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Heavy Metal Pollution and Biomonitoring Plants in Lake Manzala, Egypt

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Abstract: In this study, the pollution levels and the toxicity status were estimated regarding four heavy metals (Zn, Pb, Cd and Hg) thought to be among the major contaminants in the environment of Lake Manzala. Our target was to define and utilize certain plant species, from the lake's vegetation, as biomonitors, in comparison with the sediments as abiotic monitor for heavy metal pollution. The native wild plants (passive biomonitors) were represented by eight species (*Atriplex portulacoides, Zygophyllum album, Typha domingensis Juncus rigidus, Cyperus laevigatus, Arthrocnemum macrostachyum, Salsola sp.* and *Phragmites australis*). The introduced plants (active biomonitors) were represented by two crop-species (*Trifolium alexandrinum* and *Raphanus sativa*) grown and irrigated by polluted water at some islands in the southern sector of LM. Based on the concentration and toxicity status, induced in the lake's vegetation and sediments, the four metals are arranged in the following decreasing order: Hg > Zn > Pb > Cd. Compared with the standard normal and critical toxicity ranges in plants and soils, the detected values of Zn, Pb and Cd were within the critical ranges. However, Hg showed the highest values and alarming toxicity levels and it is considered as one of the most hazardous pollutants in Lake Manzala. The overall evaluation of the tested metals showed that their ratios were as much as 2.5 – 5 times higher in active monitors than in passive ones and 2 times than in sediments. They were also 2 times higher in sediments than in passive monitors. The monitoring materials are arranged in a decreasing order, based on their efficiency for accumulating heavy metals as follows: Introduced (active) monitors > Sediments > Native (passive) monitors. Certain species are also proposed as biomonitors (and/or biofilters) for the studied heavy metal pollutants. The results showed that there is a significant difference between the accumulation rate of some metals in different plant organs (e.g. Zn, Hg) since they showed more tendency for accumulation in root more than shoot systems. Also, there is a high positive correlation between combinations of different metal pairs in either plant's root or shoot system. It is evident that while the degree of metal pollution in the lake increased southwards, the values of water-quality parameters (e.g. dissolved oxygen %, salinity and pH-value) increased northwards.

Key words: Biomonitors, biofilters, pollution, toxicity, heavy metals, aquatic ecosystems

Introduction

In 1991 the National Conference on Lake Manzala environment was held at Port Said City, Egypt. During that conference, scientists and officials highlighted and discussed the pollution problems which dramatically reduced the fish productivity and they recommended the essential need to combat pollution hazard in the lake. Later on, we started a research program on LM, funded by the Suez Canal University, which resulted in a detailed unpublished report (Ramadan and Mekki, 1996) and a concise version of it (in Arabic), deposited at Port Said Governorate and three publications (i.e. Mekki, 1996; Ramadan, 2002.

Previous studies on pollution aspects in LM are e.g. Bishai and Yossef (1977); Shaheen and Youssef (1978), Anonymous (1982), Abdel Moati (1985), Abdel Moati and Dowidar (1988), Khalil (1985, 1990); Salib and Khalil (1986), Youssif (1992), Siegel *et al.* (1994). The toxicity by heavy metals at the level of cyto-genetic components were described (Ramadan and Mekki 1996, unpublished and Mekki, 1996) and as an example of microbiological pollution on LM is Zaki (1994).

Previous studies concerned with the vegetation and flora of LM by Montasir (1937), Anonymous (1982), Ishak and El-Halawany (1989), Zahran *et al.* (1989), Zahran *et al.* (1990). The vegetation structure of LM was investigated by Farag-Alla (2001), while the population dynamics and the multi variate analysis of the lake's vegetation were recently presented by Ramadan (2002).

Biomonitoring, as an applied approach in ecology, has several advantages, the most significant one is based on that sublethal levels of bioaccumulated contaminants within the tissues of organisms, indicate the net amount of pollutants that have been integrated over a period of time (Doust *et al.*, 1994a). Biomonitoring of pollution may be performed in two ways, based on the kind of sampled organisms: I) 'endemic', or native, organisms (passive biomonitoring) and ii) introduced organisms (active biomonitoring) (Chaphekar, 1991).

The aim of the present study was to assess the total pollution loading and the toxicity status induced by four heavy metals (Zn, Pb, Cd and Hg) in native plant species (passive biomonitors) and introduced plant species (active biomonitors), in comparison with soil sediments.

Materials and Methods

Lake Manzala is located in the northeastern quadrant of the Nile Delta between 31°, 00' - 31°, 30' N latitudes and 31° 45' - 32° 22' E longitudes (Fig. 1). Lake Mnazala is not maritime in its origin and formation, but it was created by accumulation of Nilotic water. The average water depth is 1 m and the maximum depth is 3 m, in the old tributaries of the Nile and in Manzala Canal. The lake is the principal source for food fishing and receives effluents of five big governorates from the Nile Delta, namely Ismailia, Port Said, Demietta, Sharkia and Dakahlia (Anonymous, 1982). It includes about 1022 islands, comprising 31,370 acres (ca. 17.6%) of the total area (904,8 km^2). Due to natural factors and human interference considerable changes happened in geomorphology, structure, water characteristics, hydrology and biotic composition of the five Egyptian deltaic lakes, including LM.

Climatic circumstances: The climatic data were collected from five stations covering LM area (Table 1) at Port Said, Damietta, Sirw, Mansoura and Ismailia.

Temperature: Mean daily air temperatures for the five stations ranged from 20.2 °C at Sirw to 22.2 °C at Ismailia. The highest absolute temperatures were recorded in May and June, presumably due to Khamasin winds.

Surface winds: The two inland stations (Mansoura, Ismailia) have north-northeast direction (the most important directions). however, the three coastal stations (Port Said, Damietta and Sirw) tend to show a greater tendency to the northwest direction. Damietta appears to be the most different station with northwest and southwest dominating winds (Table 1).

Evaporation: The mean annual evaporation (Piche = mm/day) within the study area shows a general increase inland except for Port Said (Table 1).

