

Water Pollution by Heavy Metals in The Western Lagoon and its Effect on Timsah Lake and Consequently on Suez Canal

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ABSTRACT

This work is devoted to assessing the sources and pollution levels of nine heavy metals (Fe, Mn, Cu, Ni, Zn, Cr, Co, Pb, and Cd) in Timsah Lake water with respect to its effect on surrounding waters. Heavy metals were measured by applying solvent extraction to 12 water samples collected, from inshore and offshore stations of Timsah Lake including the western lagoon and Suez Canal. The environmental parameter for the study area was also, measured. From the results, it appeared that heavy metals in water follow the order: Fe > Zn > Pb > Cu > Mn > Co > Cr > Cd > Ni and their concentrations are significantly high in the north and western edges of the lake more than the middle. Stations 5, 7, 9, and 12 (at the bridge near the western lagoon) had the highest levels of most studied metals, these stations characterized by a huge amount of agriculture, the domestic, and industrial pollutant. While Fe and Cu had their highest levels (15.34 and 145µg/L) at station 6 in fronts of Abo Halos drain and Villas and cabins including Tourism activities. The lowest levels of studied metals were in stations that lie away from the sources of pollution and its effects.

Keywords: Heavy metals, Suez Canal, Timsah Lake, water pollution, western lagoon.



INTRODUCTION

Timsah Lake is one of the most important lakes in Egypt. The lake plays an important role in most of the activities in Ismailia City, such as tourism and navigation and considered a source of the important local fishery (Kaiser *et al.*, 2009). It receives high salinity water from the Suez Canal mainly from the South (El-Serehy and Sleight, 1992). It also receives fresh water from the Ismailia Canal, El-Forsan drain from the North and from drains such as Al-Mahasama drain and Abu Jamous drain via western Lagoon (El-Sherbiny *et al.*, 2011). The increasing human activities on the banks of the lake affected negatively, especially along the southern shores. The dredging operations of the Suez Canal as well contributed to the deterioration of the lake's ecosystem and led to the demolition of fisheries (Abdel Sabour *et al.*, 1998). The rapid growth of population activities in recent years around Timsah Lake such as shipbuilding and maintenance, municipal wastewater dumping off and agricultural drainage loading in the lake have greatly increased the eutrophication and pollution status of the lake (Kaiser *et al.*, 2009). All of the previously mentioned conditions threatened the health of the lake; interfere with its recreational purpose, lake richness and diversity of indigenous fish, phytoplankton, zooplankton, plants and animal population (Kamel, 2013 and Mehanna *et al.*, 2016).

At least, there are three major sources responsible for the heavy metal contamination in Timsah Lake (area of interest) namely, agricultural drainage, industrial drainage and municipal (sewage) effluent. In the last three decades, the aquatic ecosystem of Timsah Lake recorded hazardous levels of a pollutant of various forms, heavy metals concentrations in the water, sediments and marine fauna (Abd El-Azim, 2002; Gabr and Gab-Alla, 2008). Heavy metals considered the most hazardous

contaminant in the environment because of their persistence in water, sediments, and bio-magnifications in tissues of the living organisms (Dembitsky, 2003). Overpopulation, industrialization, rapid urbanization, overuse of pesticides, detergent and agricultural chemicals, liquid and solid waste products and discharge of municipal wastes resulted in heavy metal pollution of natural water resources (Baruah *et al.*, 2011).

Mehanna *et al.*, (2016) mentioned that the fish production of Timsah Lake declined in the recent years to its half. This is not only for overfishing and illegal mesh sizes but also for severe pollution and the great fluctuation in salinity and temperature. Western Lagoon has not received any attention, although it is considered the entrance to Timsah Lake from the western side and the main cause of pollution in the Lake. Moreover, the specific water quality of the lake affects the essential role of the Suez Canal as a major waterway on the migration of the organisms (Lessipsian and Antilessipsian) migration (Kamel, 2013). According to the high loads of pollutants which reached the western lagoon from several sources, and mobilized at Lake Timsah and thus to the Suez Canal, which would negatively impact on them, so it became necessary to study the environment of this region and variables which have undergone, including the marine environment of water, for visualizing and the extent of its impact on the surrounding environment of Lake Timsah and try to find the appropriate solutions to the problems of pollution.

The main objectives of this study are: to determine the concentration of heavy metals in the water, of the western lagoon of Timsah Lake to assess a baseline data on the current pollution status of the lagoon and its effect on Timsah Lake and consequently on Suez Canal. In this respect, the present study demonstrates qualitative investigations of nine heavy metals, Fe, Mn, Cu, Ni, Zn, Cr, Co, Pb, and Cd, in water samples over

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four consecutive seasons and studies some environmental parameter for the study area.

