Removal of Some Heavy Metals from Treated Waste Water by Aquatic Plants

Adel E.EL-Leboudi[1], Essam M. Abd-Elmoniem[1], Ezzat M.Soliman[2] and Ola F. M. El-Sayed[3]
1. Soil Dept., Faculty of Agriculture, Ain Shams University, Cairo, Egypt
2. Institute of environmental studies and research, Ain Shams University, Cairo, Egypt
3. National organization for potable water & sanitary drainage, Cairo, Egypt

Abstract

It is a strategic target now to recycle treated waste water for irrigation to efficiently manage and maximize Egypt's water resources. So, remediation for treated waste water, obtained from stations of Mahalla using certain aquatic plants (water hyacinth), was performed for the indicated treated waste water for different exposure periods (5, 10 and 14 days). Such aquatic plants seemed to be efficient in the concerned remediation; their uptake of heavy elements seemed to be improved with increasing exposure period, periodic harvesting age of the concerned plants and their studied part, the element species being also affecting. Uptake of heavy metals (Ni, Pb, Zn and Cd) were finally evaluated for water hyacinth plants through evaluating both parameters of total accumulation rate (TAR) and bioconcentration factor (BCF); values for such useful parameters in roots were the highest compared with other parts of both young and old plants in spite of differences in absolute values.

Keywords: Aquatic plants (water hyacinth), Heavy metals, Treated waste water, Pollution, Remediation.

Introduction

In the past ten years, public and governmental awareness about the problems associated with sewage treatment increased in Egypt. In highly populated regions, i.e., the Nile Delta, there is a great need for low cost simple technologies for sewage treatment which can solve the problems related to land availability, operation and maintenance. It is a strategic target now to recycle treated waste water for irrigation to efficiently manage and maximize Egypt's water resources.

Pollution of the environment by heavy elements, such as lead, cadmium, nickel and zinc has become recognized as a world-wide public health hazard. Biological systems for waste water treatment based on aquatic plants have received a growing attention since they represent an alternative approach for pollutants removal and valuable biomass production.

Treated wastewater should play an important role in providing an important source of irrigation water, although it may also contain a significant amount of heavy metals affecting plant, animal and finally the human-being (FAO, 1985). In fact, there are growing concerns that the consumption of foodstuffs containing unacceptably high levels of heavy metals may lead to chronic toxicity (Wagner, 1993).

Wastewaters are a general term usually applied to liquid waste collected in sanitary sewers and treated in a municipal wastewater treatment plant. This is the flow of all used water from the community such as domestic and industrial types. These types of wastewater should be different from time to time during days, months and years. The Government of Egypt has launched a phased program aiming at collecting and remediates the secondary treated domestic wastewater, to enhance the potential of agricultural drainage reuse and reduce the associated health risk (Saleh, 2000). Many widespread aquatic floating weeds, such as water hyacinth and duckweed, are commonly utilized for this purpose.

The aim of the present work was the removal of some heavy elements (Pb, Ni, Cd and Zn) from the treated waste water by aquatic plants through studies for behavior of such plants including their growth and elements status, expressed as both concentration and total content, parameters of both biological accumulation rate and bioconcentration factor of hyacinth plants being included.

Material and Methods

As previously mentioned, the purpose of the present study is to remove the concerned heavy metals from treated waste water through developed aquatic plants represented by water hyacinth. Water hyacinth (Eichhornia crassipes) plants were collected from the Nile River waters at the Mazzallat area, the experimental specimens of plants were selected to be almost similar concerning the age along with volume of both root and shoot systems. The experiments were carried out in a greenhouse during autumn with a temperature range of 25-28°c.The hyacinth plants were cultivated in solution culture containers having 20 liter of treated waste water, taken from both Mahalla station, two sizes of plants (old large and young small plants) being included. Plants were let to grow for 14 days, plant samples were taken successively at 5, 10, and 14 days; correspondent time intervals for water sampling being 2, 4, 6, 8, 10, 12 and 14 days, respectively.

Plant samples were oven dried at 70°c for 72 hr, dry samples being then grinded to be finally digested using a mixture of concentrated sulphuric acid (98%) and hydrogen peroxide (30%).The digests were then used for analyses of the concerned heavy metals using the apparatus of atomic absorption spectrophotometer (Perkin-Elmer model 2380).

Both treated waste water and digests of plant samples were subjected to analysis of the concerned heavy metals, again, using the atomic absorption spectrophotometer.

Two parameters were used for evaluation of heavy metals status in and water hyacinth plants. Such parameters were, according to Zhu et al., (1999) and Abd-Elmoniem (2003).

