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Water Quality Assessment of Mahmoudia Canal in Northern West of Egypt

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Abstract

The main water source for Alexandria and Behiera governorate which locate at northern west of Egypt are Mahmoudia canal (receive about 15 Mm^3/day), which receive water from Rosetta branch at Mahmoudia city. The canal receives domestic and agriculture wastes from Zarcon Drain and other non-point sources. Drinking water in Alexandria is supplied from surface water sources of Mahmoudia canal. The water is transferred to the eight water treatment plants for treatment operations. The primary objective of conventional drinking water treatment and distribution is to deliver to the consumer water that satisfy the requirements and does not constitute human health risk. To achieve this, water utilities employ a range of physical and chemical barriers in order to reduce risks. The present study offered comprehensive water quality information of Mahmoudia canal. Cluster analysis grouped 10 sampling sites into three groups, less polluted (LP), medium polluted (MP) and highly polluted (HP). The dissolved oxygen concentrations, as indicated by the results of Mahmoudia canal during the period of study, ranged from 4.9 mg O_2/l at the beginning of canal after mixing with discharge of Zarcon drain to 5.9 mg O_2/l at the Manshia water treatment plant intake while DO values in Khandak canal, (at 15.2 km from starting of the canal) varied from 6 to 6.2 mg O_2/l. Nutrient concentrations did not comply with the permissible limits of ammonia, as well as the values of COD and BOD were exceeded the Egypt standards. Ammonia, 20 samples out of 36 samples were not complying with Egypt standard. All COD and BOD data obtained were exceeding of Egypt standard.

Keywords: Water quality; Mahmoudia canal

Introduction

Degradation of Water quality is a major issue in Egypt. The severity of present water quality problems in Egypt varies among different water bodies depending on: flow, use pattern, population density, extent of industrialization, availability of sanitation systems and the social and economic conditions existing in the area of the water source. Discharge of untreated or partially treated industrial and domestic wastewater, leaching of pesticides and residues of fertilizers; and navigation are often factors that affect the quality of water [1].

The industrial sector is an important user of natural resources and a contributor to pollution of water and soil. There are estimated to be some 24,000 industrial enterprises in Egypt, about 700 of which are major industrial facilities. The spatial distribution of industry in Egypt is influenced by the size of the employment pool, availability of services, access to transportation networks, and proximity to principal markets. The manufacturing facilities are therefore often located within the boundaries of major cities, in areas with readily available utilities and supporting services. In general, the majority of heavy industry is concentrated in Greater Cairo and Alexandria [2]. Industrial demand for water in the year 2000 has been reported to be 3.6 BCM/year. By the year 2017, the industrial demand for water is expected to reach 5.5 BCM/year. Consequently, a corresponding increase in the volume of industrial wastewater is expected [1].

Based on the population studies and rates of water consumption, the total wastewater flows generated by all governorates, assuming full coverage by wastewater facilities is estimated to be 3.5 BCM/year. Approximately 1.6 BCM/year receives treatment. By the year 2017, an additional capacity of treatment plants equivalent to 1.7 BCM is targeted. Although the capacity increase is significant, it will not be sufficient to cope with the future increase in wastewater production from municipal sources and therefore, the untreated loads that will reach water bodies are not expected to decline in the coming years [1].

The constituents of concern in domestic and municipal wastewater are: pathogens, parasites, nutrients, oxygen demanding compounds and suspended solids. In Greater Cairo and other cities, the sewerage systems also serve industrial and commercial activities. Therefore, instances of high levels of toxic substances in wastewater have been reported. As these toxic substances (heavy metals & organic micro-pollutants) are mainly attached to suspended material, most of it accumulates in the sludge. Improper sludge disposal and/or reuse may lead to contamination of surface and ground water [1].

In general, the bulk of treated and untreated domestic wastewater is discharged into agricultural drains. Total coliform bacteria reach 106 CFU/100 ml as recorded in some drains of Eastern Delta. It is important to mention that all drains of Upper Egypt flow back into the Nile. Moreover, it has become a national policy to maximize the reuse of drainage water by mixing it with canal water. Many irrigation canals may be contaminated with pollutants from domestic sources as a result [1].

Apart from being the largest consumer of water, agriculture is also a contributor to water pollution. Drainage water seeping from agriculture fields are considered non-point sources of pollution. These non-point sources are, however, collected and concentrated in agricultural drains and become point sources of pollution for the River Nile, the Northern Lakes, and irrigation canals in case of mixing water for reuse. Moreover, these non-point sources of pollution may

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also influence the groundwater quality. Major pollutants in agricultural drains are salts; nutrients (phosphorus & nitrogen); pesticide residues (from irrigated fields), pathogens (from domestic wastewater), and toxic organic and inorganic pollution (from domestic and industrial sources) [2].

Few studies were published about Mahmoudia canal, Nadia [3] reported that Lindane, DDE and DDT were found in Mahmoudia canal and the concentrations were ranged from 0.91 to 2.32 μg/l. Nadia [3] also cited that the heavy metals (Cu, Pb, Zn, Mn and Fe) were found in the canal at levels less than the maximum permissible limits, the same researcher found that the total dissolved solids (TDS), total alkalinity, total hardness (TH) and sulphates were less than the maximum permissible limits [3].

This study has been performed to follow the effect of agricultural wastewater drains and seasonal variation effects on Mahmoudia canal, which may help in giving information about variability in Mahmoudia canal quality that it is the main water sources for Alexandria residents for human uses.

Material and Methods

One hundred and twenty water samples were collected from ten stations. Ten samples were collected monthly, starting from June 2011 to May 2012 as shown in Figure 1. From each station two samples were collected using Van Dorn water sampler, the experimental procedure of the studied parameters were carried out according to APHA [4] as follows:

pH was measured on the spot by using pH meter model (CG-840 SCOTT, Germany) after buffer calibration at pH 4 and 10. Dissolved Oxygen (DO): DO was determined by using DO meter model (HACH SENION 8.) and expressed as (mg/l). The Electrical Conductivity (EC) was measured using an analytical Electrical Conductivity-Jenway 4320 after calibrated by calibrated standard 413, 1413 and 2776 uS/cm. The temperature was measured using an analytical thermometer embedded in (Electrical Conductivity-Jenway 4320).

