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Water Quality Assessment of the River Nile System: An Overview

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Objectives The main objective of the present article is to assess and evaluate the characteristics of the Nile water system , and identify the major sources of pollution and its environmental and health consequences. The article is also aimed to highlight the importance of water management via re-use and recycle of treated effluents for industrial purpose and for cultivation of desert land. **Method** An intensive effort was made by the authors to collect, assess and compile the available data about the River Nile. Physico-chemical analyses were conducted to check the validity of the collected data. For the determination of micro-pollutants, Gas Chromatography (GC) and High Performance Liquid Chromatography (HPLC) were used. Heavy metals were also determined to investigate the level of industrial pollution in the river system. **Results** The available data revealed that the river receives a large quantity of industrial, agriculture and domestic wastewater. It is worth mentioning that the river is still able to recover in virtually all the locations, with very little exception. This is due to the high dilution ratio. The collected data confirmed the presence of high concentrations of chromium and manganese in all sediment samples. The residues of organo-chlorine insecticides were detected in virtually all locations. However, the levels of such residues are usually below the limit set by the WHO for use as drinking water. The most polluted lakes are Lake Maryut and Lake Manzala. Groundwater pollution is closely related to adjacent (polluted) surface waters. High concentrations of nutrients, *E.coli*, sulfur, heavy metals, *etc*. have been observed in the shallow groundwater, largely surpassing WHO standards for drinking water use. **Conclusion** A regular and continuous monitoring scheme shall be developed for the River Nile system. The environmental law shall be enforced to prohibit the discharge of wastewater (agricultural, domestic or industrial) to River Nile system.

Key words: Water quality; River Nile; Lakes; Pollution sources; Assessment

INTRODUCTION

The availability of water of acceptable quality in Egypt is limited and getting even more restricted, while at the same time, the needs for water increase as a result of population growth, industrial development and cultivation of desert land. The country depends for more than 90 percent of its water supply on the River Nile. Groundwater resources are limited and the direct contribution of rainfall, except for the Mediterranean coastal area, is neglected. Irrigated agriculture is by far the largest consumer of water (almost 90 percent) and, although advances in irrigation and agricultural technologies stimulate water conservation, further intensification of crop schedules and extension of agricultural areas put an increasing demand on the already scarce water resources. Competing demands between industrial development and human consumption are putting a severe strain on a balanced allocation of the limited resources to the various users.

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Water Resources

The River Nile forms the main water resource of Egypt. Through the 1959 Nile Water Agreement with Sudan and the completion of the High Aswan Dam in 1968, a stable 55.5 billion m^3/yr. was allocated to Egypt. The actual release from the High Aswan Dam shows very little yearly variation. Annual variation of the release of water from the High Aswan Dam depends mainly on irrigation needs. The release from the high Aswan Dam ranges from approximately 800 m^3/s during the (winter) closure period to approximately 2 760 m^3/s during the summer months. In the Nile Valley and Nile Delta, groundwater resource use account for approximately 4.4 billion m^3/yr., mainly being recharged from the Nile and from seepage from irrigated agriculture. Rainfalls plays a minor role in Egypt's water resources, with average rainfall rates declining from 200 million m^3/yr. at the Mediterranean Coast to 20 mm^3/yr. in Cairo and almost zero in Upper Egypt.

Water Consumption

In the 1993/94 hydrological season, gross water consumption of irrigated agriculture amounted to approximately 54.5 B. (billion) m^3/yr. (of which almost 30 B. m^3/yr. occurred in the Delta). Other water users, such as municipal and domestic drinking water supply, industry and others consumed approximately 8.8 B. m^3/yr., and an estimated 2.0 B. m^3/yr. was lost through evaporation and about 14.0 B. m^3/yr. was discharged to the Mediterranean Sea (Table 1). In recent years, the amount discharged to the Mediterranean Sea directly from the River Nile system, declined sharply, in favour of agricultural and drinking water supply use (approximately 2.3 B. m^3 discharged in 1990 compared with approximately 1.2 B. m^3).

TABLE 1

Water Budget Calculation of the River Nile System

Resources	Billion m^3/yr.	Water Diversions/ Intakes	Billion m^3/yr.
Release From Lake Naser	55.470	Agricultural Intake	54.410
Groundwater Extraction	4.400	Drinking Water Supply	2.910
Irrigation Excess Water Return	16.910	Industrial Water Supply	5.890
Industrial Wastewater Return	5.480	Nile Flow to the Med. Sea	1.160
Domestic Wastewater Return	1.400	Drainage Outflow	12.890
		Evaporation From System	2.000
		Groundwater Recharge	4.400
Total	83.660	Total	83.660

Currently the release of water from the High Aswan Dam (HAD), varies between 52.9 and 57.4 B. m^3/yr. With increasing expected uses, Egypt will have to rely on groundwater aquifers and on expensive desalinization of sea water. Therefore the existing renewable resources must be extremely carefully managed to adequately supply the rapidly increasing population and industrial activity, through options such as increased efficiency of irrigation and/or changes in crop types, and reducing areas under irrigation.

