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Environmental Evaluation of Major and Minor Metals in Ismailia Canal Sediment

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ABSTRACT

Sixteen sediment samples collected along the canal, from 8 stations during four seasons (winter, spring, summer and autumn) 2011 in the Ismailia region from Cairo to Ismailia Governorate and 4 stations in both Suez and Port Said branches. The present study deals with nutrient salts (NH_3, NO^{-}_{2}, NO^{-}_{3} and PO^{3-}_{4}), where human population is high on the two banks of the canal, there are several factories constructed. They discharge their wastes into the canal water, making change in the water and sediment of the canal. Major cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) were analyzed. As well as 3 heavy metals (Au^{+}, Ag^{+} and Cd^{2+}) were also determined Au^{+}, Ag^{+} as economic metals and less toxic, where Cd^{2+} exhibit extreme toxicity even at trace levels, where Ismailia Canal is considered as one of the most important irrigation and drinking water resources. Statistical studies have been carried out by calculating mean, standard deviation and correlation coefficient between different pairs of parameters. It is observed that the parameters studied have positive and negative correlation with each other, the major cations concentrations represent according to average of the total cations are found in the order $Ca^{2+} > Mg^{2+} > K^{+} > Na^{+}$, where nutrients in the order as $NH_3 > PO^{3-}_{4} > NO^{-}_{3} > NO^{-}_{2}$.

Key words: Ismailia canal, Sediment Analysis, Trace metals

Introduction

Ismailia canal was established during many years started from 1858 to 1863 and it is one of the largest freshwater canal branched from the Nile and has become of importance, since it provides water for irrigation, navigation, industrial and domestic purposes to area in the eastern region of Egypt and it exposure to different types of pollutants due to increased industrial, agricultural activity and heavy metals. The canal is 128 km long with 1-3m depth and about 30-70m width from the River Nile, north of Cairo, and runs directly to the east of Ismailia. At Ismailia it bifurcates into two branches as: one to the north to supply port-Said governorate (90km long) and the second to the south to Suez governorate (about 80km long). The water canal discharge is 433.56 m^3/sec. The total area surrounded the canal is about 108.200 fedden and transported 5.000.000 m^3 per day for drinking, industrial and irrigation purposes. It is worthy to note that some factories are constructed on the two banks of the canal, discharging their wastes into the canal water, leading to change in the water quality of the canal (El-Hadad, 2005 and El-Sayed, 2008. The water quality of Ismailia canal has been studied by number of authors (Stahl and Ramadan, 2008; Abdo and El-Nasharty, 2010; Abdo, 2013). Stahl and Ramadan (2008) indicated that the water is carbonated and that its quality is fair. Because of the velocity of the water in the canal and continuous inflow of the Nile water, the canal has the capacity for self-cleaning from pollutants. Abdo and El-Nasharty (2010) evaluated the physico-chemical parameters of Ismailia canal water during drought period months and concluded that, the water quality parameters were slightly increase especial ortho-P and TP. The point discharge of Abu-Zaball fertilizers company (IV) acts as a source of pollution in the Ismailia canal. Abdo *et al.* (2010) reported that the main pollution sources of Ismailia canal were due to domestic and effluents of police camp and petroleum companies.

Therefore, the wastewater effluents should be treated before its drainage in the canal. El-Hadad, (2005) studied the distribution and concentration of Fe, Mn, Zn, Cu and Pb in water and sediment of Ismailia canal and were found that the ranges of these metals in water are: Fe: 110-640, Mn: 40-360 µg/l, Zn: 1.8-54.8, Cu: 3.6-18.9 and Pb: 7.5-35.7 µg/l. In sediment 7500-26900, 150-710, 31.1-78.5, 3.3-56.5 and 12.8-32.5 µg/g for the same metals respectively. El-Sayed (2008) determined that physical and chemical variables of Ismailia canal water and recorded that the ranges of these variables were found to be water temperature: 16.5-34.6 ºC, transparency: 50-140 cm, EC: 246-510 µmohs/cm. pH: 7.17-8.17, DO: 8.4-13.6 mg/l, BOD: 0.8-6.0 mg/l, COD: 4.2-35.6 mg/l, CO^{2-}_{3}: nil-15.1 mg/l, HCO^{-}_{3}: 172-250 mg/l, SO^{-2}_{4}: 31.1-40.6 mg/l, NO^{-}_{2}: 7.77-10.22 µg/l, NO^{-}_{3}: 17.0-19.38 µg/l, NH_3: 1.03-1.94 mg/l and PO^{3-}_{4}: 30.6-90.2 µg/l. As well as trace elements are concerned, Ibrahim *et al.* (2009) studied the distribution of Cd, Cu, Cr, Pb, Ni, Co and Zn in the bottom sediments at the part of Ismailia canal near Cairo. They found that the concentration of Cd was below detection limit and that the concentration of Pb and Zn were above their values in the reference shale. The mean concentration of Cr, Co

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and Ni was found to be below reference shale. The aim of the present study carried out to estimate major ions, nutrients and some trace elements in the bottom sediments of Ismailia canal, along its entire course, where Ismailia canal is facing some environmental pollutants like agricultural drains and throwing wastes and garbage as well as dead animals into the canal. All these activities affected negatively on natural and chemical properties of the water in Ismailia canal and its branches. So there is a deep need and maximum importance to follow up the properties of water and sediment in Ismailia canal through laboratories tests to inspect how much its quality and much it is suitable for man use, and also to determine pollution sources and solve it.

