 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 nearly constant at level of about 170 mg/L. The chloride concentration increases from 16 mg/L constantly with about 0.025 mg per L and km (Fig 15). Near the end of the canal the contact to the marine water of the Suez Canal increases the chloride content. Sulphate concentration starts at a level of 16 mg/L (Fig 15). Similar to the SAC200 the concentration decreases a little bit after mixing at the new barrage (km 12). After ~20 km a significant increase was observed which might be caused by a neighbouring fertiliser plant. The German “Trinkwasserverordnung” published in Mai 2001 for the use of drinking water has set the upper limit for the chloride concentration in drinking water at 250 mg/L (= 412 mg NaCl /L) and for sulphate at 240 mg/L.

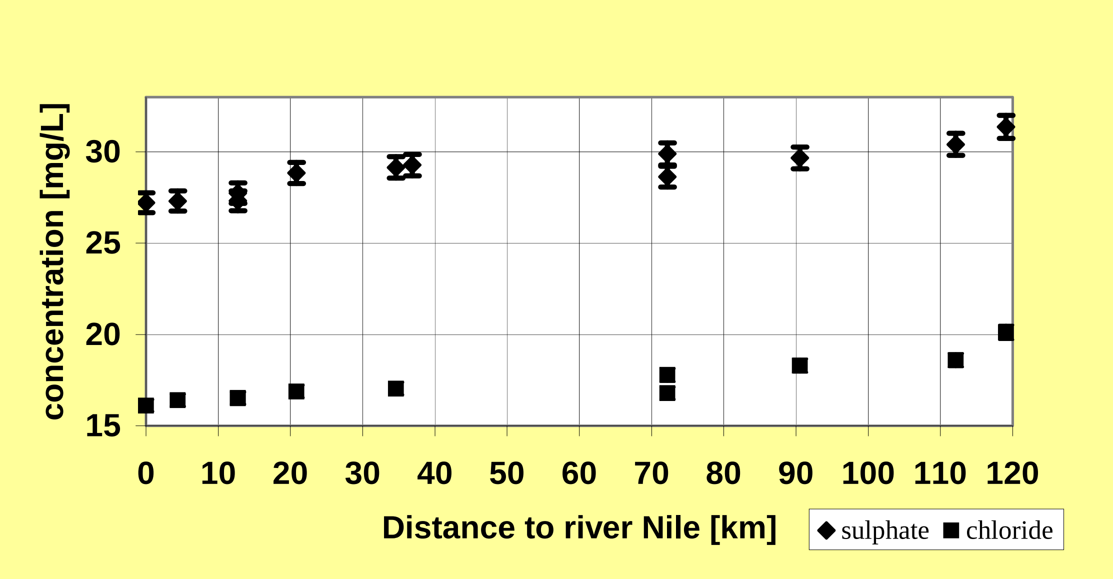

Figure 15: Chloride and sulphate concentrations

7.7 Cations

7.7.1 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 Fig. 16. The calcium concentration increased from 30 to 32 mg/L during the first 20 km of the canal. The magnesium concentration increased slightly starting from 11.2 mg/L up to 12.6 mg/L (km 116). No significant changes in the other concentrations were observed (sodium ~ 29 mg/L, potassium ~ 7 ppm). All concentrations increasd at the end of the canal (km 124) due to the marine area. The potassium concentration for natural waters is about 0-3 mg/L. 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 ratios of K+/Na+ are often found to be about 0.1. In this study the ratio was found to be about 0.2 – 0.25. This might be caused by either the decomposition of clay minerals or a surplus of potassium based fertiliser upstream of the river Nile. The Mg^{2+}/Ca^{2+} ratio is constant at the level of ~0.38 (normal range 0.1 –0.4).

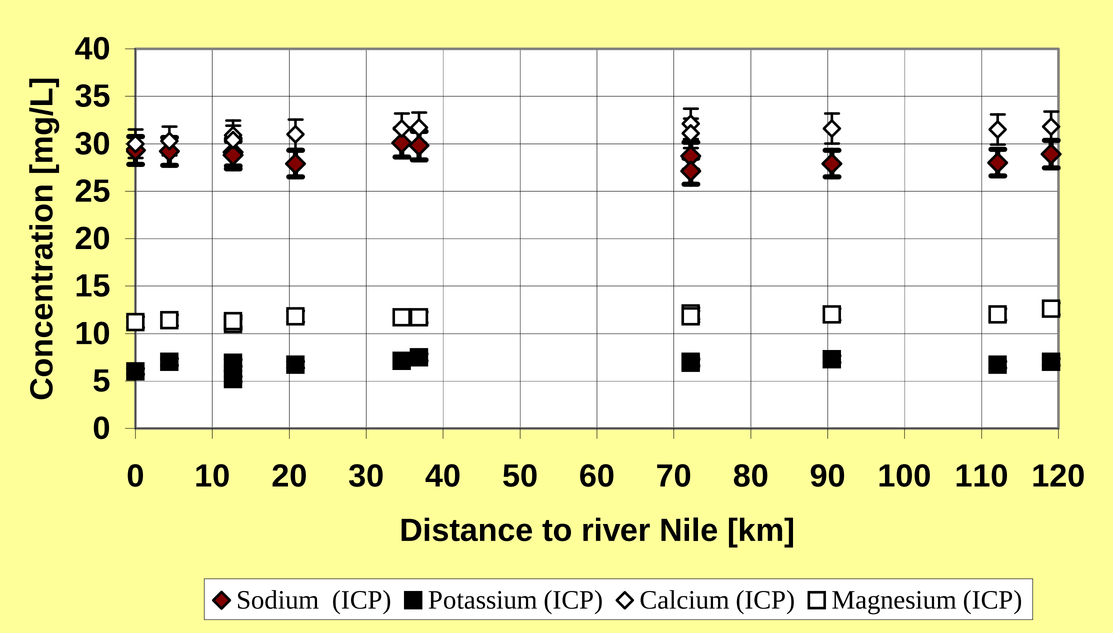

Figure 16: Concentrations of Sodium, Potassium, Magnesium and Calcium

7.7.2 Boron, aluminium, silicon and heavy metals

Boron, aluminium, silicon and the heavy metals were determined using AAS or ICP technology. Several elements were studied additionally, but their concentrations in the canal water were found to be below the detection limit (brackets in µg/L): Cr(1), Ni(2,5), Pb(5), Cu(1), Cd(1), Mo(5), Co(2,5), V(20),Ti(100). Only in the discharged water some of these elements were found. The concentrations of Fe, Mn and Zn are given in Fig.17. The Mn and Zn concentrations along the canal remained nearly constant at ~ 0.06 mg/L and 0.1 mg/l respectively. Only at canal km 36 at a bridge near Inshas the zinc level was confirmed to be higher.

