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Assessment of Natural Self Restoration of the Water of Al-Mahmoudia Canal, Western Part of Nile Delta, Egypt

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Abstract

Al-Mahmoudia canal in northern edge of Beheira Governorate, west part of Nile Delta, has important role in the economic development and prosperity of the people in Beheira and Alexandria Governorates. It has been exploited to support agriculture, fisheries, public water supply, industry, hydroelectric power and recreation. The continuing deterioration of water quality in the canal has become a routine water pollution case. Therefore, it is necessary to solve the canal pollution problems and upgrade the water quality. The objective of this study was to characterize and understand the water quality of Al-Mahmoudia canal. Samples of water were collected monthly from eleven locations for 12 month during 2010-2011. *In situ* measurements included; Temp, TDS, pH and DO, and laboratory determinations included TSS, BOD_5, COD, NO^-_3, NH_4^+, TC and FC, in addition to Cd, Cu, Fe, Mn, Ni, Pb and Zn. Natural self-purification model based on oxygen sag curve introduced by Streeter and Phelps was applied. The obtained results showed that the majority of water quality problems of Al-Mahmoudia canal are due to receive low grade water quality of Rosetta Branch. Natural self-purification is calculated and observed in two cases. The first is normal case, which no drainage water is discharging into Al-Mahmoudia canal; hence, Edko irrigation pump station is stopping lift drainage water of Zarkon drain into the canal. The result of this case showed that the deoxygenation rate is higher than the reoxygenation rate from km 14 to km 17.87 of Al-Mahmoudia canal. The second is simulated case, which simulated Edko irrigation pump station is lifting drainage water of Zarkon drain into the canal. The result of this case showed the deoxygenation rate is higher than the reoxygenation rate from km 14 to km 18.06 of the canal and the reach need 10.83 km to get rid of the influence of pollutants from Edko irrigation pump station discharge. The difference between conceptual and pragmatic approaches was used in identifying the most polluted reaches by non-point pollution sources along the canal. According to the obtained result the difference between observed and calculated values in the watercourse from south to north direction has been increased and contribution of the nonpoint pollution sources at Al-Mahmoudia canal is related to the four reaches.

Keywords: Al-Mahmoudia canal; Oxygen sag curve; Dissolved oxygen deficit; Natural self-purification

Introduction

Al-Mahmoudia canal is located at the northern edge of Beheira Governorate. The canal off-takes from Rosetta branch at km 194.200. The actual served area for the canal is 130,200 hectares. The total length of the canal is 77.170 km and there are seventy canals off-take from this canal. Al-Mahmoudia canal has three sources of water; two fresh water sources which are from Rosetta branch via El-Atf pump stations at the head of the canal, and Al-Khandaq Eastern canal at km 13.200 on Al-Mahmoudia canal, the third is drainage water from Zarkon drain at km 8.500 on Al-Mahmoudia canal *via* Edko irrigation pump station which lifting part of Zarkon drain water into Al-Mahmoudia canal. The canal receives pollutants from point and non-point sources [1,2]. These pollutants lead to significant deterioration of the quality of the water in the canal. The point source of pollutants is Edko drain in Beheira Governorate which supplies Al-Mahmoudia canal with water in order to cover irrigation needs along the canal and the drinking water for Alexandria city. The intake of the water treatment plant of Alexandria and many water treatment plants of Beheira Governorates are the upstream of these mixed three sources (Figure 1). The water treatment plants which feeding by Al-Mahmoudia canal are listed in the table 1. In Alexandria, water supply companies are producing various amounts of water in different seasons. In summer due to huge number of tourists, the water demands increases and thus the production too. Al-Mahmoudia canal suffered from the negative effects of nonpoint pollution sources [1,2].

The Dissolved Oxygen (DO) concentration is a primary measure of a stream's health, but the dissolved oxygen concentration responds to the Biochemical Oxygen Demand (BOD) load. Many streams in Egypt have suffered from DO deficit, which is very critical to aquatic life [3].

Water quality modeling in a river has developed from the pioneering work of Streeter and Phelps [4] who developed a balance between the dissolved oxygen supply rate from reaeration and the dissolved oxygen consumption rate from stabilization of an organic waste in which the Biochemical Oxygen Demand (BOD) deoxygenation rate was expressed as an empirical first order reaction, producing the classic dissolved oxygen sag model and it was really a great achievement when Streeter and Phelps [4], in 1925, were able to propose a mathematical equation that demonstrating how dissolved oxygen in the Ohio River decreased with downstream distance due to degradation of soluble organic biochemical oxygen demand. By considering a first order of degradation reaction, for a constant river velocity [5].

This paper presents calculations on stream sanitation and the main portion covers the evaluation of water assimilative capacities of Al-Mahmoudia canal. The procedures include classical conceptual approaches and pragmatic approaches; the conceptual approaches use simulation models based on Streeter-Phelps equation [4]. The pragmatica approaches uses observed Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD_5) levels which are measured

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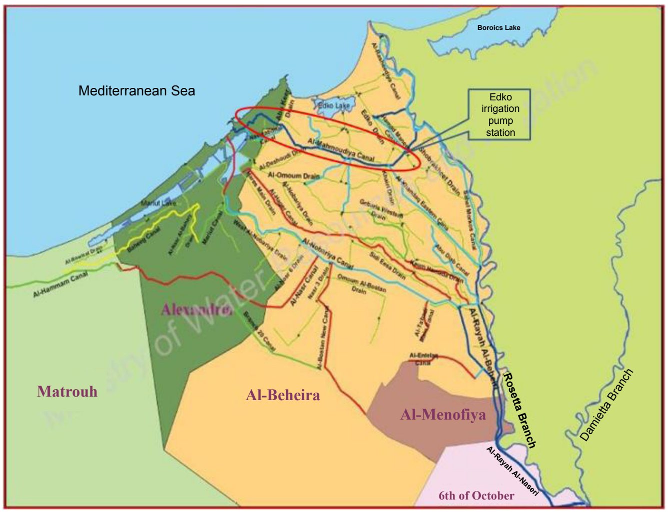

Figure 1: Al-Mahmoudia canal.

Governorate	Water treatment plant	Production (m^3/day)
Beheira	Algadih*	25,000
	Ficha*	25,000
	MonchatNassar	25,000
	AbouHommos	100,000
	Com Alkuenatur	250,000
	Kafr El-Dawar	100,000
Alexandria	Al-Sayouif	970,000
	Al-Mamoura	240,000
	Bab Sharki	630,000
	Al-Manshia	420,000
	Forn el garia	50,000
	Al-Nozha	200,000

Table 1: Water supply companies which feeding by Al-Mahmoudiacanal.

at several sampling points along Al-Mahmoudia canal reach. Both approaches are useful for estimating oxygen deficit and related dissolved oxygen with respect to time and space. The difference between conceptual and pragmatic approaches was used in identifying the most polluted reaches by non-point pollution sources along the canal.