The current water use from the Nile River and projections to year 2000 shows a rapid increase in demand, which is projected to be met by using water from the drains and reducing the flow from drains to the sea. This poses serious issues since the water in the drains is currently of poor quality due to pollution from industrial, municipal and agricultural sources.

POLLUTION SOURCES

Industrial Pollution

Egypt faces a rapidly increasing deterioration of its surface and groundwater due to increasing discharges of heavily polluted domestic and industrial effluents into its waterways. Excessive use of pesticides and fertilizers in agriculture also causes water pollution problems.

Egyptian industry uses 638 M. m^3/yr. of water, of which 549 M. m^3/yr. is discharged to the drainage system. Industrial activities in the Greater Cairo and Alexandria regions use 40% of the total. The River Nile supplies 65% of the industrial water needs and receives more than 57% of its effluents. More detailed information about water consumption, wastewater discharge and point sources of pollution and loads from different industrial sectors are provided (Table 2A, B, and C).

TABLE 2 A

Industrial Wastewater Discharge to the River Nile System

District	Ultimate Sink (M.m^3/yr.)*				Total
	Nile	Canals	Drains	Lakes	
Upper Egypt	192	5	2	5	204
Greater Cairo	80	21	20	7	128
Delta	27	85	13	1	126
Alexandria	13	7	33	35	88
Others	0	0	3	1	4
Total	312	118	71	49	550

TABLE 2 B

Water Use and Wastewater Discharged From Different Industrial Sectors

Industrial Sectors	(M.m^3/yr.)			
	No. Plants	Water Use	Water Discharge	Consumption
Chemical	53	127	98	29
Food	119	296	277	19
Textile	75	114	88	26
Engineering	39	13	12	1
Mining	11	69	60	9
Metal	33	19	14	5
Total	330	638	549	89

TABLE 2 C

Pollution Loads Discharged to Different Districts

Distric	Flow (M.m^3/d)	(Ton/day)					
		BOD	COD	Oil	TSS	TDS	HM
Upper Egypt	204	37	72	5	68	532	0.20
Greater Cairo	128	71	120	93	97	135	0.75
Delta	125	34	42	24	86	224	0.50
Alexandria	88	91	186	45	40	246	0.17
Other Gov.	5	2	3	1	5	15	0.03
Total	550	235	423	168	296	1152	1.65

Upper Egypt Sources of industrial pollution along the Nile in Upper Egypt area are mainly agro-industrial and small private industry. Sugar cane industries are significantly influences Nile water quality at Upper Egypt-South zone, while hydrogenated oil and onion drying factories influence Nile water quality at Upper Egypt-North zone.

Greater Cairo The area has a population of approximately 15 million and encompasses many industrial and commercial activities. Heavy industry is located around South of Cairo, and, North of Cairo. Many small industries and some heavy industry are randomly located throughout the city. Although wastewater discharges of the small industries are generally low, concentrations of certain industries in specific areas, such as the tanning industry may cause local contamination problems. An overview of pollution sources is given[1]. They include 23 chemical industries, 27 textile and spinning industries, 7 steel and galvanizing industries, 32 food processing industries (including a brewery), 29 engineering industries, 9 mining and refraction industries, and petrol and car service stations. Bakeries (>350), marble and tile factories (>120) and tanneries are located in South Cairo.

Rosetta and damietta branch The Rosetta receives the water of a number of agricultural drains, which are heavily polluted by industrial and domestic sewage. The drains receive large parts of the wastewater in Cairo. The wastes in the drains contain high levels of suspended and dissolved solids, oil, grease, nutrients, pesticides and organic matters. It is suspected that toxic substances are present as well. The Damietta Branch also receives polluted water of a number of agricultural drains, The Fertilizer Company is considered as the major point source of industrial pollution at Damietta branch.

Alexandria area Alexandria is a major industrial center with some 175 industries, about 25 percent of the total in Egypt. These industries include paper, metal, chemical, textile, plastic, pharmaceutical, oil and soap, and food processing. These plants are reported to contribute some 20 percent of the total wastewater of Alexandria. The industries discharge their effluents mainly to Lake Mariut and partially to the sewerage network. According to a survey made by Drainage Research Institute[2], different types of industrial wastes are disposed to Lake Maryut. At least 17 factories discharging directly to the lake through pipelines; 4 factories collect their wastewater in trenches. Moreover, 19 factories lying in the vicinity of the treatment plants; 22 factories discharging to nearby drains and then to the lake.