Field work: Several visits were done to the lake, for sampling, during two years (1994, 1995). Plant species were identified according to Täckholm (1974) and updated according to Boulos (1995). Classification and ordination of the species composition of the lake was previously presented, based on habitat types by Ramadan (2002).

Plant sampling: Eight native plant species, from the lake and two introduced (cultivated) species were selected as biomonitors, at the population level for estimating the potential loading and the toxicity status induced by four heavy metals (Kovacks and Podani, 1986; Maltby and Calow 1989; Doust *et al.*, 1994b). Most of species were collected from the most polluted southern sector of the lake. At least three different sites were sampled for each species at random, sorted into shoot and root organs, dried at 70-80°C for 48 h, then grounded and labeled for analysis.

Soil sampling: Ten surficial composite (of three) soil samples were collected at random from bottom sediments and dry islands, then they were air-dried, sieved by 2 mm-sieve and kept for analyses.

Water characters along a transect: Three ecological parameters were measured (*in situ*) for the lake's water, in 48 sequential stations along a transect crossing the lake from the southwest (Mataria town) to the northeast (Manasra village). These parameters were: pH-value, measured by pH-meter model HI 8014 Hanna Inst, dissolved oxygen percentage (DO$_2$%), measured by oxygen meter model 9071, Jenway, England and the electric conductivity (EC, μ-mohs/cm), measured by conductivity meter model HI 8033 Hanna Inst. Salinity was calculated from EC, as total soluble salts (TSS), according to Pipers (1947).

Lab work

Chemical analysis of plant and soil samples: Plant's shoot and root organs and soil samples were chemically analyzed for detection of heavy metals (Zn, Pb, Cd and Hg), using the digestion technique by HNO$_3$. Measurements were done by atomic spectro-photometer, model PYE UNICAM SP9, England. Mean values of duplicate sub-samples of the plant (and soil) samples were considered.

For the soil samples the pH-value, EC (μ-mohs/cm) were measured, in soil extract (obtained from saturated soil paste). Total soluble salts (TSS) of the soils was calculated from EC according to Pipers (1947), while the total CaCO3% content of the soils was estimated by back titration method (Jackson, 1974).

The levels of toxicity were detected in plant and soil samples by comparison against the standard critical concentration ranges (Kabata-Pendias and Pendias 1992), who derived data mainly from Bowen (1979).

Table 1: Average wind speed and annual evaporation in five stations at Lake Manzala

Station	Mean scalar wind speed * (Knots)	Mean annual evaporation (Piche = mm/day)
Port Said	9.3	6.7
Damietta	5.1	4.3
Sirw	4.4	4.3
Mansoura	4.3	4.7
Ismailia	3.5	7.0

* Mean wind speed (Knots), courtesy of Anonymous (1982).

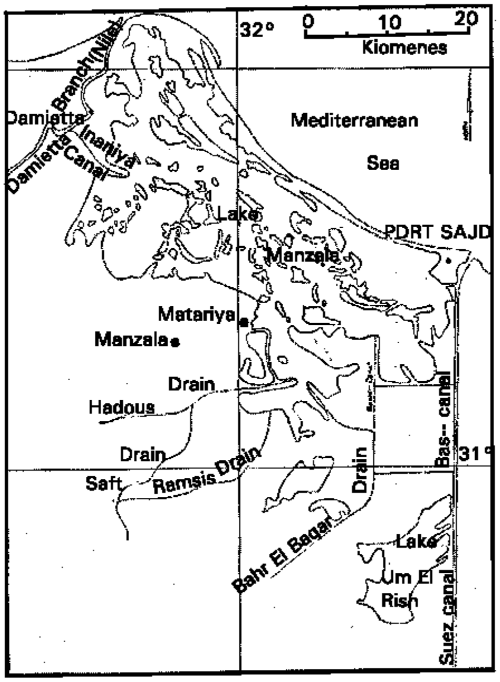


Fig. 1: Location map of Lake Manzala, Egypt

Data analysis: For plant and soil samples the mean values of heavy metals, salinity and $CaCO_3$ were illustrated in diagrams. The unilateral F-test was carried out between heavy metal contents in roots and shoots to check if significant differences exist between the accumulation rate of each metal and different plant organs.

Pearson correlation coefficient analysis was done between metal-pairs in plants to check if differences exist between different metal combinations in either root or shoot system. Also, Pearson correlation coefficient analysis was done between soil variables (pH-value, TSS and $CaCO_3$%) and the soil content of individual heavy metals. The products of the correlation coefficient (r) were evaluated as follows:

0.0–0.3: No correlation; 0.3–0.5: Low correlation;
0.5–0.7: Medium correlation; 0.7–0.9: High correlation;
0.9–1.0: Very high correlation

Results

At least three different sources of contamination are responsible for pollution in LM, namely agricultural, industrial and municipal (sewage) effluents, coming through several drains from the south and north-west directions. Heavy metals are the most dangerous contaminants since they are persistent and accumulate in water, sediments and in tissues of the living organisms, through two mechanisms, namely 'bioconcentration' (uptake from the ambient environment and 'biomagnification' (uptake through the food chain) (Lambou and Williams, 1980; Chaphekar, 1991).

The results of the present study include assessment of four heavy metals (Zn, Pb, Cd and Hg) and evaluation of their toxicity status in tissues of ten plant species (8 wild+2 cultivated species, Figs. 2 and 3). The same assessment was also done in the soil samples (Fig. 4) along with the total soluble salts (TSS) and $CaCO_3$ (Fig. 5), EC and pH-value (Table 3). A total of 48 stations were sampled, from the water column, along a transect crossing the lake, from the south-west to the north-east directions, in order to assess the dissolved oxygen (DO_2), pH-value and total soluble salts TSS (Fig. 6).