Monitoring the concentration of some heavy metals in sediment gives vital information regarding their sources, distribution and degree of pollution. Sedimentation has been regarded as one of the most important fluxes in aquatic system, being an integral part of the cycling of elements which reflects the nature of overlying water at the time of deposition. A wide variety of metals in various forms can be found in water. Some concentrations occur naturally; their presence being influenced by soil or rock mineralogy, while others can be introduced by anthropogenic activities. Metals after entering water, may precipitate, absorb on solid surfaces, remain soluble, suspended in water or may be taken up by fauna and eventually accumulate in aquatic organisms. All metals are virtually toxic if the exposure is sufficiently high to exceed the tolerance limit. Pollution of aquatic system by heavy metals inhibits primary production, nitrogen fixation, mineralization of carbon, nitrogen, phosphorus, litter decomposition, and enzyme synthesis and activities in the sediments and surface water.

Materials and Methods

Sampling stations

Samples of bottom sediments were collected seasonally (winter, spring, summer and autumn) during 2011. The sites of samples collection were eight stations (1-8) selected along the area extended from the mouth of the canal at Mazalat region to Ismailia city. Four stations (9-12) selected to cover Suez branch.

In spite of four stations (13-16) to cover Port-Said branch. All sampling stations are representing in Figure (1).

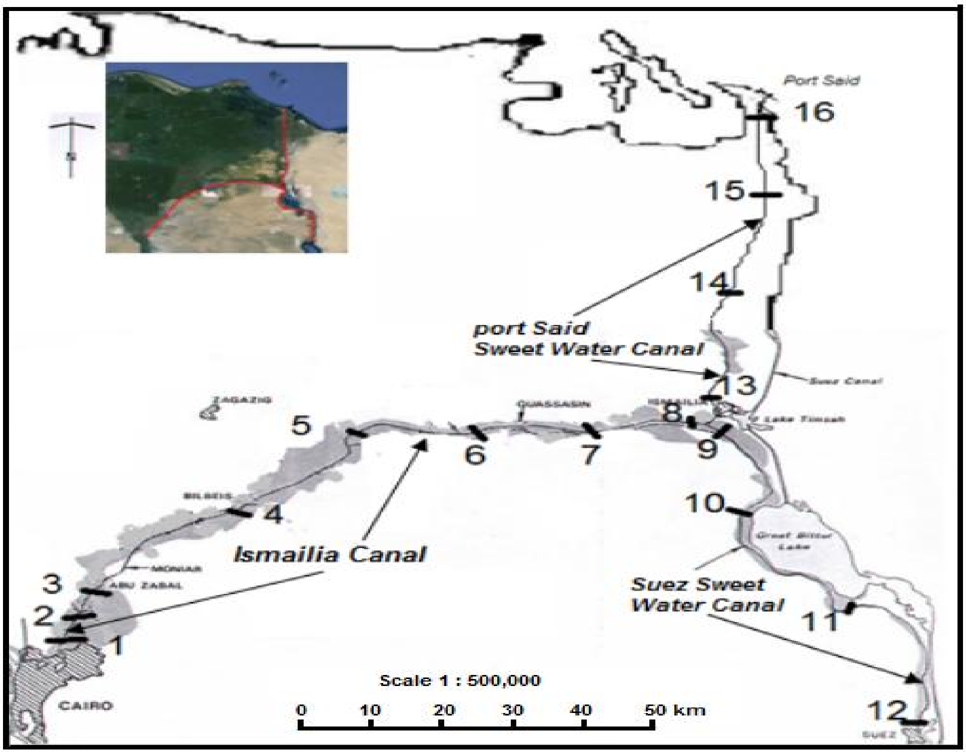

Fig. 1: Map of Ismailia canal and branches illustrated the selected stations

Ismailia canal: 1- Al-Mazalat, 2- Al-Amiryia water station, 3- Circular road, 4- Abu Z'abaal city, 5- Belbas city, 6- El-Abasa, 7- El-Tal Al-Kepeir city, 8- Shoeib bridge (before burification)

Suez canal: 9- Start of Suez canal, 10- Fayed center, 11- Al-Oshashyia, 12- End of Suez canal.

Port Said canal: 13- Start of Port-Said canal, 14- El-Salam bridge, 15- After of El-Salam canal, 16- End of Port-Said canal.