Materials and Methods

Water sampling

Samples of water were collected monthly from eleven locations, during a period of 12 months starting from May 2010 to April 2011, nine from Al-Mahmoudia canal, one from Al-Khandaq Eastern canal and one from Zarkon drain (Figure 1). The collected water samples were transported preserved and the physical, chemical and biological analyses were determined by the procedures recommended in the Standard Methods for the Examination of Water and Wastewater [6].

In situ measurements

The *in situ* measured parameters: temperature, Total Dissolved Solid (TDS, mg/l), pH, Dissolved Oxygen (DO, mg/l) were carried out by WTW Multi 350i multimeter.

Laboratory measurements

Total Suspended Solid (TSS, mg/l), Biochemical Oxygen Demand (BOD_5, mg/l), Chemical Oxygen Demand (COD, mg/l), nitrate (NO_3^-, mg/l), ammonium (NH_4^+, mg/l), Boron (B, mg/l) total coliform (TC, CFU/100ml) and fecal coliform (FC, CFU/100ml) were carried out according to APHA [6]. Metals were determined after preliminary treatment of water sample [6] and the concentrations of Cd, Cu, Fe, Mn, Ni, Pb and Zn were measured by atomic absorption spectrophotometer (Perkin Elmer 5300 DV).

Natural self-purification of Al-Mahmoudia canal

The Natural self-purification model consists of five measures. These five measures are described as follows:

Dissolved oxygen saturation, DO_{sat}: Which represents values for various water temperatures can be computed using the American Society of Civil Engineers formula [7] was calculated as equation (1).

$$DO_{Sat} = 14.652 - 0.41022T + 0.0079910T^2 - 0.000077774T^3 \quad (1)$$

Where

DO_{sat} = dissolved oxygen saturation concentration, mg/l

T = water temperature, °C

The DO_{sat} concentrations generated by the formula must be corrected for differences in air pressure caused by air temperature changes and for elevation above the Mean Sea Level (MSL). The correction factor can be calculated as equation (2).

$$f = \frac{2116.8 - (0.08 - 0.000115A) \times E}{2116.8} \quad (2)$$

The corrected DO_{sat} = outputequation$_1$ × outputequation$_2$ (3)

Where

f = correction factor for above MSL

A = air temperature, °C

E = elevation of the site, feet above MSL

Because elevation of Al-Mahmoudia canal is between 0 to less than 2 meter above the MSL, the equations 2 and equation 3 are neglected.

Ultimate BOD_5, L_a: The BOD test measures (1) the molecular oxygen consumed during a specific incubation period for the biochemical degradation of organic matter (carbonaceous BOD_5); (2) oxygen used to oxidize inorganic material such as sulfide and ferrous iron; and (3) reduced forms of nitrogen (nitrogenous BOD_5) with an inhibitor (trichloromethyl pyridine). If an inhibiting chemical is not used, the oxygen demand measured is the sum of carbonaceous and nitrogenous demands, so-called total BOD_5 or ultimate BOD_5. Ultimate BOD_5 can be computed according to Lee and Lin [8] which was calculated using equation (4).

$$L_a = BOD_5 \times 1.46 \quad (4)$$

Where

L_a = Ultimate BOD_5, mg/l

Streeter-Phelps oxygen sag formula: The method most widely used for assessing the oxygen resources in streams and rivers subjected to effluent discharges is the Streeter-Phelps oxygen sag formula that was developed for use on the Ohio River in 1914. The well-known formula is defined as follows [4] was calculated as equation (5).

$$D_t = \frac{k_d \times L_{aU}}{k_2 - K_d}\left(10^{-k_d t} - 10^{-k_2 t}\right) + D_a 10^{-K_2 t} \quad (5)$$

Where

D_t = DO saturation deficit downstream, mg/l (DO_{sat} - DOa) at time t

t = time of travel from two points, days

D_a = initial DO saturation deficit of upstream water, kg/day

L_{au} = ultimate upstream biochemical oxygen demand (BOD_5), kg/day

k_d = deoxygenation coefficient to the base 10, per day

k_2 = reoxygenation coefficient to the base 10, per day

Deoxygenationrate, k_d: The Streeter-Phelps oxygen sag equation is based on two assumptions: (1) at any instant the deoxygenation rate is directly proportional to the amount of oxidizable organic material present; and (2) the reoxygenation rate is directly proportional to the dissolved oxygen deficit. According to Lee and Shun Dar Lin [8] mathematical expressions for k_d can calculated as equation (6).

$$k_d = \frac{1}{\Delta t}\log\frac{L_{au}}{L_{ad}} \quad (6)$$

Where

k_d = Deoxygenation rate, day

Δt = time of travel from upstream to downstream, days

L_{ad} = ultimate downstream biochemical oxygen demand (BOD_5), mg/l

The K_d values are needed to correct for stream temperature according to the equation (7)

$$k_{d@T} = k_{d@20} \times (1.047)^{T-20} \quad (7)$$

k_d value at any temperature T °C and $k_{d@20}$ = k_d value at 20

Because BOD_5 has determined laboratory at 20°C so equation (7) not use.

Reoxygenation rate, k_2: According to Lee and Shun Dar Lin [8] mathematical expressions for k_d can calculated according to equation (8).

$$k_2 = k_d\frac{\bar{L}}{\bar{D}} - \frac{\Delta D}{2.303\Delta t\bar{D}} \quad (8)$$

Where

k_2 = Reoxygenation rate, day

$\bar{L}$ = Average Ultimate BOD_5 load upstream and downstream (Kg/day)

$\bar{D}$ = Average Dissolved oxygen deficit load upstream and downstream (Kg/day)

ΔD = Difference Dissolved oxygen deficit upstream and downstream (Kg/day)

The k_2 values are needed to correct for stream temperature according to the equation (9)

$$k_{2@T} = k_{d@20} \times (1.02)^{T-20} \quad (9)$$

K_2 value at any temperature T °C and $k_{2@20}$ = k_2 value at 20

Because BOD_5 has determined laboratory at 20 °C so equation (9) not use.

Procedure of applied natural self-purification of Al-Mahmoudia canal and evaluated contribute of nonpoint source pollution

a) Natural self purification is calculated for the reach from km 14 to 24.2 subsequent to Edko irrigation pump station and Al-Khandaq Eastern canal discharge at km 8.5 & 13.20, respectively, (Figure 2).

b) Natural self purification is applied in two cases:

1. The first is normal case, which Edko irrigation pump station is stopped; hence, it has stopped from June, 2009.
2. The second is simulated case, which simulated data for DO, BOD_5 of Edko irrigation pump station dischargeat the same reach as equation (10).

$$C_d = \frac{Q_u \times C_u + Q_e \times C_e}{Q_u + Q_e} \quad (10)$$

Where

C_d = Completely mixed new constituent concentration at the test location, mg/l.