Heavy metal pollution in plants: The chemical analysis (for roots and shoots) of eight native plant species from Lake Manzala was carried out. These species are: *Arthrocnemum macrostachyum (A. glaucum), Zygophyllum album, Phragmites australis, Juncus rigidus, Typha domingensis, Salsola sp., Atriplex portulacoides* and *Cyperus laevigatus* (shoot only). These species were collected mostly from the southern sector of the lake. The two cultivated species are: the forage crop *Trifolium alexandrinum* and the edible vegetable *Raphanus sativa* (root only), collected from El-Makhnaa Island near Manzala Town.

Zinc (Zn) in plants: Compared with the standard critical range of Zn in plants 100-400 ppm, a critical amount (283 ppm) existed in roots of *Raphanus sativa* and in roots of *Typha domingensis* (144 ppm). The same applies to shoots of *Trifolium alexandrinum* (137.5 ppm) (Figs. 2, 3).

Table 2: Correlation coefficient between concentrations of heavy metal-pairs, allocated in root and shoot systems of plant species

Analysis metal pair	Correlation coefficient (r) Root system	Shoot system
Zn x Hg *	0.865	0.802
Pb x Hg *	0.783	0.855
Cd x Hg *	0.881	0.836
Zn x Pb *	0.890	0.814
Zn x Cd **	0.914	0.969
Pb x Cd *	0.830	0.885

* High correlation (r = 0.7 – 0.9). ** Very high correlation (r = 0.9 – 1.0)

Table 3: Electric conductivity (EC, μ mohs/cm) and pH-values in ten soil samples from Lake Manzala

Sample no.	EC (μ mohs/cm)	pH-value	Locality
1	2.76	8.5	Bashtir Canal area
2	16.6	8.28	Dawasa Section Island
3	28.0	8.63	Bahr El-Baqar bottom-1
4	27.8	9.0	Bahr El-Baqar bottom 2
5	31.5	8.6	Bahr El-Baqar-Ginka area
6	2.55	8.25	El-Gayara Island-1
7	2.12	8.13	El-Gayara Island-2
8	7.14	8.24	El-Ramad Island
9	1.4	8.88	Kom Tannis Island
10	1.44	8.3	El-Samara Island

Table 4: Results of Pearson correlation coefficient analysis between 4 heavy metals' concentration in soil samples against : pH-value, TSS and $CaCO_3$)

Metal x Variable	Correl. Coeff. (r)
Zinc (Zn)	
Zn x pH-value	- 0.351*
Zn x TSS	+ 0.221 no
Zn x $CaCO_3$	+ 0.546 **
Lead (Pb)	
Pb x pH value	- 0.665 **
Pb x TSS	- 0.060 no
Pb x $CaCO_3$	+ 0.633 **
Cadmium (Cd)	
Cd x pH-value	- 0.390 *
Cd x TSS	- 0.368 *
Cd x $CaCO_3$	+ 0.379 *
Mercury (Hg)	
Hg x pH-value	+ 0.138 no
Hg x TSS	+ 0.515 **
Hg x $CaCO_3$	+ 0.431 *

\- and + : Negative and positive correlation coefficient.
no : Non correlation (0.0 – 0.3). * : Low correlation (r = 0.3 - 0.5).
** : Medium correlation (r = 0.5 – 0.7).

Table 5: Ranges of heavy metals contents and toxicity status in the tested plant species, compared with normal and critical ranges in plants

Metal	Range in tested plants (ppm)	Normal range in plants (ppm)*	Critical range in plants (ppm)*	Toxicity status
Zn	25-283	1-400	100-400	Critical
Pb	11-102.5	0.2-20	30-300	Critical
Cd	2.5-12.1	0.1-2.4	5-30	Critical
Hg	32.5-231.3	0.005-0.17	1-3	High toxic

* Data after Kabata-Pendias and Pendias (1992)

Lead (Pb) in plants: Compared with the standard critical range of Pb in plants 30-300 ppm, critical amounts existed in shoots of *Trifolium alexandrinum* (102.5 ppm), in roots of *Raphanus sativa* (83.25 ppm) and in roots of *Salsola* sp. (45 ppm) (Figs. 2, 3).

Table 6: Ranges of heavy metals and toxicity status in the tested soil samples compared with normal and critical ranges in soils

Metal	Range in tested plants (ppm)	Normal range in plants (ppm)*	Critical range in plants (ppm)*	Toxicity status
Zn	30-275	1-900	70-400	Critical
Pb	40-65	2-300	30-300	Critical
Cd	5-9	0.01-2.0	3-8	Critical
Hg	40-245	0.01-0.5	0.3-5	High Toxic

* Data after Kabata-Pendias and Pendias (1992)

Cadmium (Cd) in plants: Compared with the standard critical range of Cd in plants (5-30 ppm), a critical amount existed in shoots of *Trifolium alexandrinum* (20 ppm) (Figs. 2, 3).

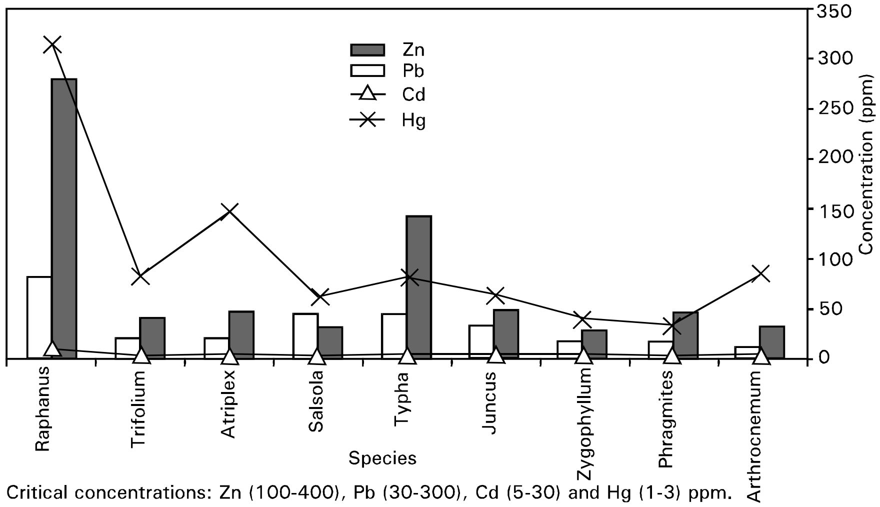
Mercury (Hg) in plants: In contrast with the previous three metals, Hg seems to be the most epidemic and hazardous pollutant in Lake Manzala, since it reached extremely high concentrations and may cause serious toxicity in most of the studied species. Compared with the standard critical range of Hg in plants (1-3 ppm), all the studied species may be considered as highly toxified by mercury. Values of 32.5 and 316.4 ppm were found in roots of *Phragmites* and *Raphanus*, respectively and values of 61.25 and 231.3 ppm were found in shoots of *Phragmites* and *Trifolium*, respectively (Figs. 2, 3).