It is worth mentioning that the total amount of BOD discharged to the River Nile by industrial plants equals 270 ton/day. This amount corresponds to the untreated discharge of wastewater from more than six million people. It can be concluded that these substances are discharged mainly from the industrial activities in the Greater Cairo region and in Delta (0.75 and 0.50 ton/day). The average concentration of heavy metals (HM) in the effluent is less than 5 μg/L, which is slightlymore than a normal background figure (Table 2 C).

TABLE 2 D

Pollution Loads From Different Industrial Sectors

Industrial Sectors	Flow ($M.m^3/d$)	(Ton/day)					
		BOD	COD	Oil	TSS	TDS	HM
Chemical	98	26	178	23	33	241	0.94
Food	277	142	182	110	168	666	0.17
Textile	88	39	47	24	64	191	0.30
Engineering	12	5	7	2	3	13	0.03
Mining	60	14	17	8	24	29	0.20
Metal	14	3	-	1	4	11	0.01
Total	549	225	431	168	296	1151	1.65

Note. * Million metric

The results represented in Table (2 D) show that the food processing industry is responsible for more than 50% of the BOD load. However, the chemical industry is responsible for more than 60% of the heavy metal discharges. The high BOD load from the food processing industry is attributable to 10 sugar factories between Aswan and Cairo, for which the total BOD load was estimated at 490 ton/day in 1980. More recently the BOD load from some sugar factories has been reduced significantly due to recovery of molasses at the source. Since the economic viability of this industry is not clear, a restructuring program for the industry would need to consider both environmental and economic viability issues for this industry.

Domestic Pollution

The way domestic pollution affects water quality heavily depends on the way of disposal of this pollution. Approximately 65 percent of Egypt's population is connected to drinking water supply and only 24 percent to sewerage services, although the latter percentage is expected to grow rapidly, due to works under construction. The population not connected to sewerage systems relies on individual means of excreta and wastewater disposal such as latrines and septic tanks.

According to an analysis of the different references (World Bank, 1993), in Upper Egypt, 8 wastewater treatment facilities exist with a total capacity of roughly 120 000 m^3/day, with approximately the same amount under construction now. In Greater Cairo, 5 wastewater treatment plants exist, with a total capacity of approximately 1 850 000 m^3/day. In the delta there are more than 30 wastewater treatment facilities with a total capacity of almost 400 000 m^3/day, with some 100 000 m^3/day under construction. In Upper Egypt and in the Delta, some domestic wastewater receives only primary treatment. In the Greater Cairo area, the sewerage systems also serve small industries and commerce.

In many cases, domestic wastewater is collected from the center of the towns and from the villages and dumping it into a nearby irrigation canal is quite common[3]. Therefore, domestic waste disposal significantly contributes towards water quality degradation.

It is worse mentioning that no well-controlled sludge management program exists in Egypt. This may, especially in urban areas such as Greater Cairo, lead to inadequate sludge disposal, cause general environmental problem and, in the worst case, eventually influence water quality in a negative way.

Agricultural Pollution

Agricultural is the major non-point source pollution, with a number of potential impacts on the environmental and human health. In many agricultural areas, local surface and groundwater contamination has resulted from leaching of nitrates from fertilizers, and bacteria from livestock and feed wastes. Agricultural pesticides are both a potential diffuse source of water contamination.

The major impacts of agriculture on water quality in Egypt: (i) changes in salinity, (ii) deterioration of quality due to fertilizers and pesticides and (iii) possible eutrophication of water bodies due to an increase in nutrients from fertilization[2].

It is estimated that in Upper Egypt, approximately 4 billion m^3 of drainage water returns to the Nile every year[4]. This drainage water has a much higher salinity than the originally ingested irrigation water and contributes to an increase of salinity of the River Nile along its course from the High Aswan Dam to the Delta. Fortunately, the high mixing ratio of Nile and drainage water keeps the increase of salinity within acceptable limits. Salinity increases from 160 mg/L at the High Aswan Dam to 250 mg/L in Cairo.

In the Delta, because of the domestic and industrial pollution from Cairo and because of intensive agriculture, salinity in the drainage and irrigation systems further increases, and salinity of drainage water discharged into the Mediterranean Sea or the northern Lakes averaged 2 000 mg/L in 1984, 3 000 mg/L in 1990 and 2 260 mg/L in 1992/1993. More than half of this drainage water has a salinity <2 000 mg/L and could be potentially reused for irrigation and drinking water supply after appropriate treatment and mixing. Due to more intensive use, salinity of the discharged drainage water may increase in the next years and re-use of drainage water may become more complicated than before.

With the construction of the High Aswan Dam in 1964, silt deposits on the Nile floodplains has decreased from 24 million tons per year to 2.1 million tons per year[3]. This decrease has been responsible for a significant increase in the use of chemical fertilizers, resulting in increased values of nutrients in canals and drains. The amount of chemical fertilizers and pesticides used in Egypt is presented in Table 3.