Heavy metals: heavy metals were measured in water samples using (coupled plasma 400 emission spectrometer Perkin Elemer Emission Spectrometer). The Preservation and digestion were carried out as follows:

- Preservation: Samples were preserved immediately after collection by acidifying with concentrated HNO_3 to pH <2 by adding 5 ml nitric acid to l liter water samples. After acidification store in refrigerator.

- Digestion: Heavy metals were extracted in water samples using digestion by nitric acid method as follow: Mix well 500 ml of sample in a beaker at hot plate, add 10 ml nitric acid bring slow boil, evaporate on a hot plate to reduce the volume 200-100 ml, continue heating add another 10 ml of nitric acid until the volume reached to 100-80 ml until digestion is complete. The samples do not dry during digestion, mix well and complete to 100 ml by distilled water, and take portion of their solution for required determination [4].

Chemical oxygen demand (COD), biological oxygen demand (BOD) and total organic carbon (TOC) were determined according to standard methods for water and wastewater (5220 A, 5210 A and 5310

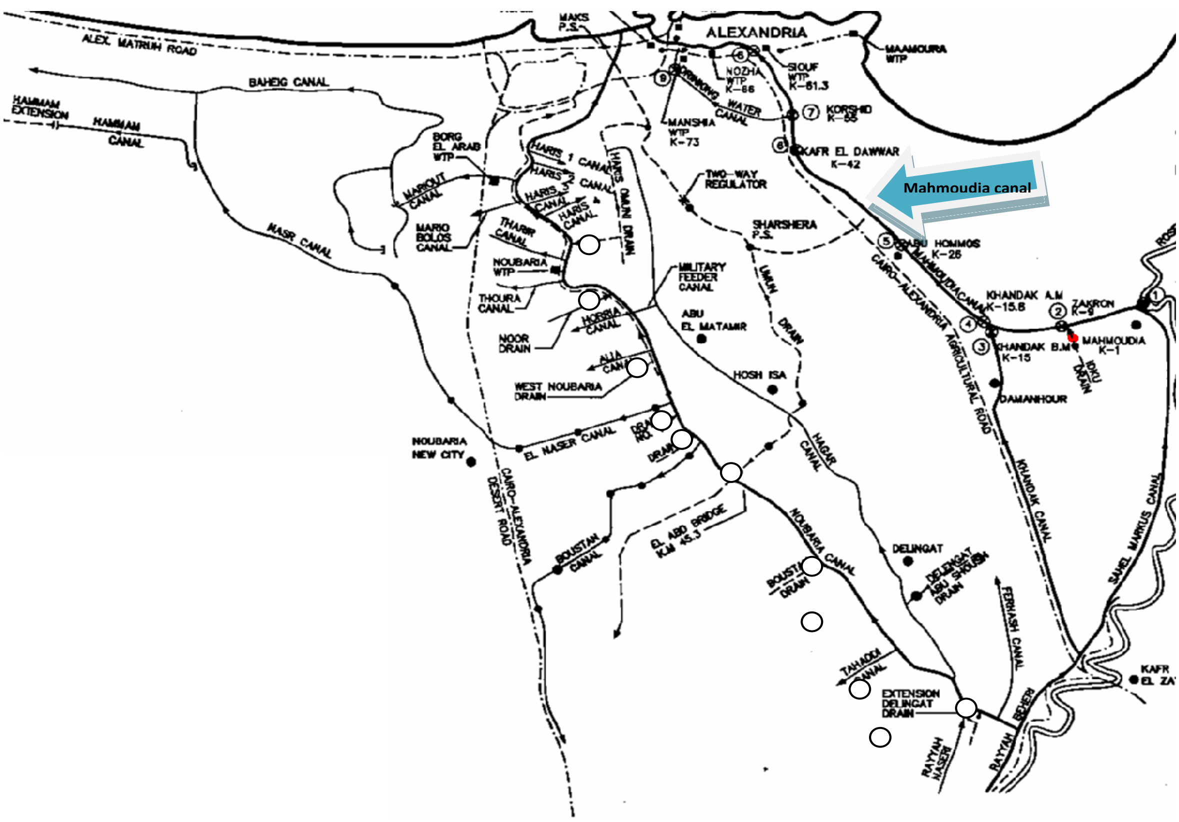

Figure 1: Sampling sites a long of Mahmoudia canal (northern west of Egypt).

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A, respectively) [4]. Ammonia (NH_3), Nitrates (NO_3), Nitrites (NO_2) and Phosphates (PO_4) were determined according to standard methods for water and wastewater (4500-NH_3 A, 4500-NO_3 A, and 4500-NO_2 and 4500-P A, respectively) [4].

Total hardness (TH), chloride (Cl), UV_{254} absorption, total dissolved solids at 105°C (TDS) and sulphates (SO_4) were determined according to standard methods for water and wastewater [4].

Chlorinated pesticides, n-methyl Carbamates and PCBs were determined according to EPA 508.1, 537.1 and 508.1 methods [5] by using GC/ECD and HPLC/FLD instruments.

Total algal count (TGC), filter clogging algae, taste and odour algae and polluted water algae were investigating according to standard methods for water and wastewater [4].

Total plate count (TPC), total coliform (TC) and fecal coliform (FC) were investigating according to standard methods for water and wastewater [4].

All analytical test methods used in the present study were verified and validated according to the test method validation for chemistry methods and biological examination [6].

The MS Excel 2007 software and NordTest TR 537 were used for calculations of validation parameters for analytical test method in water: uncertainty, selectivity, linearity, accuracy, precision, range, detection and quantitaition limit, system suitability and solution stability [7].

SPSS 18 software was used for calculation of the principal component, factor analysis and cluster analysis (LEAD Technologies, Inc).

The Canadian Council of Ministries of the Environment (CCME) Water quality Index (WQI) was used to evaluate surface water qualities. Calculations of the index are based on scope (F_1)-number of parameters that are not complaint with water quality guidelines; frequency (F_2)-number of times that the guide lines are not respected and the amplitude (F_3)-the difference between non-complaint measurement and the corresponding guidelines [8].