Accumulation patterns of heavy metals in root and shoot systems: Applying unilateral F-test on the concentrations of each metal, separately (in roots against shoots), indicated significant differences only for Zn and Hg ($p<0.05$) as follows:

Metal:	Zn	Pb	Cd	Hg
F-value:	0.019*	0.664	0.600	0.164*

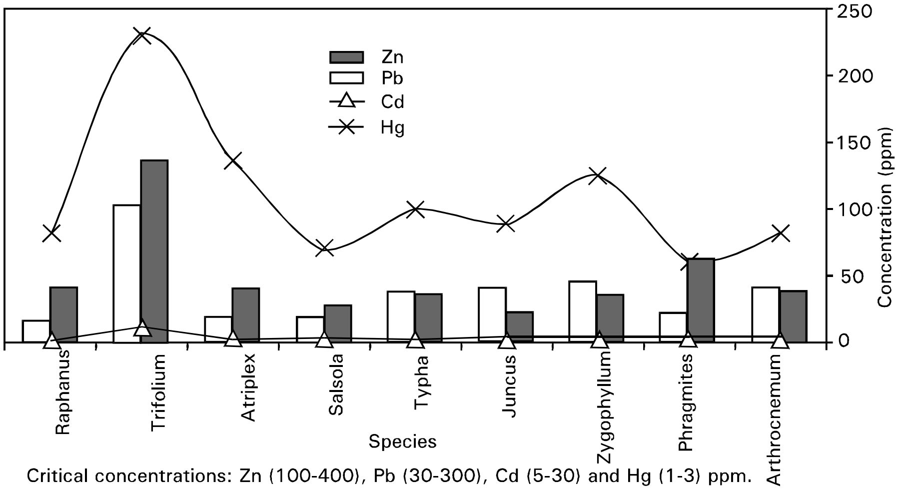
Based on the above results, it is obvious that zinc and mercury seem to accumulate, with more tendency towards roots more than shoots of the tested species.

The output of Pearson correlation coefficient analysis on combinations of different metal-pairs which are present together in either roots or shoots of the tested plant species (Table 2) and showed high + ve correlations (r > 0.7) between all metal pairs (Table 2). These results indicated that both roots and shoot systems may have a kind of natural controlling mechanism regarding the quantity of specific metals taken from the ambient environment, but in the mean time, they don't have controlling mechanism to suppress the combination between specific metal pairs in their tissues. Moreover, it seems that the tested metals don't have antagonistic behavior in between, inside the plant tissues, which may be confirmed by further studies.



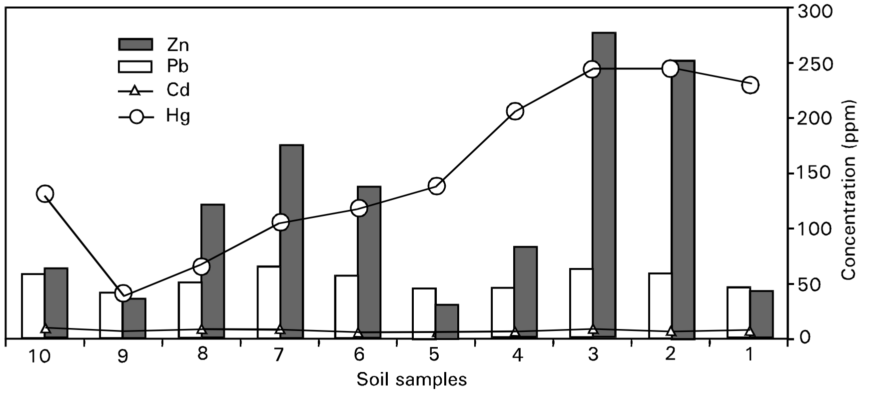
Critical concentrations: Zn (100-400), Pb (30-300), Cd (5-30) and Hg (1-3) ppm.
(From Kabata-Pendias and Pendias, 1992).

Fig. 2: Mean concentration of four heavy metals in roots of nine plant species from Lake Manzala



Critical concentrations: Zn (100-400), Pb (30-300), Cd (5-30) and Hg (1-3) ppm.
(From Kabata-Pendias and Pendias, 1992).

Fig. 3: Mean concentration (ppm) of four heavy metals in shoots of nine plant species from Lake Manzala



Critical concentrations: Zn (70-400), Pb (100-400), Cd (3-8) and Hg (0.3-5) ppm.
(From Kabata-Pendias and Pendias, 1992).