Q_u = Discharge at the test location, m^3/month.

C_u = Constituent concentration at the test location, mg/l

Q_e = Edko irrigation pump station discharge, According to United States Agency for International Development [9] available drainage water at this pump station is 13,000,000 m^3/month.

C_e = Constituent concentration of the effluent of Edko irrigation pump station, mg/l.

C) Compared calculated data with observed value along Al-Mahmoudia canal to assess the contribution of nonpoint sources pollution.

Statistical analysis

The obtained data is analyzed statistically using SPSS software Version 16.0.2 [10].

Results and Discussion

Assessment of water quantity which feeding Al-Mahmoudia canal

According to Egyptian Ministry of Water Recourses and Irrigation,

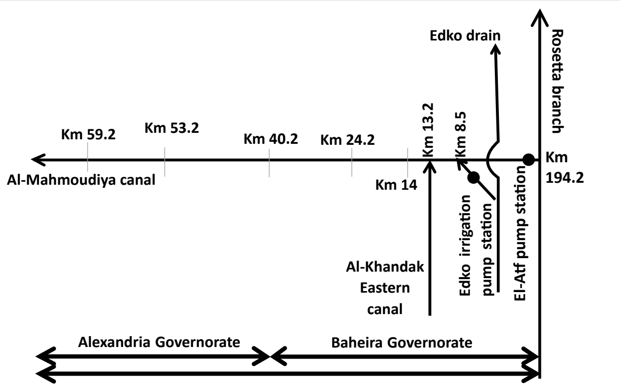

Figure 2: Schematic diagram of the measured water samples.

a quantity of 3.360 billion m^3/year have been discharged into Al-Mahmoudia canal (Table 2) from both Rosetta branch (km 1940) via El-Atf pump stations at the head of the canal and Al-Khandaq Eastern at km 13.200 on Al-Mahmoudia canal and the third water source is the drainage water from Zarkon drain at km 8.500 on Al-Mahmoudia canal via Edko irrigation pump station which lifts part of Zarkon drain into the canal. It is worthy to not that Edko Irrigation Pump Station has been stopped science June, 2009 due to water quality problems. This is because many drinking water intakes located on downstream of the mixing point.

Assessment of water quality which feeding Al-Mahmoudia canal

Table 3 represents the statistical analysis of the water quality of Al-Mahmoudia canal at km 0.0; out fall of Al-Khandaq Eastern at km 13.200 on Al-Mahmoudia canal and Zarkon drain. The variations in water quality can be summarized as follows:

Al-Mahmoudia canal (km 0.0):

- pH of water are within the permitted standard range (pH 6.5-8.4) according to FAO [11].
- The concentrations of TDS in water varied from 281 to 546 mg/l. No health-based guideline value for TDS has been proposed by WHO [12]. However, the palatability of water with a TDS level of less than 600 mg/litre is generally considered to be good since drinking-water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/litre [12]. The quality of irrigation water is defined by the type and the concentrations of dissolved salts and substances. The most significations are the cations of calcium, magnesium, sodium and the anions of carbonate, sulfate, and chloride. They are apart from the absolute concentrations of ions [13]. The quality criteria of irrigation water have deducted from FAO regulations for three hazard categories: I) No problems, II) Gradual increasing problems from the continuous use of water, III) Immediate development of severe problems [11]. The water quality for irrigation use according to the criteria indicates that is no problem when Al-Mahmoudia canal water is used for irrigation.
- The concentrations of TSS in the waters varied from 1.10 to 5.80 mg/l.
- The median value of dissolved oxygen concentrationsis 5.62 mg O_2/L. This indicates that pollution loading is depleting oxygen levels.
- The median values of BOD_5 and COD concentrations are 17.60 mg BOD_5/L and 29.33 mg COD/L. which are reflecting the high organic load in water of Al-Mahmoudia canal which are from Rosetta branch.
- Nitrate and ammonia concentrations were within the permissible limits (<10 and<5, respectively) according to FAO [11].
- Fecal coliform counts exceeded the WHO Guidelines [14] of 1000 CFU/100 ml in almost all waterhence, the median is 3050 CFU/100ml. This is an indication of the discharge of human wastes in Al-Mahmoudia canal through Rosetta branch.

According to United States Agency for International Development [9] Rosetta Branch, starting downstream of Delta Barrage receives relatively high concentrations of organic compounds, nutrients and oil & grease. The major sources of pollution are Rahawy drain (which receives part of Greater Cairo wastewater), Sabal drain, El-Tahrrer drain, Zawiet El-Bahr drain and Tala drain. At Kafr El-Zayat, Rosetta branch receives wastewater from Maleya and salt and soda companies. This indicates that the majority of water quality problems are occurring in the intake of Al-Mahmoudia canal due to receive low-grade water quality from Rosetta Branch.

Outfall of Al-Khandaq eastern canal: Al-Khandaq Eastern canal has discharged at km 13.200 on Al-Mahmoudia canal. The water quality of this canal can be summarized as follows:-

- pH of water are withinthe permitted standard.
- The concentrations of TDS are less than TDS concentrations in Al-Mahmoudia canal. The maximum concentration is 317mg TDS/L.
- The concentrations of TSS in the waters varied from 2.95 to 9.5mg/l.
- Dissolved oxygen concentrations ranged from 5.17 to 7.31mg/l.
- The median values of BOD_5 and COD concentrations are 11 mg BOD_5/L and 19 mg COD/L. which are reflecting the organic load received in Al-Khandaq Eastern canal.
- Nitrate and ammonia concentrations were within the permissible limits (<10 and<5, respectively) according to FAO [11].
- Fecal coliform counts exceeded WHO Guidelines [14] of 1000 CFU/100 ml in almost all water hence, the median is 2550 CFU/100ml. This is an indication of the discharge of human wastes intoAl-Khandaq Eastern canal.

The mixing of the drainage water at Etay El-Barud pump station in Al-Khandaq Eastern canal lowered water quality of Al-Khandaq Eastern canal downstream of the point of re-supply. More water with high pollution load results in worse water quality. This reproduces high concentration of BOD_5, COD, total coliform and fecal coliform. However,the concentration of contaminates in water of Al-Khandaq Eastern canal were less than Al-Mahmoudia canal.

ZarkonDrain: Zarkon drain discharges its water at km 8.500 of Al-Mahmoudia canal via Edko irrigation pump station which is lifting part of Zarkon drainage water into Al-Mahmoudia canal. As previously

Month	Discharge (billion m^3/month)	
	El-Atf pump station	Al-Khandaq Eastern Canal
May, 2010	0.313024	0.0465
Jun, 2010	0.328546	0.0450
Jul, 2010	0.371786	0.0465
Aug, 2010	0.346819	0.0465
Sep, 2010	0.288056	0.0450
Oct, 2010	0.240332	0.0465
Nov, 2010	0.197236	0.0450
Dec, 2010	0.14797	0.0465
Jan, 2011	0.079902	0.0465
Feb, 2011	0.131224	0.0420
Mar, 2011	0.139648	0.0465
Apr, 2011	0.228372	0.0450
Total	2.812915	0.5475***3.360***

Table 2: Water Resources lifted by El-Atf pump station and Al-Khandaq Eastern Canal.