WQI was calculated according to the following equation:

$$WQI = 100 - \left(\sqrt{f_1^2 + f_2^2 + f_3^2}\right)/1.732$$

$$\text{Scope} \quad F_1 = \frac{\text{Number of failed variables}}{\text{Total no. of variables}} \times 100$$

$$\text{Frequency} \quad F_2 = \frac{\text{Number of failed tests}}{\text{Total no. of tests}} \times 100$$

F_3 represents Amplitude: The extent (excursion) to which the failed test exceeds the guideline.

This is calculated in three stages. First, the excursion is calculated

$$Excursion = \left(\frac{\text{failed test value}}{\text{guideline value}}\right) - 1$$

Second, the normalized sum of excursions (nse) is calculated as follows:

$$nse = \left(\frac{\sum excursion}{\text{total of tests}}\right)$$

Then, F_3 calculated as the following:

$$F_3 = \left(\frac{nse}{0.01 \times nse + 0.01}\right)$$

Results

Results presented in Tables 1 and 2 and Figures 2-5 showed the seasonal and spatial variations of Mahmoudia canal parameters (physical, chemical and biological) from June 2011 to May 2012 and also showed the correlation matrix and principle component analysis of the same canal. The bolded values were exceeding the Egypt maximum permissible limit [9].

The Atrazine, Chlordane-alpha, Chlordane-gamma, Aldrin, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, Endosulfan I, Endosulfan II, Endrin Aldehyde, HCH-delta, Lindane, Heptachlor Epoxide, Methoxychlor, 3-hydroxy carbofuran, carbofuran, chloropyrofos, Aroclor 1016, Aroclor 1232, Aroclor 1242, Aroclor 1248 and Aroclor 1260 were not

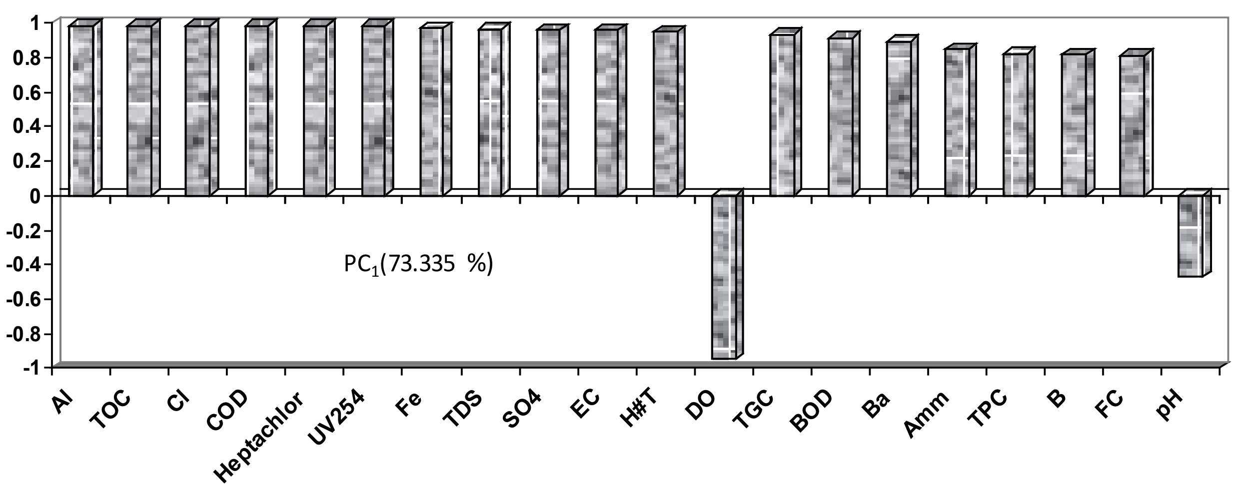

Figure 2: Component loading for first component (PC1).

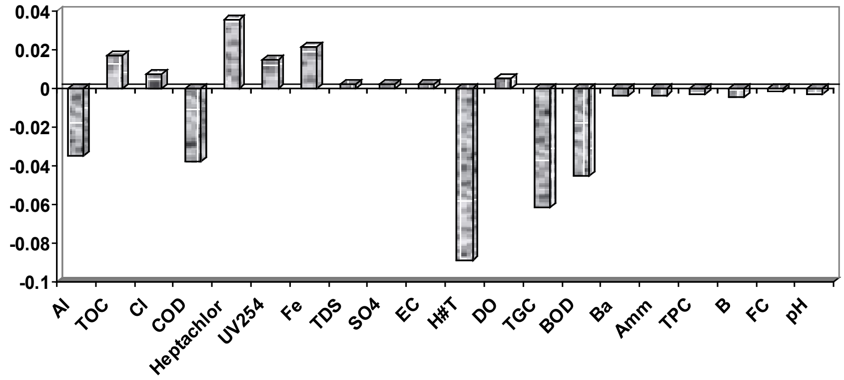

Figure 3: Component loading for first component (PC2).

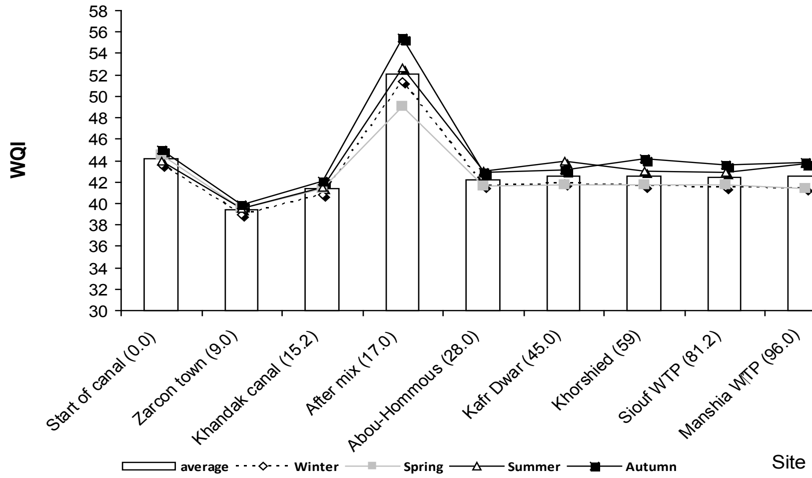

Figure 4: WQI of Mahmoudia canal.

