WATER QUALITY DETERIORATION OF MIDDLE NILE DELTA DUE TO URBANIZATIONS EXPANSION, EGYPT

S. S. Zaghloul[1], Hussein Elwan[2]

[1] Sohair Saad Zaghloul National Water Research Center, Egypt, sohaahm@yahoo.com
[2] Hussein Elwan, Minister Advisor, Ministry of Water Resources and Irrigation, Egypt. epadp@link.net

ABSTRACT

The objective of this research is to study, analyze and illustrate the effect of urbanization growth on water quality of the old agricultural land drains. This study focuses geographically on the Middle Delta and provides insight into the ongoing loss of agricultural land due to urbanization, the intensification of agricultural production using national data on input of applied fertilizers as well as water quality in place.

One of the main reasons of the problem, which has started in the beginning of the 80's and has negative impact on the water resources quantity and agriculture and the irrigated agricultural areas, is the expansion of urbanization in the old delta lands. The loss in old lands in the valley and delta is being to progress and approximately estimated by 26,000 feddans/year (10,900 hectare/year). This means that the loss in the old agricultural land during the last 20 year period from 1990 to 2010 is more than 0.5 million feddans.

Based on national data showing fertilizer input on agricultural land, the overall loss in agricultural land seems still - at least partly - compensated by an enhanced intensification of agricultural production by using more fertilizer. However, this ongoing urbanization as well as intensification of agricultural production is having a strong impact on surface water as demonstrated by monitoring data of the two main water resources in this area;Alriah El-Menoufi and Alriah El-Abbassi.

It is concluded that the water quality is very poor in the Middle Nile Delta as demonstrated by the assessment of water quality parameters of three main agricultural drains in Middle Delta. All ongoing efforts to improve water quality are oppositely faced by ongoing both urbanization and intensification of agricultural production.

Keywords: Middle Nile Delta Region, Egypt, Urbanization, Water Quality Issues, Agricultural Intensification.

1. INTRODUCTION

Agricultural production in Egypt is negatively affected by the encroachment of urban settlements onto previously cultivated lands "urbanization". In contrast, reclamation

efforts in the desert and coastal areas increase the amount of cultivated land. There is no doubt that the reclaimed lands cost higher than the old ones and, on the other hand, some of the main crops like cotton could not be cultivated in the new lands.

Despite the fact that the growth of urbanization area is markedly pronounced around the cities, the growth around the thousands of small villages poses the largest risk to the loss of agricultural productivity as well as the degradation of water quality. The average loss of agriculture land is about 26.000 feddans/year (10,900 hectare/year), Khaled Abu-Zeid [5]. Till now, Egypt has lost about 10% of its total agricultural area to urbanization. This loss may be partly compensated by intensification of agricultural production by using more fertilizers and land reclamation. Ongoing urbanization as well as intensification of agriculture will continue to impact water quality excessively.

2. STUDY AREA

The Nile Delta extends over approximately 22,000 km^2. In the northern part of the Delta near the coast, the Delta embraces a series of salt marshes and lakes; the most notable among them are Idku, Al Burullus, and Manzilah. The Middle Delta Area (MNDR) is the middle region of the Nile Delta and it is limited by the two main branches Damietta (240 km long) and Rosetta (235 Km long). About 40% of all Egyptian industry is located in the Nile Delta. It is amongst the most densely populated agricultural areas in the world, with 1,360 inhabitants per km^2. About half of the area is used for agriculture.

It is characterized by a clay cap of considerable thickness overlying a coarse texture aquifer. The heaviest type of clay soils are found in the northern part while lighter textured soils are found in the southern part. There is some potential for land reclamation but it is not as great as in the eastern or western deltas. The Middle Nile Delta is composed of three Governorates, Menoufia, Kafr El Shiek and Gharbia as shown in figure 1. The irrigated area is 1.273 million feddans. The main water resources of the Middle Delta are Alriah El-Menoufi, Alriah El-Abbassi. The main drainage water Pump stations are; Tala Drain, Nashart Drain, Gharbia Drain, Drain No. 11, Drain No. 7, Drain No. 8, Tira Drain, Baltim Drain, Drain No. 1, Sabal Drain, Baher Tira, Coastal Areas, Burllus and Zaghloul P.S.

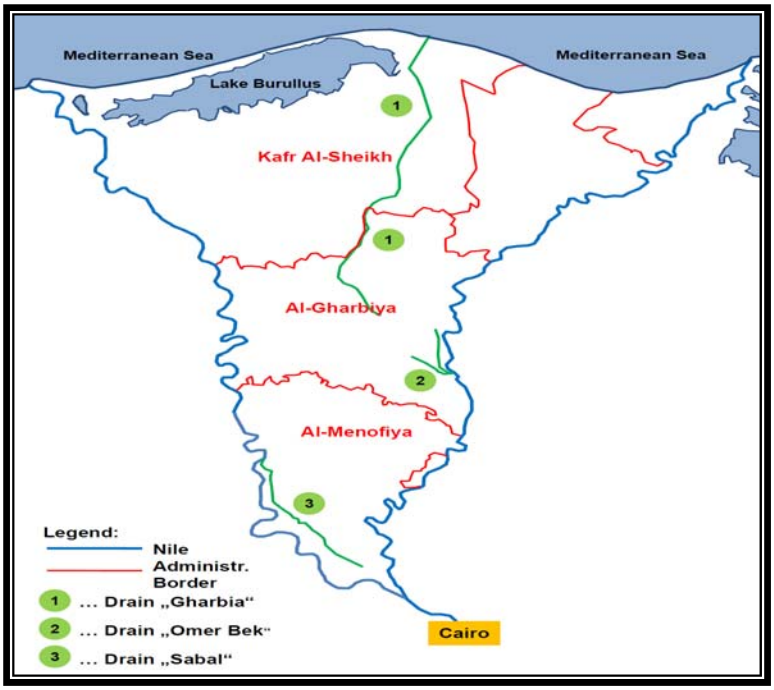


Fig 1 the Middle Delta Map

3. URBAN ENCROACHMENT ON AGRICULTURE LAND

The task to bring new land under cultivation has been the cornerstone of Egyptian agricultural policy since the 1950s. At the same time, overpopulation in the Nile delta and valley, and the gradual shifting of economy from agricultural to industrial cause together different forms of desertification processes, led to the loss of highly fertile agricultural land. Fig. 2 shows two satellite images indicating the urban encroachment in the study area (MNDR).