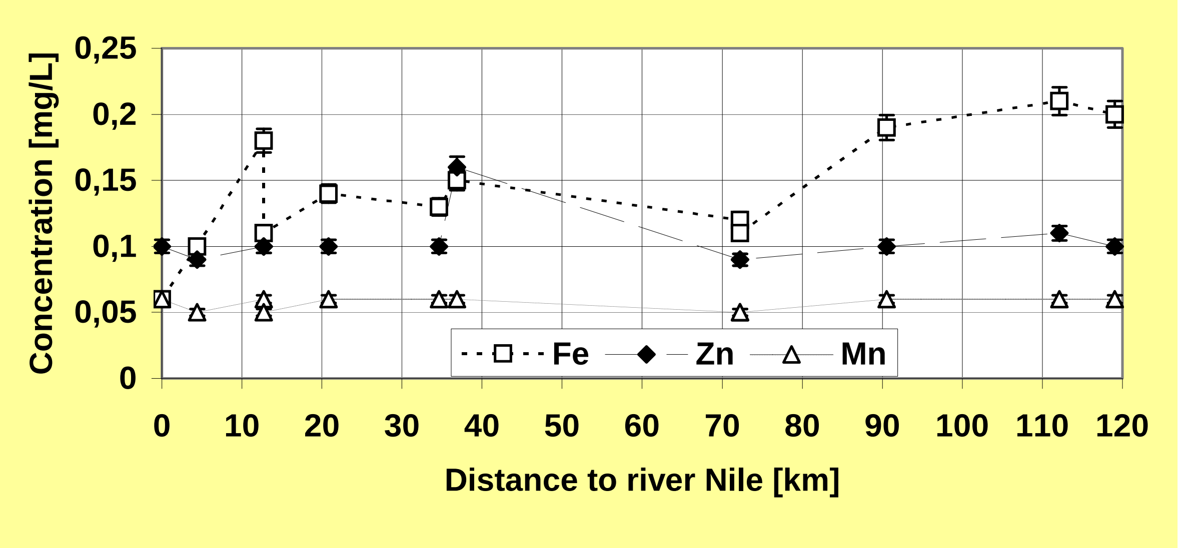

Figure 17: Concentrations of Iron(Fe), Zinc(Zn) and Manganese(Mn)

In contrast the iron concentration increased significantly starting at about 0.06 mg/L up to 0.18 mg/L during the first kilometres. Similar to other parameters by the mixing at the barrage at km 12 the concentration was reduced down to 0.11 mg/L to increase again in the further flow up to 0.2 mg/L. The concentrations of Al, B and Si are shown in Fig.18. The boron concentration at the first section of the canal varies between 6 – 8 mg/L but at km 72 it drops down to be zero. This fact might be due to daily fluctuations as the samples of the second section were taken one day later. The daily influence is also indicated by the concentrations of Al and Si. Their concentration profiles show the back mixing effect at the barrage at km 12 too.

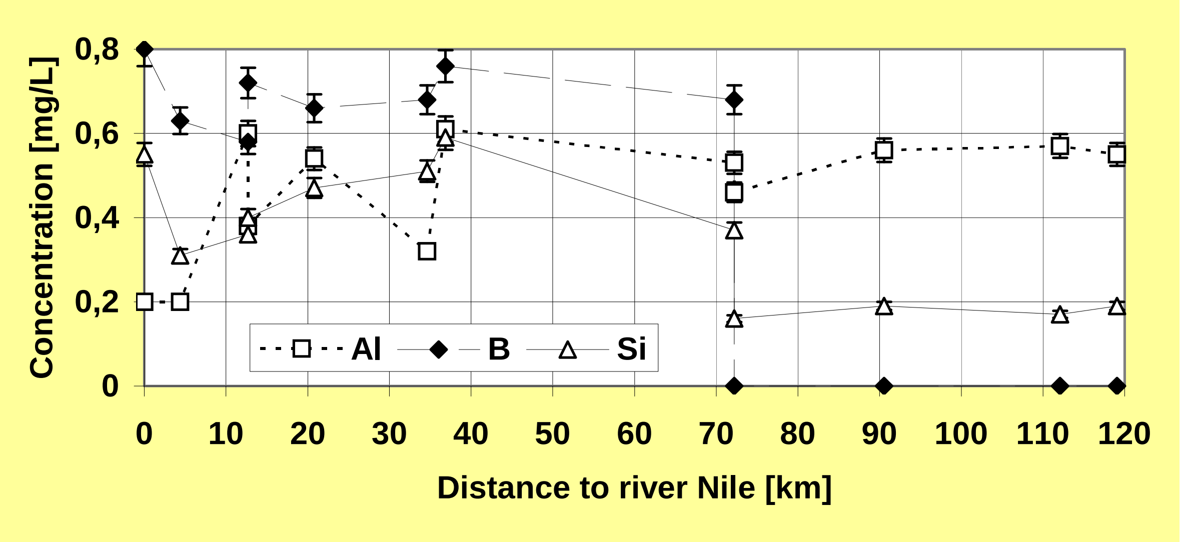

Figure 18: Concentrations of Aluminium(Al), Boron(B) and Silicon(Si)

8 Industrial Effluents

Three different discharges in the Greater Cairo area were studied additionally. The main concentrations are summarised in attachment V, tab. VIII. The given discharge values are only for orientation as it has been very difficult to estimate their volumes.

Discharge No.1

The first discharge has a volume of about 0.4 m^3/s. As the water had a temperature of ~30°C thermal pollution is the result of using it for cooling purposes or as process water. The sum parameters, pH, conductivity, redox potential and SAC 200 indicated also that wastewater has been added. The concentration of sulphate raised from about 27.3 mg/L up to 35.7 mg/L. Lead was found to be about 7.1 mg/L.