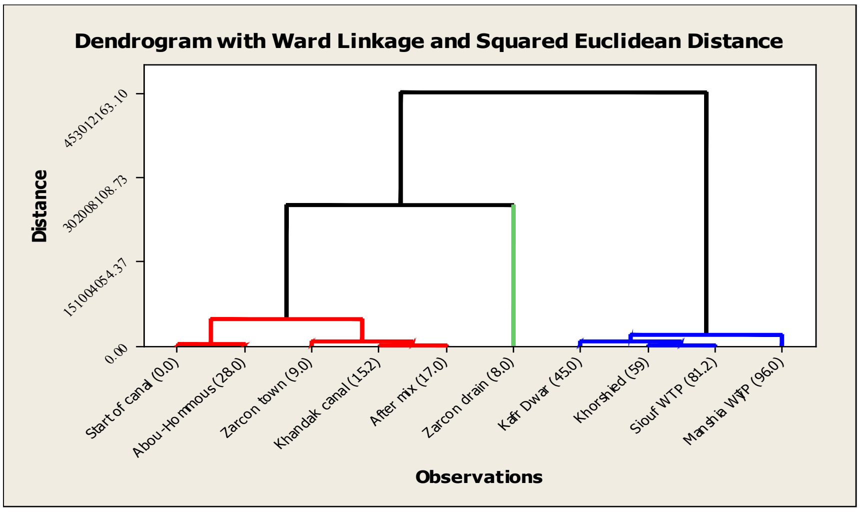

Figure 5: Dendrogram showing the relationship among sampling sites in Mahmoudia canal.

detected during the present study period were not detected during the present study period.

The beryllium, copper, nickel, silver, cadmium, lead and zinc were not detected during the present study period were not detected during the present study period.

The seasonal variation are shown in the values of standard deviation

(RSD), EC, UV254 absorption values, NH3, chloride, TOC, COD, BOD, sulphate, nitrite, nitrates, phosphates, heavy metals, a-BHC, b-BHC, heptachlor and the biological parameters (Table 1).

The values of COD and BOD exceed the Egyptian maximum permissible limit (10 and 5 mg/l, respectively) [10].

All analytical test methods used in the present study were verified and validated according to the test method validation for chemistry methods and biological examination as shown in Table 2.

The test method validation parameters were calculated for analytical test method in water: uncertainty, linearity, accuracy, precision, range, detection and quantitaition limit, system suitability and solution stability as shown in Table 2.

Data analysis for Mahmoudia canal water parameters (correlation matrix, principle component and cluster analysis) were carried out by using SPSS 18 as shown in Tables 3-7 and Figures 2, 3 and 5.

Cluster analysis

To verify data of the most influential factor among the stations of Mahmoudia canals; cluster analysis was done using Word's method (linkage between groups), with Euclidian distance as a similarity measure. Data were then amalgamated into Dendrogram plots (Figure 5).

	Start of canal (0.0)	Zarcon drain (8.0)	Zarcon town (9.0)	Khandak canal (15.2)	After mix (17.0)	Abou-Hommous (28.0)	Kafr Dwar (45.0)	Khorshied (59)	Siouf WTP (81.2)	Manshia W TP (96.0)	RSD
Temp. (°C)	21.8	20.4	20.6	20.7	20.7	20.7	20.9	21.0	21.1	20.7	12.7
pH	7.9	7.8	7.9	7.9	7.9	7.8	7.8	8.0	7.9	7.8	2.92
EC (µmosh/cm)	534	956	475	347	467	466	480	485	478	480	31.3
UV_{254}	0.082	0.248	0.105	0.076	0.086	0.08	0.078	0.08	0.079	0.073	55.4
DO (mg/l)	5.5	**4.3**	5.1	6.1	5.5	5.4	5.4	5.5	5.7	5.7	8.9
NH_3 (mg/l)	**1.7**	**2.6**	**2.1**	0.3	1.3	**0.8**	**0.8**	**0.6**	**0.7**	**0.7**	83.2
Chloride (mg/l)	48.4	106.5	54.0	27.0	38.1	39.0	40.5	41.5	39.5	41.8	50.12
H. total (mg/l)	175	218	176	137	161	160	161	162	160	161	19.2
TOC(mg/l)	5.6	17.0	7.2	5.1	5.9	5.5	5.4	5.5	5.4	5.0	55.66
COD (mg/l)	**41.0**	**66.5**	**46.3**	**28.8**	**38.8**	**40.5**	**39.3**	**36.0**	**36.0**	**36.5**	25.8
BOD (mg/l)	**17.3**	**25.8**	**19.5**	**12.3**	**18.0**	**19.5**	**16.5**	**15.0**	**13.0**	**14.0**	26.07
TDS (mg/l)	320	574	285	208	280	279	288	291	287	288	31.3
Sulphate (mg/l)	85.4	153.0	76.0	55.6	74.8	74.6	76.9	77.6	76.6	76.9	31.3
Nitrite (mg/l)	**0.2**	**0.3**	0.1	**0.2**	**0.2**	**0.2**	**0.3**	**0.2**	**0.2**	**0.2**	48.8
Nitrate (mg/l)	3.5	4.0	1.3	2.8	3.6	3.6	4.0	4.2	3.2	3.5	94.9
PO_4 (µg/l)	496	712	105	340	481	602	554	506	269	496	58.37
Al (mg/l)	0.0228	0.125	0.0445	0.018	0.0215	0.0233	0.0223	0.0233	0.019	0.0185	104.3
Fe (mg/l)	0.0095	0.081	0.0118	0.0048	0.0023	0.0013	ND	ND	0.0035	0.0008	155.4
Ba (mg/l)	0.0058	0.0205	0.012	0.0063	0.0023	0.003	0.0028	ND	ND	ND	58.4
B (mg/l)	0.009	0.0145	0.0115	ND	0.0065	0.0013	0.001	ND	ND	ND	49.2
a-BHC (µg/l)	0.0023	0.0395	0.0058	0.0003	0.002	0.002	0.0008	ND	ND	ND	364
b-BHC (µg/l)	ND	0.0395	0.0043	0.003	ND	ND	ND	ND	ND	ND	434
Heptachlor (µg/l)	0.0025	0.393	0.0065	0.0023	0.004	0.0038	0.0018	ND	ND	ND	317
Aldrin (µg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0
TGC (u/ml)	351	2720	963	906	642	592	586	532	379	343	116
F. clog (u/ml)	328	1528	810	825	628	490	535	492	384	221	86.8
T & O (u/ml)	75	366	173	160	129	116	153	118	108	53	93
P. W (u/ml)	31	148	65	89	60	81	31	29	33	30	105
TPC (CFU/ml)	15200	29300	20450	17800	18700	14000	11950	9975	9325	6950	76.4
TC (CFU/ml)	5100	9750	7300	7800	7450	6850	5875	6425	4500	3475	64
FC (CFU/ml)	**175**	**1600**	**1100**	**475**	**595**	**670**	**895**	**650**	**175**	**150**	107