Fig. 4: mean values of four heavy metals in soil samples from Lake Manzala

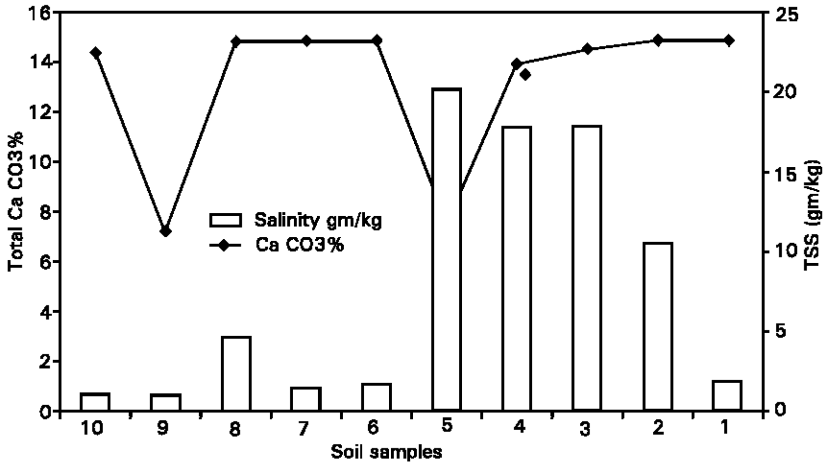


Fig. 5: Mean values of total soluble salts (TSS) and total Ca CO3% in soils from Lake Manzala

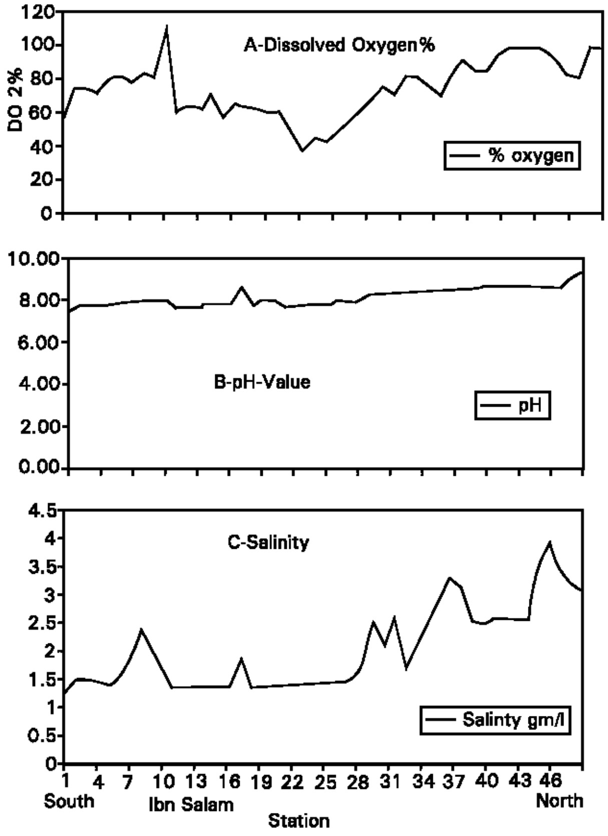


Fig. 6: Values of DO_2% (A), pH-value (B) and salinity (gm/l) of the water body of Lake Manzala along a transect from mataria (south west) to Manasra (north east) (May, 25, 1995)

Species proposed as biomonitors / biofilters for heavy metals: The next notation of metals, versus species (arranged in a decreasing order) containing metals higher than the minimum critical limits (Kabata-Pendias and Pendias, 1992) as follow:

Metal	Proposed 'biomonitors / biofilters (*= active monitors):
Zn	(*Raphanus** > *Typha* > *Trifolium**).
Pb	(*Trifolium** > *Raphanus** > *Salsola)*.
Cd	(*Trifolium** *Raphanus** > *Phragmites* > *Zygophyllum)*.
Hg;	(*Raphanus** > *Trifolium** > *Atriplex* > *Zygophyllum* > *Typha*> *Juncus* > *Arthrocnemum* > *Salsola* > *Phragmites*).

Based on the above results, it was concluded that the two introduced species (*Raphanus sativ*a and *Trifolium alexandrinum*) accumulated heavy metals in concentrations much higher than the native species. Accordingly it might be argued that the introduced species (active biomonitors) are more efficient than the native species (passive biomonitors) in treatment of metal pollution.

Heavy metal pollution in soil: Soil samples from ten localities in the eastern sector of Lake Manzala were chemically analyzed for the same heavy metals (Zn, Pb, Cd and Hg) (Fig. 4). Mean Zinc concentrations in the soil of Bahr El-Baqar-Ginka area, Dawasa Section, Gayara Island and Kom El-Ramad were within the standard critical range in soils (70-400 ppm). Mean lead concentrations in soils of LM was also within the standard critical range in soils (30-300 ppm). The same applies on cadmium concentrations in soils showing a range of values (5-9 ppm) almost fitting with the standard critical range (3-8 ppm). Mean mercury concentrations in soils showed that it is the most epidemic pollutant with a range of (40-245 ppm) much higher than the standard critical range (0.3-5 ppm). The heavily polluted sites with zinc are the bottom of Bahr El-Baqar drain and Dawasa section. The same applies on mercury.

Soil ecology in relation to heavy metal pollution: Total soluble salts showed that lowest value (1.0 gm/l) in Kom Tannis island, in the eastern sector of the lake and the highest value (20.2 gm/l) in Bahr El-Baqar-Ginka area (Fig. 5). The total $CaCO_3$ content of the soil showed mostly intermediate values ($\cong$ 15 %) in most localities. Soil pH-values were generally alkaline, ranging from 8.13 in Gayara island to 9.0 in Bahr El-Baqar area (Table 3) (Ramadan, 2002).

The output of Pearson correlation analysis on the soil samples (Table 4) shows that the soil $CaCO_3$ content has a medium +ve correlation with both of Zn and Pb and a low positive correlation with both of Cd and Hg. Also, TSS has a medium +ve correlation with Hg, but a low –ve correlation with Cd. On the other hand, pH-value has a medium -ve correlation with Pb and a low –ve correlation with Zn.

Water quality of the lake: The lake's water quality was checked through records of dissolved oxygen percentage, pH-value and total soluble salts, along 48 stations forming a transect from the southwest to the northeast of Lake Manzala.

Dissolved oxygen (DO%): The measurement of DO2% showed oxygen concentration range (70-98%), in the northern sector, higher than the southern sector (40–80%). An exceptional high value (108%) was recorded once in the southern sector. The general trend shows a gradual increase in DO_2% from south to north of the lake (Fig. 6A).

pH – value: Its range varied from about (7.5) in the south, where fresh water is found, to about (9.15) in the north, where saline water is found (Fig. 6B).