Sediment analysis

Sediment treatment

The sediment samples were air dried and then sieved to separate the <63 µm fraction. This fraction is used by several workers to eliminate the effect of particle size and to obtain a more homogenous grain distribution (Duquesne *et al*., 2006). This fraction which consists of silt and clay is known to entrap most of the trace elements (Farkas *et al*., 2007). 0.5 gram of the powdered sample was digested with a mixture of HF, HNO_3 and $HClO_4$ as described by standard methods (1998). Metal concentrations were determined using Atomic Absorption Spectrophotometer model (Solaar 969 AA Spectrometer). The concentrations of exchangeable ammonia, nitrite were measured using the KCl extraction and quantified directly indophenol blue, Griess-Hosvay and hydrazine-$CuSO_4$ reduction methods, respectively following American Society of Agronomy (1982). Available phosphorus is extracted by $NaHCO_3$ and colorimetrically determined as orthophosphate by molybdenum blue method (APHA, 2005).

Ca^{2+} and Mg^{2+} were determined by EDTA titrimetric method. Na+ and K+ were measured using the flame photometer "Model Jenway PFP.K"

Statistical analysis

Statistical studies have been carried out by calculating mean, standard deviation, the correlation coefficient "r" between the quality parameter pairs of the sediment samples were calculated by the application of Pearson correlation analysis and show the degree of linear relationship between two sets of data [X] and [Y]. An ANOVA is an experiment in order to indicate the nature and the sources of the polluting substances.

Results and Discussion

Sediments analysis

Results of sediments analysis from the selected sites are presented in Table (1). Ismailia canal basin is a booming agricultural zone, crops, vegetables, cereals are planted on both sides of the canal bank throughout the year, fertilizers, herbicides and insecticides are used. Many industries located in canal discharge their wastes directly into the canal. Therefore analyses of Ismailia canal sediments may provide important information on contaminate inputs into aquatic ecosystem.

Major cations

a- *Calcium and magnesium concentrations*

Low value 320 µg/g of calcium concentrations in sediment of Ismailia canal at stations 2 & 4 during winter, while high values 7200, 3760 µg/g at stations 8 & 11 respectively in the same season (Tables 1). During spring low values 480 µg/g was recorded at stations 3, 10 while high values 2800, 3760, 3840 µg/g at stations 2, 11, 12 respectively. In summer, the range fluctuated between 640 to 6720 µg/g as low and high values at stations l and 12 respectively. In autumn, calcium concentrations exhibit lower values than other seasons, from Table (1) Fig. (2), mean values exhibit minimum values were recorded at stations 1, 5, 14 while maximum mean values were registered at stations 8, 11, 12. The ranges of Mg^{2+} concentrations were found to be 192-5280, 432-4400, 384-2352 and 144-1200 µg/g during winter, spring, summer and autumn respectively. From Table (1), Fig. (2) minimum mean values at stations 4, 6 and 16 while maximum mean values were detected at stations 8 and 11 respectively. The maximum values of Ca^{2+} and Mg^{2+} due to the effluent discharges of industries company, or mainly attributed to the ability of phytoplankton to extract CO_2 from water and diminish of carbonic acid and raise the pH consequently the $CaCO_3$ and MgCO3 crystallized out and precipitates to the sediment (Korium, 2001). Calcium value was high during the hot season probably due to decay of organic matter and organisms present in bottom sediment which containing considerable amount of calcium (Korium *et al*., 2006). Ca and Mg are positive significant with each other (r = 0.634) which indicate the common source of these elements.

b- Sodium and potassium

Concentration of sodium depending on geological conditions and wastewater contamination. The values of Na concentrations in sediment were ranged from 190-316, 194-260, 216-308 and 192-224 µg/g during winter, spring, summer and autumn respectively. The absolute maximum value 316 µg/g was measured at site 7 during winter, as well as maximum mean value 276.6±7.10 µg/g in the same site Table (2) Fig. (2), this related to drought period effect and effluents discharged from industries companies (Abdo, 2013). However relatively low values were estimated during autumn. Potassium concentrations in sediment of Ismailia canal fluctuated between 104-658, 74-732, 896-704.8 and 85.4-505.2 µg/g during 4 seasons respectively. From these results, the lowest K^+ concentrations were estimated for site 14 where is mean value 93.6±0.40 µg/g for this site, while the highest values were determined at site 11, and the mean value 574.2±16.06 µg/g, this is due to its adsorption on the clay minerals and precipitate to bottom sediment (El-Dardir *et al*., 1995) or can be attributed to amount of sewage industrial and agricultural wastes discharged into some sites of the canal. Over all Ismailia canal sediments are slightly enriched in Ca, Mg, K and Na, Table (1) and graphically represented in Fig. (2). Na is a positive significant with Ca, Mg and K (r = 0.419, 0.516 and 0.630 respectively). K^+ also is significant with Ca, Mg (0.674, 0.608) respectively.