1- Bioconcentration factor (BCF) =
Heavy element concentration in plant tissue ($mgkg^{-1}$) at harvest/Initial concentration of the element in the external nutrient solution (mgl^{-1})

2-The total accumulation rate (TAR) for plants ($mgkg^{-1}d^{-1}$) = Shoot element concentration x shoot biomass + root element concentration x root biomass/ {(shoot biomass+ root biomass) x day}

Such parameter was evaluated for each plant part, root, shoot or stem, leaves and grains separately.

The least significant difference (L.S.D.) was employed to test the statistical significance of differences among means according to Steel and Torrie, (1980).

Result and Discussion

The analyses of water samples taken from the treated waste water of Mahalla stations are shown in Table (1).

The concentrations of both of Ni and Cd in the treated waste water exceeded the permissible limits for irrigation purposes; levels of both Pb and Zn were less than the permissible limits for irrigation purposes (FAO, (1975).

Table (1): Concentrations of the studied heavy elements (mg/l) in the treated waste water taken from Mahalla station before planting of water hyacinth,

	Heavy metals Concentration	
Element	**Mahalla**	***Limit**
Pb	4.06	5.0
Ni	5.18	0.2
Cd	1.25	0.01
Zn	1.43	2.0

*According to FAO, (1975)

- Heavy elements presence in the treated waste water after cultivation with water hyacinth plants:

The values representing status of the concerned elements in the studied samples of treated waste water taken from both Mahalla and October stations before and after cultivation with both young and old plants were evaluated.

Table (2) and Fig.(2) show that the change in the status of the studied heavy metals, due to cultivation of young water hyacinth plants, was dependent on the concerned element and the period of plant presence in the indicated waste water. The level of Pb in the concerned treated waste water of Mahalla station decreased. These changes may suggest the favorable effect of the studied aquatic plants on purification of the waste water due to the efficiency of Pb uptake particularly at longer exposure periods. In fact, such suggestion may go along with several studies indicating that water hyacinth has been used for removing Ag, Co, Sn, Pb, Cd, Ni and Hg from polluted water (Muramoto and Oki, 1983).

A relatively different trend was followed by both Ni and Cd whose concentrations in the treated waste water

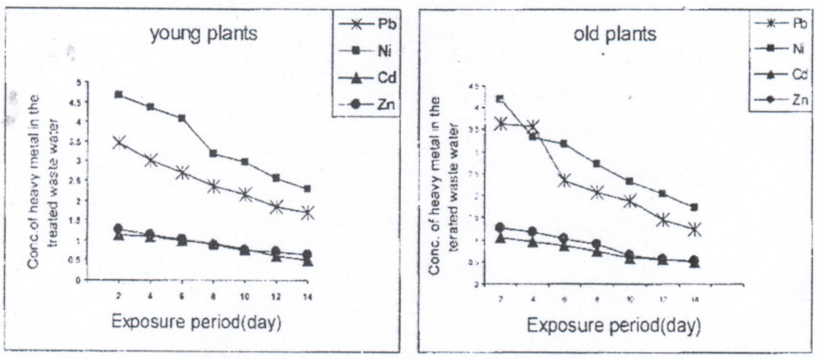

Fig (1): Changes in the heavy elements concentrations (ppm) in the treated waste water of Mahalla station after planting hyacinth plants.

sample (control) was 5.18 mg/l and 1.25 mg/l, respectively before growing the water hyacinth plants. After planting, the concentrations were decreased with different times. The residual Ni in the treated waste water after planting was relatively small, compared with the initial waste concentration, but still higher than the previously indicated permissible levels of 0.2 mg/l and 0.01mg/l, respectively (FAO, 1975). This may suggest the relative absence of efficiency for removal of the two concerned elements by grown aquatic plants even after 14days of exposure.

Finally, the zinc concentration in the treated waste water before planting was 1.43 mg/l and become 1.25, 1.17, 1.03, 0.84, 0.65, 0.54 and 0.50 after planting of water hyacinth plants for the concerned exposure periods, respectively, the residual Zn in the treated waste water after being planted was less than the allowable Zn contamination limit which is 2.0 mg/l according to FAO,(1975).Therefore, water hyacinth plant may be considered to be efficient in phytoextracting such heavy element from the concerned waste water.

Fig. (1) also shows the corresponding data representing the heavy element concentration (mg/L) in the treated waste water taken from Mahalla station after planting the old water hyacinth plants, a trend being found almost similar to that obtained with correspondent young plants; the absolute values of heavy elements were, however, higher than those in young plants which seemed to be more efficient in removal of studied heavy elements.

