Prospective Speculation for Safe Reuse of Agricultural Drainage Water in Irrigation

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ABSTRACT

The main and almost exclusive source of surface fresh water in Egypt is the River Nile. It is obvious that the Nile water agreement with Sudan in 1959 had defined Egypt's budget by 55.5 billion cubic meter per year, of which 84% is used by the agricultural sector. Of the greatest interest is the quality of Nile water in Egypt has been changed after the construction of Aswan High Dam (AHD) in 1968 and the water became silt free even at the annual flood season. At present, the major challenge that facing Egypt is how to meet the water demand for food production and also to protect Nile water from pollution. According to water quality impact assessment study carried out since 1990, the water quality of Nasser Lake was deemed good and the water quality of Nile River downstream AHD has reflected the quality of the water of Nasser Lake. However, significant changes were recorded in the water along the main stem of the river between Aswan and Delta Barrage because of discharge of agricultural drainage water in Nile stream. The water quality of most of these drains were not complying with the standards set by law 48/1982 (Art. 65) regulating the quality of drainage water which can be mixed with fresh water. However, significant amounts of organic load were biodegraded and the level DO increased from 4 mg/l at Aswan to 9-10 mg/l at 200 Km downstream Aswan. Currently, the concentration levels of TDS increased from 150 mg// at Aswan 250mg/l near Cairo. As a result, the water quality between Aswan and Delta Barrage is considered of good quality.

The waters of Damietta and Rosetta Branches of Nile Delta receive high loads of biological, inorganic and organic compounds and consequently are characterized by low quality water. In general, the water of Rosetta Branch is highly polluted than that of Damietta Branch. Of great concern is the water of the agriculture drains which discharge in River Nile; the main stem and delta branches. These drains receive, in addition to agriculture seeping, domestic and industrial effluents from point sources and diffuse sources. As a result, the water quality of these drains did not comply with law 48/1982 (Art. 65). The sources of water of the collected main drain are the small drains, which receive un-treated domestic and industrial effluents from villages and small communities. In order to improve the water quality of the main drain to cope with standards of law 48/1982, the water of the small drain should be treated before discharging into the main collector drain. This treatment should be designed at the point sources just before entering the main drain. It is well known that villages in Egypt are still without sanitation facilities and construction of conventional wastewater treatment plants is not applicable and expensive. This makes the non-conventional treatment system are most acceptable. Of these is the in-stream wetlands treatment system which has several advantages such as the treatment efficiency is high, requires low capitals investment, and easy operation and maintenance.

Keywords: Nile River, Drainage water, Wetlands, Pollution, COD, BOD_5, DO.

INTRODUCTION

Water Scarcity and lack of acceptable water quality are the most serious challenges in the twenty-first century. According to FAO (1992), low quality water is defined as "water that possesses certain characteristics which have the potential to cause problems when it is used for an intended purpose". Thus, optimizing the management of available fresh water and controlling water pollution are being major issues to preserve water under good conditions for future generations On world wide scale, it seems that no river no lake and no part of the oceans is entirely free from pollution (Dybern, 1974). This may be due to integration of several causes such as increasing population growth, industrial production, mis-use of land and water for food production, lack of knowledge how the natural environment is built up and function, and lack of money for pollution abatement and prevention (Bouwer, 2002). Under such circumstances, Egypt is a country facing both water scarcity and deterioration of the quality of water of Nile River for irrigation use and for other purposes.

It is obvious that the main source of surface fresh water in Egypt is the Nile River. According to Nile water agreement of 1959 between Egypt and Sudan, Egypt's share of water is limited by 55.5 billion cubic meter per year. Agriculture use accounts by 84% of this quantity, while industrial, municipal and navigation use account by 8, 5 and 3%, respectively (Abu Zeid, 1992).

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At downstream old Aswan Dam, the quality of Nile water, on the basis of salinity, is good for irrigation use with slight monthly variation in salinity, varying from 93 to 165 mg/l (Whittingtan and Guariso, 1983). According to Ball (1939), salinity of Nile water at Cairo, during the period 1915-1936, recorded salinity levels between 115 and 217 mg/l (Table 1), with slight variations in the concentrations of water soluble ions (Table 2). It has been reported also that appreciable amounts of elements had entered the Nile River from agricultural drains (Tables 3 and 4) which indicates earlier contamination of the water of Nile River by agricultural chemicals (Ball, 1939). Due to natural dilution regime occurring along the river stream, these chemicals did not adversely influence the quality of Nile water at that time. Another factor, which had eliminated the effect of these disposed chemicals on water quality, is the seasonal Nile flood, as expressed by total suspended matter (Table 5) or turbidity (Tables 6) which acted for flushing the river body and cleanse water from these additives.

Table 1. Average values of the concentration of total dissolved solids (mg/l) in water of Nile River at Cairo in the period 1915- 1936 (Ball, 1939) and in 1963 (El-Gamal and Shafik, 1985)

Month	1915-1936	1963	Month	1915-1936	1963
Jan.	162	190	July	200	210
Feb.	115	199	Aug.	140	167
Mar.	196	200	Sept.	138	172
Apr.	216	191	Oct.	132	167
May	217	192	Nov.	138	175
June	212	182	Dec	154	170

Table 2. Average values of the concentration of water soluble ions (mg/l) in Nile River at Cairo city at different times (Ball, 1939)

Ions	1880	1906	(1924-1927)	(1906-1936)	
				Aug.-Nov.	Dec.-July
Ca	15.9	14.7	23.6	23.6	28.8
Mg	8.8	4.6	6.9	6.9	8.8
Na	15.6	11.3	11.6	11.6	25.2
K	3.9	2.6	3.7	3.7	5.5
Cl	3.4	7.5	5.1	5.1	16.4
SO_4	4.7	5.4	7.7	7.7	11.4
SiO_2	20.1	11.6	12.4	12.4	13.2

Table 3. Average concentration of water soluble ions and O.M. (mg/l) entering the water of Nile River at Cairo in the periods 1924-1927 and 1936 (Ball, 1939)

Element	1924-1927	1963	Element	1924-1927	1963
Ca	15.7	28.8	Cl	7.5	16.4
Mg	4.6	8.8	SO_4	5.4	11.4
Na	11.3	25.2	SiO_2	11.6	13.2
K	2.6	5.5	O.M.	1.4	1.7

Table 4. The quantity (tons) of various constituents entered the Nile River from agricultural drainage water (Ball, 1939)

Constituents	Year			
	1906	1916	1926	1936
Ca	-	-	411	3411
Na	189	348	3110	3732
NH_4	13	48	63	1221
CO_3	-	-	-	999
NO_3	510	939	9684	21198
SO_4	33	126	168	1539

Table 5. Average values of the concentration (mg/l) 0f total suspended matter (TSM) in River Nile at Cairo at 0.5 m depth in mid stream during the period 1913-1932 (Ball, 1939)

Month	TSM	Month	TSM
Jan.	95	July	43
Feb.	52	Aug.	976
Mar.	36	Sept.	1411
Apr.	32	Oct.	790
May	28	Nov.	381
June	29	Dec	171

Table 6. Monthly chemical analysis of the water of Nile River at Cairo during the year 1963 (El-Gamal and Shafik, 1985)

Month	Turbidity (Silica Scale)	TDS (mg/l)
Jan.	125	190
Feb.	65	199
Mar.	26	200
Apr.	25	191
May	20	192
June	26	182
July	910	210
Aug.	950	167
Sept.	6935	172
Oct.	2550	167
Nov.	500	175
Dec	340	170

After the construction of Aswan high Dam (AHD) in 1968, the quality of Nile water had been changed. Because of the continuous increase of agricultural, domestic and industrial discharging in the river beside the absence of suspended matter of seasonal flood, water pollution progressively increased to an extent considered to be a serious problem affecting water quality. By time proceeding, pollutants have been accumulated in the river body and there were rapid drastic changes in water quality which could influence its future use for the intended purposes.

