IMPACT OF DIFFUSE POLLUTION ON THE SOCIO-ECONOMIC DEVELOPMENT OPPORTUNITIES IN THE COASTAL NILE DELTA LAKES

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ABSTRACT

The coastal Delta lakes, as transitional zone between land and sea, are among the most productive natural systems in Egypt. The current configuration of these lakes is changing rapidly, due to man's activities and natural processes. Most of their water supply comes from polluted agricultural drains. Several problems affect the conservation of the Nile Delta lakes, mainly pollution, land reclamation, intensive aquatic vegetation, over fishing and coastal erosion. This paper deals with the pollution problems. Erection of Aswan High Dam accompanied by considerable increase in population and consequently in man's activities constitutes the main causes of pollution in the Nile Delta lakes. Eutrophication, as well as occurrence of metal and pesticide contaminants constituted in these lakes problems of increasing concern. The levels of pollution in these lakes are Lake Mariut> Lake Manzalah> Lake Edku> Nozha Hydrodrome> Lake Brollus. With the expected increases in urbanization, industrialization and socio-economic activities following the increase in population, it is strongly recommended that the existing pollution control policies and measures covering legislation, standards, criteria, waste minimization, effluent treatment, monitoring, education and public awareness should be enforced, especially before new industries are established, in order to increase opportunities of the socio-economic development of the country:
Keywords: **Nile Delta lakes, pollution, socio-economy**

INTRODUCTION

Before early 1960, only few scattered limnological information and data in Egypt have been collected by foreign visitors. Since 1967 till present, several limnological research projects were conducted. The rapid population growth in Egypt, especially in the Nile Delta covered by several wetlands, poses serious problems including water pollution and land reclamation, leading to deterioration and decrease in available healthy water supplies, Accordingly, conservation of these water bodies is very urgent and became a must for their better management, mainly for the benefit of the Egyptian economy and public health. The Nile Delta lakes, as transitional zone between land and sea, are among the most productive natural systems in Egypt. They are internationally known for their abundant bird life. Over 25% of all Mediterranean wetlands are found along the Mediterranean coast of Egypt. This paper briefly reviews the main water characteristics of the Nile Delta lakes and the different pollution levels in their compartments, particularly in waters, as the principal problem affecting their conservation.

STUDY AREAS

Five water bodies lie adjacent to the Mediterranean Sea on the fringe of the Nile Delta; Lake Mariut, Nozha Hydrodrome, Lake Edku, Lake Brollus and Lak Manzalah. The current configuration of these lakes is changing rapidly, due to the natural processes and man's activities (Saad, 1990). Contrary to the first two lakes, the latter three ones are connected to the Mediterranean Sea. The main water supply to the Delta lakes comes from the contaminated agricultural drains. However, the Hydrodrome is fed with the Nile water (Saad, 1974 a), which

became also recently contaminated. Additional water resources are rainfall, seepage of underground water, the sea through sea-lake connections, as well as sewage and industrial wastewaters.

Lake Mariut, located SW of Alexandria, is the heavily polluted lake in Egypt and its water is pumped to the sea. It is now divided artificially into four basins and the area of the lake proper reaches 27.3 km^2 and its depth ranges from 90-150 cm. The Nozha Hydrodrome was isolated from Lake Mariut. It has an area of 5.0 km^2 and average water depth of 3 m. Lake Edku, situated at 30 km NE of Alexandria, has an area of 126 km^2 and water depth ranging from 50-150 cm. Lake Brollus , situated between the two Nile branches, has an area of 420 km^2 and water depth varying from 70-240 cm. Lake Manzalah, the largest Delta lake, is lying in the eastern region of the Nile Delta. Its area had been reduced to 1200 km^2 by 1980 (Meininger and Mullie, 1981).

The coastal Delta lakes are used for fishery, water supply for agriculture and industry. The fish populations in these lakes are comprised from fresh and marine water fish species. Many of the latter migrate for feeding in these lakes through their connections with the sea. The chemistry of the lake waters controls the distribution of these fishes (Alsyes and Soliman, 1993).

PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE WATERS

The ranges of the environmental characteristics of the surface waters of the Delta lakes are listed in Tables 1 and 2. The surface water temperature usually follows that of the air. Both showed local variations between sites in each sampling time. No thermal stratification was observed, due to shallowness of the lakes and mixing of their waters by wind action. These lakes are influenced by the climatic conditions of the southeastern Mediterranean. The highest turbidity coincided

with stirring up of the bottom sediments by strong wind action in these shallow lakes and the lowest with stability of the lake waters. The Secchi values varied widely, reflecting man's impact on these lakes. Variations in pH values coincided mainly with differences in photosynthetic activities and carbon dioxide. Distribution of Dissolved Oxygen (DO) was influenced by external and internal events and showed a considerable wide range of variations in the Delta lakes. Its depletion occurred in several places, particularly in Lake Mariut, causing liberation of hydrogen sulfide. The oxygen demand of the decomposing plankton brings about effects similar to those caused by the addition of allochthonous organic substances. According to Safty (1994), the lowest DO and highest H_2S were found in the feeding water of Lake Mariut, confirming the acute effect of pollution on its environment. The chlorosity values considerably in the three lakes connected to the Mediterranean Sea. The low values in some seasons in the drains feeding the Delta lakes reflect their high contents of sewage wastes.

The dissolved organic matter (DOM) decreases the DO content during decomposition causing hazardous effects on the aquatic life. The levels of DOM in Lake Mariut gave a considerable wide range of variations, compared with those in the Hydrodrome and Lake Edku (Saad, 1985a). The increase in DOM in the Delta lakes is associated with undesirable algal level. Nitrate is an essential nutrient and may constitute the growth-limiting factor. Nitrite is an intermediate oxidation state of nitrogen, both in the reduction of NO_3 and in the oxidation of NH_4. Inspite of the importance of phosphorus for phytoplankton growth, it is a potential pollutant if it is found in abnormal higher concentration, as in Lake Mariut (Saad, 1973 a, b). Considerable amounts of silicate entered into Lake Mariut in drainage waters Saad (1980a), several factors are responsible for the regional and seasonal variations of each nutrient in the Delta lakes. The increase in nutrient concentrations coincided with the increase in the amounts of allochthonous and autochthonous nutrient supply. The effect of eutrophication on Lake Mariut can be clearly illustrated by comparing the annual mean concentrations of its nutrients with those from its daughter lake (Table 3 from Ahdy, 1982). The mean concentrations of all nutrients, except silicate, in Lake Mariut were several times higher than those in the Hydrodrome. The high silicate content in the Hydrodrome resulted from the feeding Nile water enriched with silicate (Saad *et. al.,* 1984).

Table 1. Physical and chemical characteristics of the waters of Lake Mariut and the Hydrodrome

Parameters	Nozha Hydrodrome		Lake Mariut	
	Ranges	References	Ranges	References
Temp. (C)	13.0-27.5	Saad, 1973 a	12.7-29.0	Saad, 1973 b
Transp. (cm)	37-51	Saad, 1973 a	10-105	Saad, 1973 b
pH	7.45-8.85	Saad, 1973 a	7.28-9.70	Saad, 1973 b
DO (mg/l)	6.21-10.73	Saad, 1973 a	ND-9.08	Safty, 1994
Cl_v (g/l)	0.12-0.48	Saad, 1973 a	1.09-2.63	Saad, 1973 b
DOM (mg/l)	0.87-2.68	Saad, 1974 b	2.85-19.80	Saad, 1974 b
NO_2 (µg-at/l)	0.6-14.5	Ahdy, 1982	2.4-43.7	Ahdy, 1982
NO_3(µg-at/l)	5.0-40.0	Ahdy, 1982	14.0-70.0	Ahdy, 1982
PO_4(µg-at/l)	0.4-3.6	Ahdy, 1982	10.8-94.2	Ahdy, 1982
SiO_3(µg-at/l)	136-547	Ahdy, 1982	74-296	Ahdy, 1982