To complete the picture, it was thought advisable to express the obtained results through evaluating the changes encountered for different studied treatments. Calculations for the net removal values expressing the percentages of variations obtained with the studied young plants which indicate that within the 2 days exposure period, values were 10.6% , 18.9% 16.8% and 12.5% of the original Pb , Ni, Cd and Zn, respectively. Relatively longer period gave higher values, such values being 69.4%, 66.6%, 62.4% and 64.3% following the end of the whole exposure period of 14 days.

Response trend, for the obtained net removal values for the concerned heavy metals from the treated waste water of Mahalla station has two phases: The first phase stands for the period from 2 to 4 days for Pb, from 2 to 6 days for Ni and 2 to 8 days for both Cd and Zn. Concerning both Pb and Ni, the line slope of changes is relatively larger indicating a relatively high efficiency for uptake. The second phase stands for the exposure period from 4 to 14 days for Pb and from 6 to14 days for Ni, with slope relatively less indicating a relatively slower uptake with advance in age. With respect of Cd and Zn, the second phase was from 8 to 14 day with line slope relatively greater indicating a relatively higher rate of uptake.

With regard to the studied old plants, the correspondent calculations indicate that within the 2 days exposure period, 14.4% 11.3% 10.4 and 11.2% of Pb, Ni, Cd and Zn, respectively, were removed; relatively longer period gave higher values of, 58.1%, 55.4%, 52% and 54.5% at the end exposure period of 14 day. The lines representing the heavy metal removal from the studied treated waste water of Mahalla station show, similar to those of young plants, positive responses to the exposure period, the responses being different in successive investigated periods. This is reflected on the slope of lines representing the indicated relationship, such trend being, again, possibly expressed as two successive phases. The duration of the slow initial phase of removal for Pb was during the period 2 to 6 days; thereafter, a much rapid rate of removal continued for remaining duration (up to 14 days). However, the increment of Cd, and Zn removal had almost linear shape with time of exposure; thus, the uptake of these elements seems to be almost constant through the period of study with removal being again lower than young plants. Obtained results may be coincident with those obtained by Lehn and Bopp, (1987) who showed that young plants showed a greater metal uptake capacity than old plants. Rophael et al., (1990) reported, however, that the tissue concentration of heavy metal in young plants developed during the exposure period, accumulated ions as high as those found in the old plants.

* Plant growth

Table (2) shows that both fresh and dry biomass of different parts of both young and old water hyacinth plants grown in the treated waste water of

Mahalla station were, again, dependent on the studied exposure period; such responses being dependent on the concerned station and may be attributed, according to Mohammad and Ayadi, (2004), to the original nutrient content in the used waste water. This may be confirmed by variation in values of both studied stations which may reflect differences in the nutritional status of their waste water. Finally, moisture content in the different studied plant parts was almost constant not greatly affected with pollution source; the followed patterns of the studied parameters were almost similar during the 14 days exposure period.

It may be worth mentioning that Jain et al., (1989) pointed out that heavy metal presence in the treated waste water was effective on ducks weed aquatic plants. Zhu et al., (1999) added that growth rate of water hyacinth showed a progressive decrease when external concentration of Cd, Ni,

Table (2): Fresh and dry matter contents (g/plant) and moisture content (%) for the different parts of water hyacinth (both young and old plants) grown in the treated waste water of Mahalla station.

Exposure periods	Young plants								
	Fresh weight			Dry weight			Moisture content		
	Leaves	Stems	Roots	Leaves	Stems	Roots	Leaves	Stems	Roots
Control	8.7	11.3	12.9	1.00	1.40	1.90	88.5%	87.6%	85.2%
5 days After planting	9.80	13.2	16.3	1.03	1.63	2.30	89.4	87.6%	85.8%
10 days After planting	11.8	15.3	21.2	1.25	1.71	2.80	89.4%	88.8%	86.7%
14 days After planting	14.0	17.1	26.9	1.50	1.90	2.86	89.3%	88.8%	89.3%
L.S.D.	0.21	1.11	1.21	0.01	0.05	0.02	-	-	-
	Old plants								
Control	9.9	16.8	30.2	1.06	2.00	2.46	89.2%	88.0%	89.1%
5days After planting	11.9	20.4	34.0	1.21	2.05	3.14	89.8%	89.4%	90.7%
10days After planting	13.1	23.3	36.7	1.52	2.31	3.26	88.3%	90.0%	91.1%
14 days After planting	14.3	24.6	37.9	1.54	2.42	3.39	89.2%	90.0%	91.0%
L.S.D.	0.91	1.04	1.01	0.02	0.61	0.03	-	-	-