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Location	Statistical analysis	pH	TDS (mg/l)	TSS (mg/l)	DO (mg/l)	BOD_5 (mg/l)	COD (mg/l)	NO_3-N (mg/l)	NH_4-N (mg/l)	Total Coliform (CFU/100ml)	Fecal Coliform (CFU/100ml)
Al-Mahmoudia canal (km 0.0)	Maximum	8.50	546	5.80	6.97	26	46	7.86	4.20	27000	17000
	Minimum	7.65	281	1.10	5.00	14	24	2.25	0.72	2400	1100
	Range	0.85	265	4.70	1.97	12	22	5.61	3.48	24600	15900
	Mean	8.03	383	3.13	5.70	18.10	30.61	3.38	2.08	8308	3975
	Median	8.03	384	3.07	5.62	18	29	2.54	2.12	7250	3050
	S.D.	0.25	77	1.29	0.58	3.09	5.96	1.88	1.04	6495	4238
	Skew	0.14	0.80	0.57	0.85	1.50	1.65	1.98	0.46	2.43	3.08
	Kurtosis	0.13	0.72	0.36	0.53	3.33	3.53	2.76	-0.05	7.01	10.11
Outfall of Al-Khandaq Eastern Canal	Maximum	8.47	317	9.50	7.31	14	24	4.31	1.56	15000	5000
	Minimum	7.80	227	2.95	5.17	7	12	1.54	0.04	1500	100
	Range	0.67	90	6.55	2.14	7	12	2.77	1.52	13500	4900
	Mean	8.20	260	4.95	6.23	10.67	18.25	2.51	0.47	8125	2525
	Median	8.21	254	4.90	6.20	11	19	2.11	0.29	9450	2550
	S.D.	0.18	30	1.66	0.52	1.97	3.52	0.97	0.43	3600	1128
	Skew	-0.73	0.57	1.98	0.06	-0.38	-0.44	1.01	1.85	-0.13	0.04
	Kurtosis	1.40	-0.81	5.32	1.84	-0.10	-0.30	-0.19	3.17	0.34	3.06
Zarkon Drain	Maximum	8.06	1074	7.00	3.80	36	60	11.00	4.20	82000	30000
	Minimum	7.45	537	5.50	0.37	24	40	5.11	1.44	9000	4000
	Range	0.61	537	1.50	3.43	12	20	5.89	2.76	73000	26000
	Mean	7.81	764	6.44	2.01	28.75	48.00	6.38	2.49	21558	9042
	Median	7.80	700	6.47	2.00	29	48	5.73	2.32	17400	7750
	S.D.	0.16	168	0.40	1.11	3.36	5.53	1.78	0.90	19279	6905
	Skew	-0.56	0.70	-0.84	0.39	0.50	0.56	2.15	0.55	3.30	2.94
	Kurtosis	1.13	-0.68	1.65	-0.71	0.64	0.73	4.05	-0.61	11.23	9.45

S.D. = Standard deviation

Table 3: Statistical analysis of water quality sources, which feeds Al-Mahmoudiacanal.

mentioned, Edko Irrigation Pump Station has been stopped from June, 2009 up till now. The water quality of this drain can be summarized as follows:

- pH of water are within the permitted standard.
- The concentrations of TDS in water varied from 537 to 1074 mg/l. It is less than the maximum limit (2000 mg/l) according to FAO [11].
- The concentrations of TSS in the waters varied from 7 to 5.5 mg/l.
- Dissolved oxygen concentrations ranged from 0.37 to 3.80 mg/l. This indicates that pollution loading is depleting oxygen levels.
- The median values of BOD_5 and COD were 29 mg BOD_5/l and 48 mg COD/l.
- Nitrate concentrations were within the permissible limits (<10) except at July, 2010 which was 11 mg NO_3-N/l.
- Ammonia concentrations were within the permissible limits (<5) according to FAO [11]
- The median count of fecal coliform was 7750 CFU/100ml. This is an indication of the discharge of human wastes into Zarkon drain.

According to United States Agency for International Development [9] Delta drains are mainly used for discharge of predominantly untreated or poorly treated wastewater (domestic and industrial), and for drainage of agricultural areas. Therefore, they contain high concentrations of various pollutants such as organic compounds (BOD_5, COD), nutrients, fecal bacteria, heavy metals and pesticides. This explains increased concentrations of BOD_5, COD and fecal coliform.

Calculation procedures to evaluate natural self-purification in Al-Mahmoudia canal

Natural self-purification is calculated for the reach from km 14 to 24.2 subsequent to Edko irrigation pump station and Al-Khandaq Eastern canal discharge at km 8.5 & 13.20, respectively (Figure 2). Table 4-7 represent an example of calculation of natural self-purification using the data set from the reach from km 14 to 24.2

Natural self purification in Al-Mahmoudia canal according to case 1: Case 1 represents no drainage water is discharging into Al-Mahmoudia canal. Hence, Edko irrigation pump station is stopping lift drainage water of Zarkon drain into the canal.

Figure 3, illustrates the oxygen sag curve based on dissolved oxygen deficit. The data showed that dissolved oxygen deficit increased with distance and the lowest point of the oxygen sag curve (critical point) is at km 3.87. This point out that the deoxygenation rate is higher than the reoxygenation rate from km 0.0 to km 3.87, then dissolved oxygen deficit decreased with distance, consequently after km 3.87. Thus, the reoxygenation rate is higher than deoxygenation rate. It is clear that the first point on the oxygen sag curve where the oxygen deficit is less than the oxygen deficit at km 0.0 (restore activity point) is at km 10.31.

Figure 4 pointed out to the oxygen sag curve based on dissolved oxygen andas a result, the same trends for dissolved oxygen, the critical point is at km 3.87. Therefore, from km 0.0 to km 3.87 the deoxygenation rate is higher than the reoxygenation rate. Hence, dissolved oxygen was 5.59 and 5.44 mg/l, respectively. The restore activity point is at km 10.31and was 5.62 mg DO/l. According to Chapman, [15] the release into stream of untreated domestic or industrial wastes high in organic

Case	Q_b (m³/month)	Q_e (m³/month)	Q_b (m³/sec)	Q_e (m³/sec)	Q_a (m³/sec)	V (m/sec)	V (Km/h)
1	273,232,200	242,355,633	105.41	93.50	99.46	0.99	3.58
2	286,232,200	255,355,633	110.43	98.52	104.47	1.04	3.76

Q_b= Q at Km 14, Q_e= Q at Km 24.2, $Q_a = 0.5(Q_b + Q_e)$, V=velocity

Table 4: Measured hydraulic data of the stream.