Discharge No.2 and 3

At the second site brown water was a strong chemical smell was discharged into the canal (~0.2 m^3/s). The water contained ~ 7.6 vol% of suspend brown solid particles consisting of about 34% volatile organic matter and 66% minerals (Tab.I).

Table I. Composition of suspended particles (weight %)

Compound	Org. Matter	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	TiO_2	K_2O
%	34	28	15	12	5	3	1	1

The third discharge is in a distance of about 3 m from the second one. The smell was not so intense like that of No.2 and the amount of suspended material was about 2 vol%. The flow rate of the water was estimated to be about 0.6 m^3/s. The pH (7.5) of both discharges were lower than that of the canal water (8.4) and their measured redox potential was relatively high (500 – 660 mV). The tendency of the redox potential along the cross section at a distance of 20m, 290m, and 430m downstream

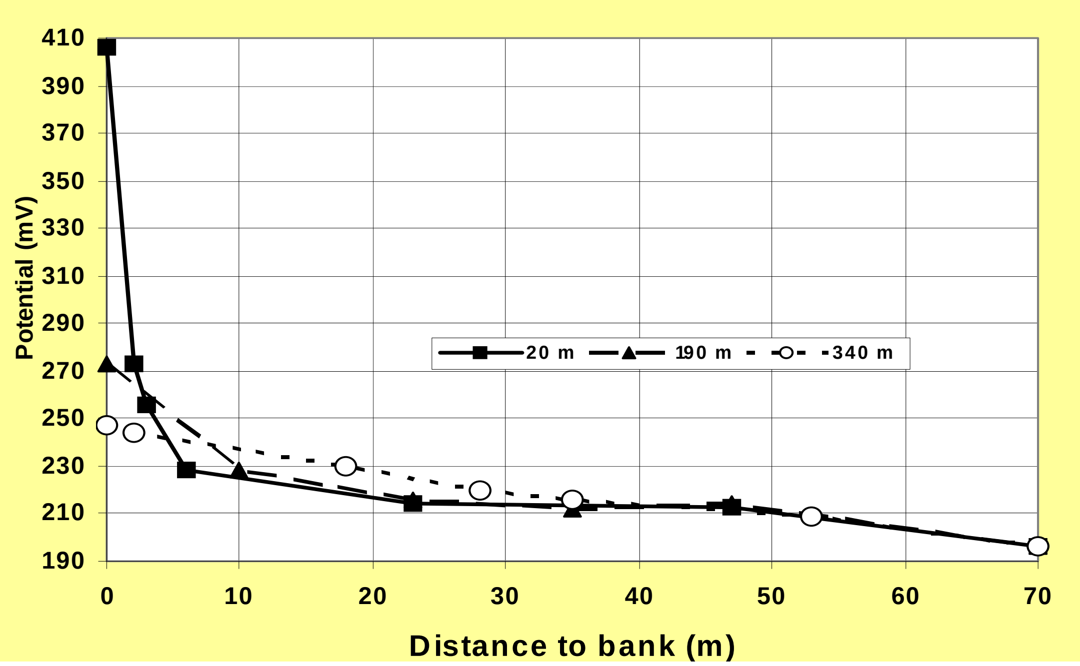

Figure 19: Redoxpotential along the cross section of the Ismailia canal, at 20,190 and 340 m downstream from the discharge.

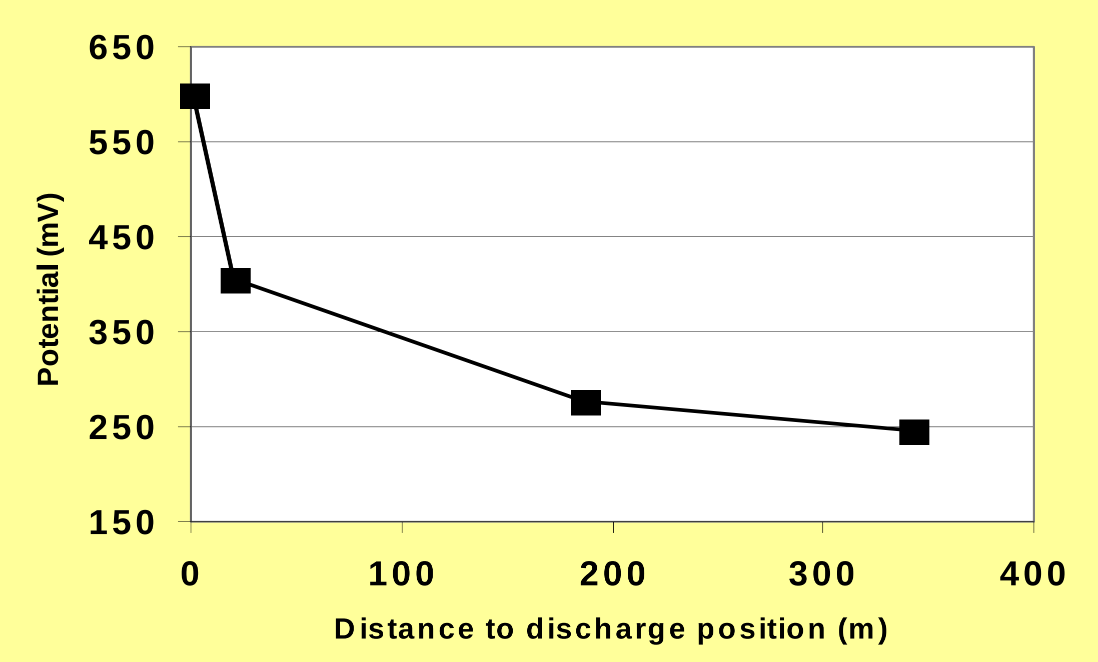

Figure 20: Redoxpotential along the bank of the Ismailia Canal

from the discharge is given in Fig. 19. A higher potential was observed within a 2 to 35m broad zone along the bank of the canal. Fig. 20 shows the curse along the bank (1m) of the canal. After a distance of 360m the potential was still 20-30 mV higher than usual.

