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Effect of heavy metals concentration on River Nile water on its quality in El-Hawamdia and Shobra El-Khima

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Summary Heavy metal contamination of water is considered as a potential threat to the human health. The objective of the study is to evaluate quality of water by using pollution index (PI) at different seasons, from autumn 2014 to summer 2015. Fe^{+2}, Mn^{+2}, Zn^{+2}, Cu^{+2}, Pb^{+2} are studied for this goal. The area under study is two sites. Site I, in front of the Sugar Cane Factory at El-Hawamdia (Latitude 29°52'31"N and Longitude 31°17'3"E) which receive all the fermented waste products. Site II, in the front of electricity station at Shobra El-Khima (Latitude 30° 7'29"N and Longitude 31°14'4" E) which suffers from the thermal pollution, El-Kanater El-Khairia city (30°11'1"N and Longitude 31° 8'20 "E) is considered as a reference site.

Introduction

Nile water which are available for use in Egypt amount to 55.5 BCM/yr, and 1.3 BCM/yr effective rainfall on the northern strip of the Delta, non-renewable groundwater for western desert and Sinai, while water requirements for different sectors are in the order of 79.5 BCM/yr. The gap between the needs and availability of water is about 20 BCM/yr. This gap is overcomed by recycling. The overall efficiency of the Nile system in Egypt is about 75%(1). On the other hand, it is also considered as the traditional receptor of waste and drainage water produced from different activities(2). Egypt almost depends on River Nile for its water supply. River Nile provides about approximately 97% of supplies needed for urban population and 70% or rural population of Egypt relies on piped water supply(1). Sources of pollution which can affect River Nile are industrial, domestic, and agricultural pollution. Many industry wastes are directly discharged into River Nile; there are more than 30 major industries in Helwan-El Teeben area(3). For Agricultural waste it was found that nitrate may be released from decomposed plants, using excess fertilizer and from animal production(4). Domestic pollution increased at sites with high level of sedimentation(5).

Heavy metals are naturally present in earth crust so they enter our body in a small amount by different ways; drinking water and food, they also have important role in our body to maintain the vital processes. Higher concentration of them can cause health problems(6,7).

On the basis of the health effect of heavy metals on humans, this study aims to evaluate the quality of water using PI at different seasons (from autumn 2014 to summer 2015) in El-Hawamdia and Shobra El-Khima. River Nile suffers from industrial, domestic and agricultural wastes. Several studies were carried out to show the hazardous effect of contaminated water. Survey of pervious results of the studied areas were collected in table 1 for water samples and methods used for heavy metal analyses.

Table 1 Heavy metals concentration of water reported from previous studies in some regions in Greater Cairo

Site / Element	mg/L				µg/L					Measured by	Ref
	Al	Mn	Fe	Zn	Cr	Ni	Cu	Cd	Pb		
El-Tbeen	--	0.047	3.05	0.268	--	--	4.30	15.0	35.48	FAAS	8
Helwan (torah cement)	--	--	0.564	0.034	--	--	19.00	0	0.15	FAAS	9
Starch& Glucose	--	--	0.231	0.045	--	--	22.00	0	0.15	FAAS	9
El-Roda	0.62	0.05	0.32	25.14	1.09	1.70	13.5	0.06	3.12	ICP-OES	10
El-Meradian	0.53	0.05	0.25	33.69	1.13	1.72	8.82	0.07	3.24	ICP-OES	10
El-Zamalek	--	0.004	0.24	0.178	--	--	0.90	3.8	8.10	FAAS	8
Rod El-Farg	0.35	0.05	0.20	30.79	1.31	2.57	7.33	0.08	2.97	ICP-OES	10
Embaba	0.43	0.05	0.25	26.63	1.35	1.46	7.10	0.05	2.69	ICP-OES	10
Zamalek&Empapa	--	--	0.147	0.030	--	--	8.00	0	0.15	FAAS	9
El-Mezallat	0.61	0.05	0.32	32.18	1.52	7.00	6.90	0.06	2.11	ICP-OES	10
El-Warrak	0.59	0.08	0.26	51.17	2.91	2.12	8.71	0.07	3.1	ICP-OES	10
El-Khayma	0.67	0.05	0.38	29.67	1.52	3.25	7.80	0.07	2.82	ICP-OES	10
El-Kanater	0.48	0.05	0.35	34.35	1.47	2.49	10.50	0.1	2.63	ICP-OES	10

Experimental

Study areas

Samples of water were collected seasonally from autumn 2014 to summer 2015 at the mid-stream of each site as shown in Fig. 1. Site description is as follows, Site I, in front of the Sugar Cane Factory at El-Hawamdia (Latitude 29°52'31"N and Longitude 31°17'3"E) which receives all the fermented waste products. Where, Site II is in the front of electricity station at

Shobra El-Khima (Latitude 30° 7'29"N and Longitude 31°14'4" E) which suffers from the thermal pollution.