and Zn were higher than 0.1 mg/l; at very high concentrations (5 and 10 mg/l Cd), water hyacinth showed net fresh weight losses. Almost similar trend was encountered when replacing the young hyacinth plants with relatively older ones, responses to exposure period being less pronounced. It may be worth to mention that yellowish coloration and relatively sluggish leaf growth were observed on some plants subjected to relatively longer exposure periods. These results coincide with those obtained by Ornes and Sajwan, (1993) who mentioned that growth measurements of dry weight were negatively correlated to increased metal-ion treatment. More recently, Kara, (2004) pointed out that the toxicity effect of each heavy element on plant growth was reflected on damage of plants. Further, the growth rate and harvest potential make duckweed aquatic plants a good species for hyperaccumlation activities.

*Status of the concerned heavy elements in grown plants:

Heavy metals, such as Pb, Ni, Cd and Zn, are present in the natural environment, but their redistribution is frequently a result of human activities. Industrial activities have raised the level of such metals in the waste water to be then uptaken by plants and then finally transferred to human through the known food chain. Water hyacinth (Eichhornia crassipes) plants have been, as previously mentioned, used as a trial for removing Pb, Ni, Cd and Zn from treated waste water. Accordingly, evaluation has bean performed for the status, based on either concentration or total content of different studied heavy elements in both young and old water hyacinth aquatic plants grown in waste water of both studied stations, such status being evaluated through evaluating both concentration and total content of the concerned heavy elements in the studied water hyacinth plant parts.

*Concentration of the studied heavy elements in the concerned plants:

The roots, stems and leaves of water hyacinth plants accumulated lead to great levels as to have high concentration values; such concentrations were 63.4, 74.5 and 79.8 mg/kg DW but 56.9, 67.9, and 71.3 mg/kg DW and 42.3, 46.7, and 52.1 mg/kg DW for Mahalla station for duration treatments of 5,10 and 14 days, respectively. Again, results indicate positive responses to exposure period; leaves had relatively lowest values compared to roots. In fact, Sen et al., (1993) reported that the uptake of lead affects Salvinia matins aquatic plants and their plants absorbed almost 10 ug/ml of lead per day. Chen et al., (1993) added that the lead pollutant was accumulated mainly in the epidermal tissue, cortex, parenchyma and vascular tissues of the roots. These results coincide with those obtained by Xiong, (1998) who mentioned that roots seem to be more sensitive to lead than both stems and leaves. Of course, such variations might be due to the specialized absorptive feature for root organ as to be subjected to accumulation of more heavy metals than any of the other organs. With respect to the studied old water hyacinth plants for both studied stations, an almost similar trend to the young ones was obtained in spite of their relatively lower values.

Ni concentration in different parts of water hyacinth plants grown in the treated waste water of Mahalla station was again a function of exposure period.

This may indicate that Ni content significantly increased with increasing the studied duration time. In fact, nickel has recently been defined as an essential micronutrient due to its involvement in enzymatic activity in legumes (Welch, 1995), but it is toxic at supra–optimal concentration in plants (Rao and Sresty, 2000). Of course, the rate of Ni accumulation in different plant parts should be dependent on its concentration in the uptake media and its transfer from root to shoot which may be controlled by partitioning of absorbed Ni between transport and storage pools, or through metabolic regulation by cells of the stellar parenchyma (Abd–Elmonien, 2003). Saltabas and Akcim., (1994) investigated the growth of water hyacinth plants in solutions containing 14 ppm Ni for 24 h; at the end of this period, plant samples contained Ni ranged between 804 and 950 ug/g. Sharma and Gaur, (1995) added, however, that Duckweed aquatic plants were exposed to 10 mg/L of Ni for four days and accumulated 5.5 ug Ni /mg DW. This may again confirm the previously suggested great dependence of heavy metal status in grown plants on plant species, concentration of element in the growth media and absorption duration.

The Cd concentrations for roots were 5.66, 7.08, and 8.40 mg/kg DW but 4.18, 5.56, and 5.96 mg/kg DW for stem and 4.04, 4.82, and 5.24 mg/kg DW for leaves for duration treatments of 5,10 and 14 days, respectively, cadmium concentration in root being the highest compared to other parts. Maine et al., (2001) reported that the increase of Cd concentration in plant tissues occurred especially in roots and was linearly related to the quantity of added Cd, sorption by roots being faster than translocation to the plant aerial parts particularly during the first 24 h. This may agree with results of Rophael et al., (1990) who previously cited up that maximum Cd concentration was found in plant roots exposed to 0.4 ppm for 3 weeks in the roots; accordingly, the roots constitute the main sink for the Cd removed from solution (80%).