- The value between two bracket meant that "the distance by km from the beginning of canal"
- The Atrazine, Chlordane-alpha, Chlordane-gamma, Aldrin, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, Endosulfan I, Endosulfan II, Endrin Aldehyde, HCH-delta, Lindane, Heptachlor Epoxide, Methoxychlor, 3-hydroxy carbofuran, carbofuran, chloropyrofos, Aroclor 1016, Aroclor 1232, Aroclor 1242, Aroclor 1248 and Aroclor 1260 were not detected during the present study period.
- The beryllium, copper, nickel, silver, cadmium, lead and zinc were not detected during the present study period.
- RSD is the standard deviation of the result over the period of study

Table 1: Average and standard deviation values of physical, chemical and biological analysis of Mahmoudia water characteristics (2011/2012).

	MDL (mg/l)	LOQ (mg/l)	Repeatability limit (r) (mg/l)	Reproducibility limit (R) (mg/l)	Recovery %	Linearity (R^2)	Measurement uncertainty %	Notes
Temp. (°C)	NA	NA	NA	NA	NA	NA	NA	
pH	0.1	0.2	0.2	0.3	102.6	0.992	8	
EC (µmosh/cm)	2	4	5	7	98	0.994	7	
UV_{254}	NA	NA	NA	NA	NA	NA	NA	
DO (mg/l)	NA	NA	NA	NA	NA	NA	NA	
NH_3 (mg/l)	0.01	0.02	0.04	0.05	98	0.991	12	
Chloride (mg/l)	0.5	1.0	1.0	1.0	99	0.994	10	
H. total (mg/l)	0.5	1.0	1.0	1.0	98	0.993	10	
TOC(mg/l)	0.2	0.4	0.4	0.4	97.5	0.991	15	
COD (mg/l)	0.2	0.4	0.3	0.4	94.8	0.996	12	
BOD (mg/l)	NA	NA	NA	NA	NA	NA	NA	
TDS (mg/l)	1.0	2.0	2.0	3.0	96.8	0.991	11	
Sulphate (mg/l)	1.0	2.0	2.0	3.0	97.4	0.992	12	
Nitrite (mg/l)	0.01	0.02	0.04	0.04	93.1	0.992	20	
Nitrate (mg/l)	0.01	0.02	0.04	0.04	93.1	0.992	20	
Heavy metals	0.0005	0.001	0.002	0.004	91.8	0.995	25	
Chlorinated pesticides (µg/l)	0.01	0.02	0.02	0.025	94.8	0.996	25	
PCBs (µg/l)	0.01	0.02	0.02	0.025	98.1	0.997	25	
N-methyl Carbamates (µg/l)	1.0	2.0	2.0	3.0	103.0	0.998	30	
TGC (u/ml)	2	4	5	6	95.8	0.99	20	
F. clogging (u/ml)	2	4	5	6	95.8	0.99	20	
T & O (u/ml)	2	4	5	6	95.8	0.99	20	
P. W (u/ml)	2	4	5	6	95.8	0.99	20	
TPC (CFU/ml)	1	2	2	4	96.8	0.992	25	
TC (CFU/ml)	1	2	2	4	96.8	0.992	25	
FC (CFU/ml)	1	2	2	4	96.8	0.992	25	

Table 2: Performance data and quality control for the analytical test methods.

The physico-chemical water parameters pH, EC, UV_{254}, DO, ammonia, Cl, TDS, TH, SO_4, NO_3, NO_2, PO_4, TOC, Al, Fe, Ba, B, a-BHC,b-BHC, Heptachlor, Aldrin, TGC, TPC, FC, BOD and COD were used as variables to show the spatial heterogeneity among the stations (Figure 5).

Water Quality Index" (WQI):

Estimation of WQI of Mahmoudia canals: Results presented in Table 7 and Figure 4 showed the seasonal and spatial variations of WQI in Mahmoudia canal from June 2011 to May 2012.

WQI as judged according to The Canadian Council of Ministries of the Environment (CCME) Water quality Index as follows: Values of WQI of Mahmoudia canal ranged from 38.98 (poor water quality) to 55.39 (marginal water quality). The lowest value was observed at Zarcon town (Km9.0) during winter, and the highest value was observed at after mix (Km17.0) during autumn. WQI values of Khandak canal ranged from 40.84 (poor water quality) during winter to 42.04 (poor water quality) during autumn as shown in Figure 4.

Discussion

In Egypt, the used primary and secondary treatment systems inefficient to remove residues of pesticides and organ chlorinated pollutants or parasites, viruses, and other non-parasitic microorganisms. As a result, these residues of chemical and biological pollutants may persistently remain in drinking water and we still cannot obtain safe clean water, moreover the increase of levels of the usually added chlorine to filtered or raw water leads to increased concentration of organic-chlorinated compounds that are known as carcinogenic and mutagenic [11].

Drinking water in Alexandria is supplied from surface water sources of Mahmoudia and Noubaria canals. The water is transferred to the eight water treatment plants for treatment operations. The primary objective of conventional drinking water treatment and distribution is to deliver to the consumer water that satisfy the requirements and does not constitute human health risk. To achieve this, water utilities employ a range of physical and chemical barriers in order to reduce risks. The treatment process is comprised from different steps coagulation, flocculation, sedimentation, filtration and disinfection in the treatment plants, source waters are treated to comply with Egyptian water quality standards in reference to World Health Organization (WHO) standards [10,12].