TABLE 3

Amount of Pesticides and Chemical Fertilizers Used in Egypt

Year	Pesticides (tons)	Chemical Fertilizer (1000 tons)
1952	2 100	730
1960	16 300	1 400
1965	25 100	2 150
1970	25 600	2 450
1975	27 400	5 750
1980	20 500	4 500
1985	18 400	5 900
1990	17 200	6 240

Pesticide use strongly increased in the late 50s to reach a maximum in the middle of the 70s. Since then, pesticide use has declined steadily. Furthermore, the used pesticides changed from organochlorine in the 60s towards organophosphorus, carbamate and (some) pyrethroids. About 650 000 tons of about 200 different types of pesticides have been used in the Egyptian environment from 1952 to1989.

Pesticide residues may seep from the soil into drains, irrigation water and finally into the Nile and pose serious environmental and health risks. It is worth mentioning that this phenomenon could also happen even under controlled application methods, which is not always the case in Egypt. This leaching mainly depends on the type of pesticide, soil characteristics, hydrogeological conditions, climatic factors, agro-technical factors, and human factors.

Acceptable daily intake (ADI) was calculated on the basis of 70 kg person consuming 150 g of fish (fresh weight) per day. DDT and its toxic degradation product. PCB was calculated as Ar 1254.

It is therefore extremely difficult to predict how much pesticide will finally reach the water bodies. Moreover, their negative effects on environment and health are difficult to predict as a number of complicated physicochemical and biological process influences their persistence in surface and ground water and even mutations in toxicity may occur during the transition process.

In 1995, a condensed monitoring program was carried out by the Ministry of Public Work and Water Recourses (MPWWR) to analyze water samples along the River Nile. Beta

HCH lindane, aldrin, dieldrin, heptacholr, endrin, P, P´DDT, and its analogous were detected. The highest detected level of DDTs was at Aswan Dam, reaching 1.048 μg/L, which is considered slightly above World Health Organization (WHO, 1994) and Egyptian guidelines of 1 μg/L in the drinking water. The highest concentration of total organochlorine insecticides was found 7.5-km up-stream of Aswan[7].

High concentration of P, P´DDT in water samples taken from upstream of Aswan sites indicated a recent application of the product by some upstream countries. Generally, the levels of organochlorine insecticides in River Nile water are still within safety margins compared to the permissible limits for drinking waters[6] (Table 4).

TABLE 4

Organochlorine Insecticides and PCBs in Water Samples Collected From River Nile

Sampling Site	ng/L					
	ΣHCH	ΣHCBs	ΣDDTs	Cyclodiene	ΣOCs	PCBs
Lake Nasser	650.46	81.30	841.47	20.86	1594.1	59.86
Aswan	220.36	36.66	1048.24	28.50	1333.8	56.38
Kom Ombo	187.71	31.16	1035.25	41.27	1295.4	85.65
Esna	177.62	32.20	586.3	75.37	871.49	15.65
Naga Hamady	123.16	24.56	297.72	40.65	486.09	32.84
Assiut	143.65	28.37	100.56	75.28	247.86	58.46
El-Minia	163.76	30.35	82.42	16.77	293.30	28.58
Beni Suef	285.40	42.85	56.83	26.50	411.58	25.30
Delta Barrage	22.00	10.00	2.65	29.75	64.40	8.28
Kafer-El-Ziate	249.34	49.65	29.75	415.37	744.16	652.84
Dessouk	166.27	53.56	37.21	186.82	443.86	295.46
Edfina	107.26	77.80	10.133	228.11	423.30	71.76
Rosetta	185.87	16.70	98.51	32.39	333.42	140.52
El-Mansoura	151.01	92.61	102.67	48.43	394.72	32.43
Demietta	26.12	3.90	90.87	65.57	186.46	73.66

∑ HCHs = $\alpha_{1,}$ β and γHCH
∑ HCβs = $\alpha_{1,}$ β and γHCB
∑ OCs = Total organochlorine insecticides
∑ DDTs = P, P´ DDE + P, P´ DDD +P, P´-DDT
∑ Cyclodiene = P, P´ Heptachlor + P, P´ aldrin + Heptachlorepoxide + Endrin

Data in Table 5 showed that P, P´DDT and its metabolites were predominant in fish samples collected from the River Nile. Also, the results demonstrated that fish samples from both locations are contaminated with low levels of OCI and PCBs. FAO/WHO[8] have proposed an acceptable daily intake (ADI) of 0.34 μg/kg for HCB, 0.93 μg/kg for lindane and 5 μg/kg for sum DDT. If these acceptable ADI are applied by assuming an average consumption of 150 g of fresh fishpersonday, the average concentration must not exceed 24, 65, 350 and 200 μg for HCB, lindane, DDTs and PCBs, respectively. Tables 5 and 6 showed that ADI (%) ranges in fish samples collected from the river Nile were 0.8-4.8 for HCB, 3.4-6.6 for lindane and 34.6-79.2 for sum DDTs. However, the ADIs ranges for Lake Manzala does not exceeded 4.88. Therefore, the health risk from chlorinated hydrocarbons is insignificant.