Nutrient salts

Ammonia (NH_3-N)

Nitrate and ammonia are the most common forms of nitrogen in aquatic system (Fernandez *et al*., 2002), NH_3-N contents are ranged from 1907-8850.2 µg/g at site 6 and 1 during winter respectively, the highest values were measured during summer, while lower values were recorded during autumn, maximum mean value 10587.6±8300.68 µg/g at site 3 Table (1), Fig (2). Ammonia is excreted by animals and produced during decomposition of plants and animals where the sediment act as a reservoir for all nutrients fluxes from all sources (atmospheric, agricultural, industry, households and deposition). In addition organic matter, both particulate and dissolved is broken down by bacteria and fungi to ammonia, NH_3 is a positive significant with NO_2 and NO_3 (r = 0.705 and 0.399), also is a positive significant with Ca, Mg, Na and K (r = 0.284, 0.419, 0.473 and 0.555 respectively). This indicates the same source of these elements and there are correlation between nutrients and major cations.

Nitrite (NO_2^--N)

NO_2^- concentrations in sediment of Ismailia canal were found slightly variations at different locations and seasons, Table (1), Fig. (3). It fluctuated between 0.592-189.736 µg/g, where minimum value measured during summer and maximum value 189.736 was observed during spring, minimum mean value was found at site 5, this may be related to the denitrification and deammonification by denitrifying bacteria.

Nitrate (NO_3^--N)

Nitrate (NO_3^-) contents in sediment were varied between the lowest values during summer 33.6, 33.18 µg/g at sites 3 and 6 respectively, where the highest values during winter and spring [Table (1), Fig. (3)], this can be attributed, when the sediments are aerobic, the ammonia is oxidized by nitrifying bacteria and biological nitrification yield nitrite as intermediate state during winter according to the following equation:

$$NH_4^+ + 1\frac{1}{2}O_2 \rightarrow NO_2 + 2H^+ + H_2O$$ (Shama *et al*., 2011)

Also, the high values of NO_2^-, NO_3^- at most stations during winter and spring may be related to decomposition of organic matter and decaying phyto and zooplanktons, organisms, agricultural fertilizer tailings which used in different agriculture processes from the adjacent lands.

Orthophosphate (PO_4^{3-})

From the results obtained, ortho-P increase during winter. The maximum mean values were 1484.48±2719.05 and 955.08±1601.67 µg/g at site 1 and 2 respectively. Orthophosphate (O-PO_4) were detected in low values during other seasons at different sites. The phosphate ion is a highly particle reactive molecule and thus the sorption properties of sediment are crucial for P-retention capacity. The high values of phosphorus during winter at most sites of Ismailia canal to the lower and staining water during winter, also may be facility the death and decaying of the most microorganism (Abdo, 2002) in column water, leading to liberation ortho and total-P and then it precipitates on the surface sediment. PO_4 is a positive significant with nitrate (r = 0.552).

Reactive silicate (SiO_2^{2-})

The seasonal variations of reactive silicate in the sediment of Ismailia Canal were found to be in the ranges from 1.914-17.11, 0.174-0.986, 22.794-28.043 and 20.022-37.642 µg/g during winter, spring, summer and autumn respectively, low minimum mean value was observed at location 3 (9.57±14.0 µg/g). The obvious decrease in reactive silicate during winter and spring Table (1), Fig (3), this may be attributed to the uptake by the diatoms blooms, fungi, algae and phytoplankton and zooplankton as well as fish from water (Toma, 2011), consequently precipitation will be decrease to the sediment. As well as the alkaline pH of the water accelerates the release of the silicate from sediments to the overlying water (Wetzel, 1983). The pronounced increase during summer and autumn concentration of silicate, increases with increasing temperature and consequently dissolution of the diatoms frustules (Shabana, 1999). Where it is known that sediments act as sink and source of supply of pollutants to the overlying water column in aquatic system (Davies *et al*., 1991 and Jennett *et al*., 1980). SiO_2 is a positive significant with Na and K (r = 0.710, 0.265 respectively). This related to formation of complex between these metals.

Heavy metals

Gold (Au^+)

Gold, the nobles of metals, it resistance to tarnish (Oxidation). Gold is the metal of choice for jewelry, also has been used success fully in many modern technological applications. It is used as the electrical contacts of computer chips. The concentrations of gold in Ismailia canal sediment in the ranges from 0.24-96.1, 7.54-17.66, 0.88-34.9 and 4.58-9.41 µg/g during winter, spring, summer and autumn respectively. Highest values 96.1, 34.9 µg/g were recorded during winter and summer at site 8 and 12, while low values observed during spring and autumn. The mean maximum value 30.45±43.78 µg/g was detected at site 8, this may related to the different types of wastes discharged along Ismailia canal body and increasing of pH values in these sites. Hence, metal adsorptive and precipitates mechanisms increased positively with increasing pH value (Shiller, 1997 and Toufeek, 1993), where adsorption process occurs on the surface of very fine organic particles and also can be attributed to preferential adsorption as hydroxyl metal species or hydrous iron or aluminium oxides (Toufeek *et al*., 2006). From these data obtained for Au in Ismailia sediment canal are higher than were obtained from River Nile sediment by Issa *et al*. (1996) and Korium *et al*. (2006), this also may due to the domestic and industrial wastes input canal bodies and most of its components are virtually insoluble in water. Au is a positive significant correlation with Ca and Mg (r = 0.684, 0.309 respectively).