Table 2. Physical and chemical characteristics of the waters of Lake Edku, Lake Brollus and Lake Manzalah

Parameters	LakeEdku		LakeBrollus		LakeManzalah	
	Ranges	References	Ranges	References	Ranges	References
Temp. (C)	14.5-28.5	Saad, 1976	11.0-29.01	Darrag, 1974	16.8-30.5	El-Wakeel and Wahby, 1970
Transp. (cm)	20-150	Abdullah,1994	8-37	Darrag, 1974	--	
pH	7.63-9.50	Saad, 1976	8.08-8.72	Darrag, 1974	7.85-8.50	El-Wakeel and Wahby, 1970
DO (mg/l)	1.63-18.46	Abdullah,1994	2.68-11.75	Darrag, 1974	--	
Cl_v (g/l)	0.44-23.24	Saad, 1976	0.36-13.51	Darrag, 1974	0.77-11.67	El-Wakeel and Wahby, 1970
DOM (mg/l)	2.09-6.17	Saad, 1985a	--	--	--	
NO_2 (µg-at/l)	ND-19.1	Abdullah,1994	ND-15.1	El-Sherif, 1983	0.3-3.4	Abdel-Moati, 1985
NO_3(µg-at/l)	0.04-90.2	Abdullah,1994	ND-24.4	El-Sherif, 1983	2.7-7.5	Abdel-Moati, 1985
PO_4(µg-at/l)	ND-15.4	Abdullah,1994	ND-1.2	El-Sherif, 1983	1.7-5.0	Abdel-Moati, 1985
SiO_3(µg-at/l)	11-157	Abdullah,1994	2-140	El-Sherif, 1983	45-100	Abdel-Moati, 1985

Table 3. Annual means of nutrients (ìg-at/l) in Lake Mariut and Nozha Hydrodrome

Lakes	NO_3	NO_2	NH_4	Total N	PO_4	SiO_3
Mariut	35	15.1	35.6	85.7	36.4	198
Nozha	12	3.9	2.9	18.8	1.3	254

Some hydrochemical observations including nutrients in Lake Mariut were investigated during 1985-87 (prior to diversion of sewage of the Alexandria eastern region to its main drain (Qalaa Drain); 0.75 x 10^6 m^3/day (El-Rayes *et al*., 1994). The results indicate that nutrient conditions of the lake eastern part were still getting worse compared with those in the other lake region and with those in this part before ten years. The results confirm that sewage load to Lake Mariut has doubled a decade ago.

MAIN CONSERVATION PROBLEMS

There are several problems affecting the conservation of the Nile Delta lakes, resulting from the rapid development of many improper use patterns and insufficient levels of protection. The main problems are pollution, land reclamation, intensive aquatic vegetation, over fishing and coastal erosion. This paper deals with the pollution problems

Pollution of the Nile Delta lakes including their eutrophication attracted the attention of the authors and other investigators . The levels of their pollution are in the order: Lake Mariut > Lake Manzalah > Lake Edku > Nozha Hydrodrome > Lake Brollus.

Erection of the AHD and storage of the Nile water in the High Dam Lake in 1964 accompanied by the considerable increase in population and consequently in man's activities, mainly in agriculture and industrialization, constitute the main causes of pollution in the Delta wetlands.

Eutrophication

The term eutrophication is used simply to mean enhanced nourishment and refers to the stimulation of aquatic plant growth by nutrients, especially phosphorus and nitrogenous compounds (Portman *et al*., 1990). Eutrophication of the Delta lakes constituted in the last four decades a considerable problem, as they became enriched with nutrients and organic matter originated from allochthonous and autochthonous sources.This phenomenon, which differs in its intensity in different regions of the lakes, is serious causing cases of sudden mass mortality of fishes. Accordingly, treatment of the different wastes should be highly recommended before their dumping into the receiving wetlands (Saad, 1974, 1985b, 1973a, 1973b, 1980a, 1985b, Saad *et.al.,* 1984).