Therefore, there is an urgent need to address and analyze these changes in order to serve the development plans of the country. The subsequent influences of these changes**,** Khaled Abu-Zeid, [5] as follow;

- 26,000 feddans/year expected average land loss from agriculture to urban
- High cost of preparing desert lands with nutrients and delivering water to desert areas needed for agriculture.
- Agriculture yields in new desert lands are about half of those in old lands
- Expected decrease of investment in irrigation and drainage canals in old lands
- Expected increase in pollution and requests for canal covering in new urban areas in old lands
- Expected increases in nutrients as well as pesticides to waters due to ongoing intensification of agriculture.

Fig 2 The Urban Encroachment on Agriculture Land in MNDR

Information provided by the European Environmental Agency in Copenhagen http://www.eea.europa.eu [16], [17] highlights that both sources of water pollution (that are urban agglomerations and industry) as well as diffuse sources (and here in particular agriculture) contribute to the pollution of water. This is why urbanization as well as intensification of agriculture are referred to in this study

4. CHANGE IN THE CULTIVATED AREA IN MIDDLE DELTA

As it has been mentioned before the study area (MNDR) contains three governorates. The changes in the cultivated land in those governorates for successive eleven years are shown in the following figures.

4.1 El Menofia Governorate

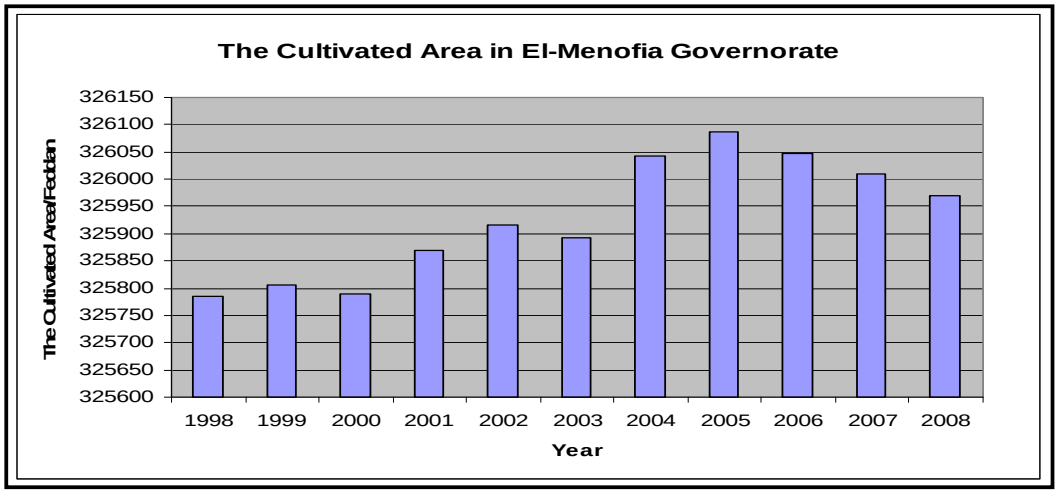


Fig 4 The change in the cultivated area in El Menofia Governorate

Fig 4 shows an increase of the cultivated area till its peak in year 2005 then followed by decrease. The reason behind this increase of the cultivated area starting in 2004 is the merging of new land in Behera Governorate west Delta reaching the desert road which is called El Sadat city. The subsequent decrease was caused by the expansion

of the urbanization. As noticed from the figure the average annual decrease in this governorate is about 40 fed/year.

4.2 Kafr El Shiekh Governorate

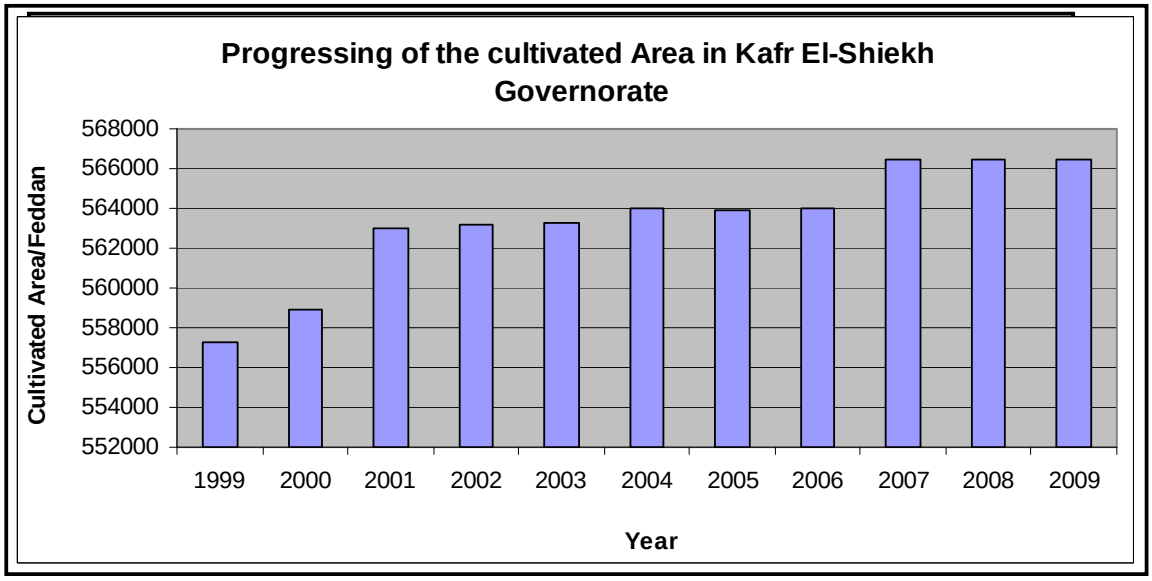


Fig 5 The change in the cultivated area in Kafr El Shiekh Governorate

Fig 5 shows the perpetual increase in the cultivated area in Kafr El Sheikh Governorate. The main reason of this increase is the expansion of the reclaimed lands in the north by using reused drainage water. In this case, the rate of the cultivated area growth is still more than the rate of urbanization growth. From the figure, it is noticed that the expansion area of the reclaimed lands from 1999 - 2009 is around 9000 feddans.