Silver (Ag^+)

Besides gold, silver is the most bendable of all metals. It is known for its high thermal and electrical conductivity commonly known are application in jewellery coins. The seasonal variations of Ag concentrations were found to be from 2.8-16.71, 7.57-15.36, 6.01-20.2 and 6.98-8.68 µg/g during winter, spring, summer and autumn respectively, Tables (1), Fig. (4), the highest value 20.2 µg/g was found at site 1 during summer, also high values were recorded during winter and spring, while lower values were recorded during autumn. As well as mean maximum concentration 12.67±2.85 at site 16, silver has a very short biological half-time, then precipitate to bottom sediments. Ag significant correlation with Na, K, NO_2 and SiO_2 (r = 0.560, 0.224, 0.348 and 0.354 respectively), also may be due to the domestic and industrial wastes input in the Ismailia canal.

Cadmium (Cd^{++})

Most sites of Ismailia canal were not exhibited high concentrations of Cd in sediment, except some sites show high concentrations as 44.65, 52.77 and 326.23 µg/g at site 2, 6 and 8 respectively during autumn, this may be related to removal of cadmium with organic matter and co-precipitation from water to sediment as CdS, or a scribed to the sewage, agricultural, industrial and domestic wastes. While the relative high values present during spring due to its precipitation as carbonate charged to sulphide or hydroxide as the following equations (Diaz *et al*., 1998):

$$CdCO_3 + S \rightleftharpoons CdS + CO_3^{-}\downarrow$$

$$CdCO_3(S) + H_2O + O_2 \rightleftharpoons Cd(OH)_2 + CO_2 + H_2$$

On the other side, the low Cd concentrations during winter may be due to oxidation of cadmium sulphide in oxygenation period in the presence of photosynthetic sulphur bacteria (Krauskopf, 1979). From these data obtained, the levels of Cd were below the detection limit. Thus the sediments were free of Cd pollution.

Table 1: Major, nutrient and some heavy metals variation, mean ± standard deviation (SD) at Ismailia canal.

S*	Seasons	Parameters											
		Ca^{2+} µg/g	Mg^{2+} µg/g	Na^{+} µg/g	K^{+} µg/g	NH_3 µg/g	NO_2 µg/g	NO_3 µg/g	PO_4 µg/g	SiO_2 µg/g	Au µg/g	Ag µg/g	Cd µg/g
1	Winter	1040	384	250	208	8850.2	150.96	1809.36	5566	1.914	11.67	5.08	ND
	Spring	1280	432	202	136.8	7595.6	32.56	111.3	124.3	0.551	10.45	7.57	ND
	Summer	640	2184	308	374.4	11645	2.072	37.38	113.3	24.795	4.92	20.2	ND
	Autumn	☼	☼	☼	☼	2193	51.504	150.78	146.3	30.503	☼	☼	☼
	Mean	986.6±27.98	1000±48.77	253.4±6.69	239.8±7.79	7570.95±3964.73	59.27±64.43	527.2±856.06	1487.48±2719.05	14.44±15.44	9.01±3.60	10.95±8.11	☼
2	Winter	320	816	294	374	3408.5	14.208	172.62	3355	3.19	10.92	15.67	ND
	Spring	2800	1536	216	265.2	6813.6	59.2	176.82	94.6	0.986	9.87	9.09	8.04
	Summer	3600	960	230	279.2	11560	0.592	44.10	111.1	28.043	10.47	6.77	ND
	Autumn	2720	288	220	324	2876.4	103.304	228.90	259.6	32.77	8.02	8.13	44.65
	Mean	2360±70.84	900±25.65	240±1.82	310.6±2.46	6164.63±3997.49	44.33±46.62	155.61±78.62	955.08±1601.67	16.25±16.49	9.82±1.27	9.9150±3.95	26.345±25.89
3	Winter	1040	1384	290	392.8	4080	13.320	177.24	1049.4	2.146	3.61	16.71	ND
	Spring	480	4400	244	376.6	13423.2	70.744	185.64	72.6	0.841	7.54	8.76	ND
	Summer	3280	1296	224	340.4	21071.5	3.552	33.60	97.9	25.723	7.36	6.01	ND
	Autumn	☼	☼	☼	☼	3775.7	145.04	245.7	82.5	☼	☼	☼	☼
	Mean	1600±72.52	2360±93.20	252.6±6.47	370±9.31	10587.6±8300.68	58.16±65.06	160.55±89.95	325.60±482.65	9.57±14.0	6.17±2.22	10.49±5.56	
4	Winter	320	192	208	172	2502.4	10.36	216.30	537.9	4.292	2.52	2.80	ND
	Spring	2000	480	202	99.8	433.5	16.28	131.46	67.1	0.667	11.32	8.14	ND
	Summer	960	480	268	173.8	9001.5	0.888	51.66	132	24.128	6.67	15.52	ND
	Autumn	☼	☼	☼	☼	1655.8	13.32	89.04	81.4	23.925	☼	☼	☼
	Mean	1093.4±44.11	384±11.76	226±5.84	148.6±4.09	3398.30±3830.79	10.21±6.67	122.12±70.75	204.60±223.94	13.25±12.53	6.84±4.40	8.82±6.39	☼
5	Winter	1120	1008	254	580.8	4233	5.920	164.22	805.2	5.307	4.78	6.41	ND
	Spring	☼	☼	☼	☼	☼	2.368	☼	☼	☼	☼	☼	☼
	Summer	720	480	238	151	8695.5	☼	74.34	305.8	23.461	11.22	9.05	ND
	Autumn	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
	Mean	920±28.38	744±25.21	246±7.11	366±15.07	6464.25±4348.25	4.14±2.98	119.28±63.55	555.50±353.13	14.38±12.84	8.00±4.55	7.73±1.86	☼

