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A COMPARATIVE STUDY AMONG CYANOBACTERIA, AZOLLA AND HUMIC ACID FOR REMOVAL OF SOME HEAVY METALS FROM WASTEWATER

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ABSTRACT

A laboratory experiment was conducted to assess the efficiency of Cyanobacteria and Azolla strains beside of the humic acid to remove and / or accumulate different concentrations of lead, cadmium and nickel from secondary treated wastewater enriched with these metal ions at concentrations of 2,4 and 8 mgL^{-1}. Humic acid was added at rates of 200,400 and 800 mgL^{-1}.Results indicated that Cyanobactria, Azolla and humic acid were able to removing significantly all tested heavy metals with different degrees directly related to the concentrations of metal themselves. Data showed also that as the rate of humic acid increased, its efficiency to remove heavy metals also increased. The relative accumulation percentages were increased as the concentration of heavy metals under study also increased. Results indicated that Cyanobacteria strain showed higher heavy metals accumulation percentage than that recorded by Azolla strain or humic acid from wastewater.

The Cyanobacteria and Azolla strains could remove the heavy metals according to the following order :Pb>Cd>Ni while in case of the humic acid, the following decending order was attained: Cd>pb>Ni.

Key words: cyanobacteria- Azolla - humic acid- heavy metals.

INTRODUCTION

The accumulation of heavy metals by plants depend on many factors such as soil type, soil physical and chemical properties, organic matter content, soil reaction and redox potential which may radically alter metal toxicity for plants. The amount of heavy metals taken up by plants does not only depend on the metal content of the soil but also is strongly influenced by other factors such as plant species, soil parameter and the kind of heavy metal itself (Fruchtenicht and Vetter, 1982). Bioremediation refers to the use of microorganisms for removing hazardous toxic pollutants from soil and wastewaters. There are five major mechanisms by which the microorganisms may interact with metals as follows: (1). The metal is bound to the surface of the organism. (2) The metal may be taken up into the cell.(3) An oxidation-reduction brought about by enzymatic processes which may cause solubilization and /or precipitation of metal.(4)The metal may be complexed by metal-specific metabolites and kept insoluble or transferred across the cell membrane. (5) Certain metals are biochemically transformed by cell which keep the toxic elements at low level (Olsen and Kelly, 1986). Algae is a group these is microorganisms which can be used for water purification and removal of heavy metals (Norberg and Persson, 1984). Biological decontamination of heavy metals in wastewater and in soils is a new branch of science which helps us to solve pollution problems without adding new problems or new pollutants. Recently, the researchs for removing heavy metals have focused on new technologies rather than traditional methods such as ion exchange, chemical precipitation, membrane process and solvent extraction, which are expensive and inefficient.

These draw backs of traditional metal removal techniques have led researchers to the investigation of the use of microbial biomass as biosorbents for heavy metals. In related studies, metal removal abilities of live cells of various species of bacteria, algae, fungi and yeast have been investigated with a great interest on the nature and mechanisms of metal- microorganisms interaction (Khodair, 1998). In bioremediation technique, the response of algae depends on the type and concentration of metal cations. Algae have a principal role in the disappearance and degradation of environmental contaminants where they are a fundamental component in the aquatic ecosystem (Rachlin *et al.*, 1983). They play a vital role in transforming sewage and wastewater into valuable bio-mass and treated water can be used for irrigation. These advantages have also generated interest in recycling the wastewaters through algal systems. During growth, algal cells convert dissolved N, P and C to algal protoplasm. They remove elements from the wastewater which can be reused (Shelef *et al.*, 1978). Factors which affect algae ability to alter chemical form of metal are, the bio-available concentration of the metal, the types and population density algae, the time period of the organism's exposed to the metal and the physico-chemical parameters of the environment (Shubert, 1984).

It is well known that algae and other microbes can adsorb dissolved metals. There is strong interest in the development of biosorbent for use in wastewater treatment (Nestle, 1996). Algae are potentially good candidates for biosorbent development and extensive body of literature deals with metal removal by various algae (Fayed *et al.*, 1983, Radway *et al.*, 2001 and Tantawy *et al.*, 2002). Xie *et al.* (1996) utilized several hundred grams of algal biomass in subsequent metal sorption tests. They added that this biosorbent was an efficient agent in the removal of Cd, Cr, Cu, Hg, Ni and Pb. Aderhold *et al.* (1996) discovered the ability of the brown algae (sea weeds) to sequester the heavy metal ions Cu, Ni, Zn, Pb and Cd from the contaminated water.