4.3 El Gharbia Governorate

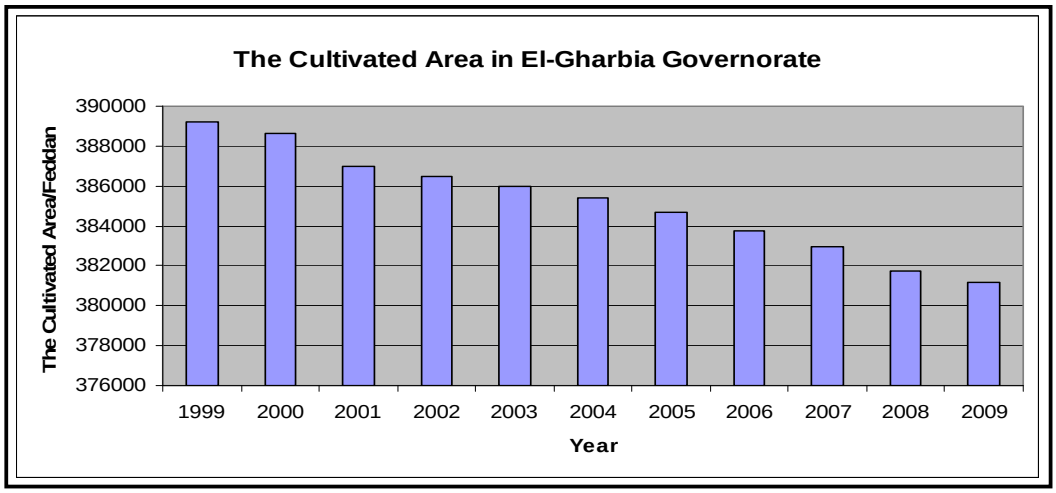


Fig 6 The change in the cultivated area in El Gharbia Governorate

Fig 6 shows continuous decrease in the cultivated area in El Gharbia Governorate. It is considered to be a very clear example to show the reduction in the cultivated area attributable to the expansion of the urbanization there. On the other hand, this governorate is enclosed between Damietta and Rosetta Branches and this does not allow an expansion of the cultivated area. Due the urbanization encroachment in this governorate, an average annual decrease of cultivated area of about 750 fed/year.

4.4 The whole middle area

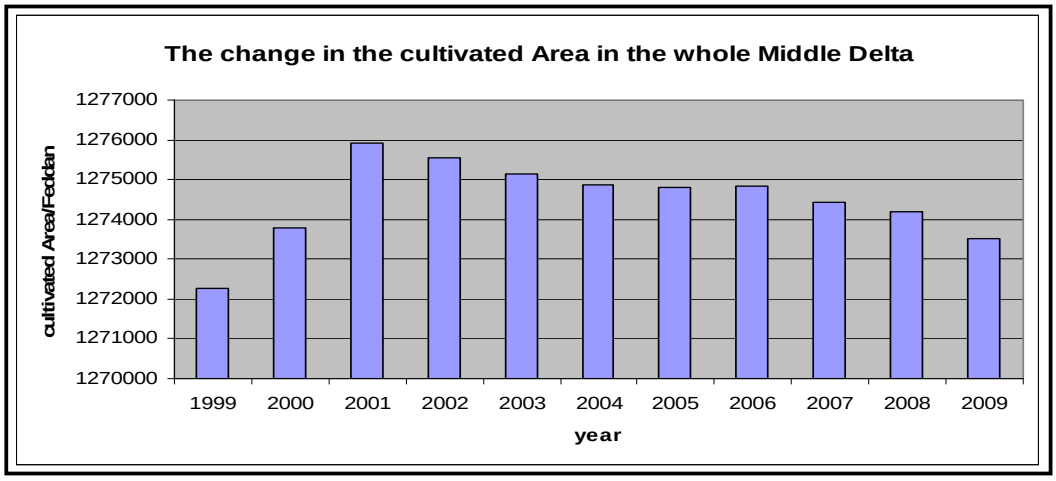
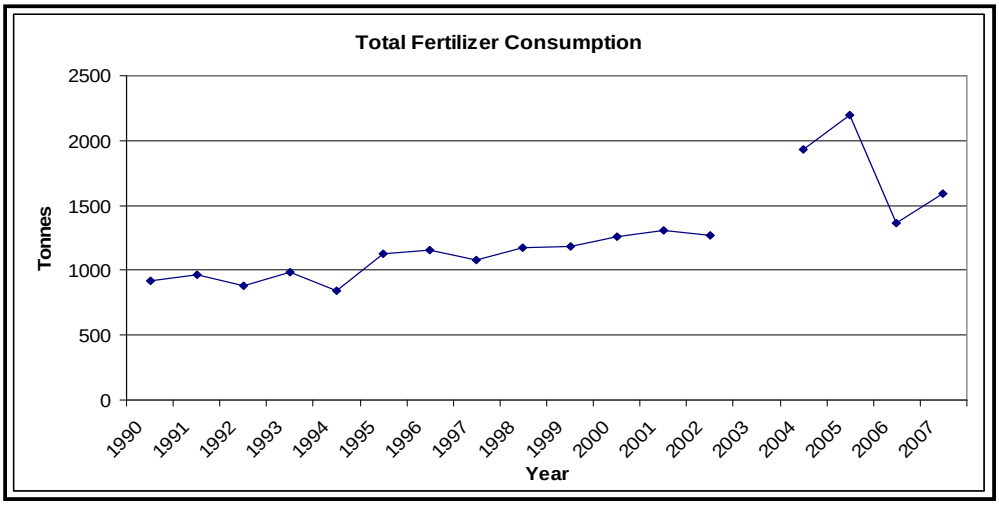


Fig 7 The change in the cultivated area in the whole middle area

It is very noticeable from Fig 7 that the cultivated land area in the whole Middle Nile Delta has been decreasing since the beginning of the new millennium according to the urban encroachment by an average rate of 255 fed/year.

5. INTENSIFICATION OF AGRICULTURAL PRODUCTION



http://www.fao.org **[18]**
http://faostat.fao.org **[19]**

Fig 8 The total fertilizers consumption in Egypt

The obvious loss of agricultural land seems to be still compensated by the ongoing intensification of agriculture. As the data on fertilizers consumption retrieved from FAO (see figure 8 & table 1) demonstrates clearly, fertilizers input on agricultural land in Egypt has increased over the past two decades. The average total annual fertilizers consumption during the mentioned period is about 1250 ton/year (1250 million Kg/year).