Station 1 (ZawyetGazal town at Km 14)								
Case	Temp ºC	BOD_5 (mg/l)	BOD_5 (Kg/day)	L_a (Kg/day)	DO_{sat} (mg/l)	DO (mg/l)	DO deficit (mg/l)	DO deficit (Kg/day)
1	24.44	16.67	151,826	221,666	8.2640	5.59	2.67	24,354
2	24.44	17.22	164,297	239,874	8.2640	5.43	2.83	27,039
Station 2 (AbouHommos city at km 24.2)								
1	24.47	14.52	117,300	171,258	8.2592	5.14	3.12	25,199
2	24.47	15.24	129,721	189,392	8.2592	4.98	3.28	27,912

BOD_5(Kg/day)= $Col_{3\ of\ Table\ 5}$, X $Col_{4\ of\ Table\ 4}$, X 60X60X24/1000, L_a (Kg/day)= $Col_{3\ of\ Table\ 5}$, X 1.46 DO_{sat} compute from $equation_1$, DO deficit (mg/l) = $Col_{6\ of\ Table\ 5}$, – $Col_{7\ of\ Table\ 5}$,
DO deficit (Kg/day)= $Col_{8\ of\ Table\ 5}$, X $Col_{4\ of\ Table\ 4}$, X 60X60X24/1000

Table 5: Measured field and laboratory chemical characteristic data of the Stream.

Case	Δt	K_d (day)	$\overline{L}$ (Kg/day)	$\overline{D}$ (Kg/day)	ΔD (Kg/day)	K_2 (day)
1	0.12	0.94	196,462	24,776	845	7.36
2	0.11	0.91	214,633	27,476	873	6.97

Δt = (distance between $station_1$ &$station_2$/$Col_{8of\ Table4}$)/24 K_d compute from $equation_6$
$\overline{L}$= Average Ultimate BOD_5 load upstream and downstream
$\overline{D}$=Average Dissolved oxygen deficit load upstream and downstream
ΔD= Difference Dissolved oxygen deficit upstream and downstreamK_2 compute from $equation_8$

Table 6: Calculation procedures to estimate decay rates.

t (day)	Case 1				Case 2			
	Distance (km)	DO deficit (Kg/day)	DO deficit (mg/l)	DO (mg/l)	Distance (km)	DO deficit (Kg/day)	DO deficit (mg/l)	DO (mg/l)
0.000	0.000	24354	2.67	5.59	0.000	27039	5.43	5.43
0.015	1.289	25161	2.76	5.50	1.354	27831	5.35	5.35
0.030	2.578	25586	2.81	5.45	2.708	28251	5.30	5.30
0.045	3.867	25721	2.82	5.44	4.062	28383	5.29	5.29
Etc….. until km 50								

t= Proposed time step to perform calculations (day) = 0.015
Distance= $Col_{1of\ Table7}$ X $Col_{8of\ Table4}$X 24
DO deficit (Kg/day) compute from $equation_5$
DO deficit (mg/l)=$Col_{3of\ Table7}$X 1000/($Col_{4of\ Table4}$ 60 X 60 X 24)
DO (mg/l)=$Col_{6of\ Table5}$– $Col_{8of\ Table7}$

Table 7: Estimated DO deficit and DO with respect to time (days) and space (km).

Case	Parameters	Distance (Km)									
		Al-Mahmoudiacanal	14	17.87	18.06	24.31	24.83	27.5	39.78	53.96	59.11
		Reach	0.0	3.87	4.06	10.31	10.83	13.5	25.78	39.96	45.11
Case 1	DO deficit (Kg/day)	Calculated	24354	25712	-	24043	-	-	16938	11866	10417
		Observed	24354	-	-	25199	-	-	19812	14916	13489
		Difference	0.0	-	-	1156	-	-	2874	3050	3072
	DO (mg/l)	Calculated	5.59	5.44	-	5.62	-	-	6.40	6.96	7.12
		Observed	5.59		-	5.14	-	-	5.01	4.97	4.92
		Difference	-	-	-	0.48	-	-	1.39	1.99	2.2
	Critical point		-	√	-	-	-	-	-	-	-
	Restore activity point		-	-	-	√	-	-	-	-	-
Case 2	DO deficit (Kg/day)	Calculated	27039	-	28383	-	26657	-	-	-	-
	DO (mg/l)	Calculated	5.43	-	5.29	-	5.47	5.59	-	-	-
	Critical point		-	-	√	-	-	-	-	-	-
	Restore activity point		-	-	-	-	√	-	-	-	-

Table 8: Natural self-purification along Al-Mahmoudiacanal.

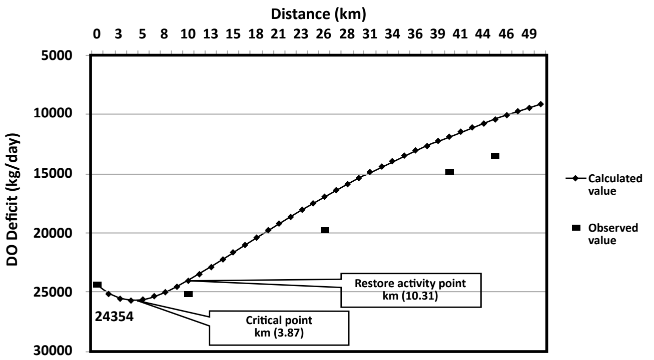

Figure 3: Calculated and observed value of DO deficit and related distance (Case 1).

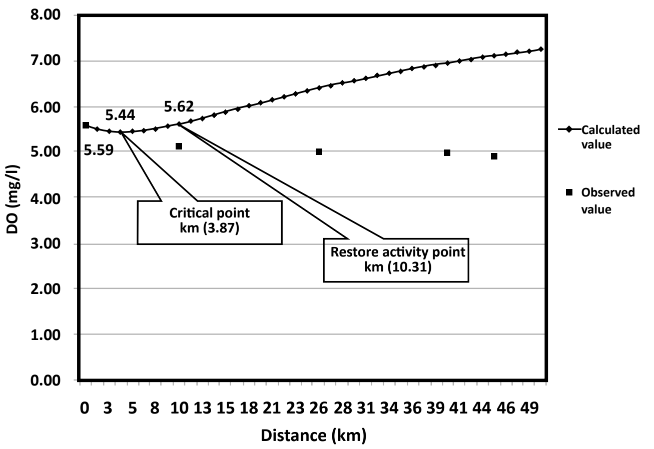

Figure 4: Calculated and observed value of DO and related distance (case1).

matter results in a marked decline in oxygen concentration (sometimes resulting in anoxia) and a release of ammonia and nitrite downstream of the effluent input. The effects on the river are directly linked to the ratio of effluent load to river water discharge. The most obvious effect of organic matter along the length of the river is the "oxygen-sag curve" which can be observed from a few kilometers to 100 km downstream of the input.