2. REVIEW OF REGULATIONS AND STANDARDS

Wastewater that is mostly entering the Nile River and causes degradation of Nile water quality is becoming major issue in Egypt. This enabled the Egyptian authorities to enact numbers of laws in order to protect the Nile water from pollution (MAB, 1983). The law 48 was issued in 1982 in order to protect The River Nile and waterways from pollution. Soon after, the Ministry of Public Works and Water Resources (MPWWR) issued the decree No. 8 in 1983 to be the implement regulation of the law 48/1982 (RNPDP, 1995). This decree was built on reviewing both law 93/1962 concerning the discharge of liquids and wastes, law 38/1976 concerning public hygiene, law 74/1971 concerning irrigation and drainage, and law 48/1982 concerning the protection of River Nile and waterways from pollution.

It is clearly understood from Decree 8/1983 that only that treated effluents are allowed permeation to discharge to waterways. It also states that the representatives of MPWWR, MOH (Ministry of Health), and concerned Sanitary Drainage Agency have full rights to enter all permitted establishments at any time for periodic and non- periodic sampling and inspection of facilities.

The implementing Decree 8 of 1983 specifies the water quality standards for the following categories; (i) Nile River and canals into which discharges are licensed (Art. 60); (ii) treated industrial discharges to Nile River, canals and groundwater: upstream Delta Barrage discharging more than 100 m^3/day (Art. 61), downstream Delta Barrage discharging more than 100 m^3/day (Art. 61), upstream Delta Barrage discharging less than 100 m^3/day (Art. 62), downstream Delta Barrage discharging less than 100 m^3/day (Art. 62); (iii) drain water to be mixed with the water of the Nile River or canals (Art. 65); (iv) treated industrial and sanitary waste discharges to drains, lakes and ponds (Art. 66); and (v)drains, lakes and ponds which discharges are licensed (Art. 68).

The Decree 8/1983 stated also that the discharge of treated sanitary effluents to Nile River and canals is not allowed to all (Art. 63), and any discharge of sanitary into other water bodies should be chlorinated (Art. 67). In addition, the use of agrochemicals for weed control is also regulated in the law (Art. 11).

The Egyptian Environmental Affairs Agency (EEAA) is responsible for protection of the environment in general. The law 4/1994 stated that with respected to the pollution of the water and environment, the law 48/1982 is not affected and the MWRI remains the responsible authority for water quality and water pollution issues, although the definition of "discharge" in law 4/1994 specifically includes discharges to the Nile River and waterways. It has been proved that EEAA is responsible for coordinating the pollution monitoring networks.

Recently, the Ministry of Housing Utilities and New Communities (MHUNC) with the agreement of Ministry of Health and Population (MOHP) issued the Mistrial Decree 44/2000, concerning Amendment of the Executive Regulation of the law 93/1962 Pertaining Discharging liquid Effluent. The decree strongly opposes the use of wastewater in irrigation of vegetables, fruits, and other crop possibly eaten raw.

According to the law 48/1982 and Decree 8/1983, the limits of microbiological parameters for discharging effluent to different water bodies are: 2500, 2500, 5000, and 5000 MPN/100 ml for River Nile, Nile branches, main canals, ditches and groundwater reservoirs, drains and brackish or saline water, respectively.

2.1 Responsibilities For Water Quality Management

Ministries involved for operational, research, monitoring and regulation purposes and management for water quality of Nile River are: Ministry of Water Resources and Irrigation (MWRI), Egyptian Environmental Affairs Agency (EEAA), Ministry of Health and Population (MOHP), Ministry of Housing, Utilities and New Communities (MHUNC), Ministry of Agriculture and Land Reclamation (MALR), Ministry of Industry (MOI), Ministry of Higher Education and Scientific Research (MHESR), Ministry of Interior.

The objectives of the present article, therefore, were to evaluate (i) the water quality of Nile River and agricultural drains and (ii) the efficiency of non conventional constructed in-stream wetlands wastewater treatment for removing pollutants from agricultural drains in order to be reused directly or after mixing with freshwater canals.

3. WATER QUALITY OF NILE RIVER

Before the construction of AHD, there were seasonal and monthly changes in the physical and chemical constituents of the water of Nile River. During the flood period (July: October), the concentrations of total dissolved solids (TDS) in the water were at the minimum and those of total suspended solids (TSS), expressed as turbidity, were at the maximum (Table 6). Ball (1939) reported that the amounts of suspended matter deposited in the River, during period 1913-1932 varied according to seasonal variations and were the highest at flood season (Table 7). Within the construction of AHD in 1964, silt deposits on the flood plains decreased from 24 million ton per year to 2.5 million tons per year (Abdel Wahaab, 1995). At the present time, the water released from AHD is practically silt free and presence of suspended particulates in water is the results of biological activities of phytoplankton and algae and of shoreline erosion (El Gamal and Shafik, 1985). As a result, Nile Water salinity increased, during its flow south-north direction, from about 150 mg/l at Aswan to about 250 mg/l near Cairo (El-Gamal and Shafik, 1985; Welsh and Mancy, 1992).

3.1Water Quality Of Lake Nasser

The inflow to Lake Nasser carries salts from the watersheds of the Blue and White Nile and, therefore, exhibits marked seasonal variations in water salinity (Whittington and Guariso, 1983). The White Nile water has higher concentrations of TDS and the flood flow of Blue Nile brings water of lower salt concentration to the southern part of Lake Nasser. Data recorded at Khartoum in the period 1974-1976 can be assumed to characterize the flow entering Lake Nasser (Table 8).

Since the construction of AHD in 1968, the Lake water quality had changed as a result of both entering several factors into the lake and to self assimilation of organic substances caused by human activities such as navigation, fishing,… etc. It seems that most changes in water quality are concerned with slight increases in the levels of TDS, COD, heavy metals and fecal coliform (Table 9).

According to data reported by NRI (2008), the surface water of the lake has pH values in the range 7.5-8.3 which are within the permissible limits of the law 48/1982 (7.0-8.5), concentrations of DO ranging between 7.5 and 9.9 mg/l which exceeded the standard of the law 48/1982 ($\geq$ 5 mg/l), concentrations of TDS varying from 124 to 168 mg/l which comply with the law 48/1982 (500 mg/l). It has been also reported that the values of COD varied, on the average, from 8.0 to 14.0 mg/l, and were higher during high flow (7-24 mg/l) than during low flow (8-11 mg/l). Thus, the levels of COD at high flow did not comply with the law 48/1982 (10 mg/l) while opposite was recorded during low flow. In Concern with BOD_5 in lake water, the levels were within the standard limits of the law 48/1982 (6 mg/l). On the Other hand, the FC counts recorded high values during high flow (10-1200 MPN/100 ml) and low values

Table 7. Average amounts (million tons per year) of suspended matter (SM) deposited in Nile River during the period 1913-1932 (Ball, 1939)

Month	SM	Month	SM
Jan.	0.36	July	0.12
Feb.	0.11	Aug.	12.10
Mar.	0.07	Sept.	25.40
Apr.	0.05	Oct.	13.48
May	0.04	Nov.	4.22
June	0.04	Dec	0.90

Table 8. Average values of characteristics of water entering Lake Nasser during the period 1974-1976 (Whittingtan and Guariso, 1983)

Month	Salinity (mg/l)	Month	Salinity (mg/l)
Jan.	115	July	98
Feb.	128	Aug.	105
Mar.	136	Sept.	106
Apr.	155	Oct.	96
May	165	Nov.	93
June	132	Dec	103

Table 9. The quality of surface water of Lake Nasser (mg/l)

Constituent	El-Gamal and Shafik (1985)	Saad et al. (2011)	Law 48/1982 (Art 60)
TDS	160	172	<500
DO	10.5	8.5	≥ 5
pH	8.2	-	7-8.5
BOD_5	1.3	1.5	<6
COD	-	7.8	<10

during low flow(10-120 MPN/100 ml) which comply with the standard of law 48/1982 and Decree 8/1983 (2500 MPN/100 ml). However, the concentrations of Cd, Fe, and Pb in lake water were higher than the standard limits of the law 48/1982 (0.01, 1.0 and 0.05 mg/l, respectively. Saad et al. (2011) interpreted an integrated water management of Lake Nasser and expected an increase in the concentration of BOD_5 from 1.5 mg/l in the year 2009 to 6.0 mg/l in the year 2020 which is a value within the standard limit of law 48/1982 (6 mg/l).