Table 1 The Total fertilizers consumption on old agricultural land in Egypt

TOTAL FERTILIZER CONSUMPTION

Year	Nitrogenous Fertilizers	Phosphate Fertilizers	Potash Fertilizers	Total [tonnes]
1990	745.146	184.100	29.700	958.946
1991	775.000	150.000	38.400	963.400
1992	743.742	104.000	29.700	877.442
1993	849.538	108.900	29.700	988.138
1994	720.736	104.300	18.200	843.236
1995	970.000	135.000	21.400	1.126.400
1996	1.002.600	121.900	33.000	1.157.500
1997	915.000	134.500	29.243	1.078.743
1998	1.014.000	128.600	28.528	1.171.128
1999	984.400	150.100	45.000	1.179.500
2000	1.073.416	153.839	32.476	1.259.731
2001	1.099.000	156.231	53.117	1.308.348
2002	1.068.923	142.179	57.701	1.268.803
2003	-	-	-	no data available
2004	-	-	-	1.930.819
2005	-	-	-	2.199.209
2006	-	-	-	1.361.720
2007	-	-	-	1.591.140

http://www.fao.org [18]
http://faostat.fao.org [19]

5. WATER QUALITY INDEX IN MIDDLE DELTA

Both developments ongoing urbanization as well as intensification of agricultural production maintains to have a heavy impact on water quality in the Nile Delta, as demonstrated by monitoring data in place. In the subsequent part the results of monitoring are provided for individual key parameters as well as by using the water Quality Index WQI.

The WQI, which was developed in the early 1970s, can be used to monitor water quality changes in a particular water course over time, or it can be used to compare the quality of a particular water course with other water courses in the region or in the world. The results can also be used to determine if a particular stretch of water is considered to be "healthy". Water greatly influences the quality of our lives. Industry, agriculture and sewage are major polluters of water.

5.1 Methodology

The basic methodology used to determine WQI scores was originally developed by the Environmental Protection Agency (EPA). The methodology appears to be similar to the well-known National Sanitation Foundation (NSF) index, which uses curves to

relate concentrations or measurements of various constituents to index scores and then aggregates scores to a single number.

According to the book *"Field Manual for Water Quality Monitoring"* (Mark K. Mitchel [8], the National Sanitation Foundation surveyed 142 experts representing a wide range of positions at the local, state, and national level and about 35 water quality tests for possible inclusion in an index. Nine factors were chosen and some were judged as being more important than others, so a weighted mean is used to combine the values as shown in table 2.

The index result represents the level of water quality in a given water basin, such as a lake, river, or stream. It is very important to monitor water quality over a period of time in order to detect changes in the water's ecosystem. The Water Quality Index can give an indication of the health of the watershed at various points and can be used to keep track of and analyze changes over time.

Table 2 the Water Quality Parameters and Weights

Parameter	Description	unit	permissible Limits Law48/1982	WQI Weight
Dissolved oxygen DO	It measures the amount of life-sustaining oxygen dissolved in the water.	Mg/l	5 mg/l	0.17
Fecal coliforms FC	FC is a form of bacteria found in human and animal waste	#/100 ml	2000 cfu/100 ml	0.16
pH values	It is a measure of the acid or alkaline content in water (alkaline>7 >acidic)	std units	7 - 8.5	0.11
Biochemical Oxygen Demand BOD_5	It is a measurement of the amount of food for bacteria that is found in water.	mg/l	10 mg/l	0.11
Temperature change	It is very important, as many of the physical, biological, and chemical characteristics of water are directly affected by temperature.	°C	5^o C over normal.	0.10
Total phosphate TP PO4-P	Phosphates are chemical compounds made from the elements phosphorous and oxygen	mg/L	1 mg/l	0.10
Nitrates NO3	Nitrates are a measurement of oxidized form of nitrogen and are an essential macronutrient in aquatic environments	mg/L	45 mg/l	0.10
Turbidity T	Turbidity is a measure of the dispersion of light in a column of water due to suspended matter. High levels of turbidity can come from urban runoff, wastewater	Nephelometric Turbidity units NTU	100 NTU	0.08

	discharges and agriculture.			
Total solids TS	It is the sum of dissolved and suspended solids materials in water includes salts, some organic materials, and a wide range of nutrients and toxic materials.	mg/L	500 mg/l	0.07
Total				100

6. DISCUSSIONS AND RESULTS

6.1 Changes in the Released Drainage Water of Middle Delta to the Mediterranean Sea

Fig. 9 shows the annual total amounts of released drainage water to the Mediterranean Sea from the Middle Delta. As shown in the figure, the trend of the released drainage water to the Sea is getting high, starting at 4110 million m^3 in 1997 and reaching almost 7000 million m^3 in 2009.

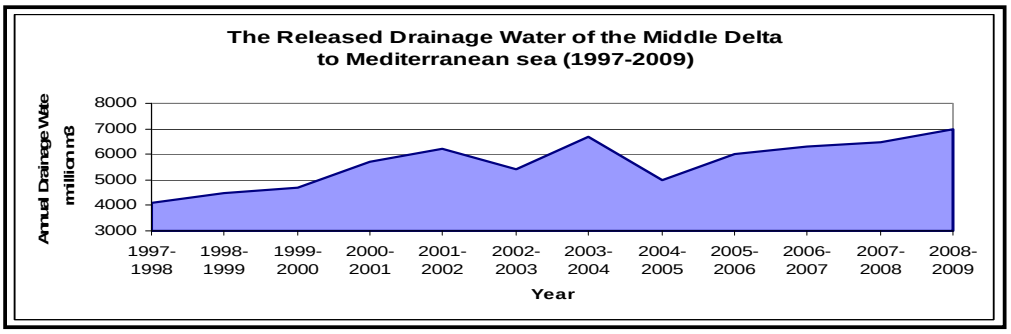


Fig 9 The Annual released drainage water of the Middle Delta to the sea

6.2 Analysis of WQI Parameters

Three drains (Gharbia, Omer Bek and Sabal drains) as shown in figure 1, according to their positions in the heaviest areas in the Middle Nile Delta have been tested. The changes in released water to Mediterranean Sea as will as the nine parameters data involved in calculating the water quality index were collected by the help of Drainage Research Institute, National Water Research Center and analyzed by the author during the period 2000-2008.

6.2.1 pH Value

The pH annual average values obtained from water analysis of the three drains during the period 2000-2008 (Figure 10) showed that they are ranged from 7.24 to 7.56 at Gharbia drain. However, it ranged between 7.78 and 7.29 at Omer Bek drain. Sabal drain recorded pH values ranged from 7.75 and 7.19. It is worth to mention that, these values are within the permissible limits (7 - 8.5), (law 48/1982). If pH is less than 2.0 or greater than 12.0, the quality index equals 0, Mark K. Mitchel [8].