Chen *et al.* (1998) found that the heavy metals were taken up by the flagellate algae in an order of Cu> Pb > Co > Cd > Ni > Ag > Hg. Tantawy *et al.* (2002) found that both Anabaen flosaqua and Nostoc muscurum wear able to accumulate significantly heavy metals (Cd,Pb and Ni) in their cells with different degrees.

El-Sayed (2003) found that increasing exposure time of Azolla ferns to wastewater increased the removal efficiencies of Cd, Cu and Pb.

Baker *et al.* (1988) reported that plants can resist harmful effect of toxic heavy metals in one of two ways. They can convert the heavy metals from entering their tissues (exclusion mechanisms) or they can convert the inorganic heavy metal inside cells into something less harmful. The accumulation of heavy metal ions by aquatic plants from the water in which they are growing has been documented by a many authors (Dietz, 1973 and Ray and White, 1979). Organic matter plays an important role in the chemical behavior of several heavy metals in soils through its active functional groups which have the ability to retain the metal in a complex form and /or in a chelating one.

The main objective of the current work was to evaluate potentialities of Cyanobacteria, Azolla and humic acid for removing heavy metals (Pb, Cd and Ni) from a wastewater sample taken from Zenin Wastewater treatment.

MATERIALS AND METHODS

A laboratory experiment was conducted to study the behavior of Pb, Cd and Ni applied individually or mixed to gether to secondary treated wastewater with Cyanobacteria, Azolla and humic acid. Pb, Cd and Ni were added at rates of 2, 4 and 8 mgL^{-1} as chloride, sulphate and sulphate, respectively. Humic acid was applied at rates of 100, 200, 400 and 800 mgL^{-1}. After 30 days, heavy metals concentrations were recorded. The experiment was subjected to statistical analysis as a factorial design involving the following factors: 1- three treatments i.e. Cyanobacteria, Azolla and humic acid. 2- heavy metals: three elements i.e. Pb, Cd and Ni. 3- Applied element concentration i.e. control (did not supplement with any metal), 2,4 and 8 mgL^{-1}.

Wastewater:

The secondary treated wastewater sample used during the current work contains 0.00119% Pb, 0.00008 % Cd and 0.0009% Ni. It was taken from Zenien Wastewater Treatment station, Giza Governorate.

Azolla pinnata:

Azolla pinnata strain was provided by Soils, Water and Environment Research Institute, Agricultural Research Center, Giza, Egypt. Azolla plants were propagated in different dishes. Four litters of secondary treated wastewater was poured in each dish.

Removal of Heavy metals from wastewater by Azolla pinnata was studied for 30 days exposure time. Azolla ferns were exposed to secondary wastewater enriched with different concentrations of heavy metals. Pb, Cd and Ni were added to the wastewater solely or mixed at concentrations of 2, 4 and 8 mgL^{-1} in addition; the control treatment was made in which the secondary treated wastewater was supplemented only with azolla ferns.

Cyanobacteria:

Nostoc muscorum isolated from rice fields was used during the current study. The algal strain was provided from Agric. Res. Microbiology, Soils, Water and Environ. Res. Inst., ARC., Giza, Egypt. Different concentrations (2,4 and 8 mgL^{-1}) of Pb, Cd and Ni were added individually or in combined mixture. Flasks were incubated with 10 ml of algal suspension (10^{12} CFU ml^{-1}) under containous illumination (5000 Lux) for 30 days. After incubation period, algal cells were harvested. The cultural filtrate was subjected to determined the residual element.

Humic acid:

Humic substances were extracted from biogas manure by treating it with 0.1 N KOH solution. Humic acid was separated from humus extract by acidification with HCl to reach pH 2.0, after standing over night. The precipitates (H.A) were purified by electrodialysis until the ash content was reduced to less than 1%.