3.2 Water Quality Of Nile Valley

After the construction of AHD, Nile Water Quality has become primarily dependent upon water quality characteristics of Lake Nasser (Table 9). In addition, the changes in Nile Water quality are found to be also due to a combination of several factors including (i) hydrodynamic regime of the river, regulated by barrages, (ii) agricultural return flows, and (iii) domestic and industrial effluents discharging in the river. Abdel Satar (2005) reported that these changes are more pronounced as the river flows south- north. He also reported that water quality of main stream of the river, from Aswan to Delta Barrage is considered good according to FAO (1992). This indicates high self assimilation capacity of Nile River. Earlier investigation claimed that the level of DO usually recovered as a result of atmospheric reaeration especially in the water of mid stream and increased from 4 mg/l at Aswan to a range from 9 to 10 mg/l at 200 km DS Aswan City (Kelley and Walsh, 1992). Abdel Satar (2005) also found that DO concentration in Nile water increased from 5.56 mg/l at Edfo City to 10.70 mg/l at Cairo City. Wahaab and Badawy (2004) recorded levels of DO, in Nile Water at 40 Km DS AHD, varying from 3.1-9.5 mg/l with 87% of the observed values exceeded the standard limit of the law 48/1982 (≥ 5 mg/l).

Taking into account the geographical features, administration, boundaries, human activities and the presence of Barrages, built for the purpose of elevating Nile water level to supply irrigation canals, the river between Aswan and Cairo has been conventionally divided into four segments as shown in Fig 1 (El-Gamal and Shafik 1985 and Elsokkary, 1992): (i) segment 1 from zero km (old Aswan Dam) to 167 Km (Esna Barrage), (ii) segment 2 from 167 km to 359 km (Naga Hamadi Barrage), (iii) segment 3 from 359 km to 544 km (Assuit Barrage) and (iv) segment 4 from 544 km to 946 km (Cairo/ Delta Barrage).

Because organic and inorganic pollutants discharged in Nile River are strongly diluted and degraded, especially within the stream between Aswan and Cairo, water of mid-stream has the average relatively good quality. On the other hand, water of riverbank is much more polluted and considered of lower quality than that of mid-stream water. Because of that, mid-stream water sampling and analysis has been utilized and adopted throughout presentation of this article.

Analytical results of Nile water samples carried out by El-Gamal and Shafik (1985) showed that the levels of DO were within the range 6.45-7.55 mg/l (Table 10). As shown in Table 11 the levels of BOD_5 are relatively high especially in waters of segment 1 (7.45mg/l) and of segment 4 (6.65 mg/l) while low levels are recorded for segment 2 (4.93 mg/l) and segment 3 (3.35 mg/l). The levels of TDS and FC were mostly low. On the other hand, samples collected in 2001 (APRP, 2002), the levels of BOD_5 and TDS (Table 12) were almost less than the standard limits of Low 48/1982 (6 BOD_5 mg/l and 500 TDS mg/l). However, the levels of COD in waters of segment 1 and 4 exceed the limits of the law 48/1982 (10 mg/l). In addition, the counts of FC in water of the four segments were within the consent of Law 48/1982. Decree 8/1983. These data point out that the water of Nile River between Aswan and Cairo is fairly good which indicates high self- assimilation capacity of the Nile River within this area of the stream.

Study on Nile water quality status carried out during 2007 (NRI, 2008) showed that the pH values of Nile water varied from 7.95 to 8.63 during low flow (Feb. 2007) and from 7.64 to 8.25 during high flow (Aug. 2007). This study showed that the concentrations of DO ranged between 7.41 and 9.44 mg/l during low flow and between 5.42 and 8.2 mg/l during high flow. These DO levels comply with the standard limits of the law 48/1982 ($\geq$5 mg/l). On the other hand, the levels of COD were higher at low flow (8.0 -27.0 mg/l) than at high flow (5-18 mg/l), about 72% of the tested sites had exceeded the standard limits of the law 48/1982 (10 mg/l). The analytical data also showed that the levels of BOD_5 varied from 2.0 to 8.0 mg/l at low flow and from 1.6 to 13.00 mg/l at high flow, about of 11% of the tested site had exceeded the standard limits of the law 48/1982 (6 mg/l). The results of this report (NRI, 2008) showed that the concentrations of TDS of water of Nile Valley were almost less than the standard limit of law 48/1982 (500 mg/l). These levels were almost higher during low flow (150-255 mg/l) than higher flow (169-190 mg/l) and increased towards south-north direction with mean values of 155 mg/l at Aswan and 215 mg/l at Cairo. It has been also reported (NRI, 2008) that the concentrations of heavy metals (Cd, Cu, Cr, Fe, Mn, Pb and Zn) in Nile water were less than the standard limits of the law 48/1982 (0.01, 1.0, 0.05, 1.0, 0.5, 0.05 and 1.0 mg/l, respectively), except for Fe in waters of segments 1 and 2, Cr of segment 4, and Mn for segments 2 and 3, which exceeded these standard limits.

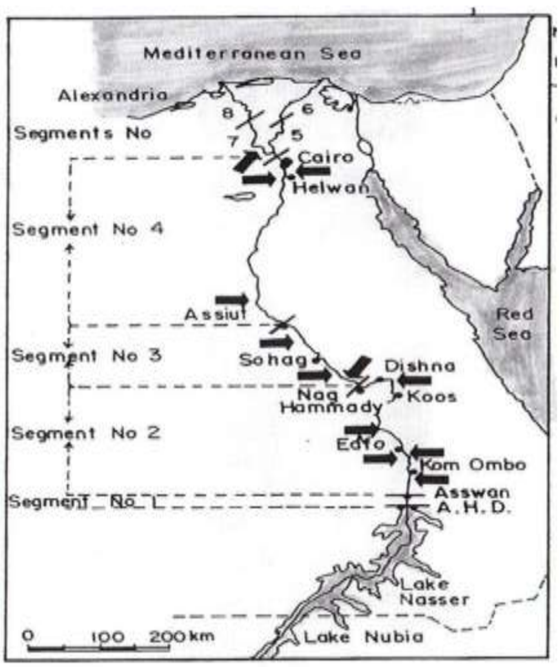

Fig. 1. Map of Egypt showing effluent outfalls and location of segments along the Nile River (Elsokkary, 1992)

Table 10. Analytical results of the water of Nile River for samples collected in 1984 (El-Gamal and Shafik, 1985)

Name and location	Distance from AHD (km)	pH	DO (mg/l)	BOD_5 (mg/l)	TDS (mg/l)	FC (MPN/100 ml)
Lake Nasser Reservoir	-9	8.20	10.5	1.3	160	7
Aswan	0	8.20	9.2	3.0	160	35
Khaur El-Sail	10.1	8.20	9.2	6.6	188	45
Kom Ombo	49.4	8.00	8.0	9.6	280	900
Menaha	55.2	7.80	8.5	10.6	286	140
Hawamdia	912.0	8.30	6.9	7.2	224	350
Kotsica	915.0	7.75	7.0	7.8	220	250
Kasr El-Nil	930	7.95	8.0	5.0	226	250

Table 11. Analytical results of the water of Nile River for samples collected in 1984 from the four segments (El-Gamal and Shafik, 1985)

Segment No.	Distance from AHD (km)	pH	DO (mg/l)	BOD_5 (mg/l)	TDS (mg/l)	FC (MPN/100 ml)
1	0-167	8.30	6.85	7.45	228	280
2	167-359	8.20	6.45	4.93	255	800
3	359-544	8.16	7.55	3.35	240	450
4	544-964	8.00	7.30	6.65	260	250

Table 12. Water quality of Nile River for samples collected in 2001 (APRP, 2002)

Segment No.	COD (mg/l)	BOD_5 (mg/l)	TDS (mg/l)	FC (MPN/100 ml)
1	12.6	1.28	179	500
2	9.3	1.75	190	1500
3	10.2	2.10	203	400
4	21.2	2.63	285	700
Law 48/1982	<10	<6	<500	-
Decree 8/1983	-	-	-	<2500

3.3 Water Quality Of Canals Of Nile Valley

According to studies carried out APRP (2002) and EPRP (2003), the water quality of the main canals of Nile valley is summarized in Table 13. Higher concentration levels of COD were recorded in waters of Naga Hamadi Canal, Ibrahimia Canal than the standard limits of the law 48/1982 (10 mg/l). There were also higher FC counts of water of Bahr Yusef Canal than the standard limits of the law 48/1982 and Decree 8/1983 (2500 MPN/100ml). On the other hand, the levels of DO, BOD_5 and TDS, in waters of this canal were within the permissible levels of Law 48/1982 (≥5 mg/l, 6mg/l and 500 mg/l).