Table 8 compared the calculated data with the observed value to assess the impact of nonpoint pollution sources. The difference between observed and calculated values represents the contribution of nonpoint sources. The data showed that the difference between observed and calculated dissolved oxygen deficit was 1156, 2874, 3050 and 3072 Kg dissolve oxygen deficit /day, at km 10.31, 25.78, 39.96 and 45.11, respectively. As a result, the same trends can be reported for the dissolved oxygen hence, the difference between observed and calculated were 0.48, 1.39, 1.99 and 2.2mg DO/l, respectively. There is a progressive increase in the contribution of nonpoint pollution sources from south to north direction since the difference between observed and calculated values in the watercourse from south to north direction have been increased. Contribution of the nonpoint pollution source sat Al-Mahmoudia canal is related to the following four reaches:

- Reach No. 1: From Zawyet Gazal town at km 14to Abou Hommos city at km 24.2. Some degree of contribution of the nonpoint pollution sources.
- Reach No. 2: From Abou Hommos city at km 24.2to Kafr El-Dawar city at km 42.0. Elevated degree of contribution of nonpoint pollution sources due to the effect of the former reach which presents residents and establishes the stables animals on the banks of Al-Mahmoudia canal, which are throwing the remnants of cattle, houses, and wash the cattle and the dumping of dead animals in Al-Mahmoudia canal.
- Reach No. 3: From Kafr El-Dawar city at km 42.0 to Khorshid city at km 55. High degree of contribution of the nonpoint pollution sources due to the effect of the previously reach and present many workshops and gasoline stations on the banks of Al-Mahmoudia canal.
- Reach No. 4: From Khorshid city at km 55 to Seiouf water treatment plant intake at km 61.3. Elevated degree of contribution of the nonpoint pollution sources due to the effect of the previously reach and effect of high population presents in Alexandria city.

Natural self-purification in Al-Mahmoudia canal according to case 2: Case 2 represents simulated case which simulated Edko irrigation pump station for lifting drainage water of Zarkon drain into the canal.

Figure 5 illustrated the oxygen sag curve based on dissolved oxygen deficit. The data showed that dissolved oxygen deficit had increased with distance until the critical point at km 4.06. Thus, from km 0.0 to km 4.06 the deoxygenation rate is higher than the reoxygenation rate. Then dissolved oxygen deficit had decreased, the restore activity point is at km 10.83.

Figure 6 showed the oxygen sag curve based on dissolved oxygen. As a result, the same trends for dissolved oxygen, the critical point is at km 4.06. Thus, before km 4.06 the deoxygenation rate was higher than the reoxygenation rate and after km 4.06 the deoxygenation rate is lower than the reoxygenation rate and the dissolved oxygen were 5.59 and 5.44 mg/l, for both respectively. The restore activity point is at km 10.31 and was 5.62 mg DO/l.

According to table 8, after 10.83 km the concentration of dissolved oxygen in the case 2 almost equal the initial concentration of dissolved oxygen in the same case. Therefore, the reach needs 10.83 km to get rid of the influence of pollutants from Edko irrigation pump station

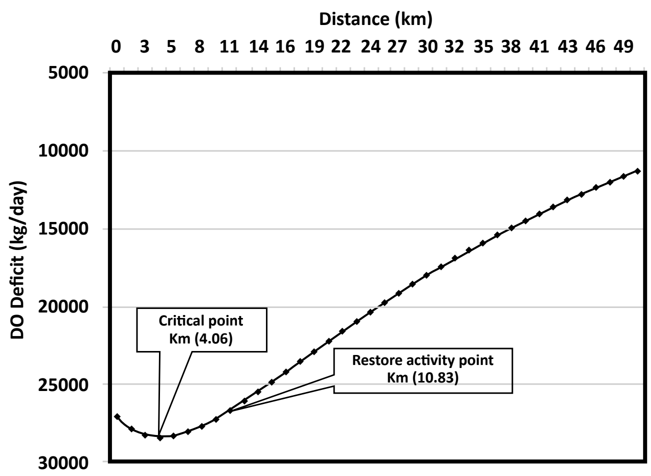

Figure 5: Calculated and observed value of DO deficit and related distance (case 2).

Citation: Abukila AF (2012) Assessment of Natural Self Restoration of the Water of Al-Mahmoudia Canal, Western Part of Nile Delta, Egypt. Irrigat Drainage Sys Eng 1:104. doi:10.4172/2168-9768.1000104

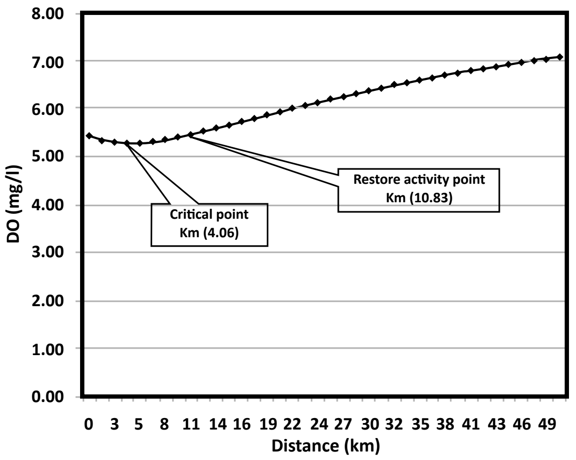

Figure 6: Calculated and observed value of DO and related distance (case2).

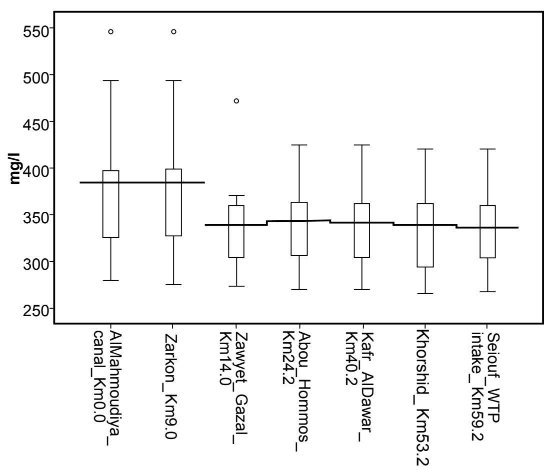

Figure 7: TDS along Al-Mahmoudia canal.

discharge. As a result, most of water treatment plant in Beheira Governorate will be affected by Edko irrigation pump station discharge in a suit running,while all water treatment plant in Alexandria Governorate will not be affected by Edko irrigation pump station discharge in a suit running.