MATERIALS AND METHODS

Study Area

Timsah Lake is a small and shallow lake, lies on the Suez Canal at mid-way between Port Said and Suez. It lies between latitude 30° 32' and 30° 36' N and longitude 32° 16' and 32° 21' E (Saad El-Din, 2013). The region divided into three basins: Timsah Lake, the western lagoon and Suez Canal pathway (Fig.1). The average

depth values for the entire Timsah Lake ranging from 4 to 10 m. In the western lagoon and southwestern part of the lake, the water depth is shallower and ranging from 2.5 to 4 m. It is a land-engulfed embayment with a total area of 15 km² (El-Sharkawy, 2012) and containing about 34 x10⁶ m³ of water (ETPS, 1995). Several water resources enrich the lake with different kinds of water *viz* saline water from the Suez Canal, freshwater from Ismailia Sweet freshwater canal, partially treated wastewater through several agricultural, industrial, domestic sewage drains such as Al-Mahsama Drain, Al-Wadi Drain, Al-Bahtimi Drain, Al-Dabiaia Drain and Al-forsan Drain (EEAA, 2010, 2011).

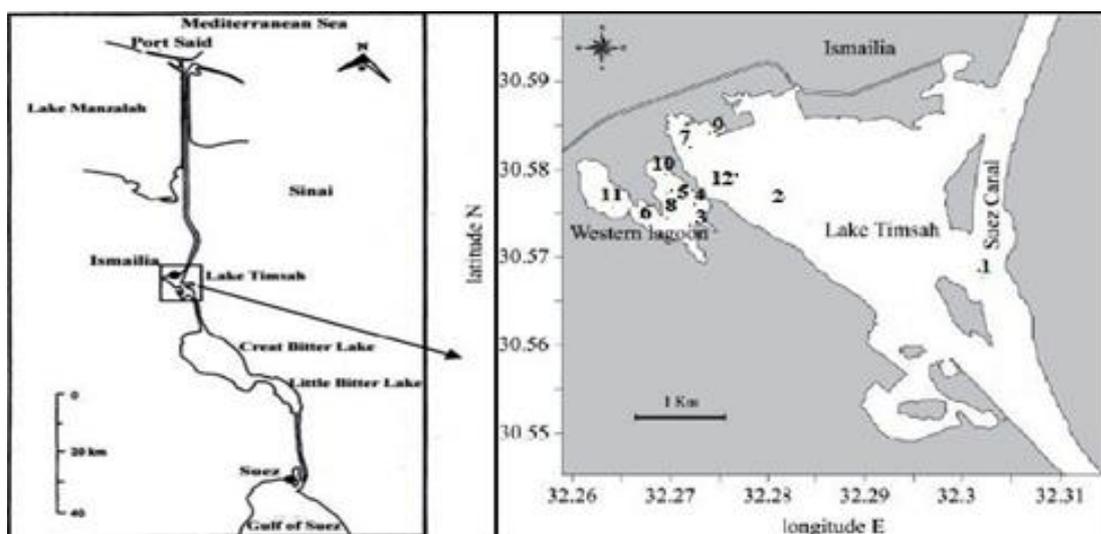


Figure (1): Map of Timsah Lake and location of sampling stations.

Sampling and Environmental parameters measurement

Samples of surface water were collected seasonally from 12 stations (Fig.1), representing different conditions in the western lagoon (9 stations) and Timsah Lake (3 stations) starting from spring 2014 to winter 2015. Water temperature was measured by using a simple pocket thermometer graduated to 0.1°C. pH value was measured in situ using a portable pH meter model Orion 210, in addition to measuring water salinity in the field. Water transparency was estimated using white enameled Secchi disc according to (Baruah and Barthakur, 1997). Water samples were analyzed for total dissolved solids (T.D.S.) according to standard methods (APHA, 1992).

Water analyses

Samples of water were collected from a depth of 30 cm using Nansen bottles then stored in acid-washed polyethylene bottles for analysis. All the precautions recommended by (Kremling, 1983) to minimize risks of sample contamination were followed during the collection and treatment of samples. The blank samples were carried through all stages of the sample preparation and measurement steps. Solvent extraction was utilized using ammonium pyrrolidone dithiocarbamate (APDC) and

methyl isobutyl ketone (MIBK). Water samples were pre-concentrated with APDC-MIBK extraction procedure according to the standard methods (APHA, 1989). Heavy metals in the obtained solution were measured using the Flame Atomic Absorption Spectrophotometer (Atomic absorption spectrometer AAS: Perkin Elmer A Analyst 100).