This may agree with results of Moreno-caselles et al.,(2000) who reported that cadmium accumulation in the different parts of plants increased with increasing Cd concentration in the medium as well as with the time of exposition; the extent of accumulation was in the descending order of root >stem + branches > leaf >fruit.

Rophael et al., (1990) pointed out that exposure of water hyacinth plants to Cd at concentration > 0.1 ppm resulted in accumulation of Cd in roots and leaves, chlorosis of leaves and suppression of plant growth being also obtained; these plants had darker, brittle roots with fewer rootlets than those of Cd–free plants. In fact, Strary and kreutzer, (1984) previously suggested that as toxicity sets in at higher concentrations of Cd, low uptake of metal is probably due to loss of membrane permeability to cations ; the cell wall acts as a polyfunctional (weakly acidic and cation exchange facilitating exchange of metal cations).

Generally, positive relation was obtained between Cd concentration in different plant parts and exposure period for the treated waste water taken from Mahalla station in spite of their relatively lower values compared to those of young plants.

Zn concentrations in roots of water hyacinth plants were 16.0, 17.0 and 19.3 mg/kg DW but 14.0, 15.6, and 16.9 mg/kg DW for stems and 9.45, 12.2, and 12.9 mg/kg DW for leaves for duration treatments of 5, 10 and 14 days, respectively. Correspondent Zn concentration values in different parts of old plants show a pattern almost similar to that obtained with young plants of Mahalla station as far as responses to exposure period as well as the concerned plant part are concerned. Such values, again, appeared to be positively correlated with exposure period, values being increased as plants advance in age; roots seemed to accumulate more Zn that other plant parts.

As a conclusion, results indicate positive responses to exposure period; roots seemed to be relatively most affected. In fact, several authors have shown that heavy metals tended to accumulate in roots of aquatic plants such as water hyacinth (Strivastav et al., 1994). This agrees with results of Yahya, (1990) who previously reported that a greater proportion of metals absorbed remained in the root system rather than being tranlocated to other plant parts. Again, Abd-Elhamid, (1996) found that the roots of aquatic plants accumulated heavy metals to a much greater extent than the stems and leaves.

More recently, Zhu et al., (1999) added that the relatively high amounts of Cd accumulation in plant roots is partially due to the binding of cationic Cd to the specific sites in the cell wall and inefficient transport to the shoot.

According to Wells et al., (1981) the distribution of heavy elements in plants can be categorized into three groups:

1. Some uniformly distributed between roots and shoots, e.g, Zn, Mn and Ni.
2. Usually more in roots than in shoots, with sometimes moderate to large quantities in shoot, e.g., Cu, Cd and Co.
3. Mostly in roots with very small amounts in shoots, e.g., Pb, Sn, Ti, Ag and V.

* Total content of the studied heavy metals in the concerned plants:

Water hyacinth plants have the capacity to take up toxic heavy metals from polluted water and accumulate them. As a continuation for evaluating the absorption of the studied heavy metals by the water hyacinth plants, their uptake by roots along with total contents of both stems and leaves have been evaluated for both young and old plants grown in waste water of studied Mahalla stations.

Finally, the total contents of Pb, Ni, Cd and Zn in the young leaves of water hyacinth plants after planting in the treated waste water of the concerned Mahalla station were 14.5, 15.5, 1.39 and 3.23 ug/plant for the 5 day exposure period, respectively. Correspondent values for 10 and 14 day exposure periods were 19.5, 20.7, 2.01 and 5.08ug/plant and 26.1, 30.4, 2.62 and 6.45 ug/plant respectively.

With regard to the studied old plants, similar pattern to that of young plants is obvious in spite of variations in the absolute values and the efficiency of uptake during the studied exposure periods.

Rao and Sresty, (2000) studied the influence of contact time on the heavy metal uptake for a period of 15 days; a rapid uptake was found during the first five days of contact time, such uptake being decreased with time until it reached saturation on the 15^{th} day. In fact, the water hyacinth (Eichhornia crassipes) plants were considered as pollution monitor for accumulation of silver and subsequent recovery of the element from the plant tissues (Pinto et al., 1987), such plants being repeatedly used for removal of certain metal pollutants from waste water (Morel et al., 1991). Rodriguez et al., (1991) added that water hyacinth may be considered as a purifier of municipal waste water.