Salinity (TSS): The lake's water salinity showed the lowest value (1.32 gm l^{-1}) in the southern part of the lake, while the highest value (3.87 gm l^{-1}) was recorded in the northern part. The presence of several peaks in the curve reflects irregular distribution of salinity in the northern sector. However, in the southern sector salinity values are less variable (Fig. 6c).

Discussion

Three different approaches may be adopted by ecologists, dealing with pollution in lakes and wetland ecosystems. The first approach is 'biotic' that depends on biotic organisms as bio-monitors (Doust *et al.*, 1994a); in two cases as follows:

Case 1: Using selected vascular plants as biomonitors (Soliman and Ramadan, 1993; Anonymous, 1994; Biernacki *et al.,* 1996, 1997), or using non-vascular plants, such as diatoms (Korhola *et al*., 1999). Investigators may measure either variations in abundance, biomass and biodiversity indices of the selected biota, as indirect indicators of contamination loadings in the ecosystems (Moriarty, 1990; Smith, 1991; Spurgeon and Hopkin, 1999); or they may measure the sub-lethal concentration of suspected pollutants in tissues of the selected organisms. The differential accumulation rates of the trace elements in shoot and/or root system of the vascular plants may be more accurate. In aquatic ecosystems, several studies concluded that submerged plants tend to accumulate higher concentrations of metals consistently more than emergent or free-floating plants (Crowder, 1991; Outridge and Noller, 1991).

Case 2: Using selected invertebrates e.g. arthropods as biomonitors (Madden and Fox, 1997).

The second approach depends on measuring concentration of pollutants in 'abiotic' ambient physical components of the ecosystem (Doust *et al.,* 1994b), such as sediments (Abdel-Moati and Dowidar, 1988; Siegel *et al.,* 1994); or in water column (Khalil, 1985; Salib and Khalil, 1986).

The third approach depends on the combination between the biotic and abiotic ones, as followed in this study (Soliman and Ramadan, 1993; Biernacki *et al.,* 1996, 1997). Among the dangerous functions of heavy metals is their quick and permanent accumulation behavior in tissues of all living organisms, what is called 'bio-accumulation or bio-magnification' (Lambou and Williams 1980; Chaphekar 1991). These terms refer to the fact that the accumulation rates of heavy metals are relatively high in living tissues, which in turn, have no mechanism to discard them.

In this study the bio-accumulation of heavy metals was generally higher in the introduced species (active biomonitors) than in native wild species (passive biomonitors). Such a behavior agrees with what was outlined by Lovett-Doust, Schmidt and Doust (1994b): 'among limitations of passive biomonitors is that they are tolerant individuals and they may contain lower levels of contaminants in their tissues, due to their inherent ability to metabolize or excrete the toxicants in question'. They also added that 'if elevated levels of pollutants lead to the death of sensitive individuals, of passive biomonitors, then a survey of such a pollution-stressed ecosystem would seriously underestimate the pollutant loadings present in the environment'. In that respect, it is clear that the introduced (active) biomonitors have more advantages in addition to that they allow investigators to recognize accurately the temporal and spatial changes in polluted ecosystems, since the exposure time is known and the location of sites is selectable.

The present results showed that the concentrations of the studied metals (in sediments and plant tissues) could be arranged in a decreasing order as follows: Hg > Zn > Pb > Cd. This agrees with Abdel Moati and Dowidar (1988), except Hg. The rational values of these metals were as much as 2.5-5 times higher in active monitors than in passive ones and 2 times than in the sediments. Also, they were 2 times higher in the sediments than in passive monitors. Accordingly, the studied materials from LM could be arranged in a decreasing order based on their content of heavy metals as follows:

Introduced (active) monitors>Sediments>Native (Passive) monitors.

Doust *et al.* (1994a) estimated that the accumulation levels of organochlorine pollutants (PCB) in aquatic ecosystems may be as much as 4 times higher in plants than in sediments and 9000 times than in water.

The present study also showed that the toxicity status, induced by Zn, Pb and Cd, in plants (Table 5) and in soils (Table 6) are close to reach dangerous conditions. However, the toxicity status induced by Hg was already in danger. This largely agrees with the findings of Siegel *et al.* (1994) who investigated the Ginka sub-basin, south of LM. Thus, the following decreasing order of the studied metals in Lake Manzala, was done based on the degree of toxicity status induced by them in both cases of plants and sediments as follows: Hg > Zn> Pb > Cd. The above sequence agrees with the findings of Abdel-Moati and Dowidar (1988) and also with Siegel *et al.* (1994).

It is evident that while the degree of metal pollution is increasing southwards in the lake, three parameters of water quality (dissolved oxygen %, salinity and pH) show decreasing values southwards, so that it reaches the condition of eutrophication in some heavily polluted sites, due to shortage in the dissolved oxygen. It is known that the portion of total pollutant loading present in the ambient environment that is accessible to biota is called 'bioavailability' (Phillips, 1978) which is inversely related to their reactivity or solubility in aerobic and anaerobic soils (Engler and Patrick, 1975; Abdel Moati, 1985). It is also known that in the reduced soils and sediments containing sulphides, the precipitation of insoluble metal sulphides could be useful in controlling the soluble levels of toxic metals (Hem, 1972; Holmes *et al.,* 1974; Engler and Patrick, 1975; Gambrell *et al.,* 1976).

Considering the above information, in addition to the fact that native species may become tolerant to heavy metals and they may metabolize and secrete them, we may derive a relevant interpretation for the obtained results since the concentrations of heavy metals were much lower, in tissues of the native plant species, than in tissues of the introduced species. In order to introduce (cultivate) plants in a lake's environment one must disturb the habitat through plantation and irrigation processes, which in turn will induce better aerated conditions and the soluble fraction of metal sulphates may prevail and becomes available in the surroundings of the introduced plants. In contrast, in the relatively stable (undisturbed) habitats, with stagnant or slow-moving water currents, the insoluble fraction of metal sulphides may prevail, precipitate and becomes unavailable in the surroundings of the native plant species.