Heavy metals

In the last four decades, the occurrence of metal contaminants in the Delta lakes, particularly in Lake Mariut, has become a problem of increasing concern. This situation has arisen as a result of the rapid growth of population and thus the increase in man's activities. Heavy metals may accumulate unnoticed in the aquatic environment to toxic levels. They are partitioned among the various aquatic compartments and may occur in dissolved, particulate and complex forms. The main processes governing their distribution and partition are dilution, dispersion, sedimentation and adsorption /desorption.

Some heavy metals, such as Zn, Cu, Mn, and Fe, are essential for aquatic organisms, but show toxic effects when organisms are exposed to higher abnormal concentrations. Others (Pb, Hg, and Cd) are not essential for metabolic activities and exhibit toxic properties. Heavy metals and pesticides in the Delta lakes, particularly in Lake Mariut were studied more recently than other chemical parameters. The compartments water, sediments and fish have been investigated.

The occurrence and distribution of heavy metals in the heavily polluted Lake Mariut and their accumulation in the different parts of its common fish (*Tilapia* species) were investigated during 1978 to 1979 (Saad *et al.*, 1981). The variations in concentrations of metals in the lake water during the 14 months study were mostly attributed to variations in the discharge rates of the dumped wastes. The data differentiated Lake Mariut into two water bodies. The levels of Zn, Cu, Fe, and Mn in the eastern anoxic water were relatively higher than those in the western oxic water, due to the direct effect of waste discharges on the eastern part of the lake.

The mean levels of heavy metals in the liver and stomach of *Tilapia* were markedly higher than those present in the edible flesh of the fish. The mean concentrations of metals in the lake water were much lower than those found in different parts of the fishes. This shows the ability of fish to accumulate the heavy metals

Based on composite surfacial sediment samples collected from the Hydrodrome, Lake Mariut, and Lake Manzalah, the heavy metal enrichment in these sediments was evaluated by Fe ratios, as the total digestion of bulk sediments can underestimate the metal enrichment associated with clay- size particles (Saad *et al.*, 1985). Relative metal enrichment was evaluated by computing ratios of heavy metals to Fe (Table 4). A high ratio of a metal to Fe indicates enrichment by that

metal. The Zn/Fe ratio indicates that Lake Mariut showed a higher Zn enrichment than that for the other two lakes. The large volume of wastewater inputs to Lake Mariut may be an important factor in this relative enrichment. Iron, Ni and Cu association within each lake indicates that Fe chemistry is an important factor in the heavy metal distribution. These three metals are significantly correlated with one another in all three lakes, even though Lake Mariut had relatively lower concentrations of these metals than the other two lakes. This association may indicate a similar geochemical process for all three lakes.

Table 4. Mean ratios of Mn, Cd, Cr, Cu, Ni, Pb and Zn to Fe for three Delta Lakes

Lakes	Mn/Fe	Cd/Fe	Cr/Fe	Cu/Fe	Ni/Fe	Pb/Fe	Zn/Fe
Mariut	37.4	0.01	1.64	1.48	1.40	0.29	3.66
Nozha	21.6	0.03	1.62	1.38	1.52	0.18	1.83
Manzala	17.2	0.04	1.80	4.65	1.42	0.22	2.67

Recently, metal speciation in the Delta lakes has been started by a study on zinc speciation in the sediments of Lake Mariut (Saad *et al.,* 1995). By investigating the distribution of the metal different species, its risk can be ascertained. This is because the more mobile (more dangerous) fractions, which are introduced by man' activities, are the adsorptive (exchangeable), bound to carbonate and bound to reducible form. The order of abundance of the Zn fractions was Fe/Mn oxides fraction (F3)>residual fraction (F5)>organic matter/ sulfide fraction (F4) >carbonate fraction (F2) >exchangeable fraction (F1), giving means of 194.2, 148.0, 99.4, 49.4 and 9.7 ìg/g, respectively.