Sample collection

Five water samples were collected seasonally from the surface and over the bottom. Ruttner sampler with reversible thermometer was used to obtain sub surface samples. Transparency, pH, electrical conductivity and temperature were measured in the field during collection. Water samples collected for dissolved oxygen DO were kept in bottles after addition of 2 mL manganese II sulphate followed by 2 mL alkali potassium iodide. The BOD water samples were kept in dark bottles to prevent exposure to light as possible until reaching the laboratory location. Water samples used for heavy metal measurements were kept in a cleaned 1 L plastic bottle and preserved with 5 mL concentrated nitric acid on spot and was stored in a cooler at 4 ºC till analysis.

Fig. 1. Map showing area under investigation (✸).

Reagents and standards

All reagents were of analytical grade (Sigma-Aldrich, Merck). Distilled water was used for solutions preparation. Standard solutions used for calibration were Merck certified AA standards.

Physical and Chemical Parameters

Electrical conductivity, pH and temperature were measured in the field using a multi-probe portable meter (Model CRISON-Spain), transparency was measured using Secchi desk (20 cm diameter). BOD, COD and DO were measured using APHA 1992 methods[11].

Heavy metals concentration (Mn, Fe, Cu, Zn, and Pb) were determined in water samples after digestion by nitric acid method as in (APHA1992) [11], 20 mL nitric acid (65%) was added to 500 mL of mixed sample in beaker then evaporated till complete dryness after that the sample was dilute to 100 mL. Finally, inductively coupled plasma optical emission spectroscopy (ICP-OES) Varian liberty series II, Italy was used for determination of the heavy metals. The wavelengths for detection were 259.610, 259.993, 324.752, 283.305 and 206.200 nm for Mn, Fe, Cu, Pb and Zn, respectively.

Assessment of water contamination

Effect of heavy metal contamination in water can be illustrated using water pollution index (PI), calculated using equation (1)[12]

$$PI = ((Ci/Si)^2_{max} + (Ci/Si)^2_{min})^{1/2}/2 \qquad (1)$$

Where Ci is the concentration of each element; Si is the metal level according to national water quality criteria for aquatic life.

PI value indicates the effect of pollution according to, PI < 1 (there is no pollution), 1-2 (slightly affected), 2-3 (moderately affected), 3-5 (strongly affected) and >5 (seriously affected).

Statistical Analysis

All data were expressed as mean ± standard deviation. The data were statistically analyzed by one way ANOVA. Results with p value < 0.05 were considered significant. The statistical analysis was carried out by bonferroni and confirmed by LSD with respect to the reference site (El-Kanater El-Khairia city 30°11'1"N and Longitude 31° 8'20 "E).

Results and Discussion

Greater Cairo is the suitable area in the study of surface water quality due to the presence of different kind of pollutants: industrial, municipal wastes, agricultural and runoff from developing areas which directly or indirectly contaminate River Nile[13]. El-Hawamdia and Shobra El-Khima were tested for their water pollution effect.

Physical and chemical parameters

Water temperatures fluctuated between 23.06±1.44-22.76±1.23, 16.44±1.51-16.44±1.33, 23.98±3.31-24.14±2.84, and 35.46±1.91-35.46±1.84 ºC during autumn, winter, spring and summer, respectively as shown in table 2. Maximum value was recorded in site I (35.46±1.91 ºC) while; the minimum value was recorded at site II during winter (16.44±1.33 ºC). Changes in temperature depend on climate conditions, number of sunshine hours and also affected by specific character of water environment; turbidity, wind force, plant cover and humidity[14,15].

The transparency varied from 90.00±7.91to 109.00±6.52, 70.00±7.91to 72.00±13.51, 41.00±8.94 to 50.00±7.91 and 74.00±6.52 to 78.00±10.37 cm during autumn, winter, spring and summer, respectively, as shown in table 2. The minimum value was recorded during spring in site II (41.00±8.94 cm), while the maximum value was recorded during autumn in site II (109.00±6.52 cm). The decrease in transparency during spring may be related the increase in amount of phytoplankton, where transparency depends on suspended solids and organic matter[14,16]. Higher value of transparency is correlated to solar radiation as well as settling out of suspended particles to the bottom sediments which increase during summer and autumn seasons[17].