Turnquist et al., (1990) reported that the uptake of heavy metals was limited by diffusion, removal of such metals from effluents by plants being expected to be affected by specific conditions of the medium such as temperature, pH, ionic strength, presence of other metals. This may go along with results of Simkiss and Taylor, (1989) who previously discussed various pathways by which heavy elements may be taken up by aquatic biota. They considered that uptake was frequently a passive process, occurring down a concentration gradient into the tissues of organism; proportions of the total uptake of a particular metal such as cadmium may be linked to active ion pumps, which serve to transport ions into or out the organism.

In fact, obtained results may agree with those of the afore-mentioned investigators in spite of the absence of complete saturation with the concerned heavy element even at the 14 day exposure period. Of course, such differences may be attributed to variations in the previously reported factors affecting the pollution status of the studied area particularly what concern the element species and its level in the growth media and the concerned plant.

Finally, it may be worth to mention that young plants of both studied stations were, generally, higher in the total contents of the concerned heavy elements in different plant parts, compared to those of old plants. Such differences appeared to be, again, dependent on the different factors affecting the polluting stations in the studied area.

It may be also worth to mention that for total contents of the studied heavy elements in different parts of all tested plants, representing both concerned waste water stations, followed, regarding their response to the studied exposure period, a general biphasic pattern; the first phase was relatively slow encountered at relatively short exposure period, the second phase was relatively rapid encountered at relatively longer exposure period. This may go along with results of El-Falaky et al., (1999) who reported that certain aquatic plants were able to remove heavy metals of Cd, Ni and Pb from a media of polluted water over the entire range of the used concentrations (0.1 to 5.0 ppm), the rate of removal being decreased at a rate depending on the used plant species. The plant total contents of the mentioned heavy metals followed a biphase rate of uptake that made the plants unable to completely purify the solution from heavy metals when the concentration was relatively high. Replacing the studied plants by new ones every tow days accelerated metals removal even after exposure to relatively high concentrations of heavy metals (20ppm).

* Parameters monitoring the quantitative evaluation for status of the studied heavy elements in the studied water hyacinth plant:

To complete the picture, it was thought advisable to express the responses of uptake for the studied heavy elements by the investigated aquatic plants, young and old, through evaluation of certain known parameters of total accumulation rate and bioconcentration factor.

As for the first parameter of total accumulation rate (TAR), it was expressed, as previously mentioned, by Zhu et al., (1999) and Abd-Elmoniem,

(2003) to be the element concentration per unit dry biomass per day; it reflects the affinity of the studied aquatic macrophytes to accumulation. Values of roots, stems and leaves of young water hyacinth plants grown in the waste water of both studied treatment stations are respectively shown in Table (3), such values being 12.7, 11.4 and 10.5 mg Pb/ kg biomes/day, respectively during the first 5 day exposure period; this means that 1kg biomass of young water hyacinth plant parts has the potential to remove 12.7, 11.4 and 10.5 mg pb per day, respectively. Correspondent values for the concerned rate were 7.45, 6.79 and 4.67 mg Pb /kg biomass/day during the 10 day exposure period, i.e., 1 kg biomass of young

Table (3): Total accumulation rate (TAR), mg/kg/day, for the studied heavy elements in young water hyacinth plants after planting in the treated waste water,

	Total accumulation rate (TAR)		
	Mahalla station		
Exposure periods / *P	Roots	Stems	Leaves
		Pb	
5	12.7	11.4	10.5
10	7.45	6.79	4.67
14	5.69	5.09	3.72
		Ni	
5	17.1	11.8	9.04
10	9.29	7.36	4.98
14	7.09	5.71	4.34
		Cd	
5	1.13	0.84	0.83
10	0.71	0.56	0.48
14	0.61	0.43	0.37
		Zn	
5	3.20	2.80	1.38
10	1.70	1.56	1.22
14	1.37	1.21	9.02

* Plants part

plant parts has the potential to remove 7.45, 6.79 and 4.67 mg pb every day, respectively. Finally, during the studied 14 days exposure period, the value of total accumulation rate was 5.69, 5.09 and 3.72 mg Pb/ kg biomass/day i.e., 1 kg biomass of young plants has the potential to remove 5.69, 5.09 and 3.72 mg Pb every day for roots, stems and leaves, respectively. Correspondent values for the concerned rate for Ni were 17.1, 11.8 and 9.04 mg Ni/ kg biomass/day, respectively during the first 5 day exposure period; this means 1 kg biomass of young water hyacinth plant parts has the potential to remove 17.1, 11.8 and 9.04 mg Ni every day, respectively. The correspondent values were 9.29, 7.36 and 4.98 mg Ni/kg biomass/ day, respectively for the10 day exposure period ,i.e., 1 kg biomass plant parts has the potential to remove 9.29, 7.36 and 4.98

mg Ni every day, respectively. During the studied14 day exposure period, the values of total accumulation rate were 7.09, 5.71 and 4.34 mg Ni/ kg biomass/day, i.e., 1 kg biomass of young plants has the potential to remove 7.09, 5.71 and 4.34 mg Ni every day, respectively.