TABLE 5

Risk Assessment of Some Chlorinated Insecticides in Tilapia Fish Cached From the River Nile Comparing With FAO/WHO Recommendation Acceptable Daily Intake (ADI)

Compound Name	ADI µg	Upper Egypt (South)	Upper Egypt (North)	Greater Cairo	Damietta Branch		Rosetta Branch	
					Up-Stream	Down-Stream	Up-Stream	Down-Stream
BHC	42	1.9%	2.9%	5.3%	0.9%	1.0%	0.8%	4.8%
Lindane	65	3.4%	4.5%	5.5%	6.6%	5.1%	6.2%	4.0%
DDTs	350	74.5%	54.5%	34.6%	64.8%	45.5%	39.2%	79.2%
Heptachlor	350	12.7%	10.8%	8.6%	10.6%	9.0%	7.8%	9.2%

TABLE 6

Risk Assessment of Organochlorine Hydrocarbons in Lake Manzala Comparing With FAO/WHO Recommendations Acceptable Daily Intake

Compound Name	ADI µg	Clarius Angullaris				Anguilla		*Tilipia* sp.		Mullet Mugil Cephalus
		Liver		Muscle						
Year		1992	1995	1992	1995	1992	1995	1992	1995	1995
HCB	24	0.1%	0.2%	0.03%	0.08%	0.25%	0.3%	0.02%	0.1%	0.26%
Lindane	65	0.2%	0.18%	0.14%	0.18%	0.02%	0.5%	0.11%	0.29%	0.36%
DDTs	350	4.8%	4.1%	1.6%	2.1%	2.7%	0.4%	0.83%	0.8%	2.1%
PCBs	200	0.5%	0.5%	0.26%	0.26%	0.1%	0.84%	0.24%	0.49%	0.56%

EFFECT OF POLLUTION ON WATER QUALITY

River Nile

Since the construction of the High Aswan Dam, the water quality of the Nile became primarily dependent on the quality and ecosystem characteristics of the Lake Nasser reservoir and less directly dependent on the water quality of the upper reaches of the Nile. Water released from the Lake Nasser generally exhibits the same seasonal variation and the same overall characteristics from one year to another.

Downstream changes in river water quality are primarily due to (i) the hydrodynamic regime of the river, regulated by the Nile barrages, (ii) agricultural return flows, and (iii) domestic and industrial waste discharges including oil and waste from boats. These changes are more pronounced as the river flows through the densely populated urban and industrial centers of Cairo and the Delta region[9].

Nile Research Institute of the National Water Research Center is intensively involved in the monitoring of water quality of the River Nile and its branches. All the pollution parameters are to be measured according to the updated edition of the American Standard Methods for Examination of Water and Wastewater.

As reported[5], because organic and inorganic pollutants discharged into the River Nile are strongly diluted and degraded, mid-stream conditions are still, on the average, at a fairly clean level. However, Riverbanks are clearly much more polluted. Bacteriological conditions in the River Nile are not alarming. *E. coli* ranges from 14 to 12 000 MPN/100 mL, with 90 percent of the values below the use-as-drinking-water norm of 2 000 MPN/100 mL. Dissolved oxygen, except for the first 40 km below the High Aswan Dam, is usually close to saturation. Values range from 3.1 to 9.5 mg/L with 87 percent of the observed values over the norm of 5 mg/L. A number of parameters, such as total P, nitrates, BOD_5 stay below the maximum norms in all cases. It has to be commented that the number of parameters measured is very limited and does not include any toxic substances in the regular monitoring program.

Studies of spatial and seasonal distribution of trace metals in river water and sediment reveal the presence of high concentrations of chromium and manganese in all sediments. In most examined samples, however, concentrations of copper and lead were found to be low [5]. Residues of organo-chlorine pesticides were detected in nearly all observation locations. However the levels of such residues are usually below the limit set by the WHO for use as drinking water[10].

Drainage and Irrigation Canals

There is no monitoring of the water quality in the drains and irrigation canals in Upper Egypt. Values measured at the outflow of the drains into the Nile indicate occasionally high levels of pollution (TDS up to 4 000 mg/L, *E. coli* up to 10^6 MPN /100 mL, *etc.*).