To confirm the influence of industrial discharges into the canal additional samples were taken in the region near Abou Za'bel (sample No.14) in June 2004. As the end of the discharge pipe was behind a factory fence it has not been possible to estimate the water flow. Even the measured concentrations may be too low because of back mixing with canal water. The discharged water had a very low pH (~3.8). The amount of dissolved salt was high: sulphate 3.2 g/L, calcium 272 mg/L and aluminium 451 mg/L . As a consequence the conductivity of the effluent was high (392 mS/m). Both facts as well as the measured redox potential (425 mV) change the water quality in this section at canal kilometre 20 – 35. (decrease of the pH, increase of conductivity; see Fig's. 9, 10, 12).

In respect to the German environmental legislation (Abwasserverordnung; sewage decree [25]) all the industrial effluents are problematic (legislation limits in brackets): Especially the high aluminium level (5 mg/L), the amount of suspended material (1,0 mL/L) and sample No. 14 with its sulphate concentration (400 – 500 mg/L) and low pH (6,0 – 9,0) make it impossible to discharge these process waters into the public sewerage system without pre-treatment.

9 Groundwater

For the construction of the new barrage near Sarikoos the groundwater table was lowered by the extraction of groundwater by pumping it into the Ismailia canal. As a consequence the wells of local villages were out of function and the population had to take the water from the outlet of the extraction pumps. The results of the groundwater analysis are summarised in appendix V, tab. VIII (sample No. 13). In comparison to the canal water the electrical conductivity of the groundwater was about 2.5 times higher. This was mainly caused by a higher level of chloride (61mg/L), sulphate (119 mg/L) and calcium (87 mg/L). The redox potential was higher (0.43 V) than expected for normal groundwater (~ 0,2V) indicating a close connection to the canal water. It seems that seepage water from the canal and the neighbouring Bahr El-Baqar drain passes the permeable underground dissolves Ca, Cl and Sulphate and is finally pumped up again.

10 River Nile water at Aswan

In order to classify the water entering the Isamaila canal at Cairo four additional water samples were taken upstream the river Nile at Aswan. Only the main components were analysed there with the results given in brackets in mg/L Cl(4.6), K(5.6), Na(15.1), Ca(24.9), Mg(8.8) and TOC(3). Especially the chloride content and the TOC are about three times lower when compared to those at the beginning of the Ismailia canal. This fact indicates a certain pollution of the water along its flow down to Cairo. The level of heavy metals was below the detection limit. Only iron (~10ug/L) and aluminium (~6ug/L) were found in low concentrations. This corresponds to the results of Abdel-Hamid and Shaaban-Dessouki [20] who reported an increasing Nile water contamination starting about 40 km upstream Cairo.

11 Natural radioactivity

Natural radioactivity analysis in water samples from Ismailia canal was performed by using a gamma spectrometry system based on high purity Ge detector connected to the electronic components and multichannel analyser. A direct method of analysis was followed for the determination of natural radioactivity where one litre of the natural water was analysed by gamma spectrometry without any treatments after being aged to attain secular equilibrium due to the formation of radon–222 emanations to the respective decay series.

The results show that the activity concentration of U-238 was found to be in range of 0.78 – 3.4 βq/L, where the highest value of 3.4 βq/L was found in samples collected from Ismailia canal direct in the front of Abu Za'bal Fertilizer Factory and the lowest value of 0.78 βq/L was found in water samples collected from Abou – Souir area as shown in Table II.

Radium – 226

The activity concentrations levels of radium – 226 in the same water samples representing the different collection sites were in the range of 0.1 - 2.8 βq/L, with lowest value in samples collected from Abou-Souir Area and the highest level in the front of Abu Za'bal fertilizer factory and on the front of Nuclear Research Centre, almost similar to the level of U-238

Thorium –232

The results show that the activity level concentration of Th-232 in the different water samples collected from Ismailia canal are in range of 0.1 to 2.3 βq/L where the lowest value of 0.1 βq/L was found in water samples collected from Moustorod area and the highest value of 2.3 βq/L was found in samples collected from the front of Nuclear Research Centre.

Potassium -40

In case of K-40, the activity level concentrations was found to be in the range of 0.4 – 1,2 βq/L, where the lowest value of 0.4βq/L was found in samples collected from Moustorod area and the highest of 1,1βq/L was found in samples collected from Ismailia canal in the front of Abu Za'bal Fertilizer Factory.

The variability of the radioactivity level of U-238, Ra-226, Th-232 and K-40 in water samples collected from Ismailia canal can be explained due to a number of variable environmental factors that might be encountered in such cases. These factors might include differences in the soil-water interface characteristics which are a typical case in such systems, where the sediments are commonly considered as a reservoir for several trace elemental components. Besides, human activities and chemical factors, as pH changes caused by agriculture drainage or the uncontrolled release of industrial effluents might also interfere. The presence of such isotopes is thought to be mostly from atmospheric depositions and wind transformations, especially from the nearby phosphate processing plant and the discharge of agricultural and other waste disposals into the canal. Resuspended dust from surface soils around the area and subsequent fallout as well as the effluents of Abu Za'bal fertilizer factory are probably the main origin of natural radioactivity in this area and in the front of the Nuclear Research Centre.

Table II. Activity level concentrations of U-238, Ra-226, Th-232 and K-40 in water samples collected from Ismailia canal.

Elements Site	U-238 Bq/L	Ra-226 Bq/L	Th-232 Bq/L	K-40 Bq/L
A) Moustorod	1.9 ± 0.3	1.1 ± 0.2	0.1 ± 0.02	0.4 ± 0.02
B) Fertilizer Factory	3.4 ± 0.90	2.8 ± 0.5	2.1 ± 0.3	1.2 ± 0.04
C) Nuclear Research Centre	3.0 ± 0.90	0.7 ± 0.4	2.3 ± 0.4	1.1 ± 0.04
D) El- Menayar	1.8 ± 0.30	1.2 ± 0.2	1.3 ± 0.2	0.79 ± 0.03
E) El- Qassasin	2.7 ± 0.40	1.4 ± 0.3	0.98 ± 0.03	0.78 ± 0.03
F) El Tell El Kebir	1.9 ± 0.30	1.5 ± 0.40	0.92 ± 0.03	0.46 ± 0.03
G) Abu Suwer	0.78 ± 0.08	0.1 ± 0.02	1.5 ± 0.08	0.52 ± 0.04
H) Ismailia	1.4 ± 0.20	0.92 ± 0.10	1.1 ± 0.05	0.80 ± 0.06