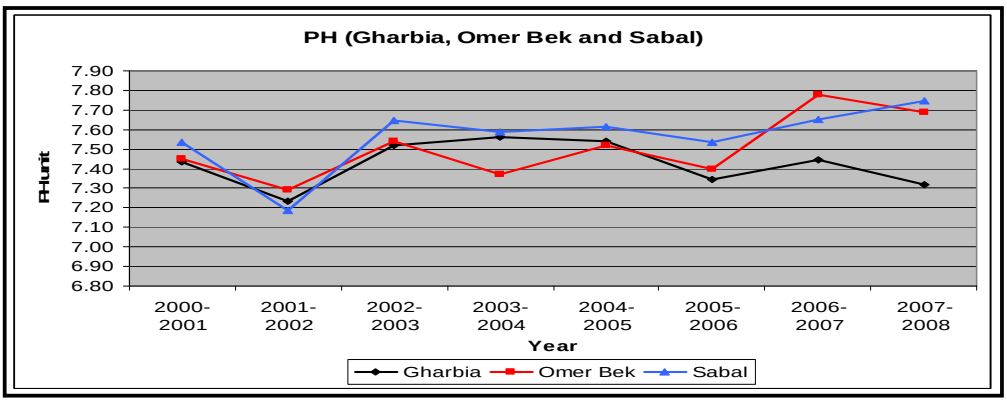


Fig 10 pH variations at Gharbia, Omer Bek and Sabal drains during the period 2000-2008

6.2.2 Dissolved Oxgen (DO)

The annual average values of dissolved oxygen concentrations are alarmingly low in the three drains (Figure 11) and varied between 2.23 mg/l and 2.97 mg/l at Gharbia drain. At Omer Bek drain, the DO concentration ranged from 0.74 mg/l to 2.58 mg/l. However, it recorded values ranging between 1.84 mg/l and 5.34 mg/l at Sabal drain. The severe conditions are recorded at Gharbia and Omar Bek drains which they were found out of the standard limits (5 mg/l) of Law 48/1982. On the other hand, it is clear that there is deterioration in DO concentration in Sabal drain starting in 2003. The decrease of dissolved oxygen concentration in these drains may be related to the domestic wastes discharged directly into the drains, which contain high amounts of biodegradable organic matter.

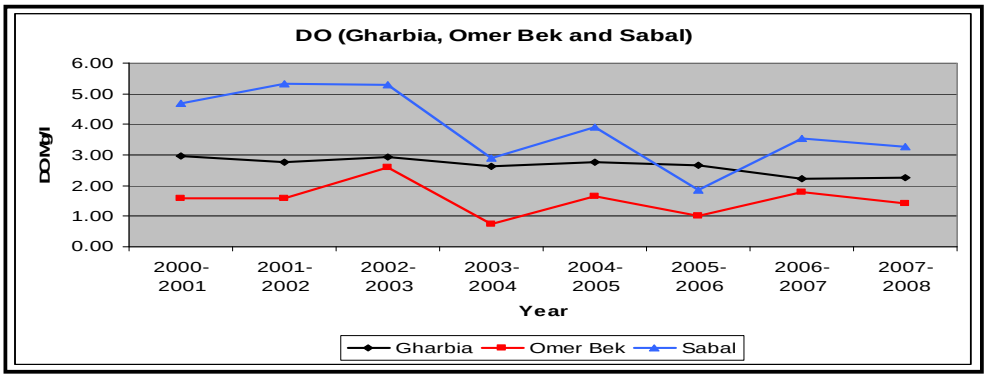


Fig 11 DO concentration at Gharbia, Omer Bek and Sabal drains during the period 2000-2008

6.2.3 Turbidity

The results of Turbidity obtained from water analysis of the three agricultural drains (Figure 12) varied between 56.58 and 85.62 NTUs at Gharbia drain during the period 2000-2008. However, Turbidity ranged from 21.42 to 87.09 NTUs at Omer Bek drain. At Sabal drain, it recorded values of Turbidity ranged from 26.42 to 93.5 NTUs. Suspended material may be objectionable in water for several reasons; it is aesthetically displeasing and provides adsorption sites for chemical and biological agents. Biologically active suspended solids may include disease-causing organisms as well as organisms such as toxin-producing strains

ofalgae, Peavy et al. [6]. If turbidity is greater than 100 ntu, the quality index equals 5, Mark K. Mitchel [8].

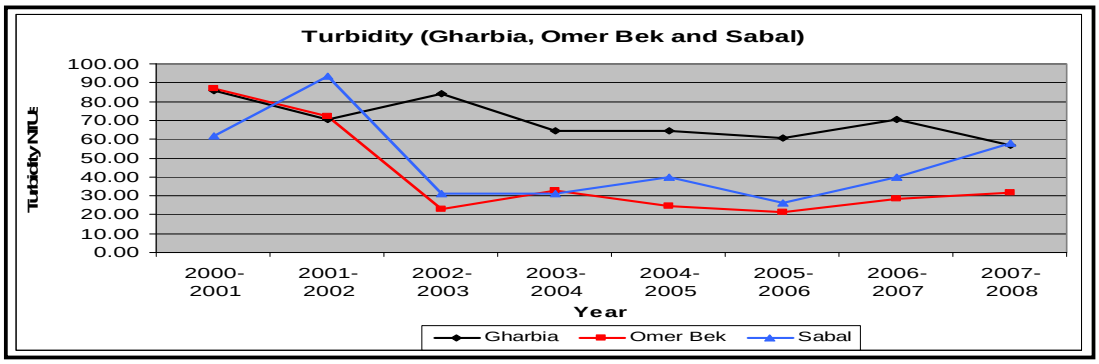


Fig 12 Turbidity variations at Gharbia, Omer Bek and Sabal drains during the period 2000-2008

6.2.4 Total Phosphate (TP)

TP concentrations in the three drains (Figure 13) are quite elevated and range between 0.47 mg/l and 1.23 mg/l at Gharbia drain. At Omer Bek drain, the values of TP ranged between 0.55 mg/l and 1.68 mg/l. TP concentrations ranged from 0.66 mg/l to 0.97 mg/l at Sabal drain. The national limit of TP is 1 mg/l (law 48/1982). High concentrations of phosphate may indicate the presence of pollution and are largely responsible for eutrophic conditions Peavy et al. [6]. If total phosphate is greater than 10 mg/l, the quality index equals 2, Mark K.Mitchel [8].