As major chemical toxicants, heavy metals may cause phytotoxic damage to the vegetation (Atkins *et al.*, 1982; Mekki, 1996; Angold, 1997). Such a damage was tested on mitotic division and chromosomal abnormality of some crops irrigated by polluted water from LM (Mekki, 1996; Ramadan and Mekki, 1996). The damage will undoubtedly affect the food web components in the affected ecosystem.

Lead, for example, is a highly toxic metal to man since it causes brain damages, particularly to the young and induce aggressive behavior. The major ways of toxicity by lead to man are caused through air respiration (inhalation), water contamination from lead piping and from the polluted food staff. Lead toxicity is due to it mimics many aspects of the metabolic behavior of Ca and inhibits many enzyme systems (Mengel and Kirkby, 1982). About 80% of the atmospheric pollution by Pb may arise from petrol combustion. Recently lead became no longer added (as tetra methyl lead) to petrol and the rest of countries should follow the same strategy. In the study area, an action plan was suggested by Siegel, Slaboda and Stanely (1994) for reducing the pollution hazard at Lake Manzala, especially in the food chain through plants and fishes (Halem and Guerguess, 1978; Anonymous, 1994).

Although our results showed that the toxicity status of the studied heavy metals (except mercury) are not very serious at Lake Manzala, in the present time, as outlined before (Ramadan and Mekki 1996; Mekki 1996), we recommend that combating all kinds of pollution in Lake Manzala became eminent. This can be through prevention, controlling or by applying fine treatments on the drainage loads which discharge into the lake. Well-designed action plans should be developed, strongly supported and strictly executed within intensive rehabilitation programs. Because of the great importance of Lake Manzala, the threatened components of its food web should immediately be saved, starting by its physical elements and primary producers and terminating by man.

That is because human populations of the five surrounding governorates depend mostly on the food fish produced from Lake Manzala.

References

Abdel-Moati, A.R., 1985: Studies on the Chemistry of Lake Manzala Waters Egypt. Ph.D. Thesis, Faculty of Science, Alexandria University.

Abdel-Moati, A.R. and N.M. Dowidar, 1988: Trace elements of Lake Manzala - Egypt, Bull, Nat. Inst. Oceanogr. and Fish. A. R. E., 14: 183 - 202.

Angold, P.G., 1997: The impact of a road upon adjacent heathland vegetation: effects on plant species composition. J. Ecol., 34: 409-417.

Anonymous, 1982. Engineers, Planners and Scientific Inc. Lake Manzala Study. Egy/ 76/001-07. Draft report to Arab Republic of Egypt. Ministry of Development and New Communities and UNDP Scientists, Inc. Toronto, Canada 12 vols.

Anonymous, 1994. Global Environmental Facility. Report on Egyptian Engineered Wetlands. Washington, DC, UNDP/UNEP, World Bank.

Atkins, D.P., I.G. Truemen, C.B. Klarke and A.D. Bradshaw, 1982. The evolution of lead tolerance by *Festuca rubra* on a motorway verge. Environmental Pollution (series A), 27: 233-241.

Biernacki, M., J. Lovett-Doust and L. Lovett-Doust, 1996. *Vallisneria americana* as a biomonitor of aquatic ecosystems: leaf-to-root surface area ratios and organic contamination in the Huron-Erie Corridor. Journal of Great Lakes Research, 22: 289-303.

Biernacki, M., J. Lovett-Doust and L. Lovett-Doust, 1997: Temporal biomonitoring using wild celery, *Vallisneria americana*. Journal of Great Lakes Research, 23: 97-107.

Bishai, M.H. and S.F. Yossef, 1977. Some aspects on the hydrography, physio-chemical characteristics and fisheries of Lake Manzala, Bull. Inst. Ocean and Fish., A.R.E., 7: 31-51.

Boulos, L., 1995. Flora of Egypt (Checklist). Al-Hadara Publishing, Cairo, Egypt.

Bowen, H.J.M., 1979: Environmental Chemistry of the Elements. Academic Press, London.

Chaphekar, S.B., 1991. An overview on bioindicators. Journal of Environmental Biol., 12: 163-168.

Crowder, A., 1991. Acidification, metals and macrophytes. Environmental Pollution, 71: 171-203.

Doust, J.L., M. Schmidt and L.L. Doust, 1994. Biological assessment of aquatic pollution: A review, with emphasis on plants as biomonitors. Biol. Rev., 69: 147-186.

Doust, L.L., J.L. Doust and M. Biernacki, 1994. American wildcelery, Vallisneria Americana, as a biomonitor of organic contaminants in aquatic ecosystems. J. Great Lakes Res., 20: 333-354.

Engler, R.M. and W.H. Patrick Jr., 1975: Stability of sulphides of manganese, iron, zinc, copper, mercury in flooded and nonflooded soil. Soil Science, 119: 217-221.

Farag-Alla, K.A.K., 2001: Vegetation Structure in Lake Manzala, Egypt. M.Sc. Thesis, Botany Department, Fac. Sci., Suez Canal Univ. Ismailia, Egypt, pp: 170.

Gambrell, R.P., P.A. Khalid and W.H. Patrick Jr., 1976: Physicochemical parameters that regulate mobilization and immobilization of toxic heavy metals. In: Dredging and Its Environmental Effects; P.A. Krenkel, John Harrison and J.C. Burdick (eds.). American Society of Civil Engineers. NY., pp: 418-434.

Halem, Y. and S.K. Guerguess, 1978. Eutrophication in a brackish delta lake. J. Etud Pollut Attaya. Monaco CIESM, 4: 435-438.

Hem, J.D., 1972; Chemistry and occurrence of cadmium and zinc in surface water and ground water. Water Resources Res., 8: 661-679.

Holmes, C.M., E.A. Slade and C.J. McLerran, 1974: Migration and redistribution of zinc and cadmium in marine estuarine system. Environ. Sci. Technol., 8: 255-259.

Ishak, I.F. and E.F. El- Halawany, 1989. Aquatic and terrestrial flora of Lake Manzala. Egyptian J. Bot., 32: 95-107.