S: Station*
ND: not detected & ☼: not available

Table 1:Cont.

S*	Seasons	Parameters											
		Ca^{2+} µg/g	Mg^{2+} µg/g	Na^{+} µg/g	K^{+} µg/g	NH_3 µg/g	NO_2 µg/g	NO_3 µg/g	PO_4 µg/g	SiO_2 µg/g	Au µg/g	Ag µg/g	Cd µg/g
6	Winter	1040	288	244	111	1907.4	10.064	231.42	683.1	4.64	33	4.9	ND
	Spring	☼	☼	☼	☼	2935.9	31.08	202.44	218.9	0.58	☼	☼	☼
	Summer	1600	672	226	266.8	10676	1.184	33.18	146.3	24.795	6.26	7.02	ND
	Autumn	3600	144	210	273	1502.8	88.504	349.86	214.5	23.345	7.41	8.51	52.77
	Mean	2080±75.65	368±14.45	226.6±5.71	217±6.59	4255.53±4322.62	32.71±39.25	204.23±130.65	315.70±247.18	13.34±12.51	15.56±15.12	6.81±1.81	
7	Winter	1360	3024	316	658	4250	6.808	80.22	2860	10.585	9.0	14.88	ND
	Spring	640	1728	238	396.4	1205.3	36.704	260.82	90.2	0.377	9.81	8.57	ND
	Summer	1200	1008	276	157.6	11101	3.848	36.96	685.3	26.854	7.28	16.42	ND
	Autumn	☼	☼	☼	☼	2072.3	145.04	230.58	114.4	21.489	☼	☼	☼
		1066.6±30.81	1920±63.59	276.6±7.10	404±14.37	4657.15±4482.77	48.10±66.31	152.15±110.16	937.48±1310.85	14.83±11.77	8.70±1.29	13.29±4.15	☼
8	Winter	7200	5280	300	372.4	4137.8	9.768	160.86	236.5	4.437	96.1	15.95	ND
	Spring	1040	672	194	74	331.5	32.264	249.06	106.7	0.319	9.47	8.90	14.01
	Summer	960	1008	252	103.2	5550.5	6.512	63.0	831.6	22.794	7.9	6.57	ND
	Autumn	☼	☼	192	104	1237.6	21.904	76.86	660	37.642	8.31	7.57	326.23
	Mean	3066.6±165.03	2320±119.85	234.6±2.59	163.4±7.0	2814.35±2441.91	17.61±11.80	137.45±86.06	458.70±342.95	16.30±17.26	30.45±43.78	9.75±4.24	170.12±220.77
9	Winter	1440	1680	258	348	3172.2	8.584	86.49	570.9	6.96	6.45	7.28	ND
	Spring	☼	☼	☼	☼	317.9	29.008	256.62	99	0.957	☼	☼	☼
	Summer	960	720	218	208	13591.5	2.368	46.62	438.9	23.258	0.88	6.29	ND
	Autumn	☼	☼	☼	☼	2233.8	37.888	139.86	240.9	26.187	☼	☼	☼
	Mean	1200±36.0	1200±39.80	238±6.92	278±8.52	4828.85±5961.31	19.46±16.74	132.40±91.20	337.43±208.94	14.34±12.29	3.67±3.94	6.79±0.70	☼
10	Winter	1040	816	190	133	2074.0	12.136	133.14	1463	11.31	15.88	5.35	☼
	Spring	480	768	228	137.4	707.2	23.088	209.58	108.9	0.87	16.30	12.23	5.79
	Summer	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
	Autumn	2800	1200	218	252.2	1536.8	15.984	90.30	325.6	24.476	7.02	6.98	15.02
	Mean	1440±60.53	928±11.84	212±0.98	174.2±3.38	1439.33±688.59	17.07±5.56	144.34±60.42	632.50±727.35	12.22±11.83	13.07±5.24	8.19±3.60	10.41±6.53

S: Station*

Table 1: Cont.