Study carried out by NRI (2008) showed pH values varying from 8.3 to 8.5 in water of Ibrahimia Canal, from 7.5 to 7.8 in Nag Hamadi Canals, and an average of 7.8 in Bahr Yusef Canal. These pH values were higher during low flow than high flow and were within the standard limit of law 48/1982 (7.0-8.5). This study also showed that the levels of DO varied from 8.5 to 9.5 mg/l in water of Naga Hamadi Canal, from 8.6 to 9.5 mg/l in water of Ibrahimia Canal and around 6.0 mg/l in water of Bahr Yusef Canal. Lower levels of DO were recorded during high flow than low flow, and were almost within the permissible limits of law 48/1982 (≥5 mg/l). In addition, the concentration levels of COD varied from 11.0 to 17 mg/l in water of Naga Hamadi Canal, from 4.0 to 8.0 mg/l in water of Ibrahimia Canal and from 4.0 to 5.0 mg/l in water of Bahr Yusef Canal. These levels were almost higher during low flow than high flow. It is clear from these data that water of Naga Hamadi Canal contains higher levels of COD than the permissible limit of law 48/1982 (10 mg/l). With respect to BOD_5 levels, the water of Naga Hamadi Canal contained from 1.5 to 3.2 mg/l, of Ibrahimia Canal from 2.0 to 3.0 mg/l and Bahr Yusef Canal from 1.0 to 4.0 mg/l. These levels were generally less than the standard limit of law 48/1982 (6 mg/l). As reported by NRI (2008), the concentrations of TDS in the water of the three canals were almost less than the standard limit of the law 48/1982 (500 mg/l) and were almost higher during low flow than during high flow. Fecal coliform counts were the highest in water of Bahr Yusef (6000 MPN/100 ml) and the lowest in water of

Table 13. Water quality of canals of Nile Valley for samples collected in 2001 (APRP, 2002)

Segment No.	Distance from AHD (km)	DO (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TDS (mg/l)	FC (MPN/100 ml)
West Naga Hamadi	416	7.22	18.2	4.32	200	2500
East Naga Hamadi	424	6.31	25.3	5.78	213	1750
Ibrahimia Canal at Dariout	580	7.84	37.2	3.55	200	2000
Bahr Yusef Lahoun	860	7.08	10.0	1.89	305	5000
Law 48/1982		≥5	<10	<6	<500	-
Decree 8/1983		-	-	-	-	<2500

Ibrahimia Canal at Dairout (45 MPN/100ml) and were 1000 MPN/100 ml in water of Naga Hamadi Canal The FC counts were higher during high flow than low flow, and were higher than the standard limit of law 48/1982-Decree 8/1983 (2500 MPN/100 ml) especially in water of Bahr Yusef Canal.

3.4 Water Quality Of Rayahs Of Nile Delta

Higher concentration levels of COD were recorded in waters of Menoufi, Beheri, Nasery Rayahs (Table 14) than the permissible level of law 48/1982. On the other hand, the concentrations of BOD_5 and TDS were within the standard limits of this law. However, the concentrations of DO in water of Beheri and Nasery Rayahs were within the standard limit of Law 48/1982 while that of Menoufi was little fir. Table 14 also showed high counts of FC in waters of Menoufi and Nasery Rayahs than the standard limit of Law 48/1982-Decree 8/1983 (2500 MPN/100ml).

Study carried out by NRI (2008) showed that the waters of Menoufi Rayah have pH values between 6.8 and 8.0, DO values between 5.0 and 8.0 mg/l, BOD_5 values from 1.0 to 6.0 mg/l. Higher values of pH, DO, COD and BOD_5 were recorded during high flow than low flow. The levels of TDS varied from 200 to 250 mg/l with higher level during low flow than high flow. The counts of FC in the water of Rayah varied from 2000 to 4000 MPN/100 ml with higher values during high flow than low flow. In additions, the concentrations of Cd, Cr, Cu, Fe, Mn, Pb and Zn in water of Menoufi Rayah were less than the standard limits of Law 48/1982.

3.5 Water Quality Of Damietta Branch

The average value of COD in water of Damietta Branch of Nile Delta was higher than the standard value of law 45/1982 (Table 15 and Fig 2). On the other hand, the levels of BOD_5 and TDS were within the standard limits of this law. However, FC counts had exceeded the limits of Law 48/1982-Decree 8/1983 (2500 MPN/100 ml).

According to NRI (2008), the pH values in water of Damietta Branch varied from 7.34 to 7.98, and those of DO varied from 6.3 mg/l (high flow) to 8.4 mg/l (low flow). Both values of pH and DO are within the standard limits of law 48/1982. On the other hand, the levels of COD were higher during low flow (average of 12.0 mg/l) than high flow (average 10.5 mg/l) and, therefore, exceeded the standard limit of law 48/1982 (10mg/l). However, the levels of BOD_5 were higher during high flow (average 5.8 mg/l) than low flow (Average of 4.0 mg/l) and within the standard of law 48/1982 (6 mg/l).

According to NRI (2008), the concentrations of TDS were higher during low flow (range of 316-346 mg/l) than high flow (range of 205 -271 mg/l) which are less than the limit of law 48/1982 (500 mg/l). In addition, FC counts varied from 250 to 10000 MPN/100 ml during high flow and from 20 to 2500 MPN 100 ml during low flow. These values, on the average, exceeded the limit of Law 48/1982- Decree 8/1983 (2500 MPN/100 ml). There were generally low concentration levels of Cd, Cr, Cu, Fe, Mn, Pb and Zn in water of Damietta Branch than the limits of Law 48/1982.

Table 14. Water quality of Rayahs of Nile Delta for samples collected in 2001 (APRP, 2002)

Segment	DO (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TDS (mg/l)	FC (MPN/100 ml)
Menoufi Rayah	5.97	16.1	3.02	225	10000
Beheri Rayah	7.58	14.2	1.74	220	1000
Nasery Rayah	6.71	12.3	3.96	220	10000
Law 48/1982	≥5	<10	<6	<500	-
Decree 8/1983	-	-	-	-	<2500

Table 15. Water quality of Damietta and Rosetta Branches of Nile Delta (APRP, 2002)

Segment	COD (mg/l)	BOD_5 (mg/l)	TDS (mg/l)	FC (MPN/100 ml)
Damietta	15.4	2.13	320	20800
Rosetta	19.0	6.61	387	500
Law 48/1982	<10	<6	<500	-
Decree 8/1983	-	-	-	<2500

3.6 Water Quality Of Rosetta Branch

High levels of COD were recorded in water of Rosetta Branch (Table 15 and Fig. 2). These levels exceeded the standard limit of Law 48/1982. However, the concentrations of BOD_5, TDS and FC counts were within the limits of Law 48/1982-Decree 8/1983 (Table 15). According to study carried out by NRI (2008), the pH values of water of Rosetta Branch varied from 7.64 to 7.94 during high flow and from 7.5 to 7.73 during low flow which comply with law 48/1982. On the other hand, the levels of DO varied 1.8 to 9.5 mg/l during low flow and from 4.9 to 5.2 mg/l during high flow. On the average, it seems that DO levels in water of Rosetta Branch are low and did not comply with law 48/1982. In addition, the levels of COD varied from 18 to 24 mg/l during low flow and from 13 to 14 mg/l during high flow. These values exceeded the standard limit of Law 48/1982. The values of BOD_5 varied from 4.0 to 10.0 mg/l during low flow and from 7.0 to 13.5 mg/l during high flow which indicate high levels of BOD_5 in water of Rosetta Branch than the limit of Law 48/1982.

The concentrations of TDS in water of Rosetta Branch varied from 375 to 480 mg/l during low flow and from 280 to 300 mg/l during high flow. These levels of TDS comply with the limit of Law 48/1982 (500 mg/l).