Total uranium

Total uranium concentration was carried out using UA-3 analyser. The measurements performed by a laser fluorimeter based on the fluorescence of uranyl complex that was formed by the addition of buffered inorganic complexing reagent Fluran to the sample analysis. The results are shown in Table III. The specific activity concentration was detected in all samples. It ranges from 0.20ppm (2.53 Bq/L) to 0.45ppm (5.54 Bq/L). The lowest value was found in samples collected from Abou Suwer area while the highest value was found direct in the front of Abu Za'bal Fertilizer factory. As the results show, the specific activity concentration of uranium varied from one sample to another, resulting in different concentrations of uranium in natural waters. This fact is due to its varied chemical behaviour in response to redox conditions from the insoluble oxidation state 4+ in reducing conditions up to the soluble 6+ valence state under oxidation conditions.

Table III. Total uranium concentration in water samples from Ismailia canal

Sample location	Concentration of total U	
	ppm	Bq/L
A) Moustorod	0.31	3.79
B) Fertilizer Factory	0.45	5.54
C)Nuclear Research Centre	0.40	5.02
D) El- Menayar	0.38	4.67
E) El- Quassasin	0.37	4.59
F) El Tell El Kebir	0.36	4.52
G) Abu Suwer	0.20	2.53
H) Ismailia	0.33	4.22

12 Summary

The dominant ions are shown in the Schöller Diagram (Fig. 21) [21]. The water is characterised by Calcium, Sodium and Hydrogen carbonate caused by the limestone based banks of the river Nile valley.

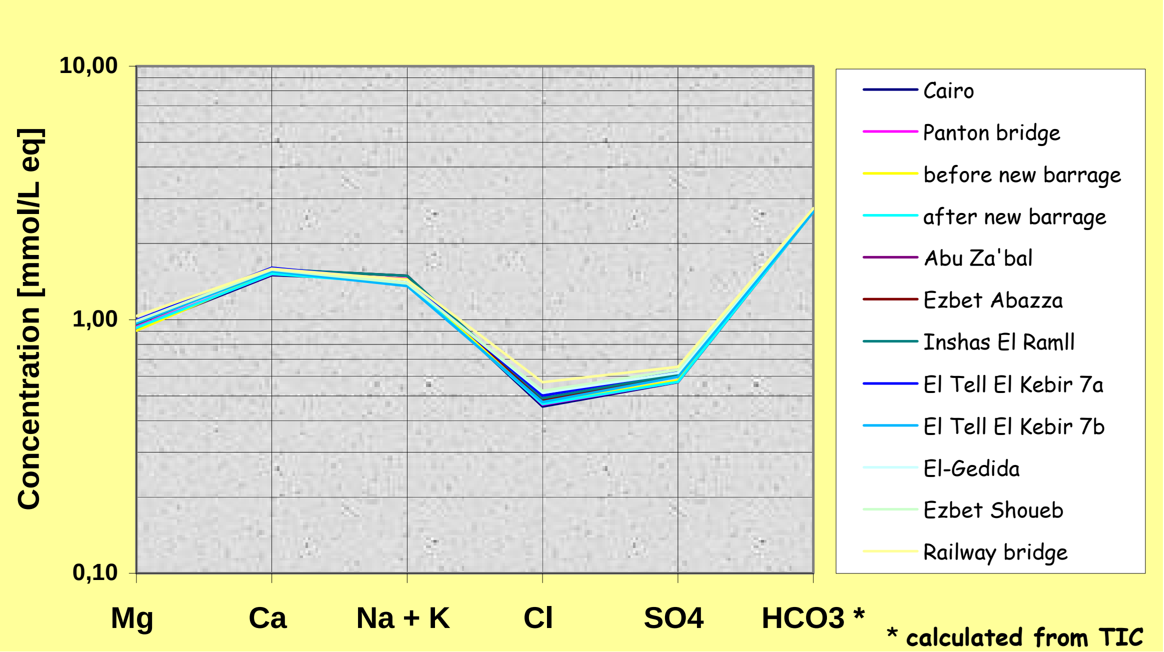

Figure 21: Schöller-Diagram of the water samples (Ismailia Canal)

From the inorganic point of view the water quality of the Ismailia Canal is still on a normal level. The amounts of dissolved salts are below the German “Trinkwasserverordnung”. Our results agree very well with those published in 1992 [22]. The levels of heavy metals found are lower than those given in 1998 for Nile water by Osman and Levin [23]. Compared to the results given by Gupta and El-Hamid [24] in 2003 for Nile water the electrical conductivity is a little bit higher but the chloride content is lower by a factor of 5. Several wastewater discharges from the Greater Cairo Area are problematic. The dilution of the discharged volumes by the canal water reduces the possible negative consequences and the canal is able to clean itself and break down pollutants. However the impact of canal water on adjacent soil and groundwater systems is great. According to Fatma [3] in Greater Cairo the vulnerability of groundwater to pollution from the surface varies from moderate to high. 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. For example the silt transported by the canal settles near banks and has to be dredged from time to time. The heavy metals attach themselves to silt particles and hence the polluted silt cannot be used on the fields. As the population and the industry are increasing the volume of waste rises. The high amount of total organic carbon found in the canal water is a first indicator that the river Nile and its derivate canals are in danger to become a giant waste collection system. The results of the analysis of the natural radioactivity in the Ismailia Canal water show that the radioactive levels are within an acceptable low level,

13 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 drainages like the Bahr El Baqar drain and Bilbis drain 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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15. 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:*
(range 0,0 ... 42,0)	+/- 0,1 +/- 0,2	5°C ... 25°C 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	**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

Correction functions

temperature compensation:	Accuracy better then 2% at 0 ... 40°C
salinity correction:	0 ... 70°C SAL
air pressure correction:	Automatic by integrated pressure sensor in the range 500 ... 1100 mbar

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 IV. 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)

Table V 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. 1 “Entrance of Ismailia Canal “

Distance to River Nile:	0	km			
Time and date:	8:25		26.	March	2004
Weather:	Sunny, hazy				
Canal width (weir with 3 sections):	3 x 5	m	**Canal depth**	2-4	m
Flow velocity (estimated)	3-4	m/s	**Rate of flow:** ~150m^3/s		

Remarks:
Entrance of the River Nile water into the Ismailia canal;
Directly at the entrance the flow is turbulent (3-4m/s), after the weir the canal is about 45m wide and the flow is moderate (~1 m/s).