Table (1): Elemental composition of the humic acid extracted from biogas manure:-

C %	N %	H %	O %	S %	C/N ratio	C/O ratio	O/H ratio	N/H ratio
48.7	2.1	6.79	39.06	3.35	23.19	1.24	5.75	0.30

The purified humic acid was air dried and finely ground in porcelain mortar. Different amounts of humic acid being 100, 200, 400 and 800 mg were added to one litter of the secondary treated wastewater enriched with different concentrations of Pb, Cd and Ni (2,4 and 8 mgL^{-1})

Total organic carbon of humic acid was determined using potassium dichromate method and O-phenanthroline as an indicator (Jackson, 1967). Total N was determined using micro kjeldahl method (Sposito *et al.*, 1976). Hydrogen was determined using the dry combustion, it was oxidized to water which was absorbed by calcium chloride and weighted (Karrer, 1950).Sulfur was determined using barium chloranilate method (Beaton *et al.*,1968). Oxygen was calculated by difference (Goh and Steevenson, 1971). Pb, Cd and Ni were determined by Atomic Absorption Spectrophotometer, Perkin Elmer model 3110

Statistical analysis:

The obtained results were subjected to analysis of variance using Minitab program according to Ryan and Joiner (1994) and the treatments were compared by using LSD at 0.01 level of probability

RESULTS AND DISCUSSION

Effect of Cyanobacteria strain on removal of the studied heavy metals:

Data presented in Table (2) reveal that addition of Cyanobacteria to the wastewater enriched with Pb exhibited variable accumulated amounts of 0.81, 2.07 and 4.69 mgL^{-1} in respective to the initial lead concentrations i.e. 2.4 and 8 mgL^{-1}. The relative Pb. accumulation percentages by Cyanobacteria were 40.5, 51.8 and 58.6 corresponding to the initial Pb concentrations of 2,4 and 8 mgL^{-1} respectively.

In case of Cd metal, Cyanobacteria cells were able to accumulate 0.62, 1.68 and 3.83 mgL^{-1}when the wastewater was supplied with 2, 4 and mgL^{-1} corresponding to accumulation percentages 31.0, 42.0 and 47.9% for the abovementioned concentrations, respectively. These results agree well with those obtained by Tantawy *et al.* (2002).

Table (2): Heavy metals accumulation by cyanobacteria

Applied element concentration (mgL^{-1})	Upon application of individual elements (mgL^{-1})	Element accumulation percentage	Upon application of mixed elements (mgL^{-1})	Element accumulation percentage
Lead (Pb)				
Control	0.0	0.0	0.0	0.0
2.0	0.81	40.5	0.43	26.0
4.0	2.07	51.8	1.47	52.3
8.0	4.69	58.6	3.58	46.4
Cadmium (Cd)				
Control	0.0	0.0	0.0	0.0
2.0	0.62	31.0	0.43	21.5
4.0	1.68	42.0	1.47	36.8
8.0	3.83	47.9	3.58	44.8
Nickel (Ni)				
Control	0.0	0.0	0.0	0.0
2.0	0.54	27.0	0.39	19.5
4.0	1.59	39.8	1.33	33.3
8.0	3.66	45.8	3.37	42.1

L.S.D 0.01: **Pb** = 0.32 **Cd** = 0.29 **Ni** = 0.25

The variation in this process could be attributed to the algal species (Cho *et al.*, 1994); nature of cell wall and organic compound released (Laube *et al.*, 1980); as well as metal concentration. Moreover, Gadd (1991) reported that heavy metal uptake by algae could be divided into rapid passive biosorption on the cell surface followed by a slower intracellular bioaccumulation. Hammouda *et al.* (1995) found that the pattern of Pb and Cd uptake by algae especially cyanophyta evaluate the active regulatory mechanisms by the algae to keep the metals in non- toxic levels. This may be controlled through the secretion of specific ligand to the metal. The nature of these ligands may be polypeptides or polysaccharides (Murphy *et al.*, 1976). The nature of suitable ligand has no effective role on varity whatever the ion is desorbed or absorbed. Also, the binding process was mainly related to the conditions of organism at which it was allowed to metal accumulation. Radway *et al.* (2001) came to a conclusion that algae biosorption of heavy metals occurs by both metabolically and metabolically mediated processes.