In the Delta, an extensive monitoring network was carried out which mainly observed salinity and related parameters. In the southern part of the Delta, drainage waters salinity ranges between 750 and 1 000 mg/L. In the middle part of the Delta, because of soil salinity and some influence of saline groundwater, salinity may reach to 2 000 mg/L. In the northern part of the Delta, drain water salinity reaches maximum values ranging between 3 500 and 7 000 mg/L. Most drains in the Delta are heavily polluted with sewage and (partly) industrial wastewater. Only few measurements have been made during the last ten years or so. High levels of organophosphorus insecticide and PCBs have been reported by the National Research Center[9]. High levels of boron have been reported by the Drainage Research Institute[2] with concentrations toxic for plants; NO_3-levels around 40-50 mg/L are quite common; *E. coli* as high as 10^6 MPN/100 mL; BOD_5 from 0-160 mg/L.

Northern Lakes

There are 4 major lakes in the northern part of Egypt (Lake Maryut close to Alexandria, Lake Idku, Lake Burullus and Lake Manzala in the eastern part of the Delta). Some of them interact directly with the Mediterranean Sea, as is the case with Lake Manzala. These lakes are separated from the sea by narrow splits and are not more than 2 m deep. They provided fish and recreation and part of lake Maryut was once used as a landing place for seaplanes. Unfortunately most of these lakes have deteriorated sharply over the last twenty years due to wastewater being discharged into them. Three types of wastewater contributed to the problem: domestic sewage, untreated industrial effluents and agricultural drainage water. The first used to be discharged directly into the sea. The second has increased dramatically due to the growth of new industries. The third has also increased after the building of the High Dam because the agricultural land has been switched to producing more than one crop a year.

The most polluted Lakes are Lake Maryut and Lake Manzala. Lake Maryut receives agricultural drainage and domestic and industrial wastewater from agricultural drains. A number of factories lead their wastewater directly into the lake, leading to high concentration of pollutants such as BOD_5 (up to 2 000 mg/L), oil and grease (up to 2 000 mg/L), Hg (30-90 ug/L), Cr (50-200 mg/L) and very high levels of *E.coli*. The ecological situation of the lake is critical[11]. Fish production has substantially declined from 7 000 tons a year in the 1960s to less than 100 tons a year in recent years. This was alarming. Fishermen had to leave the area or turn to other menial jobs like cheap temporary agricultural labor or rubbish collecting and sorting (because of the proximity of the solid waste landfill).

Lake Manzala serves as a final repository for much of the municipal and agricultural wastewater of the eastern Delta, including the wastewater of most of Cairo. There are a number of publications on the water quality of the lake, but no systematic monitoring is reported. High levels of DDT, organophosphorus pesticides and PCBs have been found in the water of the lake as well in fish caught from the lake. Eutrophication became a major problem in large parts of the lake and heavy metals are reported to be observed in its sediments and in fish (e.g. Cadmium: 0.057 mg/kg average). Direct environmental and health effects have also been reported (changes in aquatic ecosystems, malformed fish, and illness because of eating fish from the lake[11].

The main contributors to the lake are the Bahr El Baqar Drain, Hadous Drain and the drainage water delivered by Mataria, lower Serw and Faraskor pumping stations. The Bahr El Baqar Drain carries sewage effluent from Cairo and the drainage water of more than 200 000 ha of agricultural land. Its waters have high heavy metal contents, high BOD_5, high-suspended solids and high ammonia. The drain also carries various types of pesticides (e.g. Lindane 12.4 µg/L). Water samples taken from the drain indicate high levels of polycyclic aromatic hydrocarbons such as naphtalenes, alkylated aromatics and heavy fuel oils. Bahr El Baqar drain also carries 60 percent of the total nitrogen load to the lake. Hadous Drain is more than a typical agricultural drain, not polluted with industrial wastes, but carrying even bigger loads of pesticides[9].

Groundwater

Although several aquifer systems exist in Egypt, the most important is the Nile aquifer system, which covers the Nile flood plain region and the desert fringes where 90 percent of Egypt's population lives. In the center of the flood plain, the aquifer is semi-confined by an average of 10 m of silt-clay; the aquifer becomes phreatic on the edges of the flood plain and the desert fringes. The thickness of the aquifer ranges from 300 m in the south, to 800 m in the Delta. The flow direction is, with a few local exceptions, south north.

The main source of recharge is percolation from agriculture and infiltration from irrigation and drainage canals. Recharge varies according to hydrogeological conditions. Extraction from the aquifer is by seepage to the river, and extraction from wells. The pattern of infiltration/drainage may be reversed according to the season. Due to the interaction of groundwater with surface waters, pollution of aquifers is closely related to adjacent (polluted) surface waters. Direct interaction of groundwater with the unsaturated zone may play an equally important role as well[13].

The main pollutants encountered in groundwater are:

• *E. coli* (>100 MPN/100 mL), found at shallow depths in regions with highly vulnerable groundwater.

• Nitrate (occasionally 70-100 mg/L and expected to increase with time) in regions with highly vulnerable groundwater and intensive fertilizer application.

• Organochlorine pesticides in highly vulnerable groundwater, also at greater depths.

• Organophosphorus and carbamate pesticides, especially in shallow groundwater.