Values of the accumulation rate for Cd were 1.13, 0.84 and 0.83 mg Cd/ kg for different plant parts, respectively during the first 5 day exposure periods; this means that 1 kg biomass of young water hyacinth plant parts has the potential to remove 1.13, 0.84 and 0.83 mg Cd per day, respectively. Correspondent values for the concerned rate for roots, stems and leaves during both 10 days and 14 days exposure periods, respectively were 0.71, 0.56 and 0.48 but 0.61, 0.43 and 0.37 mg Cd/kg biomass/day. This means that a 1 kg biomass plant part has the potential to remove 0.71, 0.56 and 0.48 but 0.61, 0.43 and 0.37 mg Cd per day. Finally, correspondent values of accumulation rate for the studied plant parts for Zn were 3.20, 2.80 and 1.38 but 1.70, 1.56 and 1.22 and 1.37, 1.21 and 0.92 mg Zn/kg biomass/day during for the 5, 10 and 14 day exposure periods respectively; this means that 1 kg biomass of young water hyacinth plant parts has the potential to remove 3.20, 2.80 and 1.38 but 1.70, 1.56 and 1.22 and 1.37, 1.21 and 0.92 mg Zn per day for roots, stems and leaves, respectively.

As for the old studied plants, values of accumulation rate (Table 4) for the studied roots, stems and leaves followed a trend almost similar to that followed by the studied young plants of Mahalla station possibly due to the same interacting factors previously mentioned.

As previously mentioned by Zhu et al., (1999) and Abd-Elmoniem, (2003), the ratio between plant metal concentration and that of the growth media expresses the bioconcentration factor (BCF) which, again, may reflect the affinity of the studied aquatic macrophytes to a specific heavy element or pollutant. Tissue concentration of the studied plants has been used to be a criterion for water hyacinth aquatic plants to identify the hyperaccumlation (Zhu et al., 1999); in spite of that, BCF may frequently be a better indicator for that criterion as it takes in account the element concentration in the substrate.

The data in table (5) show relatively high efficiency for the young water hyacinth plants as an advice for phytoremediation. BCF values seemed to be relatively high for different parts of the water hyacinth plants grown in waste water of Mahalla station in spite of their variations, again, depending on the ion species, exposure period and the concerned station. This trend seemed to reflect the specialization of the concerned aquatic plants to accusation for the studied heavy metals of Pb, Ni, Zn and Cd.

The previously mentioned presentation may suggest the suitability of water hyacinth aquatic plant for the objective of remediation for the concerned waste waters of both the studied treatment stations Of course, more studies should be performed to design the practical implications of this proposed remediation technique taking in consideration the problems possibly encountered with this suggested technique particularly the restriction in the water canals and the great consumption of the concerned plants for water. In fact, Zayed et al., (1999) pointed out that, from the view of phytoremediation, a good accumulator should have (i) the ability to take up more than 0.5% dry wt. of a given heavy element and (ii) the ability to bioconcentrate the elements in its tissues as to have a bioconcentration factor of more than 1000 (a 100 – fold compared on a fresh weight, or in vivo basis). Abd-Elmonien, (2003) found that the BCF values of Sunflower plants were high in roots than in the corresponding ones in shoots; an opposite behavior was, however, found with B. coddii. This fact suggested that translocation of Ni from roots to shoots could be a limiting factor for the bioconcentration factor shoots of Sunflower and roots of B. coddii.

Table (4). Total accumulation rate (TAR), mg/kg/day, for the studied heavy elements in old water hyacinth plants after planting in the treated waste water

	Total accumulation rate (TAR)		
	Mahalla station		
*P / Exposure periods	Roots	Stems	Leaves
		Pb	
5	8.10	7.96	5.28
10	5.38	4.71	3.18
14	4.24	3.75	3.42
		Ni	
5	13.4	8.74	6.84
10	7.65	5.18	4.37
14	6.85	4.28	4.04
		Cd	
5	0.83	0.59	0.50
10	0.40	0.32	0.27
14	0.56	0.31	0.27
		Zn	
5	1.93	1.87	1.13
10	1.49	1.42	0.71
14	1.28	1.24	0.70

* Plants part

Table (5): Bioconcentration factor (BCF), for the studied heavy elements in young water hyacinth plants after planting in the treated waste water.