RESULTS

Environmental parameters

A spatial variability of different water quality parameters are shown in table (1). From that table, it is clear that water temperature did not deviate from the normal fluctuations of the Egyptian waters (26.4-32.7°C). pH of Timsah Lake and western lagoon that lies in the alkaline side in all the studied stations, the lowest pH value was 7.33 recorded in station (5) (at Mahsama drain). The highest pH value was 9.20 in station (12) (at the bridge in the western lagoon). Variation in salinity appeared to be the key factor to all changes in the lake's water quality. Assessment of water from different stations in Timsah Lake showed salinity, a minimum of (1.50 ‰) exists in the western site, and a maximum of (33.7 ‰) was recorded in the eastern site in Timsah Lake.

Values of total dissolved solids (T.D.S.) that was rec-

orded near the south western side are very high. The lake is considered a low transparent water body; transparency increased gradually eastwards and recorded a fluctuation between 0.20 and 0.95 m.

Levels of heavy metals in the water of the study area

Table and figure (2) illustrated that the heavy metals in water follows the order: Fe > Zn > Pb > Cu > Mn > Co > Cr > Cd > Ni. Iron (Fe) in water showed high concentrations, but Cd and Ni estimated the lowest values. Generally, the concentrations of measured heavy metals in the water were not comparable in these stations.

Spatial variations

From table (2), the mean concentration of iron (Fe) ranged from 7.181µg/L at station (5) to 15.34µg/L at station (6).

The maximum concentration of Manganese (Mn) is

1.044µg/L and recorded at station (12) while the minimum value is 0.294µg/L and recorded at station (8). Cop-per (Cu) concentration ranged from 0.815µg/L at station 11 to 1.447 µg/L and 1.451µg/L at stations (1) and (6) respectively. The concentration of Nickel (Ni) ranged from 0.101µg/L at station 10 to 0.260 µg/L at station (8). Zinc (Zn) attended its minimum value (1.143µg/L) at station (8) and its highest value (2.834µg/L) at station (12) Station (12) has the highest concentration of Chromium (Cr) (0.441 µg/L) while its minimum level was 0.177 µg/L and recorded at station (3). Cobalt (Co) has its maximum concentration (0.541 µg/L) at station (12) while its minimum one (0.377 µg/L) is at stations (5) and (8). The concentration of lead (Pb) ranged from 0.915µg/L at station (1) to 2.629µg/L at station (7) in Abo Gamos drain. Finally, Cadmium (Cd) concentration ranged from 0.235µg/L at station (5) to 0.319µg/L at station (12).

Table (1): Physicochemical parameters measured in the different stations in the western lagoon and Timsah Lake in the period from spring 2014 to winter 2015.

Station no.	Transparency (cm)	Temperature (°c)	pH	Salinity (‰)	T.D.S.	Depth (m)
1	95	28.1	8.45	28.87	15.70	2.50
2	70	27.0	8.33	33.69	19.96	6.00
3	40	26.4	7.57	3.00	12.01	1.00
4	30	27.4	8.14	1.50	510.0	0.50
5	20	30.5	7.33	1.55	620.0	1.00
6	30	32.7	7.90	1.66	670.0	1.00
7	20	30.0	8.16	1.95	980.0	0.50
8	25	30.9	8.31	1.65	645.0	1.50
9	27	30.3	8.24	1.57	610.0	1.00
10	20	31.1	9.00	1.60	640.0	0.50
11	20	30.8	9.18	1.61	665.0	0.55
12	25	31.1	9.20	1.60	666.0	0.75

*TDS= Total dissolved solids.

Table (2): Annual mean value of heavy metals concentration (µg/L) in different stations of the studied area in the period from spring 2014 to winter 2015.

Station no.	Fe	Mn	Cu	Ni	Zn	Cr	Co	Pb	Cd
1	10.64	0.567	1.447	0.193	1.889	0.323	0.447	0.915	0.240
2	11.78	0.425	0.986	0.146	1.486	0.236	0.387	1.304	0.267
3	11.74	0.367	1.045	0.121	1.873	0.177	0.379	1.758	0.281
4	9.605	0.367	0.979	0.150	1.472	0.255	0.389	1.273	0.265
5	7.181	0.481	1.066	0.118	1.721	0.259	0.377	1.161	0.235
6	15.34	0.323	1.451	0.129	1.655	0.387	0.408	1.269	0.268
7	11.84	0.326	0.911	0.200	1.790	0.259	0.407	2.629	0.240
8	9.635	0.294	0.986	0.260	1.143	0.283	0.377	1.027	0.241
9	12.33	0.422	1.247	0.114	1.265	0.248	0.459	1.355	0.273
10	8.688	0.377	1.091	0.101	1.475	0.338	0.456	1.527	0.277
11	11.96	0.668	0.815	0.235	2.689	0.274	0.481	1.575	0.290
12	12.66	1.044	0.875	0.191	2.834	0.441	0.541	1.101	0.319
Mean	11.12	0.472	1.075	0.163	1.774	0.290	0.426	1.408	0.266