• Iron and manganese (mostly natural) and

• High salinity due to sea water intrusion and (locally) return flow from irrigation.

Pollution is more severe on the edges and desert fringes of the Nile Valley and in the shallow portions of the aquifers underneath urban areas (domestic sewage). Verbal communications of the National Research Centre and the Cairo University staff suggest that there is, for example, severe pollution in the Southern Helwan area. High concentrations of nutrients, *E. coli*, sulfur, heavy metals, *etc*. have been observed in the shallow groundwater, largely surpassing WHO standards for drinking water use.

ENVIRONMENTAL IMPACTS

Biological Contaminations

As a result of poor wastewater treatment, high concentrations of coliform bacteria are found in the Nile and its branches downstream of Cairo. Values of 1 to 10 million (Most Probable Number) MPN/100 mL have been measured in the Rosetta branch. This is far above the standard of five thousand MPN/100 mL as given in Law 48 of 1982. Since exposure to pathogenic bacteria can cause serious health problems, adequate treatment of sewage should be given high priority.

Pesticides

High concentrations of pesticides are found in the Nile and Rosetta Branch. For example, the reported concentration for linadane (y-HCH) and DDT are 5 to 10 times above European standards. As agricultural activities are the principal source, it is expected that concentrations in agricultural drain are even higher. The risk of pesticides relates to drinking water supply without proper treatment (by means of active carbon) and the accumulation in fish products.

The problem asks for a sound baseline study, including a review of pesticide use, import and production and measured concentrations in various water bodies, with special attention given to drinking water resources and fishing areas. Short-term, or immediate, actions might be necessary in case unacceptable concentrations are found in drinking water.

Heavy Metals

High concentration of various metals are reported for the Rosetta Branch, the Alexandria region (coastal waters and Lake Maryut) and Lake Manzala. Measurements in the Rosetta Branch show that cadmium, copper and zinc are above standards. It should be noted, however, that Egyptian standards for copper and zinc (of 1 000 μg/L) in receiving water bodies are too high (European stand are 50 μg/L for copper and 150 μg/L for zinc). High levels of mercury are also reported for the Alexandria region. Increased concentration of metals is also found in the bottom sediment of Lake Manzala. The impact on the lake's fish resources remains unknown. As the heavy metals settle in sedimentation areas, they constitute a long-term threat for the environment. Actions are needed to determine the most important inputs and evaluate suitable reduction measures.

Public Health

Although high numbers of water-borne diseases are reported, it is believed that many more people suffer from diseases related to other forms of water pollution. Toxins such as pesticides and heavy metals in drinking water and food products can affect human health. Regular controls of drinking water quality and contamination of fish products must be achieved in the short-term, together with adequate actions to prevent further exposure of the population to harmful contaminants.

Lack of Information on Water Quality Status, Causes and Effects

Although various studies and monitoring efforts have been carried out, information on water quality status, its causes and effects shows many gaps. To enable the formulation of effective measures to prevent further pollution of the vital water resources and to restore polluted areas, more detailed information is required for pollution sources, the transport and behavior of pollutants in the water system, the assimilative (self-purification) capacity of the water system, and the impacts of pollutants on various water uses. This calls for an adequate routine monitoring system, a data base and information system and an integrated modeling approach, to analyze the impact of individual pollution sources on ambient water quality, to evaluate the efficiency of proposed actions. The design of the monitoring system could be as follows: (i) early warning system (EWS): an early warning system is recommended. The sensor system will receive and send information to a central processing unit. There can be on-line measurement equipment, the general public observing calamities, the police officially involved in all kind of accidents and the eventual polluters, which then have a legal obligation to report environmental accidents; (ii) monitoring locations: for the river Nile , the important drinking and irrigation water intake points, together with the sources of pollution along the river are recommended to be monitored according to their km locations. In order to enable some early predication of water quality at the release from the High Aswan Dam, monitoring sites must be planned at a various locations in the Lake Nasser. For Nile branches and the irrigation canals, a similar design procedure are to be followed; (iii) selection of parameters: to obtain a good overview of the water quality status at a particular monitoring location, a minimum package of 35 parameters, including organoleptic parameters, general parameters, major ions, trace metals and non-metals, biodegradable organic materials, nutrients, microbiological and parasitological parameters are to be measured. This package has to be measured, at least seasonally. However, selective parameters are to be measured monthly in some locations.

Further Degradation As a Result of Development

Population growth, industrialization and the need for new agricultural areas and water use will increase the requirements for appropriate actions to prevent further pollution. Because water plays a central role in all these developments, there is a need for a planning unit to analyze future water requirements and distribution.