HAMSL = High Above Mean Sea Level

GPS-data:

N:	30	°	6	'	16,93	"
E:	31	°	14	'	32,8	"
HAMSL:	22,31		m			

6.1.2 Site No. 2 “Panton bridge, Cairo“

Distance to River Nile:	4,395	km			
Time and date:	8:59		26.	March	2004
Weather:	Sunny, hazy				
Canal width:	70	m	**Canal depth**	2-4	m
Flow velocity (estimated)	1,5	m/s	**Rate of flow:** ~150m^3/s		

<u>Remarks:</u>

<u>GPS-data:</u>

N:	30	°	7	'	5,12	"
E:	31	°	17	'	7,34	"
HAMSL	16		m			

6.1.3 Site No. 3a “Before new barrage Sarikoos“

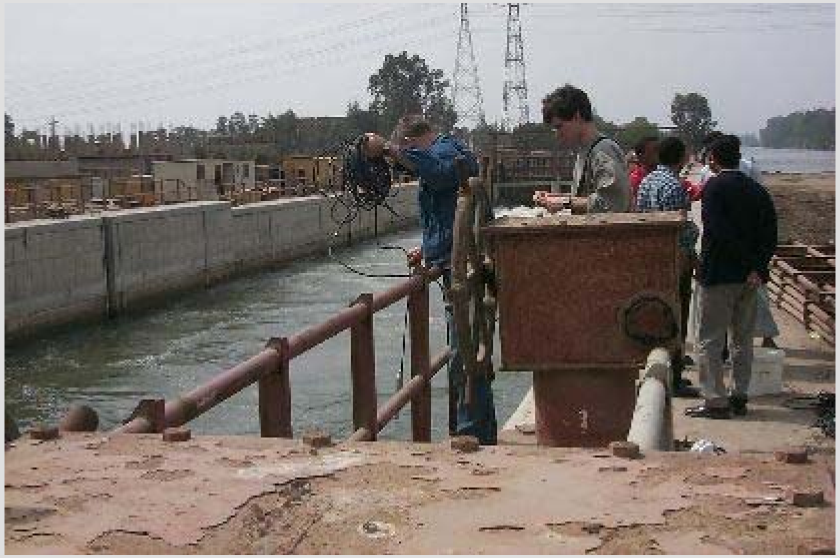
Distance to River Nile:	12,702	Km			
Time and date:	9:53		26.	March	2004
Weather:	Sunny, hazy				
Canal width:	75	m	**Canal depth**	2-4	m
Flow velocity (estimated)	----	m/s	**Rate of flow:** ~150m^3/s		

Remarks:
discharge of groundwater

GPS-data:

N:	30	°	11	'	12,56	"
E:	31	°	18	'	54,08	"
HAMSL	25,75		m			

6.1.4 Site No. 3b “After new barrage Sarikoos”



Distance to River Nile:	12,702	km			
Time and date:	10:12		26.	March	2004
Weather:	Sunny, hazy				
Canal width:	15	m	**Canal depth**	2-4	m
Flow velocity (estimated)	----	m/s	**Rate of flow:** ~150m^3/s		

Remarks:
Sehr starke Verwirbelungen, Grundwasserzuleitungen

GPS-data:

N:	30	°	11	'	12,56	"
E:	31	°	18	'	54,08	"
HAMSL	25,75		m			

6.1.5 Site No. 4 “Abu Za’bal bridge“

Distance to River Nile:	20,822	km			
Time and date:	11:32		26.	March	2004
Weather:	Sunny, hazy				
Canal width:	65	m	**Canal depth**	2-4	m
Flow velocity (estimated)	----	m/s	**Rate of flow:** ~$150 m^3/s$		

Remarks:

Lot of waste on both banks, on the right bank Abu Za’bal

GPS-data:

N:	30	°	15	'	11,99	"
E:	31	°	21	'	1,358	"
HAMSL	17,21		m			

6.1.6 Site No. 5 “Bridge near Ezbet Abazza”

Distance to River Nile:	34,628	km			
Time and date:	12:12		26.	March	2004
Weather:	Sunny, hazy				
Canal width:	65	m	**Canal depth**	2-4	m
Flow velocity (estimated)	0,5	m/s	**Rate of flow:** ~70m^3/s		

Remarks:

GPS-data:

N:	30	°	21	'	0,347	"
E:	31	°	26	'	26,7	"
HAMSL	21,77		m			

6.1.7 Site No. 6 “Bridge near Inshas El Ramll“

Distance to River Nile:	36,853	km			
Time and date:	12:35		26.	March	2004
Weather:	Sunny, hazy				
Canal width:	65	m	**Canal depth**	2-4	m
Flow velocity (estimated)	1	m/s	**Rate of flow:** ~150m^3/s		

Remarks:

Toter Fisch treibt am rechten Gewässerrand

GPS-data:

N:	30	°	21	'	38,36	"
E:	31	°	27	'	37,53	"
HAMSL	17,25		m			

6.1.8 Site No. 7a “El Tell El Kebir“

Distance to River Nile:	72,2	km			
Time and date:	13:56		26.	March	2004
Weather:	leichte Bewölkung				
Canal width:	45	m	**Canal depth**	2-4	m
Flow velocity (estimated)	----	m/s	**Rate of flow:** ~150m^3/s		

Remarks:

GPS-data:

N:	30	°	33	'	36,99	"
E:	31	°	44	'	50,72	"
HAMSL	19,12		m			

6.1.9 Site No. 7b “El Tell El Kebir“

Distance to River Nile:	72,2	km			
Time and date:	13:31		26.	March	2004
Weather:	sunny				
Canal width:	45	m	**Canal depth**	2-4	m
Flow velocity (estimated)	----	m/s	**Rate of flow:** ~150m^3/s		