The present study offered comprehensive water quality information of Mahmoudia canal. Pollution cannot be measured on an absolute scale. Pollution can be thought of as a unifying constraint or label that characterizes responses to groups of variables. Strongly correlated variables may lead to the conclusion that a 'pollution factor' is present. Therefore the magnitude of pollution can be inferred from the measurement of its directly observable variables.

Pollution can be considered as the exceeding of tolerable

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	Temp. (0C)	pH	EC (µmosh/cm)	UV 254	DO (mg/l)	NH3 (mg/l)	Chloride (mg/l)	H. total (mg/l)	TOC(mg/l)	COD (mg/l)	BOD (mg/l)	TDS (mg/l)	Sulphate (mg/l)	Nitrite (mg/l)	Nitrate (mg/l)	PO4 (µg/l)	Al (mg/l)	Fe (mg/l)	Ba (mg/l)	B (mg/l)	a-BHC (µg/l)	b-BHC (µg/l)	Heptachlor	TGC (u/ml)	F. clog (u/ml)	T& O (u/ml)	P. W (u/ml)	TPC (CFU/ml)	TC (CFU/ml)	FC (CFU/ml)
Temp. (0C)	1																													
pH	0.4	1.0																												
EC (µmosh/cm)	-0.3	-0.4	1.0																											
UV 254	-0.4	-0.3	1.0	1.0																										
DO (mg/l)	0.4	0.3	-0.9	-0.9	1.0																									
NH3 (mg/l)	-0.1	-0.2	0.8	0.8	-0.9	1.0																								
Chloride (mg/l)	-0.3	-0.3	1.0	1.0	-0.9	0.8	1.0																							
H. total (mg/l)	-0.2	-0.3	1.0	0.9	-1.0	0.9	1.0	1.0																						
TOC(mg/l)	-0.4	-0.3	1.0	1.0	-0.9	0.8	1.0	0.9	1.0																					
COD (mg/l)	-0.3	-0.4	0.9	0.9	-1.0	0.9	1.0	1.0	0.9	1.0																				
BOD (mg/l)	-0.4	-0.4	0.8	0.8	-0.9	0.9	0.9	0.9	0.8	0.9	1.0																			
TDS (mg/l)	-0.3	-0.4	1.0	1.0	-0.9	0.8	1.0	1.0	1.0	0.9	0.8	1.0																		
Sulphate (mg/l)	-0.3	-0.4	1.0	1.0	-0.9	0.8	1.0	1.0	1.0	0.9	0.8	1.0	1.0																	
Nitrite (mg/l)	-0.1	-0.5	0.5	0.5	-0.3	0.0	0.4	0.3	0.5	0.4	0.3	0.5	0.5	1.0																
Nitrate (mg/l)	0.2	-0.2	0.3	0.1	-0.1	-0.2	0.1	0.1	0.1	0.1	0.1	0.3	0.3	0.8	1.0															
PO4 (µg/l)	-0.1	-0.5	0.6	0.4	-0.4	0.1	0.4	0.4	0.4	0.4	0.4	0.5	0.6	0.8	0.9	1.0														
Al (mg/l)	-0.5	-0.3	0.9	1.0	-0.9	0.8	1.0	0.9	1.0	0.9	0.8	0.9	0.9	0.4	0.1	0.4	1.0													
Fe (mg/l)	-0.4	-0.3	0.9	1.0	-0.8	0.8	1.0	0.9	1.0	0.9	0.8	0.9	0.9	0.5	0.1	0.4	1.0	1.0												
Ba (mg/l)	-0.4	-0.3	0.8	0.9	-0.8	0.8	0.9	0.8	0.9	0.8	0.8	0.8	0.8	0.2	-0.2	0.1	0.9	0.9	1.0											
B (mg/l)	-0.1	-0.1	0.7	0.7	-0.8	1.0	0.8	0.8	0.7	0.8	0.8	0.7	0.7	0.0	-0.3	0.1	0.8	0.7	0.9	1.0										
a-BHC (µg/l)	-0.4	-0.4	1.0	1.0	-0.9	0.8	1.0	0.9	1.0	0.9	0.8	1.0	1.0	0.5	0.2	0.4	1.0	1.0	0.9	0.7	1.0									
b-BHC (µg/l)	-0.5	-0.3	0.9	1.0	-0.8	0.7	0.9	0.9	1.0	0.9	0.8	0.9	0.9	0.5	0.2	0.4	1.0	1.0	0.9	0.7	1.0	1.0								
Heptachlor	-0.4	-0.4	1.0	1.0	-0.8	0.7	0.9	0.9	1.0	0.9	0.8	1.0	1.0	0.5	0.3	0.5	1.0	1.0	0.8	0.7	1.0	1.0	1.0							
TGC (u/ml)	-0.6	-0.3	0.9	1.0	-0.8	0.7	0.9	0.8	1.0	0.9	0.8	0.9	0.9	0.4	0.1	0.4	1.0	1.0	0.9	0.7	1.0	1.0	1.0	1.0						
F. clog (u/ml)	-0.6	-0.2	0.7	0.9	-0.7	0.6	0.8	0.7	0.9	0.8	0.7	0.7	0.7	0.3	-0.1	0.2	0.9	0.9	0.9	0.7	0.9	0.9	0.9	1.0	1.0					
T& O (u/ml)	-0.6	-0.3	0.8	0.9	-0.8	0.6	0.8	0.7	0.9	0.8	0.8	0.8	0.8	0.5	0.0	0.3	0.9	0.9	0.9	0.6	0.9	0.9	0.9	1.0	1.0	1.0				
P. W (u/ml)	-0.6	-0.4	0.6	0.8	-0.6	0.5	0.7	0.6	0.8	0.7	0.7	0.6	0.6	0.3	0.0	0.3	0.8	0.8	0.8	0.6	0.8	0.8	0.8	0.9	0.9	0.9	1.0			
TPC (CFU/ml)	-0.4	-0.2	0.7	0.8	-0.7	0.8	0.7	0.7	0.8	0.8	0.8	0.7	0.7	0.2	-0.2	0.2	0.8	0.8	0.9	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0		
TC (CFU/ml)	-0.6	0.0	0.5	0.7	-0.6	0.5	0.6	0.4	0.7	0.6	0.7	0.5	0.5	0.2	-0.1	0.2	0.7	0.7	0.8	0.6	0.7	0.7	0.6	0.8	0.9	0.8	0.9	0.9	1.0	
FC (CFU/ml)	-0.6	-0.3	0.7	0.8	-0.8	0.7	0.7	0.7	0.8	0.8	0.8	0.7	0.7	0.3	0.0	0.3	0.8	0.7	0.8	0.6	0.8	0.8	0.7	0.8	0.9	0.9	0.7	0.8	0.8	1.0

Table 3: Correlation Matrix of Mahmoudia canal water parameters.