In case of Ni, data presented in Table (2) show that Ni accumulated amounts by Cyanobacteria were 0.54, 1.59 and 3.66 mgL^{-1} when the wastewater was supplied with 2, 4 and 8 mgL^{-1} Ni, respectively. However, Ni.

Percentages accumulated by cyanobacteria relative to the initial applied concentrations were 27.0, 39.8 and 45.8%, respectively. It is worthy to point out that cyanobacteria strain had showed less ability to accumulate Ni than Cd or Pb. This result could be attributed to high toxicity of Ni than Cd and Pb. These results agree well with those obtained by El-Shiekh (2007) who reported that algae succeeded for reducing concentrations of Ni, Co and Cd in wastewaters. In addition, their efficiency for removing Ni was lower.

Owing to the afore mentioned results, it could be concluded that cyanobacteria were able to accumulate Pb, Cd and Ni from the studied wastewater, however their abilities to accumulate any of these metals varied according to the heavy metal it self.

Furthermore, Pistocchi *et al.* (2000) indicated that the survival capacity of cells against heavy metals often depends on the presence of specific responses which, in algae generally follow two biochemical mechanisms (1) exclusion of the toxic elements outside the plasma membrane (2) bio synthesis of specific ligands and formation of complex entrapping heavy metals inside the cell in an inert form. They added that the first mechanism might require the presence of ligands on the cell surface having a high affinity with the metal that must be detoxified.

As for to the mixed elements applied to the wastewater, data in Table (2) indicated that these heavy metals were accumulated were by Cyanbacteria in the following descending order: Pb > Cd > Ni. However, this study needs to be extended to test the efficiency of more algal strains to remove the other toxic heavy metals from wastewaters.

Effect of Azolla on removal of the studied heavy metals:

Data presented in Table (3) show that Azolla ferns were able to remove Pb, Cd and Ni from the wastewaters supplemented with concentrations of 2, 4 and 8 mgL^{-1} Pb, Cd and Ni. Almost similar results were obtained by El- Sayed (2003).

Table (3): Heavy metals accumulation by Azolla.

Applied element concentration (mgL^{-1})	Upon application of individual elements (mgL^{-1})	Element accumulation percentage	Upon application of mixed elements (mgL^{-1})	Element accumulation percentage
Lead (Pb)				
Control	0.0	0.0	0.0	0.0
2.0	0.67	33.5	0.91	45.5
4.0	1. 79	44.8	2.30	57.5
8.0	3.88	48.5	3.29	41.1
Cadmium (Cd)				
Control	0.0	0.0	0.0	0.0
2.0	0.55	27.5	0.43	21.5
4.0	1.42	35.5	1.22	30.5
8.0	3.31	41.4	2.67	33.4
Nickel (Ni)				
Control	0.0	0.0	0.0	0.0
2.0	0.25	12.5	0.19	9.50
4.0	0.69	17.3	0.56	14.0
8.0	1.98	24.8	1.49	18.6

L.S.D 0.01: Pb = 0.27 Cd = 0.18 Ni = 0.11

The overall accumulation percentages of Pb by Azolla ferns after exposure period of 30 days were about 33.5, 44.8 and 48.5 % when the wastewater was provided with Pb at concentrations of 2,4 and 8.0 mgL^{-1}, respectively. The biological accumulation of Pb by

Azolla pinnata increased with increasing the initial concentration of Pb in the wastewater. Telor *et al* (1997) studied the biofiltration of some heavy metals by the aquatic fern Azolla (Azolla filiculoidies) and found that 66, 82, 85, 96 and 99% of Cd, Ni, Zn, Cu and Cr, respectively were recovered in the biomass at the end of the experiment (123 h).

Lead was exhibited little inhibition to Azolla pinnata which were of higher tolerance for Cd and Ni. These results are in accordance with those obtained by Kalita and Sarma (1995).

Data in Table (3) reveal that cadmium accumulation percentage in cells of Azolla strain were 27.5, 35.5 and 41.4% in respective to the initial Cd concentrations i.e. 2.4 and 8 mg/L, respectively.

Data in Table (3) indicate that percentages of Ni accumulated by Azolla were 12.5, 17.3 and 24.8 % in respective to the initial Ni concentrations i.e. 2.4 and 8 mgL^{-1}.

