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Heavy Metals Bioaccumulation by the Green Alga Cladophora *herpestica* in Lake Mariut, Alexandria, Egypt

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Abstract

The present study was carried out to evaluate the concentrations of some trace metals in the water of Lake Mariut and their accumulation in tissues of the green alga (Cladophora *herpestica*). Sampling of water and algae were carried out at four different sites throughout the period from July to Sept 2017. The water of the collected samples was mostly alkaline (7.91-8.51) and showed a wide range of variation in Biological Oxygen Demand "BOD" (5.11-18.92 mg L^{-1}), Chemical Oxygen Demand "COD" (21.36 - 81.36 mg L^{-1}) and Electric conductance "EC" (918 -1827 µS Cm^{-1}) Concentrations of heavy metals in algae were higher compared to their levels in water samples. The concentrations of the selected trace metals were ranged between 11.19 µg L^{-1} for Pb in water samples collected from site 1 to 271.36 mg Kg^{-1} for Cd in algae collected from site 3. The concentrations of trace metals exceeded the Egyptian Standards limits. The results showed that the water quality is unacceptable and should be improved for human consumption. Moreover, the study indicated that the high concentrations of trace metals in algal tissues demonstrated the utility of using Cladophora *herpestica* as a biomonitor of heavy metal contamination and bioavailability. The study included some recommendations aiming at improving both water quality and ecosystem of the lake.

Keywords: Trace metals; Lake Mariut; Bioaccumulation; Cladophora *herpestica*

Introduction

Freshwater makes up about 3% of earth's water and is the source of virtually all drinking waters. Most of this water comes from reservoirs, rivers, streams and lakes; and these sources are vulnerable to pollution [1].

Rapid urbanization and industrialization have negative implications for water quality, where the industrial effluents directly discharge into the rivers without any consideration of the environment [2].

Algae are known to be good indicators of the extent of pollution in aquatic Ecosystems [3,4]. They have s biological characteristics making them a very good "early warning system" for pollution [1,4,5].

It is necessary to study the freshwater algal flora as part of the biological monitoring and using them as indicators of water quality [5,6].

Most of the industries like textiles, pharmaceuticals, tanneries, paper mills and oil refineries are situated near the lake and discharge their effluents directly into it. Besides, huge quantities of solid waste, varieties of chemical fertilizers and residues of pesticides, petroleum products, launches, cargoes, boats, untreated sewage etc. regularly get dumped into the lake [2,4,5]. These pollutants hinder the growth of aquatic organisms [7]. Thus, aquatic diversity is now in threatened condition. The primary productivity of the aquatic ecosystem is now adversely affected by various anthropogenic activities and dumping of industrial effluents and untreated sewage into the lake.

The current anthropogenic metal emissions have resulted in increasing the concentrations of water toxic elements to a hazardous level [8]. The most important source of atmospheric lead is the combustion of fuel. Atmospheric deposition of heavy metal aerosols in the study area may originate from closed industrial activities such as waste incineration, heating plants and crude oil processing [8-10].

Heavy metal pollution of lakes is one of the most dangerous problems in aquatic ecosystems and it is approaching thresholds of toxicity for adverse effects of toxic metals [8,9].

Green algae (*Chlorophyta*) are responsible for most of the primary productivity in some water bodies through photosynthesis. In the absence of photosynthesis, the metabolic process consumes oxygen, causing oxygen depletion in the aquatic system.

Algae are used in waste water treatment due their affinity for heavy metal cations. Cladophora *sp.* is generally considered as the most proper bioindicator of heavy metals in aquatic bodies [8,9].

The present study was carried out to investigate the water quality of Lake Mariut (pH, BOD, COD and EC) and to investigate the bioaccumulation of toxic trace metals (Cr, Cd ,Ni, V and Pb) by the green algae Cladophora *herpestica*, as well as the possibility of using this alga as a bio indicator.

Materials and Methods

The study area

Lake Maruit (31° 10′ N and longitude 29° 55′ E) is a small brackish water ecosystem in the northwestern corner of the Nile Delta of Egypt

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(Figure 1). Its maximum length is about 8 km and the depth of water fluctuates between 60 and 130 cm, with an average of 100 cm.