WASTEWATER MANAGEMENT

Line of Action

Pollution control in large scale-industries The Egyptian Environment Affairs Agency (EEAA) has identified 41 industrial enterprises in the public sector, which urgently need to reduce their discharge of untreated wastewater. Feasibility studies were carried out (financed by USAID five years ago), and implementation of recommended solutions could begin immediately after review of the studies. The action also aims to introduce (a) a database system to identify all effluents from large-scale industries; and (b) an effluent monitoring program for regular sampling. This action will initiate a vital clean-up of current major industrial discharges in the chemical, textile and food processing sectors, resulting in an increased availability of surface water resources without high treatment costs. It will also provide a considerable source of important information to EEAA and other water managing authorities to support planning of future measures.

Pollution control in small-scale industries Small-scale industries are often responsible for disproportionately large contributions to overall pollution loads. Examples of this are the electroplating and painting industries, which are a primary source of heavy metals discharges to water. Before implementation of mitigation measures can take place, it will be necessary to take inventory, prepare feasibility studies recommending alternative solutions for pollution management, assess current pollution generation, and plan for an organization (new company) to handle collection and treatment of the polluting liquids and wastes.

This action will provide important information contributing to effective measures to reduce the discharge of primarily heavy metals to the Nile River and drains. It will also propose the establishment of a new enterprise to serve those industries where construction of treatment facilities is not financially viable.

Improvement of Water Supply, Sanitation and Sewage Disposal

Urban areas Currently all 33 existing sewage treatment plants for urban sewage water are in need of improvements. Sixteen plants are not even in operation. It has been shown that the plants receive disproportionately large amounts of wastewater due to both heavy household consumption and leakage from the water distribution systems. The leakage in Cairo is estimated to be as high as 70%. The plants require a considerable input of new equipment, training of personnel in operation and maintenance, and introduction of better management to finance the water and wastewater services now provided free of charge.

This action will have its greatest impact through reduction of heavy biological and bacteriological pollution of the watercourses, in particular the primary recipient, the Nile River. The measures proposed for wastewater treatment plants will reduce drinking water production costs; the improved operation of water plants and distribution systems will lower water consumption and wastewater generation. This combined action not only will result in improved quality for the Nile River and wastewater's, but will also delay demand for additional water plants and enlargement of wastewater treatment facilities. In combination with this action, a study on alternatives to more conventional wastewater technologies will be carried out, focusing on the possible use of natural and climatological conditions in Egypt, such as surface and sub-surface infiltration, to recycle wastewater for irrigation purposes, and eva-ponds. The result of the study will be an important factor in decisions on future treatment technology, with regard to efficiency and cost aspects.

Rural areas Sewerage and sewage systems are virtually non-existent in rural areas and drinking water supplies are insufficient. 4 500 villages with more than 500 inhabitants are served by 3 500 water supply systems, which do not function properly, and rehabilitation and extension are urgently required.

The action will provide services necessary to upgrade and rehabilitate existing water supply systems and install new wastewater treatment systems. These measures are of fundamental importance to improve the health status of the population and are expected to have a substantial positive impact on the high mortality rates among small children caused by water-borne diseases.

Pollution in the Nile River is not caused only by municipal and industrial wastewater discharge. Heavy traffic of passenger ships and commercial transports also contribute to pollution loads. There is a clear need for arrangements to reduce the ongoing discharge of completely untreated sanitary wastewater to the river. Ministry of Housing and Public Utilities (MHPU) has carried out several feasibility studies to address this problem.

Surface water management Surface water is the largest source for drinking water and used by industries and agriculture. The need for stringent planning is urgent as water quality is deteriorating and its use is increasing. The current situation has created increased treatment costs, which are disproportionately borne by the user, rather than by the polluter.

This action will support water management by (a) introducing cost-sharing policies; (b) institutionalizing water management; and (c) formulating operational strategies and implementation of projects supporting water management.

Quality management of groundwater resources Population increases and developments of industrial activities, which of necessity will be located to a greater extent outside current industrial areas, constitute a growing threat to the very scarce groundwater resources. Agricultural efficiency must be improved in order to support food demands and supply cotton to the important textile sector. Altogether, these facts call for immediate planning for the protection and use of groundwater resources.

The action will provide services to (a) define current groundwater status; (b) complete the mapping of groundwater vulnerability to surface pollution; (c) identify pollution sources and most threatened areas; (d) evaluate technical protection measures; and (e) evaluate plans for vertical drainage by means of tube wells. As a special component, the drainage from 3-5 undrained agricultural areas, by use of vertical tube wells, will be studied in order to evaluate the technical efficiency and economics of this method.

Water bodies, both ground and surface are of utmost importance for Egypt's future. To coordinate and optimize use of water resources, a control mechanism for water quality is urgent. This action will provide a monitoring network covering the aquifers and surface waters, laboratory facilities to support the monitoring system, and a geographical information system to organize the data and facilitate strategic planning. The action will result in detection of long-term trends, violation of standards, quality control for water use (irrigation and water intakes), and establishment of water balances.

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