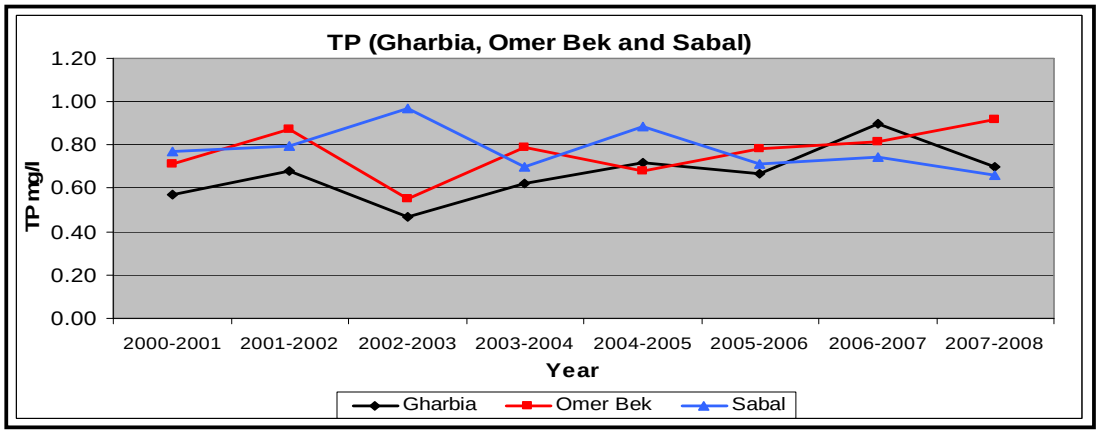


Fig 13 Total Phosphate Concentration at Gharbia drain during the period 2000-2008

6.2.5 Nitrate (NO3)

In all drains the nitrate concentrations (Figure 14) were found within the permissible limits 45 mg/l of law 48/1982. It ranged between 1.33 mg/l and 20.67 mg/l at Gharbia drain. It ranged from 1.46 mg/l to 21.27 mg/l at Omer Bek drain. At Sabal drain, it ranged between 0.43 mg/l and 37.22 mg/l. However, low concentrations may be due to eutrophication effects and low oxygen concentrations. Elevated level of Nitrate promotes high primary productivity and an excess of nitrate in surface water is taken

as a warning for algal blooms, Ravindra et al. [7]. If nitrate nitrogen is greater than 100 ppm, the quality index equals 1 Mark K. Mitchel [8].

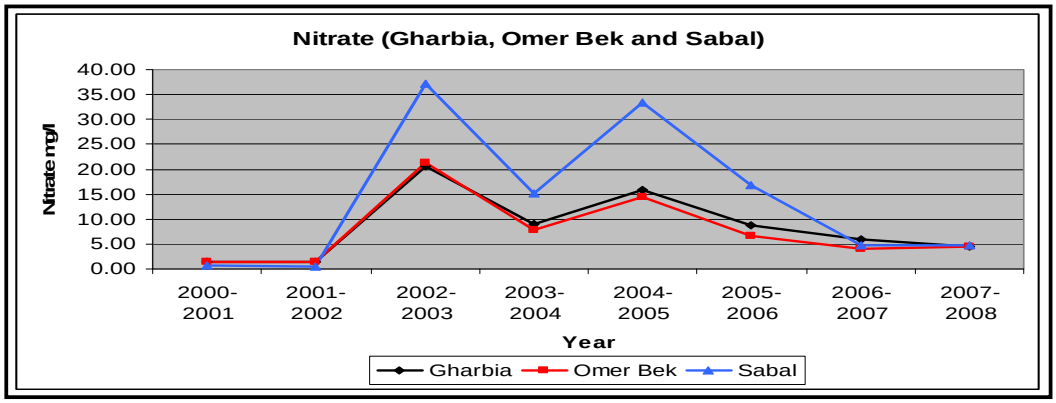


Fig 14 Nitrate concentration at Gharbia, Omer Bek and Sabal drains during the period 2000-2008

6.2.6 Biological Oxygen demand (BOD_5)

BOD_5 concentration in three drains (Figure 15) showed that, its value ranged between 23.8 mg/l and 63.23 mg/l at Gharbia drain. BOD concentration ranged from 26 mg/l to 63.9 mg/l at Omer Bek drain. At Sabal drain, the concentration of BOD_5 ranged between 16.17 mg/l and 89 mg/l. It is worth mentioning that all BOD_5 values violate the standard limits recommended by law 48/1982 (10 mg/l). Obviously, there are inverse correlation between BOD_5 and DO as shown in figs 11 and 15. These drains probably received domestic wastes containing high load of organic pollutants. If biochemical oxygen demand is greater than 30 mg/l, the quality index equals 2, Mark K. Mitchel [8]

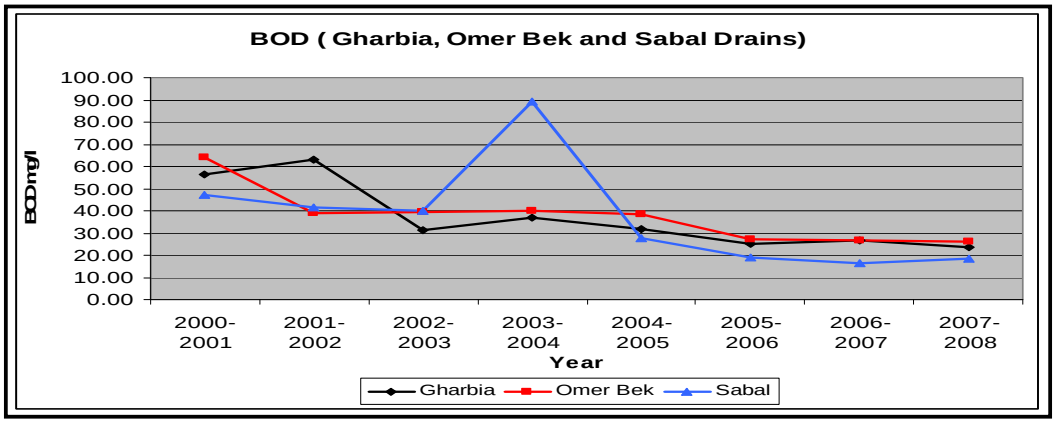


Fig 15 Biological Oxygen Demand Concentration at Gharbia, Omer Bek and Sabal drains during the period 2000-2008

6.2.7 Temperature

Temperature is a critical water quality and environmental parameter because it governs the kinds and types of aquatic life, regulates the maximum dissolved oxygen concentration of the water, and influences the rate of chemical and biological reactions. The temperature is ranged at the three drains between 21 and 24°C. If temperature is greater than 20^{o} C, the quality index is less than 20, Mark K. Mitchel [8].