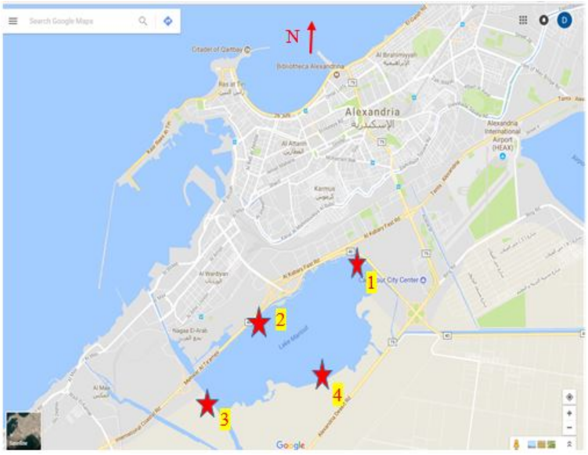

Figure 1: A map showing the sampling site from Lake Mariut.

This lake suffers from draining of large amounts of municipal and industrial wastewaters.

Water and algal samples were collected from four different sites throughout the period from July to Sept 2017. Sampling sites were located at the northern, western, southern and eastern regions of the lake to cover all points of discharging municipal and industrial wastes.

Algae (Cladophora *herpestica*) were collected in plastic bags containing seawater and transported immediately to the laboratory for analysis [3].

Water quality

The pH of water samples was measured on spot using calibrated digital multi-meter (HACH, 51910), while Electric conductance (EC) was measured at 25°C in µS cm^{-1}, using an electric conductivity meter (HANNA, HI 8033). Chemical Oxygen Demand (COD) was measured by closed reflux colorimetric method using Colorimeter (HACH, DR/890), while Biological Oxygen Demand (BOD) was done by 5-days incubation, 20°C method [1]

Extraction and elemental analysis

Air-dried algal samples were wet-digested in a mixture of HNO_3 and $HClO_4$ (4:1, v/v), and the concentrations of Cr, Cd, Ni, V and Pb were analyzed by inductively coupled plasma optical emission spectrometry (ICP-OES) using an IRIS Intrepid II XSP instrument. All chemicals used were of analytical reagent grade [4]. A six point calibration procedure was applied with multi-element calibration solution (Merck ICP multi-element standard solution IV) [11].

Bioaccumulation coefficients in correlated algae / waste water environments have been calculated to qualify the toxic elements accumulation efficiency of Cladophora *herpestica* by dividing metal content in algal biomass over metal content in Lake water.

Results and Discussions

Table 1 shows the parameters of water quality in the lake. pH of water was mostly alkaline (7.91–8.51).

Biochemical oxygen demand (BOD) is a measure of the oxygen in the water that is required by the aerobic organisms. High BOD levels indicate lower in dissolved oxygen (DO), because the oxygen that is available in the water is being consumed by the bacteria leading to the inability of fish and other aquatic organisms to survive in the water bodies [12,13]. The values of BOD of the collected samples were 5.11, 18.92, 11.65 and 8.92 mg L^{-1} for sites 1, 2, 3 and 4 respectively (Table 1). The permissible limits of BOD 0.2, 3.0, 6.0 and 10.0 mg L^{-1} for drinking water, recreation, fish culture and irrigation, respectively [1].

Electric conductivity (EC) showed a wide variation from 918 µS cm^{-1} to 1827 µS cm^{-1}. Although it is not a human or aquatic health concern; but it can serve as an indicator of other water quality parameters. The acceptable range of EC for irrigation, recreational and aquaculture water are 750, 500 and 800-1000 µS cm^{-1}, respectively [1]. Therefore EC of water exceeded permissible levels.

Sampling site	pH	BOD (mg L^{-1})	COD (mg L^{-1})	EC (µS Cm^{-1})
1	7.91	5.11	21.36	918
2	8.51	18.92	29.36	1827
3	7.95	11.65	34.62	1517
4	8.01	8.92	81.36	1227

Table 1: Physiochemical parameters of water quality at the selected sampling sites.

Table 2 shows the concentrations of trace metals in water samples and algal tissues collected from the different sampling sites in the lake.