*E / Exposure periods	Bioconcentration factor (BCF)			
	Mahalla station			
	Pb	Ni	Cd	Zn
	Roots			
5	15.6	16.5	3.53	11.2
10	18.3	17.9	5.66	11.9
14	19.6	19.2	10.5	13.4
	Stems			
5	14.0	11.4	3.34	9.79
10	16.7	14.2	4.45	10.9
14	17.6	15.4	4.22	11.8
	Leaves			
5	10.4	8.72	3.23	6.61
10	11.5	9.61	3.86	8.53
14	11.8	11.2	4.19	9.02

* Elements

As far as the studied old water hyacinth plants grown on the waste water of both studied stations are concerned, the indicated BCF data (Table, 6) may, again, suggest the studied aquatic plants to be a good accumulator for heavy metals particularly at relatively long exposure period, such trend being true for both investigated treatment stations with variations again due to the same previously mentioned factors particularly the concerned element Species. In fact, Rami et al., (2001) in a study for the aquatic phytoremediation, reported that root BCF is more relevant than that of other plant parts. In addition, Enany and Mazen, (1995) added that cadmium was accumulated, in the water hyacinth plants, against its concentration gradient, mostly as a soluble form. Isolation and Purification of Cd-binding protein showed that the accumulated Cd was associated with two major protein fractions: the first with high molecular weight containing about 35% of bound Cd, the second with low molecular weight containing about 40% of bound Cd. This type of protein, called phytochelatins (glutamine-cysteine-glycine), has been synthesized only in the plant kingdom and is thought to play a role in the ability of some plants to avoid metal toxicity (Robinson et al., 1988). Finally, Pinto et al., (1987) pointed out that water hyacinth plant was used to remove a large amount of silver from industrial waste water, the silver in the ached plant tissues being recovered efficiently.

Table (6): Bioconcentration factor (BCF), for the studied heavy elements in old water hyacinth plants after planting in the treated waste water

Exposure periods \ *E	Bioconcentration factor (BCF)			
	Mahalla station			
	Pb	Ni	Cd	Zn
	Roots			
5	10.0	12.6	3.06	6.95
10	13.3	14.7	3.22	10.4
14	14.6	15.4	3.66	12.5
	Stems			
5	9.80	8.44	2.37	6.84
10	11.6	10.0	2.54	9.93
14	13.0	12.4	3.42	12.9
	Leaves			
5	6.50	6.60	2.00	3.95
10	7.6	8.43	2.18	4.96
14	11.8	10.9	3.02	7.20

As a conclusion, after assurance for presence of a pollution problem in the area of Zeifta village, through evaluation of certain pollutants using wheat plants as a practical biological indicated for monitoring, water hyacinth plants proved to be a good remediation for such problem through efficient accumulation for heavy elements responsible for such problem of pollution.

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إزالة العناصر الثقيلة من مياه الصرف الصحي المعالج بواسطة النباتات المائية

عادل السيد اللبودى[1], عصام محمد عبد المنعم[1], عزت محمد سليمان[2], علا فاروق محمد [3]
[1]قسم الاراضى- كلية الزراعة – جامعة عين شمس- القاهرة – مصر
[2]معهد الدراسات والبحوث البيئية- جامعة عين شمس- القاهرة – مصر
[3]هيئة الصرف الصحى - مصر

اعادة استخدام ماء الصرف المعالج فى الرى يعتبر هدف استراتيجى وذلك لمعظمة كفاءة استخدام موارد المياه فى مصر.
لإزالة العناصر الثقيلة (الزنك و الكادميوم) من ماء الصرف الصحي المعالج والمأخوذ من محطة المحلة تم محاولة إزالة تلك العناصر باستخدام النباتات المائية والتي زرعت في ماء الصرف الصحي المذكور لفترات مختلفة (5، 10، 14 يوم علي التوالي). دلت النتائج علي أن امتصاص العناصر الثقيلة يزداد بزيادة وقت التجربة معتمدا علي عمر النبات والجزء النباتي وكذلك نوع العنصر.
أخيرا قيم الامتصاص المذكور بواسطة ورد النيل بمعيارين هما معدل التراكم الكلى ومعامل التراكم الحيوي حيث أوضحت هذه القيم أن الجذور كان الاعلي تأثرا بامتصاص العناصر مقارنة بأجزاء النباتات الاخري وهذا في كل من النباتات الصغيرة والنباتات الكبيرة بالرغم من اختلاف القيم.