S*	Seasons	Parameters											
		Ca^{2+} µg/g	Mg^{2+} µg/g	Na^{+} µg/g	K^{+} µg/g	NH_3 µg/g	NO_2 µg/g	NO_3 µg/g	PO_4 µg/g	SiO_2 µg/g	Au µg/g	Ag µg/g	Cd µg/g
11	Winter	3760	3984	260	373.8	2803.3	9.472	106.26	1595	17.11	0.24	10.44	ND
	Spring	3760	1920	284	644	208.9	15.688	91.98	46.2	0.638	12.43	13.66	4.30
	Summer	2960	1920	228	704.8	12095.5	1.776	37.38	610.5	24.882	4.88	7.30	ND
	Autumn	☼	☼	☼	☼	2468.4	15.688	52.92	112.2	21.837	☼	☼	☼
	Mean	3495.2±89.35	2608±81.35	257.4±6.53	574.2±16.06	4394.03±5262.02	10.66±6.61	72.14±32.33	590.98±715.18	16.12±10.80	5.8500±6.15	10.47±3.18	☼
12	Winter	☼	☼	☼	☼	1540.2	10.952	170.94	1155	7.54	☼	☼	☼
	Spring	3840	1632	244	640	10295.2	189.736	359.52	107.8	0.58	17.66	9.73	12.06
	Summer	6720	2352	276	☼	11628	0.296	26.88	170.5	25.752	34.9	6.70	ND
	Autumn	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
	Mean	5280±168.57	1992±60.26	260±7.55	☼	7821.13±5480.12	66.99±106.43	185.78±166.82	477.77±587.34	11.29±12.99	26.28±12.19	8.22±2.14	☼
13	Winter	☼	☼	☼	☼	1856.40	12.728	121.38	1430	5.249	☼	☼	☼
	Spring	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
	Summer	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
	Autumn	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
	Mean	☼	☼	☼	☼	1856.4	12.728	121.38	1430	5.249	☼	☼	☼
14	Winter	800	1296	230	104	☼	☼	☼	☼	☼	4.31	11.51	ND
	Spring	800	960	220	95.4	387.6	41.144	147.0	177.1	0.203	9.13	10.65	6.27
	Summer	720	384	226	89.6	8262	0.592	40.74	530.2	27.927	1.99	8.79	ND
	Autumn	800	144	192	85.4	1037	4.736	52.92	374	20.822	9.41	8.04	1.86
	Mean	780±2.0	696±26.33	217±0.86	93.6±0.40	3228.87±3917.0	15.49±19.80	80.22±62.16	360.43±230.98	16.32±14.3	6.21±3.66	9.75±1.61	4.07±3.12
16	Winter	560	384	262	184	☼	☼	☼	☼	☼	7.67	13.70	ND
	Spring	2000	480	260	732	550.8	31.968	167.58	79.2	0.174	11.52	15.36	5.20
	Summer	☼	☼	246	241	10217	1.184	42.42	311.3	24.708	6.81	12.95	ND
	Autumn	640	432	224	505.2	816	72.816	140.28	347.6	27.26	4.58	8.68	11.37
	Mean	1066.6±42.46	432±10.98	248±0.88	415.6±12.66	3861.27±4892.52	35.32±34.25	116.76±79.35	246.03±171.08	17.38±14.99	7.65±2.89	12.67±2.85	8.285±4.36

S:Station*

Table 2: Correlations coefficient matrix (r) and probability during period of study.

	Ca	Mg	Na	K	NH_3	NO_2	NO_3	PO_4	SiO_2	Au
Mg	0.634									
Na	0.419	0.516								
K	0.674	0.608	0.630							
NH_3	0.284	0.419	0.473	0.555						
NO_2	0.354	0.319	0.369	0.456	0.705					
NO_3	-0.051	-0.055	0.156	-0.038	0.399	0.567				
PO_4	-0.255	-0.138	-0.446	-0.217	-0.002	0.210	0.552			
SiO_2	0.161	0.170	0.710	0.265	-0.071	-0.083	-0.031	-0.330		
Au	0.684	0.309	-0.026	0.071	-0.099	0.206	0.076	-0.035	-0.098	
Ag	-0.173	0.266	0.560	0.224	0.085	0.348	0.103	0.354	0.365	-0.176

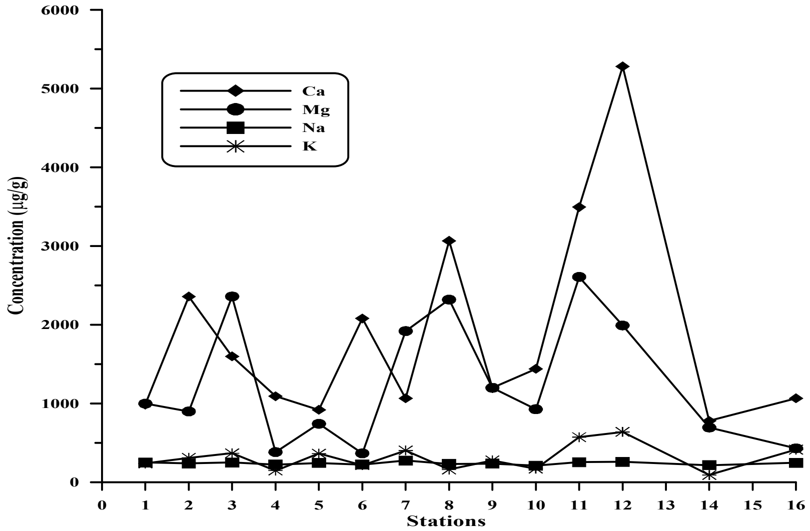

Fig. 2: The mean values of Ca, Mg, Na and K concentration (µg/g dry wt.) in sediment of Ismailia Canal at different study sites.