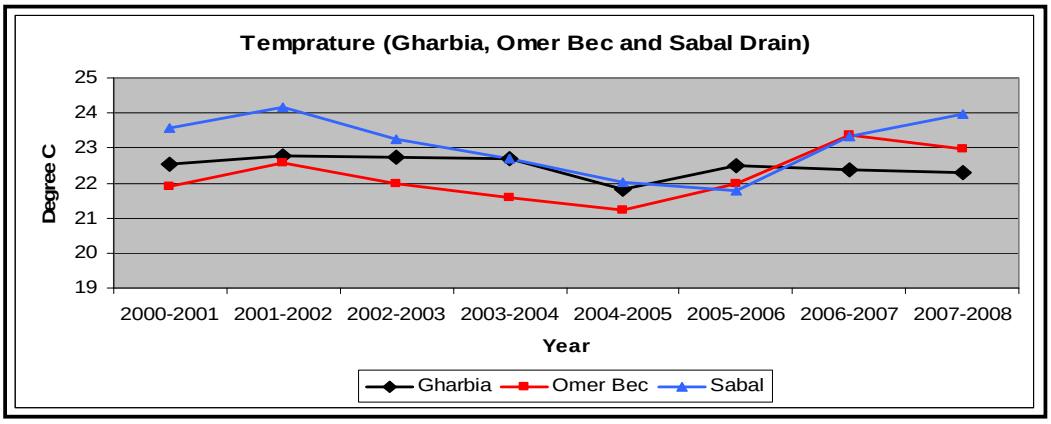


Fig 16 Temperature Change at Gharbia, Omer Bek and Sabal drains during the period 2000-2008

6.2.8 Total Solids (TS)

Total solids concentration (TS) in three drains is presented in (Figure 17). At Gaharbia drain, TDS values ranged from 1384 mg/l to 1748 mg/l. However, it ranged between 609 mg/l and 955 mg/l at Omer Bek drain. At Sabal drain, the concentration of TS ranged between 668 mg/l and 967 mg/l. In general, all values of TS violate the recommended standard by law 48/1982 (500 mg/l). The high concentration of TS in the three drains might be due to local run off from adjacent crop fields in the surrounding area as well as from discharges of urban waste water. If total solids are greater than 500 mg/l, the quality index equals 20, Mark K. Mitchel [8].

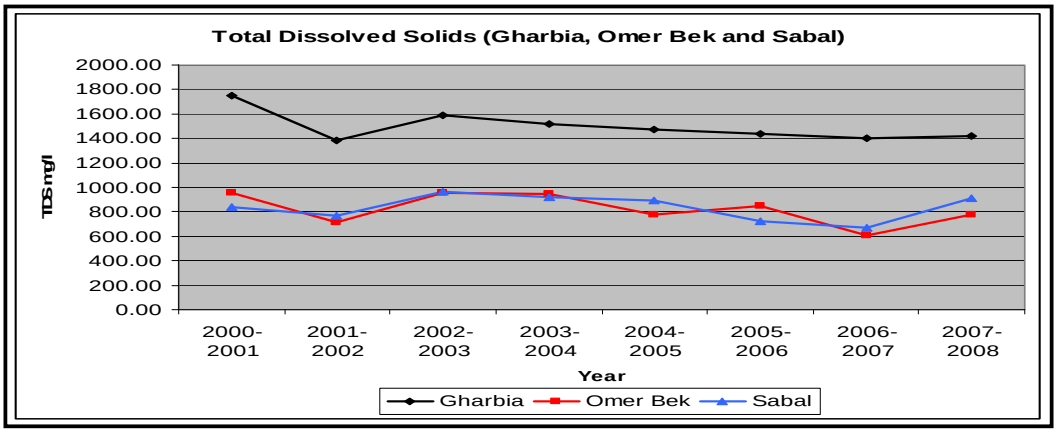


Fig 17 Total Dissolved Solids Concentration at Gharbia drain during the period 2000-2008

6.2.9 Fecal Coliforms (FC)

The fecal coliforms counts at the three drains (Figure 18) showed that, all drains violate the permissible limits of international standard 2000 cfu/100 ml recommended by Middle Brooks [9]. This may be due to that these drains received domestic wastes from human activities. It ranged between 104535 cfu/100ml and 4201839 cfu/100 ml at Gharbia drain. At Omer Bek drain, it ranged from 54217 cfu/100 ml to 3830500 cfu/100 ml. However, the FC counts ranged between 3208 cfu/100 ml and 1350833 cfu/100 ml. If the number of fecal coliforms colonies is greater than 100,000, the quality index equals 2, Mark K. Mitchel [8].

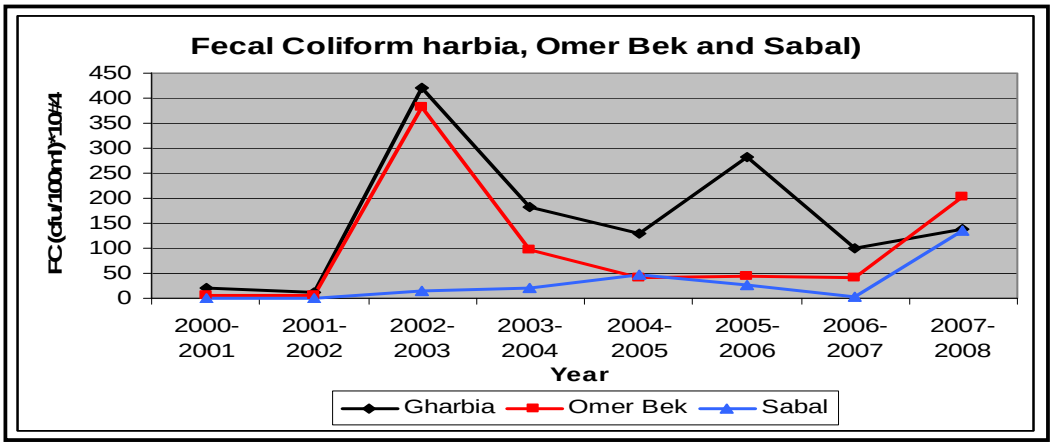


Fig 18 FC at Gharbia, Omer Bek and Sabal drains during the period 2000-2008

6.2.10 Water Quality Index (WQI)

According to (Ott, W.R. [10], water quality index provides a conventional means of summarizing complex water quality data and furnishing required information to the decision makers who are not water quality specialists. The water quality ranges are in table 3 follows:

Table 3 Water Quality Index Ranges & classifications

Range	Water Quality
From 0---- 25	Very bad
From 26----50	Bad
From 51----70	Medium
From 71----90	Good
From 91---100	Excellent