Pesticides

The organochlorine pesticides (OCPs) are deliberately introduced into the environment and have played a major role in increasing food production and protecting natural resources, e.g. DDT and aldrin. The industrial chemicals such as PCBs, however, are introduced indirectly into the environment. These substances are micro-organic pollutants, because of their toxicity and ecological effects. Population explosion, rapid urbanization and industrialization have increased reliance on the use of chlorinated hydrocarbon substances (CLHCs) in Egypt, mainly in agriculture and industry.

OCPs, especially DDT and its derivatives, were the first generation of CLHCs to be used for control of agricultural pest and human diseases in Egypt since 1950. The drains feeding the Delta lakes are the principal sources of their pesticide contamination. The occurrence and distribution of OCPs in the heavily polluted Lake Mariut were investigated during 1978 to 1979 (Saad *et al.,* 1982). The major substances detected in the lake water were lindane, p,p -DDE, o,p -DDT and p,p -DDT, with annual mean residue values of 2.091, 4.493, 0.009 and 0.134 ppb, respectively. Contamination levels in fish in ppb were 34.98 (lindane), 38.96 (p,p -DDE), 17.36 (p,p -DDT) and 60.76 (total DDT).

Based on composite sediment samples from Lake Mariut, the total DDT content was 29.8 ng /g and the PCBs level was 17.8 ng /g. The total DDT/PCBs ratio was in Lake Mariut much greater than 1, indicating that agricultural inputs of DDT rather than industrial discharges was the main source of pollution by organochlorine compounds (Saad *et al*., 1985).

Nevertheless, the occurrence of these synthetic micro pollutants in different compartments of the Delta lakes, even at trace levels, is of ecological and environmental health concern. The regulatory framework and control on the use of these chemicals should be put in place in the country.

CONCLUSIONS AND RECOMMENDATIONS

As reviewed above, several limnological information and data have been obtained from the Delta lakes, particularly from Lake Mariut during the last decades. Because the different pollution problems in these lakes increase with progress of time following the successive increase in population, the following principal proposals and measures are strongly recommended for better protection, conservation and management of these wetlands in order to increase the opportunities of the socio-economic development of the country:

1. To accelerate the restoration of the Delta lakes to better conditions for saving them as grounds for fisheries and places for recreations, the quality of the sewage and industrial wastes dumping directly into them or indirectly via agricultural drains must be much improved by suitable means, at least by limiting the amounts of oxygen demanding wastes and nutrients, especially phosphorus. Thus, full biological treatment of sewage, which oxidizes the organic matter, beside precipitation and removal of nutrients by suitable waste treatment processes became necessary.
2. Industries affecting the Delta lakes should be encouraged to adopt low and non-waste technologies at all stages of production.
3. Because agriculture is a considerable source of nutrients causing eutrophication, substantial changes may be required in the use of fertilizers in agriculture for reduction of nitrogen and phosphorus inputs into the Delta lakes.
4. Because huge amounts of contaminated drainage and fresh-waters are discharging into the Delta lakes, rationalization of the amounts of these waters accompanied by rational use of pesticides and fertilizers in agriculture and treatment of sewage wastes before dumping into these lakes are strongly recommended. This will decrease markedly the pollution load on the Delta lakes and consequently on the coastal Mediterranean water, as these lakes became after the Aswan High Dam estuaries to the Mediterranean Sea.

5. Because occurrence of CLHCs in different compartments of the Delta lakes, even in trace and ultra trace levels, is of ecological and environmental health concern, the regulatory framework and control on the use of these micro pollutants should be put in place in the country and enforce the International Code of Conduct on their proper use.
6. With the expected increases in urbanization, industrialization and socio-economic activities following the increase in population, the existing pollution control policies and measures should be enforced, especially before new industries are established around the Delta lakes to prevent the introduction of processes which may have detrimental effects on the lake environments.
7. Because public awareness of the Delta lake issues is very limited, it is necessary to upgrade it for the valuable role of the lake ecosystems in our daily lives. This can be done by providing the public with special training programs on environmental and pollution problems with Illustrative examples for protection and management.

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