According to NRI (2008), FC counts varied from 320 to 4500 MPN/100 ml during low flow and from 50 to 1000 MPN/100 ml during high flow. On the average, FC during low flow had exceeded the limit of Law 48/1982- Decree 8/1983 (2500 MPN/100 ml). On the other hand, the concentrations of Cd, Cr, Cu, Fe, Mn, Pb and Zn were less than the limits of Law 48/1982. These results indicate that the water of Rosetta Branch is highly polluted with organic loads, as indicated by low DO and high COD and BOD_5 levels. Several studies reported that the waters of the Branch receive high loads of inorganic and organic pollutants from various outfalls discharging in the Branch (Badr et al., 2006; El-Gamal and El-Shazely, 2008 and El-Bouraie et al., 2010).

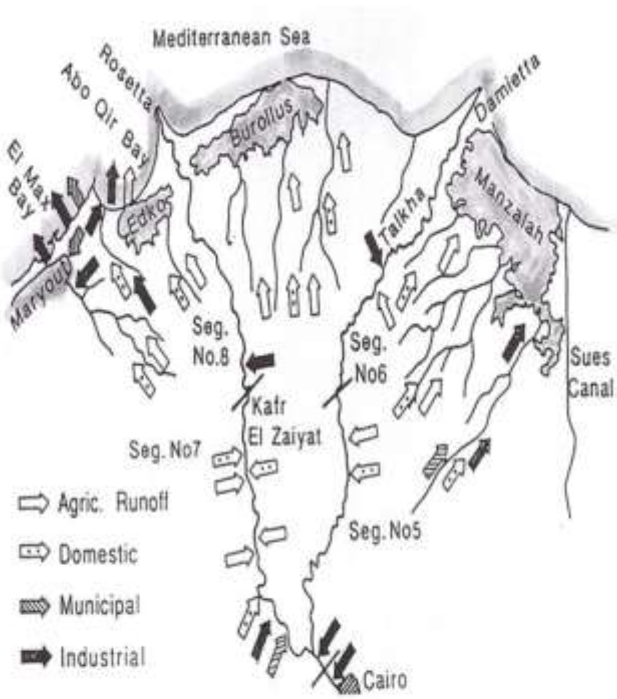

Fig. 2. Map of Delta Barrage showing effluent outfalls and location of segments along the Nile Delta (Elsokkary, 1992)

4. AGRICULTURAL DRAINAGE WATER

Drainage water seeping from agricultural fields is considered non-point sources of pollution. These non-point sources are concentrated through collecting drains to from point source of pollution for Nile River, Rayahs and canals. The major pollutants in agricultural drainage water are salts, nutrients (N and P), pesticides residues, toxic organic and inorganic chemicals and pathogens (DRI, 1995; APRP, 2002; EWRP, 2003 and Wahaab and Badawy, 2004). The pollution Load in the drain significantly increases with rural population density represented by the number of villages small communities existing in the catchment area.

Practically, domestic and industrial pollution sources are likely to exist as the drain catchment area increases (EWRP, 2003). Most of pollutants in water of agricultural drains, beside agricultural water seeping, under Egyptian conditions are from domestic diffuse sources (90.2), domestic point sources (3.2%) and industrial sources (6.6%). Monitoring study carried out by Khan et al. (2011) on agricultural drains in Egypt, defined the main types of pollution point sources input the drains as agricultural runoff, sewage and industrial effluents (Table 16).

4.1 Agricultural Drainage Water Of Nile Valley

Most of the drainage water along the Nile Valley (Upper Egypt) flows back to the River as turn flow. The quantity of this water has been accounted by 2.6 BCM/year (Welsh and Mancy, 1992). This water affected significantly the quality of Nile water where salinity increased from relatively low levels (150-250 mg/l) at Aswan to relatively high levels (250-350 mg/l) at Cairo (El-Gamal and Shafik, 1985; Abu Zeid, 1992 and Abdel Satar, 2005).

El-Gamal and Shafik, (1985) reported that the total number of liquid discharges to Nile River Between Aswan and Cairo is 67 of which 22 of industrial effluent and 45 of Agricultural drainage water (Table 17). Recent study (NWRC, 2000) reported that the Nile River between Aswan and Delta Barrage Receives wastewater discharge from 124 point sources of which 67 are agricultural drains and the rest are industrial effluents.

The quality of waters of the drains has been estimated and showed high concentration levels of TDS, COD and BOD (Table 18 and 19). Taking into account the levels of COD and BOD as measures of organic load, the Nile River between Aswan and Delta Barrage had received, during 1989/1999, about 516.632 Kg COD/day and 157.854 Kg BOD/day (APRP, 2002). The worst water quality was estimated in Khour El-Sail Aswan, El-Berba, Kom Ombo and Atsa Drains (Table 20). The organic load discharged into the Nile River between Aswan and Delta Barrage from these drains is shown in Table 21.

NRI (2008) investigated the quality of 29 drains along Nile River between Aswan and Delta Barrage. The results showed that, on the average, 26% of the drains had lower DO levels than the standard limit of

Table 16. Types of drains discharging in Nile River of Egypt (Khan et al. 2011)

Types of drains	Number of drains	% of Total
Agriculture	61	63
Industry	17	18
Electric Power Station	7	7
Treatment plant	5	5
Agriculture & Industry	3	3
Agriculture & Sewage	2	2
Agriculture & Industry & Sewage	2	2
Total	97	100

Table 17. Number, types and quantity of discharges into Nile River between Aswan and Delta Barrage (El-Gamal and Shafik, 1985)

Segment	Distance from AHD (km)	Number of Discharges		Quantity (mm^3/year)	
		Agriculture	Industry	Agriculture	Industry
1	0-167	19	6	300	50
2	167-359	7	5	1150	150
3	359-544	11	3	520	12
4	544-964	8	8	600	100
Total		45	22	2570	312

Table 18. Characteristics of liquid discharges to Nile River from Aswan to Delta Barrage for samples collected in 1984 (El-Gamal and Shafik, 1985)

Segment	TDS (mg/l)	DO (mg/l)	FC (MPN/100 ml)
1	666	6.1	1700
2	600	4.4	1800
3	675	3.2	1500
4	1975	3.9	1000

Table 19. Water quality of agriculture drains before discharge into Nile River between Aswan and Delta Barrage (APRP, 2002)

Segment	Distance from AHD (km)	TDS (mg/l)	DO (mg/l)	COD (mg/l)	BOD_5 (mg/l)	FC (MPN/100 ml)
1	0-167	588	6.94	29.6	8.32	5000
2	167-359	730	9.12	45.6	5.42	2500
3	359-544	458	7.67	11.3	2.48	1100
4	544-964	650	5.00	31.8	10.55	6000
Law 48/1982 Art 65		<500	≥5	<15	<10	<5000

Table 20. Water analysis of the most polluted drains point sources at Nile Valley (APRP, 2002)

Name of Drain	Distance from AHD (km)	TDS (mg/l)	COD (mg/l)	BOD_5 (mg/l)	DO (mg/l)	FC (MPN/100 ml)
Khour El-Sail Aswan	9.9	1190	102	32.8	1.91	33000
El-berba	49.1	414	113	42.7	3.85	22000
Kom Ombo	51.0	325	152	41.5	2.25	25000
Asta	701.2	575	100	38.0	1.38	35000
Law 48/1982 (Art 65)		<500	≥5	<15	<10	<5000

Table 21. Load of organic pollutants discharged into the Nile River between Aswan and Delta Barrage during 2001 (APRP, 2002)

Name of Drain	Distance from AHD (km)	Discharge (mm^3/day)	COD		BOD	
			Kg/day	% of Tot.	Kg/day	% of Tot.
Khour El-sail Aswan	9.9	0.1	10.08	1.98	3.24	2.05
El-berba	49.1	0.15	172.67	33.33	65.25	41.29
Kom Ombo	51.0	0.14	218.10	42.25	59.70	37.78
Asta	701.2	0.57	56.80	11.05	21.58	13.66

Law 48/1982 (not less than 5 mg/l), 45% of drains had higher levels of COD than the limit of Law 48/1982 (15 mg/l), 12% of drains had higher levels of BOD_5 than the limit of law 48/1982 (10 mg/l), 59% of the drains had higher levels of TDS than the limit of Law 48/1982 (500 mg/l), and 40% of the drains had higher FC counts than the standard limit of the law 48/1982-Decree 8/1983 (5000 MPN/100ml).