Jackson, M.L., 1974. Soil Chemical Analysis. Prentice-Hall, Englewood Cliffs. NJ.

Kabata-Pendias, A. and H. Pendias, 1992. Trace Elements in Soils and Plants. 2nd edn. CRC Press. Boca Raton, Fla.

Khalil, M.T., 1985. The effect of sewage and pollutional wastes upon Bahr El-Baqar Drain and the southern area of Lake Manzala, Egypt. Egyptian Journal of Wildlife and Natural Resoures, 6: 162 - 171.

Khalil, M.T., 1990. The physical and chemical environment of Lake Manzala, Egypt. Hydrobiologia, 196: 193-199.

Korhola, A., J. Weckström and M. Nyman, 1999. Predicting the long-term acidification trends in small subarctic lakes using diatoms. J. Appl. Ecol., 36: 1021-1034.

Kovacs, M. and J. Podani, 1986. Bioindicators. A short review on the use of plants as indicators of heavy metals. Acta Biologica Hungarica, 37: 19-29.

Lambou, V.W. and L.R. Williams, 1980. Biological monitoring of hazardous wastes in aquatic systems. Second Interagency Workshop on in-Situ Water Sensing: Biological Sensors, pp: 11-18. Pensacola Beach, Florida.

Madden, K.E. and B.J. Fox, 1997. Anthropods as indicators of the effects of fluoride pollution on the succession following sand mining. J. Appl. Ecol., 34: 1239 – 1256.

Maltby, L. and P. Calow, 1989: The application of bioassays in the resolution of environmental problems:past, present and future. Hydrobiologia, 188/189: 65-76.

Mekki, L., 1996. Effect of polluted water of Lake Manzala on mitotic division and chromosomes of *Allium cepa, Allium sativum, Vicia faba* and *Zea mays*. Proceedings 3rd Cong. Toxicol. Dev. Count., Cairo, Egypt, 19-23 Nov., 1995, 2: 267-274.

Mengel, K. and E.A. Kirkby, 1982. Principles of Plant Nutrition (3rd ed.). Int Pot. Inst. P.O. Box, CH-3048 Worblaufen – Bern., Switzerland, pp: 655.

Montasir, A.H., 1937. Ecology of lake Manzala. Egyptian Univ. Bull. Fac. Sci., 12: 1-50.

Moriarty, F., 1990. Ecotoxicology: The Study of Pollution in Ecosystems. Second Edition., Academic Press. New York.

National Conference on Lake Manzala Environment ,1991. (27 - 29 Oct., 1991), Port Said, Egypt.

Outridge, P.M. and B.N. Noller, 1991. Accumulation of toxic trace elements by freshwater vascular plants. Reviews of Environmental Communication and Toxicology, 121: 1- 63.

Phillips, D.J., 1978. Use of biological indicator organisms to quantitate organochlorine pollutants in aquatic environments– a review. Environmental Pollution, 26: 167-229.

Pipers, C.S., 1947: Soil and Plant Analysis. Interscience Publishers Inc., New York.

Ramadan, A.A., 2002. Population dynamics and multivariate analysis of vegetation in Lake Manzala, Egypt. Pakistan J. Biol. Sci., 5: 819 - 824.

Ramadan, A.A. and L. Mekki, 1996. Studies on Higher Plant Communities in Lake Manzala. Report for Suez Canal Univ., Ismailia, Egypt (Unpublished).

Salib, E.A. and M.T. Khalil, 1986. Chemical and biological studies on Hadous Drain and the southern eastern area of Lake Manzala, Egypt. Proc. Zool. Soc. A. A. E., 12: 91-100.

Shaheen, A.H. and S.F. Yossef, 1978. The effect of the cessation of Nile flood on the hydrophic features of lake Manzala, Egypt. Arch. Hydrobiol., 48: 339-367.

Siegel, F.R., M.I. Slaboda and D.J. Stanely, 1994. Metal pollution loading, Manzalah lagoon, Nile delta, Egypt: Implications for aquaculture. Environmental Geology, 23: 89-98.

Smith, B.M., 1991. An inter- and intra-agency survey of the use of plants for toxicity assessment. In: Plants for Toxicity Assessment: Second volume, ASTM STP 1115 (ed. J. W. Gorsuch, W.R. Lower, W. Wang and M.A. Lewis), pp: 41-59. American Society of Testing and Materials, Philadelphia.

Soliman, F.A. and A.A. Ramadan, 1993. Mineral pollution and plant indicators in some localities, South Sinai, Egypt. Proceedings 1st Conf. Egypt. Hung. Env. Egypt, 1993, pp: 79-87.

Spurgeon, D.J. and S.P. Hopkin, 1999. Seasonal variation in the abundance, biomass and biodiversity of earthworms in soils contaminated with metal emissions from a primary smelting works. J. Appl. Ecol., 36: 173–183.

Täckholm, V., 1974. Students' Flora of Egypt. 1 st edn. Anglo Egyptian Bookshop, Cairo. 2nd edn., pp: 888. Beirut.

Youssif, W.M.E., 1992: Movement and Distribution of Some Heavy Elements in South Port Said Soils in Relation to Plant Growth. M.Sc. Thesis. Soil Dept. Fac. Agric. Suez Canal Univ. Ismailia, Egypt, pp: 121.

Zahran, M.A., M.E. Abu Ziada, M.A. El-Demerdash and A.A. Khedr, 1989. Vegetation of Lake Manzala. islands, Egypt, Mans. Sci. Bull., 15: 607-643.

Zahran, M.A., M.A. El-Demerdash and I. Mashaly, 1990. Vegetation types of the deltaic Mediterranian coast of Egypt and their environment. J.Veg. Sci., 1: 305-310.

Zaki, M.M.M., 1994. Microbiological and Toxicological Study of the Environmental Pollution of Lake Manzala. M.Sc. Thesis, Bot. Dept. Fac. Sci., Suez Canal Univ., Ismailia, Egypt.