Electric conductivity (EC) values ranged from 265.42±1.40 to 282.14±2.40 µmohs/cm during autumn, from 288.32±4.43 to 320.44±4.77 µmohs /cm during winter, from 260.82±3.92 to 274.26±2.58 µmohs/cm during spring and from 306.26±1.86 to 322.46±1.85 µmohs /cm during summer, Table 2. The lowest value during spring in site II was 260.82±3.92 µmohs/cm. The highest value in site I during summer was 322.46±1.85 µmohs/cm. The high EC values may be due to the presence of large amount of organic and inorganic constituents that discharged into Nile as cited by Al-Afify [18]. Elewa and Mahdi[19] reported that EC values were in the range of 310-380 µmohs/cm, while the decrease of EC during spring may be attributed to the uptake of dissolved salt by phytoplankton[20].

The recorded pH values varied between 8.06±0.21-8.14±0.21, 8.04±0.24-8.58±0.19, 7.76±0.21-8.00±0.16 and 7.58±0.19-7.86±0.21 during autumn, winter, spring and summer, respectively, Table 2. Highest value was 8.58±0.19 recorded at site I during winter, where the lowest value was recorded at site II during summer (7.58±0.19). pH values showed descending order that could be arranged as winter> autumn > spring > summer. High pH value in most cases may be attributed to the photosynthetic activity; as it removes CO_2 from water.

Dissolved oxygen values ranged from 7.86±0.23 to 8.16±0.21, 10.12±0.26 to 11.20±0.25, 8.90±0.16 to 9.08±0.24 and 7.26±0.21 to 7.78±0.19 mg/L during autumn, winter, spring and summer, respectively, Table 2. DO values showed descending order that could be arranged as winter>spring>autumn>summer. Dissolved oxygen values in natural water are changeable and their concentrations at any time represent a momental balance between rate of supply and rate of consumption. Several factors can affect DO as temperature which represents reversible factor.

pH and photosynthesis activity of phytoplankton increase DO content by increasing of algae flourishing. Respiration of living organism decreases the amount of DO[14].

Biochemical oxygen demand values ranged from 2.53±0.07 to 3.45±0.09, 1.29±0.03 to 2.05±0.12, 3.05±0.14 to 3.91±0.11 and 2.22±0.11 to 3.18±0.10 mg/L during autumn, winter, spring and summer, respectively, Table 2. The maximum value was observed at site I during spring (3.91±0.11 mg/L) while the minimum value was at the same site during winter (1.29±0.03 mg/L). The values obtained during summer and autumn may be due to the presence of dead microorganisms at the bottom of water layer where they are not able to perform aerobic biochemical oxidation of wastes especially in low oxygen concentration[21]. On the other hand, in winter season, the biochemical oxygen demand values were low which may be due to lesser quantity of organic material in the form of solids and decreased microbial population[22]. Similar observations have been made by Verma [23].

Chemical oxygen demand values ranged from 4.04±0.11 to 5.08±0.14, 10.08±0.06 to 11.27±0.07, 10.14±0.09 to 10.25±0.06 and 6.20±0.04 to 7.51±0.05 mg/L during autumn, winter, spring and summer, respectively, Table 2. The maximum value at site II during winter was 11.27±0.07 mg/L while the minimum value at site II during autumn was 4.04±0.11 mg/L. COD values showed descending order that could be arranged as winter>spring>summer>autumn. Egyptian ministry of health[24] has set maximum limits of COD in Nile water from Southern parts until its branches from 10 to 15 mg/L**.** Good quality water contain among other things not more than 12 mg/L of organic matter expressed as oxygen consumed by permanganate[25]. Sherbini et al.[26] reported that COD values were in range 5-25 mg/L along river Nile from Aswan to El-Kanater El-Khyria and 65% of samples were below 10 mg/L.

Table 2 Some physical and chemical parameters for water samples from El-Hawamdia (site I) and Shobra El-Khima (site II) during the year autumn 2014-summer 2015.