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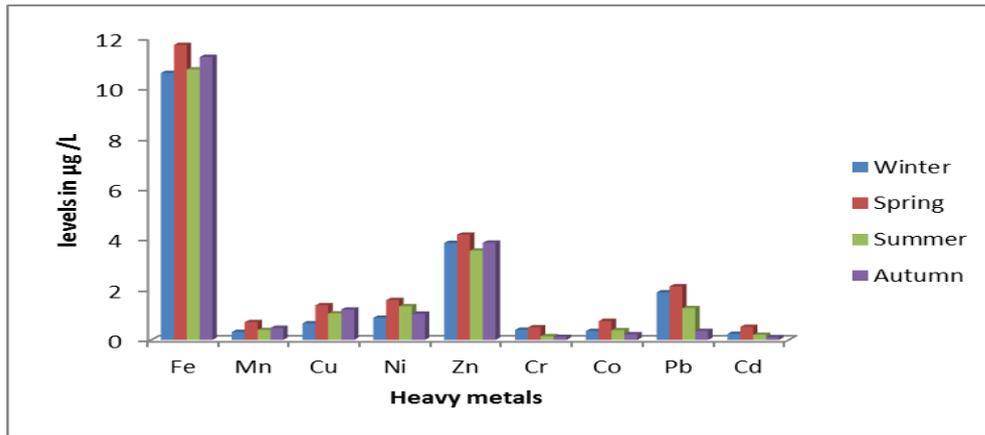


Figure (3): Seasonal variations of the mean values of heavy metals concentration in the study area in the period from spring 2014 to winter 2015.

The results revealed that heavy metals concentration is significantly higher in the northern and western edges of the lake than in the middle. Stations (5, 7, 9 and 12) at the western lagoon recorded the highest levels of almost all of the studied metals.

Seasonal variations

Figure (3) shows that in winter the highest mean value of Zn (3.856 µg/L) and the lowest mean values of Fe, Mn, Cu, and Ni were recorded. Spring has the highest mean concentration values for the most studied metals. The lowest mean value of Zn is 0.858 µg/L was recorded in summer. The highest mean value of Ni (0.182 µg/L) and the lowest mean values of Cr, Co, Pb, and Cd were found in autumn.

DISCUSSION

Environmental parameters

pH of Timsah Lake and western lagoon lies in the alkaline side in all the studied stations, the lowest pH value was recorded in station (5) (affected by Mahsama drain) while the highest pH value in station (12) (at the bridge in the western lagoon). Variation in salinity appeared to be the key factor to all changes in the lake's water quality. The lowest salinity (1.50 ‰) exists in the western site due to freshwater discharged from sewage treatment systems, untreated source and nonpoint source runoff (EL-Mahsama drain and Abu Gamous drain pours in), whereas the highest salinity was recorded in the eastern site in Timsah lake where this site receives sewage water from Covered drain and small amount of freshwater from the Ismailia Canal these results nearly agreed with those reported by (Mourad, 1996) and (Eissa *et al.*, 2008).

Values of total dissolved solids (T.D.S.) that was recorded near the south western side are very high due to the outfall of domestic and industrial wastewater. The average depth values for the entire Timsah Lake range from 4 to 10 m except in the western lagoon and south-western part of the lake, where the water depth is shallower and ranges from 0.5 to 1 m. Thus the western lag-

oon and south-western part of Lake Timsah (shallow depths) represent good environments for aquatic macro-invertebrates to exist (Saad El-Din *et al.*, 2013). The lake is considered a low transparent water body, due to the huge pollution loads (El-Sherbiny *et al.*, 2011), transparency increased gradually eastwards.

Heavy metal contents in water samples

The variation of metal concentrations in the water collected from 12 main locations studied in Timsah Lake and western lagoon depends on the amount and the type of the effluent drained in the study area (Abdel-Azim, 2002 and Abd El Samie *et al.*, 2008). This agreed with (Hamed and Emara, 2006; Gabr and Gab-Alla, 2008), who studied the heavy metal concentration in the Red Sea and Timsah Lake and found that Fe reached the maximum value in water.