4.2 Agricultural Drainage Water Of El-Fayoum

El-Batts Drain at El-Fayoum Governorate is considered the main drain in the region. It receives about 22396 m^3/day effluent from domestic point source, 26213 m^3/day from domestic diffuse sources, and 1468341 m^3/day from agricultural diffuse sources (Farag and Donia, 2006). The average concentrations of BOD_5 in the effluents were 36.7 mg// in domestic point source, and 92.5 mg/l in domestic diffuse sources. The average concentrations of TDS were 1100 and 1360 mg/l in effluents of these two sources, respectively (Farag and Donia, 2006). In addition, El-Batts Drain receives wastewater from two $WWTP_S$, two drains and one pump station (Table 22). It discharges its water in Lake Qaroun, and therefore is considered the main source of Pollutants into the lake. However, according to Law 48/1982 (Art. 66), the quality of wastewater effluents from WWTPs and from pump station comply with this law, while those of the two drains: El-Edwa and El-Roda do not comply with this law (Table 22).

Table 22. Quality and quantity of wastewater discharging in El-Batts drain at El-Fayoum (Farag and Donia, 2006)

Sources	Discharge m^3/Sec	BOD_5 (mg/l)	TDS (mg/l)
WWTP, Old Fayoum	0.260	45.0	1240
WWTP, New Fayoum	0.460	25.0	1020
El-Edwa	0.011	75.0	1360
El-Roda	0.020	110.0	1360
Reuse pump station	0.850	40.3	1050
Law 48/1982 (Art. 66)		<60	<2000

4.3 Agricultural Drainage Water Of Nile Delta

Drains of Nile Delta receive about 13.6 BCM/year of wastewater of which 90% is agricultural diffuse sources, 6.2 is domestic point sources, 3.5% is domestic diffuse sources, and 0.5% is industrial point sources (DRI, 2000). The total organic loads discharging into the main drains; Bahr El-Baker, El-Gharbia and Edko; from domestic and industrial sources have the estimated as follow: 1216097, 570264, and 157753 Kg/day into the three drains, respectively. The main constituents in waters of these drains are shown in Table 23. In terms of “organic loads” as expressed by COD and BOD_5 values; Bahr El-Baker Drain receives 775635 kg COD/day and 440462 kg BOD/day, El-Garbia Drain receives 34772 kg COD/day and 222492 kg BOD/day and Edko Drain receives 35491 kg COD/day and 27075 kg BOD/day. (APRP, 2002; and EWRP, 2003).

The salinity of drainage water of Nile Delta, generally, increased as a result of both domestic and industrial pollution and intensive agriculture. It increased from 2000 mg/l in 1984 to 3000 mg/l in 1990 and to 2260 mg/l in 1992/1993, and it is expected to increase, in the near future, to critical levels (Wahaab and Badawy, 2004). Water salinity of the drains at the southern part of Nile Delta varied from 750 to 1000 mg/l, at the middle part from 1000 to 2000 mg/l, and the northern part from 3500 to 6000 mg/l (APRP, 2002).

Of significant pollution source to Rosetta Branch is El-Rahawy Drain. This drain receives about 400,000 m^3/day partially treated wastewater from Abu Rawash wastewater treatment plant (WWTP), besides 600,000 m^3/day untreated wastewater from the same plant. It receives also 340,000m^3/day secondary treated wastewater from Zeinin WWTP. The main source of this water is El-Moheet Drain. The water of El-Rahawy Drain outlet has an average pH of 6.5, undetected DO, COD of 67.0 mg/l, BOD_5 of 44.0 mg/l and TDS of 848 mg/l (Badr et al., 2006). It has been reported that the waters of the main drains which are discharging in Rosetta Branch including El-Rahawy, Sabal, Tala, North Tahreer, Zawiet El-Bahr and the three drains of Kafr El-Zayat are of low quality (Badr et al., 2006; El-Gamal and Shazely Elewa, 2010; and El-Bouraie at al., 2010) and according to Law 48/1982 (Art. 65) are prohibited to be discharged into the branch. Each of these drains has a certain catchment covering heavily populated area with no wastewater treatment heavily facilities.

Other drains of most significant at west of Nile Delta are Edko, Abu Keer and El-Umoum. These drains receive high loads of pollutants from severl sources (Table 24).

The water of Edko Drain is of low quality (Table 25), and did not comply with Law 48/1982 (Art. 65). However, this drain supplies El-Mahmoudia Canal with water from an outlet near Khairy Drain, in order to cover the need of irrigation along the canal and need of drinking water to Alexandria City. It is clear from Table 25 that the quality of the water of EDKO Drain is low and is changing along its flow south- north direction, where levels of TDS, COD, BOD and FC counts are increased. Edko Drain catchment area covers a highly populated area in which the quality of water in the drain system (main drain and its branches) is deteriorating due to legal and illegal pumping of domestic wastewater (APRP, 2002). The drain, therefore, receives about 30678 Kg COD/day, 27075 Kg BOD/day, 35491Kg SS/day and 64906 Kg TDS/day. Most of the organic load received by the drain is from domestic diffuse sources (90.2%), domestic point sources (3.2%), and industrial sources (6.7%).

El-Umoum Drain is one of the largest drains at west Nile Delta. It receive about 5270099 m^3/day wastewater of which 2500 m^3/day from domestic point sources, 81890 m^3/day from domestic diffuse sources and 5163209 m^3/day from agricultural diffuse sources (APRP, 2002 and EWRP, 2003). The waters discharged from Abu Hommos, Shrishra, Truga, El-Deshoudy and El-Haris are the main supplies of El-Umoum Drain. The catchment of the drain covers highly populated area with villages and small communities lacking wastewater treatment facilities, and this indicates that the drain usually receives highly polluted wastewater. As a result and according to the data given in Table 26, the water of El-Umoum Drain had a wide range for each character. According to study carried out by DRI (2000) the pH of

Table 23. Average value of main characteristics of the water of main drains of Nile Delta (APRP, 2002)

Name of Drain	COD (mg/l)	BOD_5 (mg/l)	FC (MPN/100ml)
Bahr El Baqer	132	162	40000
El Gharbia	128	84	40000
Edko	80	32	20000
Law 48/1982 Art 65	<15	<10	<5000

Table 24. Quantity of effluents (m^3/day) discharged to drains of west Nile Delta (APRP, 2002)

Name of Drain	Domestic point sources	Domestic Diffuse sources	Industrial point sources	Agricultural point sources
Edko	20000	57346	7470	4232034
El-Umoum	25000	81890	-	5163209
Abu keer	-	15803	22897	621592

Table 25. Water analysis of Edko Drain

Location	Month	2001				2009			
		TDS (mg/l)	COD (mg/l)	BOD_5 (mg/l)	FC (MPN/100 ml)	TDS (mg/l)	COD (mg/l)	BOD_5 (mg/l)	FC (MPN/100 ml)
US Khairy Drain	Feb.	486	32	21	16900	760	30	7	9000
	Aug	716	37	23	65000	738	35	7	9000
DS Khairy Drain	Feb.	683	40	31	29700	881	33	8	24000
	Aug	643	91	52	20300	768	29	9	60000
US Edko irrigation PS.	Feb.	1218	41	32	3200	1025	48	12	60000
	Aug	1224	124	73	54800	938	33	8	240000

Table 26. The main characteristics of the water of the drains of El-Umoum catchment area (Elsokkary and Abukila, 2011)

Name of Drain	TDS (mg/l)			COD (mg/l)			BOD_5 (mg/l)			FC (MPN/100 ml)		
	1989	2000	2010	1989	2000	2010	1989	2000	2010	1989	2000	2010
Abu Hommos	1350	1450	1300	55	74	15	23	32	8	50000	20000	35000
Shrishra	1400	1480	1550	40	45	12	18	22	6	10000	28000	25000
Trouga	1650	2000	2500	36	30	28	20	22	20	20000	30000	35000
El-Deshoudy	3100	3500	3300	52	58	48	24	26	13	30000	28000	25000
El-Haris	2400	3500	4100	35	38	32	14	18	9	25000	18000	70000
Bab El-Abeed	4200	4300	4500	36	34	30	12	15	12	35000	40000	50000
Mean	2400	2700	2875	42	47	28	19	23	11	28300	27300	34100
Law 48/1982 Art 65	<500			<15			<10			<5000		

the water varied from 7.00 to 7.93, the concentrations of BOD_5 varied from 21.0 to 180.0 mg/l, the DO from 2.2 to 7.9 mg/l and TDS from 4500 to 8500 mg/l. These values do not comply with Law 48/1985. Study carried out by Nagy and Salem (2003) reported concentration levels of BOD in the range from 46 to 93 mg/l, of DO from 4.06 to 7.99 mg/l and TDS from 1463 to 7167 mg/l. Recently, Elsokkary and Abukila (2011) reported that the concentrations of TDS, COD, BOD_5 and FC counts, of the water of El-Umoum Drain were increasing progressively towards south-north the catchment area (Table 26). It is clear from these data that the concentration levels of TDS and FC counts have been increased during the last twenty years while the levels of COD and BOD_5 has slightly improved but still do not comply with the limits of Law 48/1982.