Remarks:

GPS-data:

N:	30	°	33	'	36,99	"
E:	31	°	44	'	50,72	"
HAMSL	19,12		m			

6.1.10 Site No. 8 “El-Gedida bridge“

Distance to River Nile:	90,522	km			
Time and date:	12:53		26.	March	2004
Weather:	sunny				
Canal width:	55	m	**Canal depth**	2-4	m
Flow velocity (estimated)	----	m/s	**Rate of flow:** ~150m^3/s		

Remarks:
Lot of waste on both banks, on the right bank town: El-Gedida

GPS-data:

N:	30	°	33	'	31,71	"
E:	31	°	56	'	18,23	"
HAMSL	13,21		m			

6.1.11 Site No. 9 “Bridge near Ezbet Shoueb“

Distance to River Nile:	112,105	km			
Time and date:	11:58		26.	March	2004
Weather:	sunny				
Canal width:	50	m	**Canal depth**	2-4	m
Flow velocity (estimated)	----	m/s	**Rate of flow:** ~150m^3/s		
Remarks:			**GPS-data:**		

N:	30	°	34	'	21,71	"
E:	32	°	9	'	46,1	"
HAMSL	10,53		m			

6.1.12 Site No. 10 “Railway bridge near Ismailia“

Distance to River Nile:	119,053	km			
Time and date:	11:22		26.	March	2004
Weather:	sunny				
Canal width:	25	m	**Canal depth**	2-4	m
Flow velocity (estimated)	0,5	m/s	**Rate of flow:** ~30m^3/s		

Remarks:
Lot of waste on both banks

GPS-data:

N:	30	°	34	'	4,499	"
E:	32	°	14	'	6,076	"
HAMSL	9,04		m			

6.1.13 Site No. 11 “Sluice in Ismailia”

Distance to River Nile:	124,284	km			
Time and date:	11:22		26.	March	2004
Weather:	sunny				
Canal width:	20	m	**Canal depth**	~ 2	m
Flow velocity (estimated)	0	m/s	**Rate of flow:** 0 m^3/s		

Remarks:
Lot of plastic waste on the water surface

GPS-data:

N:	30	°	35	'	21,98	"
E:	32	°	17	'	0,813	"
HAMSL	6,29		m			

6.1.15 Site No.12a “Cooling water discharge near Cairo“

Distance to River Nile:	6,688	km			
Time and date:	16:13		26.	March	2004
Weather:	sunny				
Outflow width:	2	m	**Canal depth**	0,2	m
Flow velocity (estimated)	1	m/s	**Rate of flow:** ~0,4m^3/s		

Remarks:
Small bay, cooling discharge

GPS-data:

N:	30	°	8	'	15,9	"
E:	31	°	17	'	34,01	"
HAMSL	19,12		m			

6.1.16 Site No. 12b “Small discharge“

Distance to River Nile:	6,688	km			
Time and date:	16:40		26.	March	2004
Weather:	sunny, clear sky				
Outflow width:	3	m	**Canal depth**	0,2	m
Flow velocity (estimated)	1,5	m/s	**Rate of flow:** ~$0{,}2 m^3/s$		

Remarks:

Brown colour of the discharge water with suspended solids
Lots of ferryboats downstream

GPS-data:

N:	30	°	8	'	15,9	"
E:	31	°	17	'	34,01	"
HAMSL	19,12		m			

6.1.17 Site No. 12c “Large discharge“

Distance to River Nile:	6,688	km			
Time and date:	16:50		26.	March	2004
Weather:	sunny				
Outflow width:	1	m	**Canal depth**	0,3	m
Flow velocity (estimated)	2	m/s	**Rate of flow:** ~0,6m^3/s		

Remarks:

Brown colour of the discharge water
Lots of ferryboats downstream

GPS-data:

N:	30	°	8	'	15,9	"
E:	31	°	17	'	34,01	"
HAMSL	19,12		m			

I6.1.18 Site No. 14 “Discharge“

Distance to River Nile:	20	km			
Time and date:	16:50		26.	March	2004
Weather:	sunny				
Outflow width:			**Canal depth**		m
Flow velocity (estimated)		m/s	**Rate of flow:**		

Remarks:
Discharge pipe behind factory fence

GPS-data:

N:	30	°	17	'	6,71	"
E:	31	°	23	'	5,479	"
HAMSL	14,15		m.			

V. Ismailia Canal – Water samples - Experimental Results

Table VI. Online measurements

Location		**Entrance**	**Panton-**	**Before new**	**After new**	**Abu**	**Ezbet**	**Inshas**	**El Tell**	**El Tell**	**El-**	**Ezbet**	**Railway**	**End of canal**
		Cairo	**bridge**	**barrage**	**barrage**	**Za'bal**	**Abazza**	**El Ramll**	**El Kebir-1**	**El Kebir-2**	**Gedida**	**Shoueb**	**bridge**	**Ismailia**
Position-No.		**1**	**2**	**3a**	**3b**	**4**	**5**	**6**	**7a**	**7b**	**8**	**9**	**10**	**11a**
Distance to Nile	km	0,00	4,40	12,70	12,70	20,82	34,63	36,85	72,20	72,20	90,52	112,11	119,05	124,28
Online data	**Unit**													
Conductivity	mS/m	36,8	36,9	37	37,1	37,5	38	37,9	38,4	37,8	38,1	38,5	38,9	78,3
Temperature	°C	19,4	19,5	19,7	19,7	19,9	19,9	20,1	20,1	20,1	20,2	20,3	20	21,4
Oxygen	mg/L	8,68	8,56	8,5	8,88	8,83	8,88	8,82	***8,96***	8,96	9,08	9,32	9,19	8,46
Oxygen	%	98,4	93,4	92,5	96,1	97	96,7	97	101,5	97,8	100,4	103,1	100,9	95,2
pH		8,56	8,51	8,46	8,42	8,36	8,34	8,34	8,37	8,38	8,33	8,34	8,33	8,13
Redoxpotential MEAS	mV	114	192	212	211	184	202	227	208	212	213	217	223	221
U REF	mV	211	211	211	211	211	211	211	211	211	211	211	211	211
Redoxpotential U_H	V	0,325	0,403	0,423	0,422	0,395	0,413	0,438	0,419	0,423	0,424	0,428	0,434	0,432