	Initial	*Extraction*
pH	1.000	0.302
EC	1.000	0.959
UV_{254}	1.000	0.961
DO	1.000	0.896
Amm	1.000	0.852
Cl	1.000	0.964
H.T	1.000	0.896
TOC	1.000	0.964
COD	1.000	0.963
BOD	1.000	0.829
TDS	1.000	0.959
SO_4	1.000	0.959
NO_2	1.000	0.960
NO_3	1.000	0.940
PO_4	1.000	0.918
Al	1.000	0.968
Fe	1.000	0.939
Ba	1.000	0.920
B	1.000	0.845
Heptachlor	1.000	0.962

Extraction Method: Principal Component Analysis.

Table 4: Factor analysis on the samples collected from Mahmoudia canal.

Initial Eigenvalues			
Component	*Total*	*% of Variance*	*Cumulative %*
1	14.667	73.335	73.335
2	2.955	14.773	88.108

Extraction Method: Principal Component Analysis.

Table 5: Total variance of Mahmoudia canal parameters.

concentration limits of specific substances in a system. Identification of such underlying dimensions or factors greatly simplifies the description and understanding of complex phenomena [13]. Pollution can be estimated by observing the number of measurable parameters, viz. concentration of various elements in water, land and air, rise in temperature, variation in rain fall, changes in biological death rate of the consumers, etc. Since pollution is a dimensionless entity, it can be quantified by the measurement of dependent variables. Factor analysis is such a tool which can be applied to the measurable variables to identify certain factors to draw inferences. Based on these assumptions, factor analysis on the chemical data obtained on the water samples of Mahmoudia canal is carried out [13].

Initially, correlation matrices of the major and minor elements of all the water samples are calculated. Factor analysis of the above data is shown in Tables 4-6 and Figures 2 and 3 which include communalities, Eigen values, percent variance and cumulative percent variance.

A critical look at Tables 4-6, for factor 1 which explains 73.33% variance shows that variables such as Al, UV_{254}, NH_3, Cl, TH, TOC, BOD, COD, SO_4, Fe, Ba, B, a-BHC, total algal count (TGC), total plate count (TPC) and BOD have higher positive loadings (+0.70 and higher), and strong negative loading with DO; suggesting their 'deposition' or 'accumulation'. Therefore, by factor analysis, it has become clear that the previous parameters are entering the environment (Mahmoudia canal water) due to the discharge of pollutants by the Zarcon Drain and non- point sources. Factor 2 which explains 14.77% variance has negative loading for the variable trace metal B, ammonia and TPC. It means that all these elements are moving together. Therefore factor 1 for this set of samples would be 'Migration of pollutants' or 'Pollution'. This factor could be agricultural activity which includes the use of excess fertilizers by farmers.

Table 1 summarizes briefly the mean value and standard deviation of the 31 measured variables in Mahmoudia canal water samples from the selected ten sites. It must be noticed the high dispersion of most variables (high relative standard deviations), which indicates variability in chemical composition between samples, thus pointing to the presence of temporal variations caused likely by polluting sources and/or climatic factors. Recommended guide levels of these variables and maximum levels allowed by the law 48/1982 and its amendments and ministerial decree 458/2007 concerning the quality of water intended for human consumption [10].

	Component	
	1	2
Al	0.983	-3.495×10^{-2}
TOC	0.982	1.699×10^{-2}
Cl	0.982	7.535×10^{-3}
COD	0.981	-3.755×10^{-2}
Heptachlor	0.980	3.558×10^{-2}
UV_{254}	0.980	1.461×10^{-2}
Fe	0.969	2.131×10^{-2}
TDS	0.960	0.195
SO_4	0.959	0.196
EC	0.959	0.196
H.T	0.946	-8.910×10^{-3}
DO	-0.945	5.030×10^{-2}
TGC	0.930	-6.125×10^{-2}
BOD	0.909	-4.494×10^{-2}
Ba	0.893	-0.350
Amm	0.845	-0.371
TPC	0.823	-0.329
B	0.814	-0.427
FC	0.812	-0.175
pH	-0.469	-0.287

Extraction Method: Principal Component Analysis.

Table 6: Score coefficient of Mahmoudia canal parameters.

It must be emphasized that, the average concentrations of some variables such as chloride, COD, TDS, BOD, ammonia, nitrite, phosphate and sulphate are higher than those recommended by the Egyptian legislation, therefore this water resource is not adequate for human consumption or industrial purposes and needs to be purified. High levels of phosphate may originate from municipal wastewater discharges since it is an important component of detergents [2,14]. The presence of nitrate in the canals section sampled is suspected to originate from discharge from agricultural drain (Zarcon drain in Mahmoudia canal, Rahawy Drain which discharges in Rosetta branch) and the use of inorganic fertilizers (usually as ammonium nitrate) is rather frequent [15]. This practice could also explain the high levels of ammonia, but this pollutant may also originate from decomposition of nitrogen containing organic compounds such as proteins and urea occurring in municipal wastewater discharges. In the presence of high levels of organic matter, nitrate can be reduced in some extent to nitrite, what could explain the high concentration of this pollutant in some samples [16,17].