Spatial variations

From the above results, it is apparent that heavy metals concentrations are significantly higher in the northern and western edges of the lake than in the middle. Stations (5, 7, 9 and 12) at the western lagoon recorded the highest levels of almost all of the studied metals. These stations characterized by receiving a massive amount from agriculture, domestic and industrial pollutant. Except for Cu at station (1), recorded the lowest level of studied metals at Timsah Lake stations, which lies away from the sources of pollution and their effects. For Cu, station (1) is located in the El-Taoun Zone, where the Arab Contractors Company is located so this might be attributed to the construction and repairing of ships and their pollutants in this area beside the antifouling paints and the activities of fishermen there (Abd El Samie *et al.*, 2008). The main reason for high metal levels is attributed to discharge of untreated wastes from drainage (mainly sewage) and agriculture effluents at the western lagoon. Additionally, the effect of Ismailia canal, shipyard of the Suez Canal and sewage discharge from Ismailia city and other small villages restricted at these stations (Abdel Sabour *et al.*, 1998; Abd El-Azim, 2002 and Donia, 2011).

Seasonal variations

Seasonally, from the results, except Ni and Zn, which had their highest level at autumn and winter respectively, all studied metals had their highest annual mean at spring. It appears that seasonal variation was not only affected by changes in temperature or physical parameters but strongly affected by seasonal variation of human activities and sources of pollution to the western lagoon and Timsah Lake (Abd El-Azim, 2002).

Comparing the previous studies of Timsah Lake water, (Saad El-Din and Gad El-Hak, 2017), found lower metal concentrations; (El-Shenawy, 2004) obtained lower Cu, Fe, and Mn levels but higher Ni levels; (Ibrahim and Abu El-Regal, 2014) recorded higher values of Cr; and (Saad El-Din *et al.*, 2014) found a higher value of Co and Cr respectively than in the present study.

CONCLUSION

Western lagoon located in the west of Timsah Lake and connected to it through a canal under the bridge. It's characterized by its low salinity due to the abundance of fresh water. Western lagoon considered the main source of pollution of the Timsah Lake as it dumps large amounts of sewage, agricultural and industrial pollutants that are mostly not fully treated. Most of these pollutants, especially heavy metals transferred to Timsah Lake and mixed with its water resulting in pollution of the lake.

Timsah Lake is a small semi-closed lake affected by these pollutants that have a dangerous effect on its environment. Timsah Lake is the main source of fish and other marine organisms for the province of Ismailia. Accordingly, discharging effluents from different sources to the western lagoon and consequently, Timsah Lake without adequate treatment is the major source of contamination which concentrated along the shallow boundaries of the lake which results of water stratification, slow water current, and low dilution rate, all these can affect the lake and Suez Canal environment.

Finally, it is necessary to know the sources and types of pollution and to purify and treat it before reaching the lake to keep it clean as it has a great importance in the province of Ismailia in terms of tourism and fish wealth.

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تلوث المياه بالمعادن الثقيلة في المصرف الغربي وتأثيرها على بحيرة التمساح وبالتالي على قناة السويس

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المخلص العربي

اهتمت هذه الدراسة بتقييم المصادر ومستوى التلوث وذلك بقياس تسعة معادن ثقيلة (الحديد، المنغنيز، النحاس، النيكل، الزنك، الكروم، الكربوهيدرات، الكاديوم) في مياه البحيرة، وما يتعقبه من تأثير على المياه المحيطة. تم جمع المعادن الثقيلة من اثني عشر محطة بشكل موسمي بداية من ربيع ٢٠١٤ إلى شتاء ٢٠١٥. تم جمع العينات من المحطات البرية والبحرية من بحيرة التمساح بما في ذلك البحيرة الغربية وقناة السويس. من النتائج، يتضح أن المعادن الثقيلة في الماء تتبع الترتيب: حديد < زنك < رصاص < نحاس < منجنيز < كوبلت < كاديوم < نيكل. تركيز المعادن الثقيلة أعلى في الجوانب الشمالية والغربية للبحيرة من الوسط. سجلت المحطات ٥ و٧ و٩ و١٢ في البحيرة الغربية أعلى مستويات لمعظم المعادن التي تمت دراستها، وهذه المحطات تتميز بكميات عالية جداً من الملوثات الناجمة عن النفايات الزراعية والصناعية. سجل الحديد والنحاس أعلى مستوياتهما في المحطة رقم ٦ في منطقة مصرف المحسمة. أما أدنى مستويات الفلزات المدروسة سجلت في بحيرة التمساح والتي تقع بعيداً عن مصادر التلوث وآثاره.