According to results obtained (Figures 3-6), the results of interplay of the biological oxidation and reaeration rates. Each is represented by first-order kinetics. In the early stages, oxidation greatly exceeds reaeration because of high CBOD concentrations and stream dissolved oxygen concentrations close to saturation (i.e., small deficit). Oxygen is used faster than it is resupplied, and stream dissolved oxygen concentrations decrease. As the wastes moves downstream, the consumption of oxygen decreases with the stabilization of wastes and the supply of oxygen from the atmosphere increases because of greater deficits. The driving force to replenish oxygen by atmospheric reaeration is directly proportional to the oxygen deficit, (i.e., low oxygen concentration). At some point downstream from the waste discharge, the decreasing utilization and the increasing supply are equal. This is the critical location, where the lowest concentration of dissolved oxygen occurs. Further downstream, the rate of supply exceeds the utilization rate, resulting in a full recovery of the dissolved oxygen concentration. This explanation is also supported by USEPA [16].

Assessment of water quality along Al-Mahmoudia canal

- There was a remarkable decrease in the levels of TDS in water samples collected from sites after Al-Khandaq Eastern canal outfall (Figure 7) due to the lower salinity of Al-Khandaq Eastern canal than that of Al-Mahmoudia canal.
- Figure 8 represents the pH values of the canal water during the study period the results indicated that pH values are within the standard pH permissible levels (pH 6.5-8.4) according to FAO [11].
- Figure 9-14 showed that there were great fluctuations in the levels of BOD_5, COD, NO_3^-, NH_4^+, total coliform and fecal coliform along Al-Mahmoudia canal. These variations can be summarized as follows:-

1. There is a marked decrease in the levels of BOD_5, COD, NO_3^-, NH_4^+, total coliform and fecal coliform in waters of sites located after the outfalls of Al-Khandaq Eastern canal. According to table 3, the pollutions load of Al-Khandaq Eastern canal is lower than that of Al-Mahmoudia canal.
2. Although there is no discharge from any drains into Al-Mahmoudia canal, the levels of tested parameters are

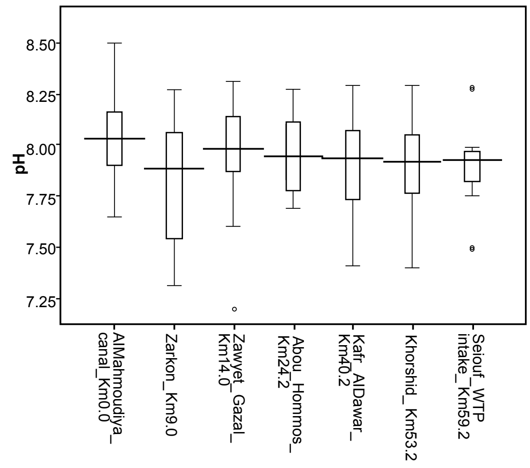

Figure 8: pH along Al-Mahmoudia canal.

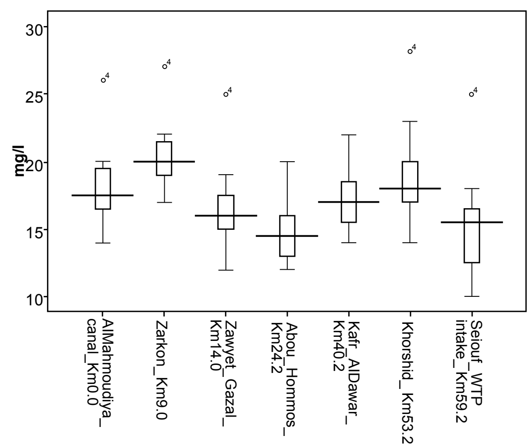

Figure 9: BOD_5 along Al-Mahmoudia canal.

Citation: Abukila AF (2012) Assessment of Natural Self Restoration of the Water of Al-Mahmoudia Canal, Western Part of Nile Delta, Egypt. Irrigat Drainage Sys Eng 1:104. doi:10.4172/2168-9768.1000104

flocculated along the canal. This is due to the impact of nonpoint pollution sources along the canal. These results agree with those previously mentioned for natural self-purification in Al-Mahmoudia canal.

3. The concentrations of the different metals in the waters along Al-Mahmoudia canal in addition to Al-Khandaq Eastern canal and Zarkon drain during the study period are within the normal range. As showing in table 9 there are no toxic levels of cadmium, copper, iron, manganese, nickel, lead and zinc since

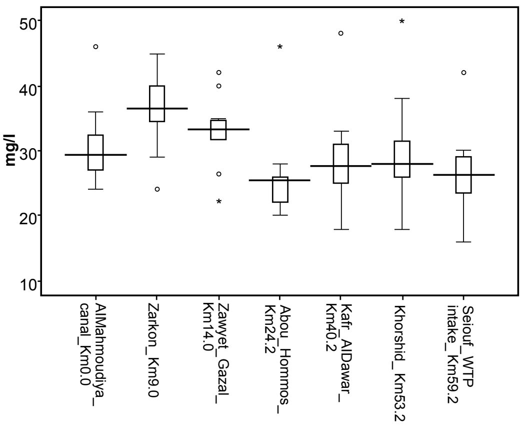

Figure 10: COD along Al-Mahmoudia canal.

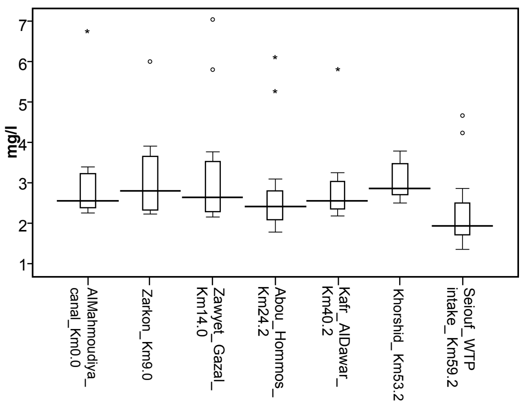

Figure 11: Nitrate along Al-Mahmoudia canal.

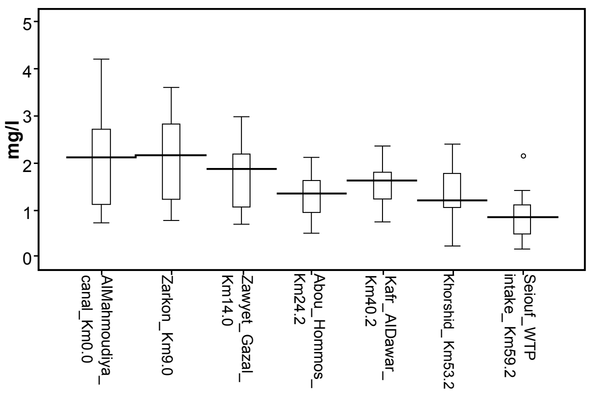

Figure 12: Ammonia along Al-Mahmoudia canal.