The northern site (site 1) had the lowest concentrations of Cr, Cd, Ni, V and Pb (32.17, 26.11, 98.31, 147.31 and 11.67 µg L^{-1}, respectively), while the southern site (site 3) had the highest concentrations of these metals (88.74, 48.21, 181.14, 101.16 and 23.26 µg L^{-1}, respectively). This was reflected in higher concentrations of these metals in algal tissues collected from these two sites. The other two sites had intermediate concentrations.

The Southern site (3) is located near the industrial zone and most of by sewage and other inputs are discharged there. Municipal and domestic wastes as well as effluents from industries; slaughterhouses are dumped in the lake daily. Large volumes of wastes, produced daily from highly populated urban areas around the lake and, are carried by drainage systems and finally find their way into the lake [14].

Cladophora *herpestica* abundantly growing on the surface of the Mariut Lake accumulates heavy metals from the aquatic environments. The next goal of our study was to investigate the heavy metal occurrence in both algae and water environment.

Element	Sampling site 1		Sampling site 2		Sampling site 3		Sampling site 4	
	Water	Algae	Water	Algae	Water	Algae	Water	Algae
Cr	32.17	56.29	38.18	54.45	88.74	141.78	41.21	60.32
Cd	26.11	48.54	30.82	51.67	48.21	73.87	32.42	49.87
Ni	98.31	143.67	101.87	150.13	181.14	271.37	127.29	201.98
V	147.31	210.81	167.11	290.37	101.16	259.38	187.37	218.83
Pb	11.67	21.11	11.19	18.76	23.26	33.38	17.87	26.48

Table 2: Concentrations of different elements in water samples (μg L^{-1}) and algal tissues (mg Kg^{-1}) at the four different sampling sites (n=15).

Table 3 shows the calculated bioaccumulation coefficients in order to compare heavy metal contents in the algal biomass at the different sampling sites [13,14].

The magnitude of Cr, Cd and Pb metal bioaccumulation was found to be higher (175, 186 and 181 times, respectively) in samples collected from northern site (site 1) when compared with metals collected from algal tissues from different sites (Table 3). This high accumulative ability indicates that bioavailability of these metals at this site; especially it has the lowest concentrations of thee metals in its water samples. This is in agreement with the results of Aydoğan et al. [14] who reported bioaccumulation of Pb, Ni, Cu, and Cr heavy metals in two bryophyte species in Turkey, at similar levels of the present study.

Algal tissues collected from southern site (site 3) had the highest concentrations of V (256 times) when compared to other three sites (143, 174 and 117 times at sites 1,2 and 4, respectively), while it has the lowest concentrations of Cd, and Pb.

There was no significant (p=0.05) differences in bioaccumulation of Pb in tissues collected from different sources indicating lower concentration and water and consequently, lower bioavailability. These variations in bioaccumulation factors may be due to dilution of the lake towards the north [4-6].

Element	Site 1	Site 2	Site 3	Site 4
Cr	175	143	160	146
Cd	186	168	153	154
Ni	146	147	150	159
V	143	174	256	117
Pb	181	168	143	148

Table 3: Bioaccumulation coefficients in algae.

Water is the most valuable and vital resource for sustenance of life. Unfortunately, agricultural, domestic and industrial wastes dumped into Lake Mariut over the years, which caused its deterioration and lower water quality. The results also showed a poor water quality.

The current waste management in Egypt is based on independent, self-solid waste incineration, including combustion of the bank-discharged algae [2]. Most the produced hazardous waste (sewage sludge, petroleum contaminated soil and concrete material) has been incinerated and dumped in the lake. This incineration causes air pollution and worsens the quality of the Ecosystem. However, some alternative waste management scenarios, e.g. composting, especially for sludge and algae, have been recommended for the future, to relieve the present incineration of solid waste, which does not satisfy the updated criteria of air pollution control and investment costs for the construction of new incinerators are extremely high.

Cladophora *herpestica* is dominating and abundantly growing on the surface of the Maruit Lake, it accumulates residual nutrients and heavy metals from both the aquatic and atmospheric environment [15].

Conclusion

The high bioaccumulation abilities of Cladophora algae for selected metals have been confirmed. We suggest composting, especially for sludge and algae as an alternative waste management scenario; especially the algal biomass is recommended on the basis of the analyzed and acceptable toxic metal content for compost processing.

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