IV. Ismailia Canal – Water samples - Experimental Results

Table VII. Laboratory results

Location		**Entrance**	**Panton-**	**Before new**	**After new**	**Abu**	**Ezbet**	**Inshas**	**El Tell**	**El Tell**	**El-**		**Railway**	**End of canal**
		Cairo	**bridge**	**barrage**	**barrage**	**Za'bal**	**Abazza**	**El Ramll**	**El Kebir-1**	**El Kebir-2**	**Gedida**	**Shoueb**	**bridge**	**Ismailia**
Position-No.		**1**	**2**	**3a**	**3b**	**4**	**5**	**6**	**7a**	**7b**	**8**	**9**	**10**	**11a**
Distance to Nile	km	0,00	4,40	12,70	12,70	20,82	34,63	36,85	72,20	72,20	90,52	112,11	119,05	124,28
Laboratory														
data														
TC	mg/L	42	43	43	43	42	42	44	43	43	44	43	42	55
TIC	mg/L	32	33	32	32	33	33	33	33	32	33	33	33	43
TOC	mg/L	10	10	11	11	9	9	11	10	11	11	10	9	12
SAK 254	A/m^{-1}	5,8	4,4	3,8	3,6	4,0	4,1	4,2	3,8	3,9	3,9	3,9	4,2	7,4
SAK 200	A/m^{-1}	27,7	25,8	25,0	26,1	24,6	25,8	27,4	26,1	27,2	26,7	26,9	26,8	44,2
Chloride (IC)	mg/L	16,11	16,40	16,53	16,51	16,88	17,04		17,78	16,79	18,29	18,59	20,11	42,13
Sulphate (IC)	mg/L	27,21	27,31	27,74	27,32	28,84	29,15	29,28	29,89	28,64	29,67	30,41	31,37	20,35
Hydrogencarbonate	mg/L	165,25	170,41	165,25	165,25	170,41	170,41	170,41	170,41	165,25	170,41	170,41	170,41	22,05
Calcium (ICP)	mg/L	30	30,3	30,9	30,4	31	31,6	31,7	32,1	31,1	31,6	31,5	31,8	48,9
Magnesium (ICP)	mg/L	11,2	11,4	11	11,3	11,8	11,7	11,7	12,1	11,8	12	12	12,6	22,9
Potassium (ICP)	mg/L	6	7	6,9	5,2	6,7	7,1	7,5	7	6,9	7,3	6,7	7	15,4
Sodium (ICP)	mg/L	29,3	29,2	29,1	28,8	27,9	30,1	29,8	28,7	27,1	27,9	28	28,9	91,1
Manganese (ICP)	mg/L	0,06	0,05	0,06	0,05	0,06	0,06	0,06	0,05	0,05	0,06	0,06	0,06	0,06
Iron (ICP)	mg/L	0,06	0,1	0,18	0,11	0,14	0,13	0,15	0,12	0,11	0,19	0,21	0,2	<0,2
Zinc (ICP)	mg/L	0,1	0,09	0,1	0,1	0,1	0,1	0,16	0,09	0,09	0,1	0,11	0,1	0,1
Aluminium (ICP)	mg/L	0,2	0,2	0,6	0,38	0,54	0,32	0,61	0,53	0,46	0,56	0,57	0,55	<0,4
Boron (ICP)	mg/L	0,8	0,63	0,58	0,72	0,66	0,68	0,76	0,68	<0,1	<0,1	<0,1	<0,1	<0,2

V. Ismailia canal – discharged water

Table VIII: discharged water

Location		**Cooling water**	**Discharge small**	**Discharge big**	**Ground water**	**Discharge**
Position-No.		**12a**	**12b**	**12c**	**13**	**14**
Distance to Nile	km	6,688	6,688	6,688	12,702	26
volume	m^3/s	0,4	0,2	0,6		
solids, sedimentation	vol%		7,6	2		
smell			chemistry	chemistry		
Online data	**Unit**					
Conductivity	mS/m	38,3	39	38,6	90,9	329
Temperature	°C	29,6	20	19,9	22,4	n.d.
Oxygen	mg/L	4,69	8,65	9,1	3	n.d.
Oxygen	%	61,4	95,4	99,6	37,5	n.d.
pH		7,88	7,41	7,55	7,59	3,7
Redoxpotential MEAS	mV	-69	521	666	222	425
U REF	mV	203	211	211	209	211
Redoxpotential U_H	V	0,134	0,732	0,877	0,431	0,636
Laboratory data						
TC	mg/L	42	37	38	5,3	n.d.
TIC	mg/L	32	25	28	0,3	n.d.
TOC	mg/L	10	12	10	5	n.d.
SAK 254	A/m^{-1}	3,8	4,5	3,2	n.d.	n.d.
SAK 200	A/m^{-1}	26,4	34,3	28,9	n.d.	n.d.
Chloride (IC)	mg/L	17,84	22,94	21,53	61,30	43,8
Sulphate (IC)	mg/L	35,72	53,38	42,11	118,50	3,21 g/L
Calcium (ICP)	mg/L	31,2	38	33,5	86,5	272
Magnesium (ICP)	mg/L	11,8	12,8	12,5	26,7	54,8
Potassium (ICP)	mg/L	7,1	7,6	6,8	7,5	19,8
Sodium (ICP)	mg/L	28,5	31	28,4	66,1	115,8
Manganese (ICP)	mg/L	0,08	0,97	0,34	0,31	2,8
Iron (ICP)	mg/L	0,12	2,66	1,05	0,090 1)	1,5
Zinc (ICP)	mg/L	0,12	0,12	0,11	0,1	0,25
Aluminium (ICP)	mg/L	1,5	61,4	12,7	0,25	451,3
Boron (ICP)	mg/L	0,69	0,59	0,71	0,6	1,8
Silicon (ICP)	mg/L	0,49	1,62	0,82	13,4	8,5
Chromium (AAS)	µg/L	<1	11,8	2,3	<1	n.d.
Lead	µg/L	7,1	13,3	<5	<5	n.d.
Cupper	µg/L	<5	17,3	7,6	<5	n.d.

1) AAS