5. NON-CONVENTIONAL WASTEWATER TREATMENT

Prohibitions of pollution point source from disposing their pollutants in freshwater bodies together with application of efficient technique of wastewater treatment are considered acceptable remediation of the disposed water. Of the most significant pollutants, in wastewater are in general; suspended solids, biodegradable organics, pathogens, nutrients, heavy metals and inorganic salts (Trattner and Woods, 1989).

According to several reports (APRP, 2002 and EWRP, 2003), the drainage water of Egypt is a combination of agricultural drainage water, domestic and industrial effluents. This attributed mainly to that most of rural villages in the country do not possess wastewater treatment facility because it is costly and cannot be designed for small and more dispersed rural settlements. Because of that, several treatment alternatives that vary in efficiency and cost should be considered in order to be used under Egyptian conditions. Non-conventional wastewater facility systems can provide realistic solution of the problem. Of these non-conventional facilities is construction in-stream wetlands system. Within the last 30 years, this system is being a growing practice to mitigate the impact of point and non-point sources of water pollution. The system requires relatively low cost and easy maintenance, and has acceptable removal efficiency for COD, BOD_5, inorganic chemicals and pathogens (Hammer, 1990 and 1997); Mitsch, 1993; Wetzel, 1993; and Zindan et al., 2005). The expected performance of the constructed in-stream wetland system, in general, is shown in Table 27.

Design types and composition of constructed wetlands vary considerably depending on the system design, objective of treatment, wastewater application, geographic climatic location and designer's experience (Hammer, 1997). The following paragraphs represent some examples of constructed in-stream wetland systems.

Gravel bed hydroponic (GBH) wetland system of 100 m length was used by Stott et al. (1999) for wastewater treatment. They found that the majority of parasite eggs of Ascaris sp., Toxocara sp., and Hymenolepis sp. were significantly removed within the first 25 m of the GBH wetland system. No eggs were detected in the final effluent from an influent containing 500 eggs/l.

Constructed wetland system established and operated during 1998-2005, at Suez Canal University, Ismailia, Egypt, showed moderate efficiency to remove the load of pathogenic bacteria from the influent. The removal efficiency of that system was 48% of Salmonell sp., 52% of Shigella sp., 49% of Vibro sp., and 49% of Pseudomn sp. (Abdulla et al., 2007).

Free water surface wetland system employed to treat wastewater showed removal efficiency of 79% of total N, 95.4% pathogens and 10% of TSS (Abdel Ghaffar and El-Saadi, 2007).

In 2001, Lake Manzala Engineering Wetland Project was designed at south west of Port Said City (GEF, 2005). The project is a cooperative effort among the Global Environmental Facility (GEF), Egyptian Environmental Affair Agency (EEAA) and the United Nation Development Program (UNDP). The wetlands were designed to treat 250000 m^3/day of water from Bahr El-Baqer Drain. The analytical results from the collected data during the period 2003-2004 (Table 28) and during Aug. 2006 (Table 29) indicated significant removal efficiency of the system for the major pollutants (GEF/UNDP, 2009). It has been proved that the Lake Manzala Engineered Wetland Project is characterized by low cost, approximately quarter of the cost of conventional wastewater treatment system. In addition, the field data reported by Zidan et al. (2005) Showed high removal efficiency of the constructed wetland at Manzala project (Table 30).

Another study carried out by Masi et al. (2010) used multistage constructed wetland system consisting of horizontal and vertical subsurface flow for wastewater treatment. revealed acceptable removal efficiency of the system, where the percent removal from COD, nitrification and total coliform were between 66 and 80, 92 and 99, and 98, respectively.

The constructed in-stream wetland system for wastewater treatment has more than an advantage; it is capable of providing high-level treatment and discharges relatively clean water, inexpensive to build, largely self-maintaining, requiring little or no operation and maintenance time or expense, manageable by operators with very limited training, and capable of providing aesthetic/ recreational / educational benefits (Hammer, 1997). It is clear, therefore, that community and stakeholders cooperation are important issues for both sustainable operation and maintenance. Although in-stream wetland treatment systems provide several hydrologic advantages at downstream, the potential for negative impact at upstream exist (Mitsch and Gosselink, 2000).

Under Egyptian conditions, the performance of in-stream wetland treatment system is expected to be equivalent to the primary, and to a certain level, to the secondary conventional treatment of wastewater. In order to minimize the failure risk of the system, three elements should be considered: (i) dredging management of sediments and plants, (ii) vegetation control, and (iii) public acceptance.

Table 27. The expected performance of wetlands system (Mitsch, 1993)

Constituent	Inflow	Outflow	Removal, %
TSS, mg/l	130	21	84
BOD_5, mg/l	40	17	58
COD, mg/l	200	92	54
Total P, mg/l	5	2.5	50
Total N, mg/l	12	5	58
NH_4-N, mg/l	10	5	50
FC, MPN/100ml	300000	30000	90

Table 28. The Removal efficiency (%) of Lake Manzala Engineered wetland for samples collected during 2003-2004 (GEF, 1993)

Constituent	Removal efficiency (%)	Constituent	Removal efficiency (%)
BOD_5, mg/l	70	Total N, mg/l	50
TSS, mg/l	80	TC, MPN/100ml	98
Total P, mg/l	50	FC, MPN/100ml	98

Table 29. The Removal efficiency (%) of GEF/UNDP Lake Manzala Engineered wetland for samples collected since Aug. 2006 (GEF/ UNDP, 2009)

Constituent	Removal efficiency (%)	Constituent	Removal efficiency (%)
BOD_5, mg/l	61.2	Total N, mg/l	51.4
TSS, mg/l	80.0	TC, MPN/100ml	25.9
Total P, mg/l	15.0	FC, MPN/100ml	99.7

Table 30. The Removal efficiency (%) of three cells wetland at Manzala project (Zidan et al., 2005)

Constituent	Cell 1	Cell 2	Cell 3	Average
BOD_5, mg/l	72	72	69	71
TSS, mg/l	63	63	63	63
Total N, mg/l	41	44	42	42
Total P, mg/l	41	44	42	42
TC, MPN/100ml	98	98	98	98
Fe, mg/l	53	58	43	51

6- CONCLUSION AND RECOMMENDATIONS

Increasing population and limited annual budget of Nile water (55.5BCM) in Egypt, according to 1959 Nile agreement between Egypt and Sudan, will pose exceeding demand on water in the near future. Because agriculture sector usually use about 84% of this budget, management of irrigation water must be integrated with other water management projects. The major challenge facing Egypt, therefore, is the urgent need to develop and manage this water budget. Another challenge affecting better water management is the deterioration of Nile water quality as a result of pollution. This is because the main stem of Nile River and the coordinated canals receive continuously enormous amounts of biological and chemical pollutants. However, it has been reported that before construction of AHD, self-assimilation of water Nile River within the stream between Aswan and Delta Barrage, was possible within the annual flood period.