Season	Site	Temp ºC	Transparency cm	EC µmohs/cm	pH	DO mg/L	BOD mg/L	COD mg/L
Autumn	**I**	23.06±1.44	90.00±7.91	282.14±2.40*	8.14±0.21	7.86±0.23	3.45±0.09*	5.08±0.14
	II	22.76±1.23	109.00±6.52*	265.42±1.40	8.06±0.21	8.16±0.21	2.53±0.07*	4.04±0.11
Winter	**I**	16.44±1.51	70.00±7.91	320.44±4.77*	8.58±0.19*	10.12±0.26*	1.29±0.03*	10.08±0.06*
	II	16.44±1.33	72.00±13.51	288.32±4.43	8.04±0.24	11.20±0.25*	2.05±0.12*	11.27±0.07*
Spring	**I**	23.98±3.31	50.00±7.91	274.26±2.58*	7.76±0.21	8.90±0.16*	3.91±0.11*	10.25±0.06*
	II	24.14±2.84	41.00±8.94	260.82±3.92*	8.00±0.16	9.08±0.24*	3.05±0.14*	10.14±0.09*
Summer	**I**	35.46±1.91	78.00±10.37	322.46±1.85*	7.86±0.21	7.26±0.21	2.22±0.11	6.20±0.04
	II	35.46±1.84	74.00±6.52	306.26±1.86*	7.58±0.19	7.78±0.19	3.18±0.10*	7.51±0.05

* means p value < 0.05, EC: Electrical conductivity, DO: Dissolved oxygen, BOD: Biological oxygen demand, COD:

Chemical oxygen demand.

Heavy metals

It is reported that, heavy metals occur in the environment both as result of natural process and as pollutants through various pollution sources from human activities. Their concentrations were recorded seasonally in mg/L for the collected water samples.

The maximum value for iron (4.52±0.37mg/L) was observed at site I in the front of the Sugar Cane Factory during autumn, and the lowest value (0.34±0.03 mg/L) was at site II during summer. the lower values of iron were observed during summer as a result of oxidation of Fe^{+2} to Fe^{+3} and precipitates as hydroxide(27).

For Cu, the maximum value (0.33 mg/L) was observed at site II during spring, and the minimum value (0.01 mg/L) was recorded at site I during summer. The copper content during spring may be due to the high evaporation rate under increase of air and water temperature(28) or due to the release of copper from sediments to surrounding water. The maximum value for Zn (0.41±0.01 mg/L) was at site II during autumn, and the minimum value (0.02±0.01 mg/L) was recorded at site II during summer. Zinc concentration increases in winter and it may be attributed to the drought period and the decrease of sorption of zinc with low temperature(29). For Pb the maximum value (0.14±0.01mg/L) was recorded at site I during spring while the minimum value (0.07±0.01mg/L) was at site I during summer. High lead concentrations were recorded during winter and spring season, this may be attributed to the effect of the drought period while low Pb concentration during summer is attributed to the formation of $Fe(OH)_3$ which act as adsorbent(31). Lead is weakly associated with air particles and can be easily dissolved in water(32).

Finally, for Mn the maximum value (0.28±0.03 mg/L) was at site II during autumn and site Iduring spring, and the minimum value (0.04 mg/L) was at site II during summer, Manganese concentration revealed that, higher concentrations were recorded during winter and spring season this may be attributed to the effect of the drought period. However, the low water level and slow motion of water current would facilitate the extraction of manganese from dead aquatic plants in addition to dissolution of manganese sediment and release to water during spring(28). table 3.

According to the Egyptian drinking water quality standards(33) limit and WHO(34), the allowed concentration of Fe, Pb, Mn, and Cu are 0.3, 0.01, 0.1 and 2 mg/L, respectively. From table 3 it is shown that Fe concentration exceeds the allowed limits, Pb, and Mn almost exceed the allowed limits which may cause a negative health effect especially for infants(35). Cu and Zn are in allowed limits.

Table 3 Heavy metals concentration (mg/L) for water samples from El-Hawamdia (site I) and Shobra El-Khima (site II) during the year autumn 2014-summer 2015.