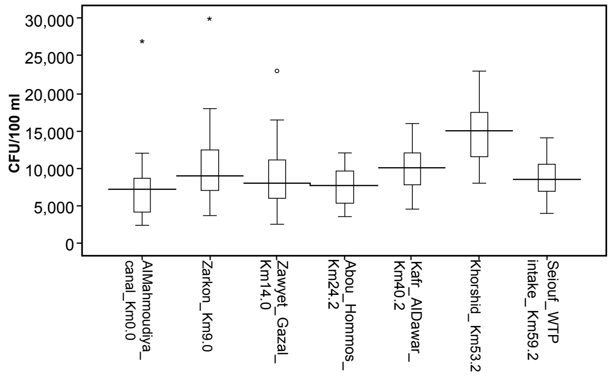

Figure 13: TC along Al-Mahmoudia canal.

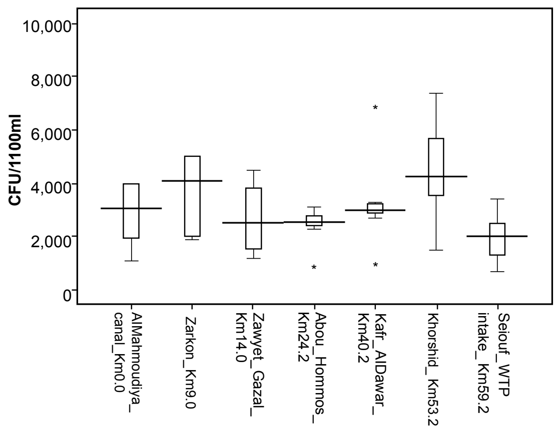

Figure 14: FC along Al-Mahmoudia canal.

these concentrations are less than the recommended maximum limits reported by the WHO [12].

Conclusion

Al-Mahmoudia canal is located at the northern edge of Beheira Governorate. It-off-takes Rosetta branch (km 194.200). It has three sources of water; two fresh water sources which are from Rosetta branch via El-Atf pump stations at the head of the canal, and Al-Khandaq Eastern canal and drainage water source which is from Zarkon drain at km 8.500 on Al-Mahmoudia canal via Edko irrigation pump station which lifting part of Zarkon drain into Mahmoudia canal. The majority of water quality problems are occurring in intake of Al-Mahmoudia canal due to receive low-grade water quality from Rosetta Branch. Edko Irrigation Pump Station has been stopped from June, 2009 due to water quality problems; especially many drinking water intakes are located on downstream of the mixing point. Contribution of the nonpoint pollution sources to Al-Mahmoudia canal is related to the following four reaches:

- Reach No. 1: From Zawyet Gazal town at km 14 to Abou Hommos city at km 24.2. Some degree of contribution of the nonpoint pollution sources.
- Reach No. 2: From Abou Hommos city at km 24.2 to Kafr El-Dawar city at km 42.0. Elevated degree of contribution of the nonpoint pollution sources.
- Reach No. 3: From Kafr El-Dawar city at km 42.0 to Khorshid

Location	Statistical	Cd	Cu	Fe	Mn	Ni	Pb	Zn
Al-Mahmoudia canal Km 0.0	max	L0.0001	0.007	0.081	0.335	0.048	L0.001	L0.0002
	min	L0.0001	L.0004	0.049	0.084	L0.0001	L0.001	L0.0002
	Median	L0.0001	L.0004	0.059	0.059	L0.0001	L0.001	L0.0002
Zarkon Km 9.0	max	L0.0001	0.006	0.083	0.338	0.052	L0.001	L0.0002
	min	L0.0001	L.0004	0.056	0.089	L0.0001	L0.001	L0.0002
	median	L0.0001	L.0004	0.069	0.065	L0.0001	L0.001	L0.0002
ZawyetGazal Km 14	max	L0.0001	0.006	0.077	0.270	0.04	L0.001	L0.0002
	min	L0.0001	L.0004	0.043	0.065	L0.0001	L0.001	L0.0002
	median	L0.0001	L.0004	0.052	0.038	L0.0001	L0.001	L0.0002
AbouHommos City Km 24.2	max	L0.0001	0.007	0.082	0.387	0.059	L0.001	L0.0002
	min	L0.0001	L.0004	0.053	0.089	L0.0001	L0.001	L0.0002
	median	L0.0001	L.0004	0.066	0.042	L0.0001	L0.001	L0.0002
Kafr El-Dawar city Km 42.0	max	L0.0001	0.006	0.079	0.131	0.018	0.004	0.002
	min	L0.0001	L.0004	0.055	0.057	L0.0001	L0.001	L0.0002
	median	L0.0001	L.0004	0.070	0.047	L0.0001	L0.001	L0.0002
Khorshid Km 55.0	max	L0.0001	0.007	0.077	0.343	0.052	0.001	L0.0002
	min	L0.0001	L.0004	0.045	0.073	L0.0001	L0.001	L0.0002
	median	L0.0001	L.0004	0.051	0.037	L0.0001	L0.001	L0.0002
Seiouf water treatment plant intake Km 61.3	max	L0.0001	0.007	0.062	0.273	0.043	L0.001	0.002
	min	L0.0001	L.0004	0.032	0.070	L0.0001	L0.001	L0.0002
	median	L0.0001	L.0004	0.030	0.044	L0.0001	L0.001	L0.0002
Outfall of Al-Khandaq Eastern canal	max	L0.0001	0.006	0.008	0.344	0.047	L0.001	L0.0002
	min	L0.0001	L.0004	0.004	0.046	L0.0001	L0.001	L0.0002
	median	L0.0001	L.0004	0.005	0.004	L0.0001	L0.001	L0.0002
Zarkon drain	max	L0.0001	0.006	0.074	0.340	0.052	L0.001	L0.0002
	min	L0.0001	L.0004	0.047	0.101	L0.0001	L0.001	L0.0002
	median	L0.0001	L.0004	0.063	0.066	L0.0001	L0.001	L0.0002

Detection limit for instrument are Cd 0.0001; Cu 0.0004; Fe 0.0001; Mn 0.0001; Ni 0.0005; Pb 0.001 and Zn 0.0002 mg/l.
WHO 2008 maximum contaminant limit for drinking water are Cd 0.0003; Cu 2; Fe 3 (PG); Mn 0.4; Ni 0.07; Pb 0.01 and Zn 3 mg/l (PG). PG means provisional guideline value

Table 9: Concentration of metals (mg/l) along Al-Mahmoudiacanal, outfall of Al-Khandaq Eastern canal and Zarkon drain.

city at km 55. High degree of contribution of the nonpoint pollution sources.

- Reach No. 4: From Khorshid city at km 55 to Seiouf water treatment plant intake at km 61.3. Elevated degree of contribution of the nonpoint pollution sources.

Natural self-purification of water of Al-Mahmoudia canal according to oxygen sag curve showed that the reach need 10.83 km to get rid of the influence of pollutants from Edko irrigation pump station discharge. As a result, most of water treatment plant in Beheira Governorate will be affected by Edko irrigation pump station discharge in a suit running, while all water treatment plant in Alexandria Governorate will not be affected by Edko irrigation pump station discharge in a suit running.

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