Assessment of ambient water quality statues of the main stem of Nile River between Aswan and Delta Barrage did not exhibit high pollution levels. In this concern the water quality had complied with Law 48/1982 and Decree 8/1983, where the concentration levels of TDS, DO, BOD_5, and FC were less than 500, ≥5, and less than 6 mg/l and 2500 MPN/100 ml, respectively. However, the levels of COD in the water, especially in the vicinity of big cities and industries along the river, had exceeded the standard limit of Law 48/1982 (10 mg/l). These high levels of COD were combined with reduced levels of DO (Less than 5 mg/l) which did not comply with this law. Because of atmospheric reaeration, in Nile water, the levels of DO increased to 9-110 mg/l, south-north direction of Nile flow. Monitoring study revealed that there are four hot pollution point sources discharge their effluent into Nile River. These are Khour El-Sail Aswan, El-Berba, Kom Ombo and Asta Drains.

Damietta and Rosetta Branches of Nile Delta receive effluents discharged from several pollution sources. The major sources of pollution to Damietta Branch are agricultural drainage water and effluent of Talkha Fertilizer Factory. On the average, the levels of DO in the water of Damette Branch varied from 6.2 to 7.8 mg/l, of BOD_5 from 1.73 to 2.64 mg/l, and of TDS from 235 to 372 mg/l, which comply with Law 48/1982. On the other hand, the levels of COD and FC exceeded the standard limits of Law 48/1982 and Decree 8/1983 (10 mg/l and 2500 MPN/100 ml).

The major sources of pollution to Rosetta Branch are El-Rahawy, Sabla, El-Tahreer, Zawiet El-Bahr and Tala Drains beside the industrial effluents at Kafr El-Zayat City. On the average, the concentration levels of COD, BOD, and FC were extremely high and did not comply with Law 48/1982 and Decree 8/1983. However, the levels of TDS and DO were complying with this Law. Estimates of water quality of the two branches of Nile Delta proved that the water of Rosetta Branch is more polluted than that of Damietta Branch.

The agricultural drains of Nile Valley between Aswan and Delta Barrage are significant sources of pollution. Studying the physicochemical characteristics and FC counts of the major 42 drains discharging into Nile River, it was found that only 10 drains comply with the standards of Law 48/1982 (Art. 65) and Decree 8/1983, and the water quality of other 32 drains exceeded the consent standard of this law. In terms of organic load, Kom Ombo and El-berba Drains contribute by 76% of the total organic load, calculated as COD, discharged into Nile River from Aswan to Delta Barrage.

The agricultural drains in Nile Delta are characterized by high concentrations of organic and inorganic pollutants. The worst water quality is that of Bahr El-Baqar, El-Gharbia, Edko and El-Umoum Drains. The sources of effluents discharged into these drains are domestic point sources (6.2%), industrial point sources (0.5%), domestic diffuse sources (3.5%), and agricultural diffuse sources (89.7). Within the catchment area, the waters of small drains are considered the supply to the main drains. These small drains receive mostly non-treated wastewater and effluents, in addition to agriculture seeping, from villages and small rural communities. This points out that the water quality of the small drains, within the catchment area, is considered effective source of water quality of the main drain. In order to improve water quality of the main drain, treatment of the water of the small drain should be carried out at the point source of pollution before entering the main collecting drain. Construction of "conventional" wastewater treatment plant (WWTP) is not practical and not economic solution of the problem because of the big numbers of villages and small settlements in the catchment area which are inneed to wastewater treatment facility. Because of that, "non-conventional" wastewater treatment systems can be used as alternatives. Of these systems is the in-stream treatment wetland. The advantages of this system can be summarized as follows (i) high removal efficiency of pollutants especially biological load (BOD), nutrients (N and P), and pathogens, (ii) require relatively low capital investment, and (iii) easy operation and maintenance. In order to minimize the failure risk of this system, three major elements should be taken in consideration: (i) management of dredged sediments and plants, (ii) vegetation and plants control, and (iii) public acceptance and cooperation. It can be recommended, therefore, that the constructed in-stream wetlands system would enhance water quality treatment to meet the requirements of Egyptian Law 48/1982.

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الملخص العربي

التوقع المأمول للاستخدام الآمن لمياه الصرف الزراعى فى الرى

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يعتبر نهر النيل المصدر الرئيسى للمياه العذبة فى مصر.وقد حددت اتفاقية مياه النيل بين مصرو السودان عام 1959 نصيب مصر من هذه المياه بمقدار 55.5 مليار متر مكعب سنويا. ادى بناء سد اسوان العالى فى عام 1968 إلى خلو مياه النيل من الطمى حتى فى اوقات و خلال موسم الفيضان. إلى جانب ذلك فأن مصر تواجه تحديا كبيرا من جهة محدودية نصيب مصر من مياه النيل وكذلك من جهة حدوث تغيرات ملحوظة فى نوعية المياه فى المجرى الرئيسى فى الوادى و فى الدلتا.ويعزى ذلك إلى ادخال التصرفات السائلة فى مياه النهر. وتشمل مصادر هذه التصرفات السائلة كل من مياه الصرف الزراعىوكذلك المخلفات السائلة للأنشطة المنزليةوللأنشطة الصناعية.وقد واجهت الحكومة المصرية هذا التحدى بإصدار قانون 48 لعام 1982وكذلك المرسوم رقم 8 لعام 1983 بهدف حماية مياه نهر النيل و المجارى المائية من التلوث. تشير نتائج الدراسات التى اجرتها معاهد البحوث و المراكز البحثية فى كل من الوزارات المعنية و فى الجامعات إلى حدوث انخفاض فى نوعية مياه نهر النيل.وقد وجد ان ذلك لم يؤثر بدرجة كبيرة على نوعية المياه فى الوادى و لكن كان التأثير اكثر سالبيه على نوعية المياه فى الدلتا.وقد اعزى ذلك إلى السعة العالية للنهر فى مجرى الوادى على التمثيل الحيوىوالفيزيائى لكل من الملوثات العضويةوالغير عضويةوالميكروبية مما ادى إلى ان تكون قيم كل من تركيز الأكسجين الذائب والأكسجين المستهلك الكيميائى والأكسجين المستهلك الحيوى وكذا عدد بكتريا القولون متوافقة مع معايير قانون 1982/48وكذا المرسوم رقم 1983/8.

وعلى الجانب الأخر كان تركيز الأكسجين المستهلك الكيميائى مرتفعا فى مياه فرعى دمياط ورشيد لدلتا النيل وقد وجد ان مياه هذين الفرعين يستقبلان مياه صرف زراعى تحتوى تركيزات مرتفعة من الملوثات العضوية والغير عضوية وكذلك الحيوية المسببة للأمراض.وقدوجد ان المصادر الرئيسية للتلوث هى المصارف الصغيرة المنتشرة بكثافة فى احواض المصارف الرئيسية المجمعة لمياه هذه المصارف. ادى ذلك إلى زيادة تلوث مياه المصارف الرئيسية إلى الحد الغير مسموح به لأجراء عمليات الخلط مع المياه العذبة للترع الرئيسية. ولكى يجرى تحسين لنوعية مياه المصارف الرئيسية يجب معالجة مياه المصارف الصغيرة. ونظرا لعدم امكانية انشاء معالجة تقليدية لمياه الصرف هذه بسبب اعدادها الكبيرةوكذا انتشارها فى تجمعات سكانية صغيرة فأنه يلزم البحث عن طرق معالجة بديلة. على ذلك فالمقترح هو انشاء نظم معالجة غير تقليدية لمياه المصارف الصغيرة قبل ان تصب فى المصارف الرئيسية. و يعتبر نظام الأرض الرطبة للمعالجة هو الأكثر قبولا تحت الظروف المصرية. حيث اثبتت كفائه عالية فى ازالة نسبة مرتفعة من كل من الكائنات الحية الميكروبية المسببة للأمراض الأكسجين المستهلك الكيميائي الأكسجين المستهلك الحيوى وكذا زيادة تركيز الأكسجين الذائب. ويمتاز نظام الأرض الرطبة لمعالجة المياه العادمة بأنه ذات كفائه عالية لإزالة الملوثات وكذا سهل الإنشاءو التركيب والصيانة كما انه لا يحتاج إلى رأس مال كبير حيث انه منخفض التكلفة.