Season	Site	Mn	Fe	Cu	Zn	Pb
Autumn	I	0.10±0.02*	4.52±0.37*	0.03	0.25±0.35	0.10
	II	0.28±0.03*	2.15±0.16*	0.02	0.41±0.01	0.07±0.01
Winter	I	0.11±0.03*	3.65±0.31*	0.02	0.11±0.01	0.12±0.01
	II	0.24±0.04*	2.67±0.47	0.02*	0.34±0.01	0.60±0.45
Spring	I	0.28±0.03*	2.12±0.19*	0.03±0.01*	0.10±0.01*	0.14±0.01
	II	0.10±0.01*	0.78±0.07	0.33*	0.07±0.01*	0.01
Summer	I	0.06	0.46±0.04	0.01*	0.04±0.01	---
	II	0.04	0.34±0.03	0.03	0.02±0.01	0.02*

* means p value < 0.05

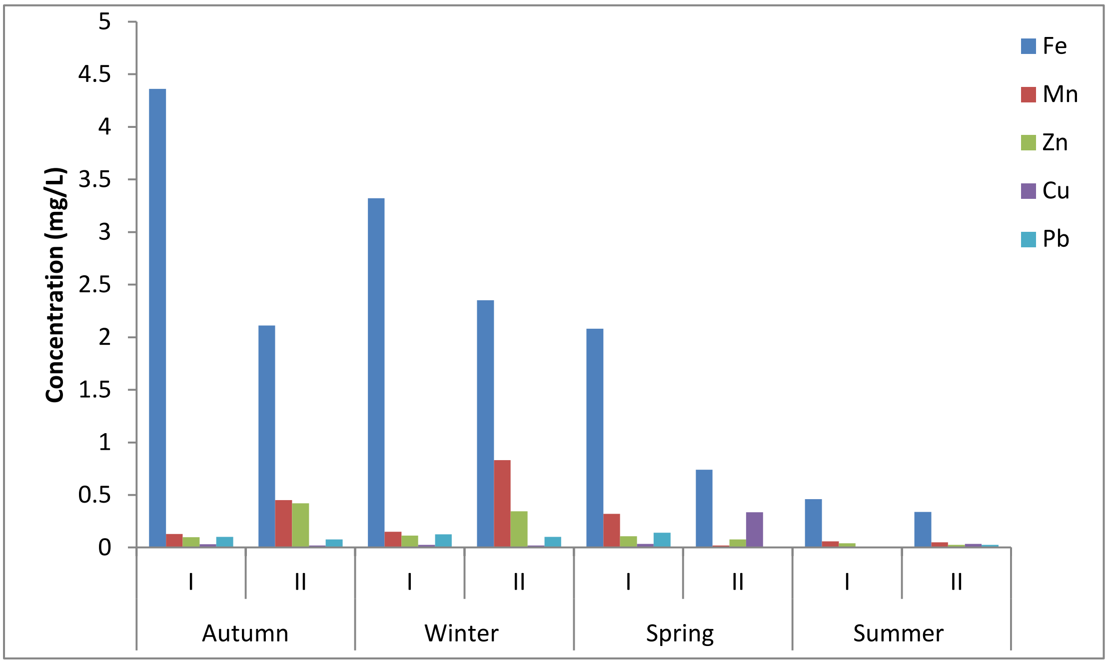

Fig. 2. Heavy metals concentration (mg/L) for water samples from El-Hawamdia (site I) and Shobra El-Khima (site II) during the year autumn 2014-summer 2015.

Water pollution index (PI)

It was calculated for each metal individually (Mn, Fe, Cu, Zn and Pb). According to the results in table 4, our calculations were only for aquatic life, that indicates suffer of sites under consideration from heavy metal contamination. It is seen that, the effect was seriously for Fe, Mn, Cu, Zn, and Pb.

Table 4 Pollution index of the measured metals in El-Hawamdia (site I) and Shobra El-Khima (site II) during the year autumn 2014-summer 2015 water according to guideline levels of aquatic life water

PI value	Site I	Effect	Site II	Effect
For Mn	3.25	Strongly	3.12	Strongly
For Fe	7.30	Seriously	3.95	Strongly
For Cu	14.03	Seriously	129.41	Seriously
For Zn	12.08	Seriously	42.17	Seriously
For Pb	4.70	Strongly	3.43	Strongly
Guideline values: Mn 50 , Fe 300 , Cu 1.300, Zn 5,000 and Pb 15 μg/L				

Conclusion

The present study shows the concentration of heavy metals in the river Nile during the year 2014-2015. From the studied results, it was found that water samples containing Fe, Pb, and Mn concentrations exceed the allowed limits in all of the studied sites, while Cu and Zn are in allowed limits. As a result, the selected region Site I, In front of the Sugar Cane Factory at El-Hawamdia and site II, In the front of electricity station at Shobra El-Khima) showed some hazards on the human health. It is recommended to apply the law 48 (part 60, 61) which is used for protection of aquatic environment of fresh water in Egypt.

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