Because the ten sampling stations were combined to calculate the correlation matrix, the correlation coefficients should be interpreted with caution as they are affected simultaneously by spatial and temporal variations. Nevertheless, some clear hydro-chemical relationships can be readily inferred: High and positive correlation can be observed between ammonia, UV_{254} absorption values, BOD, COD, TOC, sulphate, chloride, total dissolved solids, conductivity, total plate count, total coliform, algal count and hardness (R^2=0.55 to 0.99) (Table 2). BOD, TOC and COD are strongly correlated (R^2=0.82 to 0.93) in Mahmoudia canal and also with ammonia, phosphate (closely related to contamination for organic matter), dissolved oxygen is weakly correlated with temperature because the solubility of oxygen in water decreases with increasing temperature; BOD, COD and nitrogen and phosphorous compounds are also anti-correlated with dissolved oxygen as organic matter is partially oxidized by oxygen, whilst nutrients are responsible for eutrophication of freshwater, thus causing a further increase in organic matter concentration and, hence, in oxygen demand (Table 3).

Iron, nitrate and pH showed no significant correlation with any other variables [18,19]. Rosetta branch, starting from Delta Barrage receives relatively high concentrations of organic compounds, nutrients and oil AND grease. Major sources of pollution are Rahawy

Site	(km)	**Start of canal** (0.0)	**Zarcon town** (9.0)	**Khandak canal** (15.2)	**After mix** (17.0)	**Abou-Hommous** (28.0)	**Kafr Dwar** (45.0)	**Khorshied** (59)	**Siouf WTP** (81.2)	**Manshia WTP** (96.0)
Season										
WQI	**Winter**	43.65	38.98	40.84	51.42	41.58	41.83	41.65	41.54	41.44
	Spring	44.49	39.49	41.44	49.08	41.62	41.75	41.76	41.77	41.43
	Summer	43.92	39.54	41.47	52.64	42.96	43.89	43.02	42.84	43.72
	Autumn	44.98	39.93	42.04	55.39	42.90	43.09	44.19	43.55	43.84
	Average	44.2	39.4	41.4	52.1	42.2	42.6	42.6	42.4	42.6

Table 7: WQI of Mahmoudia canal at 9 sampling points.

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 [1,2]. Mahmoudia canal receive water from Rosetta branch at Mahmoudia city (receive about 15 Mm^3/day) [2].

Dissolved oxygen concentrations, as indicated by the results of Mahmoudia canal during the period of study, ranged from 4.9 mg O_2/l at the beginning of canal after mixing fresh water with discharge of Zarcon drain (k.m 8.0) to 5.9 mg O_2/l at the Manshia WTP intake (k.m 96.0) while the DO ranged in Khandak canal, which inflow water in Mahmoudia canal at (k.m 15.2); 6 to 6.2 mg O_2/l. Nutrient concentrations are not comply with the permissible limits (Table 1).

Ammonia, COD and BOD values were exceeded the Egyptian standard (law 48/1982). Ammonia, 50 samples out of 90 samples were not complying with Egypt standard. All COD and BOD data obtained were exceeding of Egyptian standard. Drains are mainly used for discharge of predominantly untreated or poorly treated wastewater (domestic & industrial), and for drainage of agricultural areas. Therefore, they contain high concentrations of various pollutants such as organic matter (BOD, COD), nutrients, fecal bacteria, heavy metals and pesticides. Mahmoudia canal is suffering from pollution resulted by the agriculture drains (Zarcon Drain) which is feeding the canal at Km 6. The drainage water inflows to Mahmoudia canal are 0.5 Mm^3 / day at Zarcon town (Km 6.0) and about 0.25 Mm^3/ day from non-point sources, which acts 5.0 % of total flow of Mahmoudia canal on average (Table 1).

The affiliation among the stations were obtained through cluster analysis using Ward's method (linkage between groups), with Euclidian distance as a similarity measure and were amalgamated into Dendrogram plots as indicated in Figure 5. The physico-chemical Characteristics were used as variables to show the spatial heterogeneity among the stations as a result of sequence in their relationship and the degree of contamination.

Mahmoudia canal cluster analysis; there were four major groups obtained from the four seasons, the first group compromise from Kafr Dwar (km 45.0), Khorished (km 54), Siouf WTP intake (km 81.2) and Manshia WTP intake (km 96.0) which high polluted, the second group include Zarcon town (km 9.0), Khandak canal (km 15.2) and after mix point (km 17.0) which moderate polluted, the third group include the start of canal (km 0.0) and Abou-Hommous (km 28.0) which lower polluted and the fourth group which very high polluted include the Zarcon Drain (km 8.0) as indicated in Figure 5.

Water, a natural resource which has been used for different purposes, namely for drinking, domestic, irrigation and industrial, mainly depends on its intrinsic quality hence it is prime importance to have prior information on quality and quality of water resources available in the region. Water quality index (WQI) is regarded as one of the most effective way to communicate water quality. The WQI, which was developed in the nearly 1970s, can be used to monitor water quality changes in a particular water supply over time, or it can be used to compare a water supply's quality with other water supplies in the region or from around the world. The result can also be used to determine if a particular stretch of water is considered as "healthy" [8].

WQI as judged according to The Canadian Council of Ministries of the Environment (CCME) [20] Water quality Index as follows: Values of WQI of Mahmoudia canal ranged from 38.98 (poor water quality) to 55.39 (marginal water quality). The lowest value was observed at Zarcon town (Km 9.0) during winter, and the highest value was observed at after mix (Km 17.0) during autumn. WQI values of Khandak canal ranged from 40.84 (poor water quality) during winter to 42.04 (poor water quality) during autumn.

The water at almost all the sites showed that; the water quality was poor as a result of outflow of irrigation drainage.

Conclusions

Assessment of the available data obtained from both Mahmoudia canal indicates the following:

- The main water quality is exhibit high pollution levels that create health risks at present, indicates unsafe levels of pollution for direct use in drinking water, irrigation and fisheries.
- The major sources of pollution in Mahmoudia canal are discharge of Zarcon drain
- Major sources of pollution of Rosetta branch is El- Rahawy drain in the southern part and industry at Kafr El-Zayat. (Reverse impact on Mahmoudia canal water quality).
- Delta drains receive high concentrations of organic and inorganic pollutants from industrial, domestic as well as diffuse agricultural wastewater. High priority should be given to those drains receiving high loads of pollution such as: El-Rahawy.
- Increase the water flow in Khandak canal reduces the salinity and COD in Mahmoudia canal water quality.

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