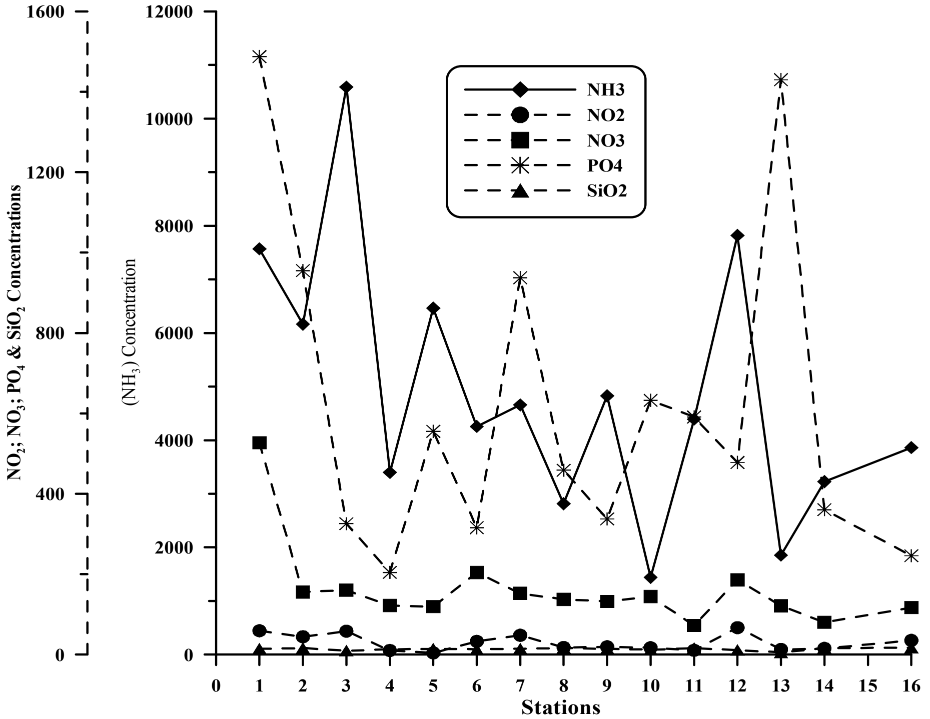

Fig. 3: The mean values of NH_3, NO_2, NO_3, PO_4 and SiO_2 concentration (µg/g dry wt.) in sediment of Ismailia Canal at different study sites.

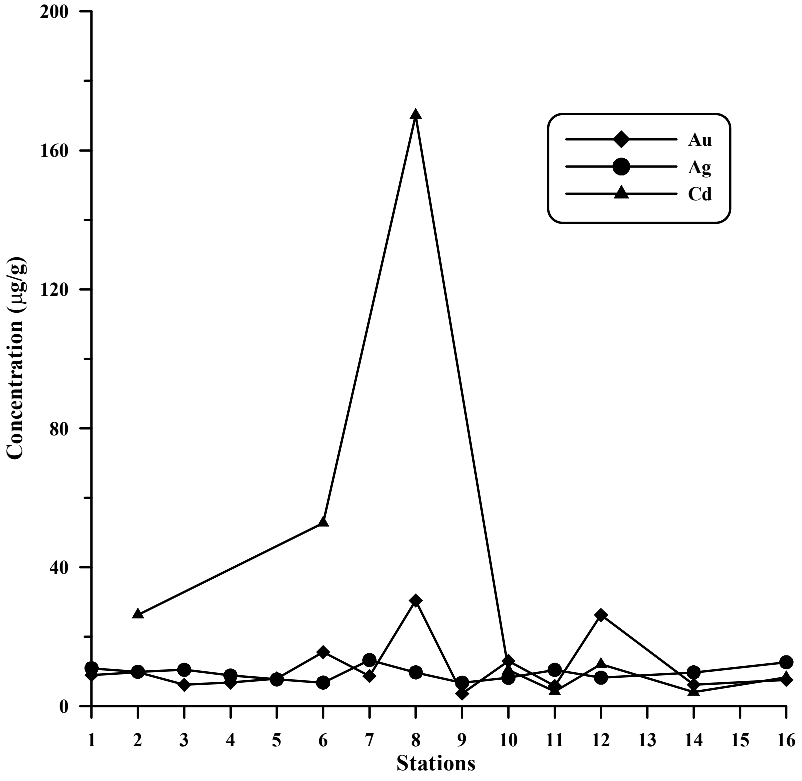

Fig. 4: The mean values of Au, Ag and Cd concentration (µg/g dry wt.) in sediment of Ismailia Canal at different study sites.

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