Figure 19 showed the WQI at Gharbia, Omer Bek and Sabal drains. They range between 20 and 23 at Gharbia drain, 19 and 22 at Omer Bek drain and 22 and 33 at Sabal drain. These ranges of water quality index are indicating that the water at the three drains continue to be in very bad quality level in spite of increasing the released discharge water amounts from middle delta to the Mediterranean Sea,

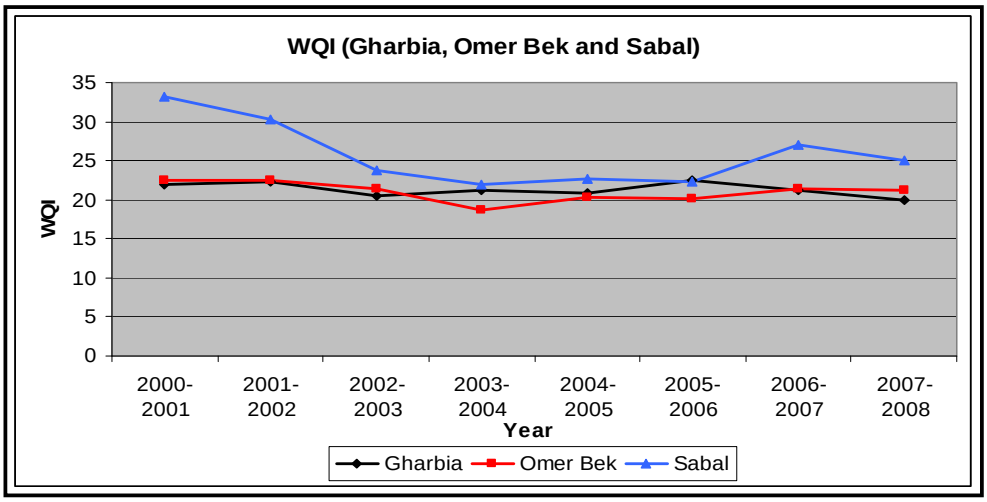


Fig 19 Variations of WQI at Gharbia, Omer Bek and Sabal drains during 2000-2008

7. CONCLUSION AND RECOMMENDATIONS

The average loss in agricultural lands due to urban encroachment is 26000 fed/year and the applied fertilizers consumption in Middle Delta is found to be about 1.25 million tons/year.

Water quality remains to be very bad in the Middle Nile Delta drains (WQI<25) as demonstrated by assessment of water quality parameters of three main agricultural drains in Middle Delta. All ongoing efforts reported by Egyptian Environmental Affairs Agency (2007, 2008) to remediate water quality seem to be at least partly compensated by continuing intensification of agricultural production.

Enhanced efforts will be necessary to remediate the situation in place. These efforts may include in particular:

- Enhancement of efforts to treat urban and industrial waste water
- Improved use of spatial planning to reduce the further loss of agricultural land. It should go well beyond 'traditional' land-use planning and sets out a strategic framework to guide future development and policy interventions.
- It would also be fundamental to maintain food production for our still growing population as well as vital to maintain jobs in the agricultural sector.
- Making sure that decisions are taken with regard to their impact beyond the immediate sectoral or directorial agricultural boundaries to sustain the core values of the development.
- Improved methods to introduce "Good Agricultural Practices" and advisory services in place in order to reduce impacts resulting from agricultural source.

- Both Ministries of Housing & New Communities and Agriculture should take serious steps to stop the urban encroachment in old agricultural lands.
- The applied fertilizers in old Nile delta agricultural land should be observed to control the consumption.

8. REFERENCES

1. APHA, AWWA, and WEF. (1995). Standard Methods for the Examination of Water and Wastewater (1042 pp., 18th ed.). Washington, DC: APHA, AWWA, WEF.

2. Chambers J., Cleveland, W., Klienter, B. and Turkey, P., Graphical Methods for Data Analysis, Wadsworth (1983).

3. Bakenaz A. Zeydan. (2005). "The Nile Delta In A Global Vision", *Ninth International Water Technology Conference, IWTC9, Sharm El-Sheikh, Egypt* **.**

4. Calculating NSF Water Quality Index, Wilkes University Center for Environmental Quality Environmental Engineering and Earth Science

5. Khaled Abu-Zeid, Ph.D. PE, PMP, **(2010)**. "Egypt's Water Situation Analysis", Task Force Sub-Group on Environment, Natural Resources & Health, Cairo Agenda for Action on Aid Effectiveness.

6. Peavy, H. S., Rowe, D. R. and George, T., "Environmental Engineering" Mc Graw-Hill Book Co., Singapore (1986).

7. Ravindra, K., Meenakshi, Rani, and Kaushik, A. (2003)**., "**Seasonal variations in physico-chemical characteristics of River Yamuna in Haryana and its ecological best-designated use" J. Environ. Monit., **5**, 419-426

8. Mark K. Mitchell & William B. Stapp. 1990. "Field Manual for Water Quality Monitoring": An Environmental Education Program for Schools (4th edition, Completely Revised 1990).

9. Middle Brooks, E.J. "Wastewater reuse on assessment of the potential and technology" In: water reuse. An Arbor Science Publisher Inc, PP. 220-223 (1982).

10. Ott, W.R., (1978). "Environmental indices": Theory and Practice. Ann ArborScience Publication, Ann Arbor, Mich., PP. 230

11. Chapman, D. (1992). Water Quality Assessments: A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring. Chapman & Hall, London, (on behalf of UNESCO/WHO/UNEP). 585 pp.

12. WISE (Water Information System for Europe, jointly run by the European Commission and the European Environmental Agency); figures on "source apportionment of phosphorous and nitrogen loads in selected regions and catchments".

13. Egyptian Environmental Affairs Agency - Egypt State of the Environment Report 2007; http://www.eeaa.gov.eg/English/info/report_search.asp

14. Egyptian Environmental Affairs Agency - Egypt State of the Environment Report 2008; http://www.eeaa.gov.eg/English/info/report_search.asp

15. FAO (Food and Agriculture Organisation) of the United Nations; FAOstat; fertilizer consumption 2004 – 2007.

16.http://www.eea.europa.eu/data-and-maps/figures/source-apportionment-of phosphorus-load-in-selected-regions-and-catchments

17.http://www.eea.europa.eu/data-and-maps/figures/source-apportionment-of-nitrogen-load-in-selected-regions-and-catchments

18.http://www.fao.org/fileadmin/templates/ess/documents/publications_studies/statisticalyearbook/yearbook2009/a07.xls

19. http://faostat.fao.org/site/422/default.aspx#ancor