The accumulation of Pb, Cd and Ni by Azolla ferns was directly related to the concentration of metals in the wastewater at the initial time. Muramoto and Oki (1983) demonstrated the potential of aquatic plants for reducing metal content in wastewater. The uptake of metal ions will ultimately depend upon the nature and amount of aquatic biomass, the metal to be removed, competing metal ions, metal concentration, as well as the volume and quality of the feeding water.

From the abovementioned results, it can be deduced that the relative removal percentages of the studied heavy metals by Azolla pinnata from the wastewater followed the descending order: Pb > Cd > Ni.

The concentrations of Pb, Cd and Ni accumulated by Azolla ferns exposed to wastewater enriched with various loads of heavy metals (Pb, Cd and Ni) in combinations for 30 days are shown in Table (3). Data reveal that Azolla ferns was accumulated higher percentage of Pb than that of Cd or Ni at the different concentrations of the applied heavy metals. Hence, we can emphasize that Azolla pinnata could be considered hyperaccumulator for Pb, Cd and Ni at the different concentrations of 2,4 and 8 mg/L. Increasing the concentrations of Pb, Cd and Ni in the wastewater increased the Pb, Cd and Ni percentages in Azolla.

Effect of humic acid:

Data presented in Table (4) show the relationship between concentration of Pb added to the secondary treated wastewater and rate of the applied humic acid (HA). It is evident that concentration of Pb significantly increased due to increasing its applied rate. The average values of Pb concentration were 1.48, 2.05 and 2. 82 mgL^{-1} corresponding to the Pb additions rates of 2, 4 and 8 mg/L, respectively.

Table (4): Effect of different rates of humic acid as well as Pb, Cd, Ni applied individually on heavy metal concentrations in the studied wastewater.

Concentration the applied of heavy metal (mgL^{-1})	Rate of applied Humic acid (mgL^{-1})														
	100			200			400			800			Mean		
	Pb	Cd	Ni	Pb	Cd	Ni	Pb	Cd	Ni	Pb	Cd	Ni	Pb	Cd	Ni
2	1.81	1.10	1.89	1.66	0.77	1.19	1.40	0.61	1.10	1.04	0.29	0.67	1.48	0.69	1.21
4	2.92	1.41	2.29	2.64	1.03	1.58	1.55	0.88	1.28	1.09	0.57	0.69	2.05	0.97	1.46
8	4.10	2.23	3.61	3.95	2.18	2.39	1.72	1.99	1.39	1.52	0.95	1.04	2.82	1.84	2.10
Mean	2.94	1.58	2.60	2.75	1.33	1.72	1.56	1.16	1.26	1.22	0.60	0.80	2.11	1.17	1.59

L.S.D 0.01 Pb = 0.35 Cd = 0.20 Ni = 0.28

As for the effect of humic acid on the concentration of Pb, results listed in Table (4) indicate that Pb was negatively and significantly affected with increasing rate of the applied humic acid. These results agree well with those obtained by El-Ghannam and El-Ghozoli (2003).

The average concentrations of Pb were 2.94, 2.75, 1.56 and 1.22 mg L^{-1} corresponding to the rates of added humic acid at 100, 200, 400 and 800 mg/L. The depression percentages in Pb concentration due to humic acid application were 26, 48.8 and 64.8 % in respective to initial lead concentration of 2, 4 and 8 mg L^{-1}

The depression in Pb could be attributed to partly to reactions involving insoluble organic compounds formation (Zimdahl and Skogerboe, 1977). Bunzl *et al.* (1976) suggested the adsorption of Pb ions on to humic acid is probably occurring through an ion exchange process between the ion adsorbed and H^{+} ions from the organic matter.

Data in Table (4) reveal the influence of the applied humic acid on Cd concentration in the wastewater enriched with Cd at different concentration. Cd concentration in wastewater was significantly and positively affected with increasing rate of Cd addition. The average values of Cd were 0.69, 0.97 and 1.84 corresponding to Cd addition rates of 2,4 and 8 mgL^{-1}, respectively.

Concerning the effect of humic acid on the concentration of Cd, results in Table (4) show that Cd was negatively and significantly affected with increasing rate of humic acid application. The average values of Cd were 1.58, 1.33, 1.16 and 0.50 mgL^{-1} corresponding to added rates of humic acid of 100, 200, 400 and 800 mg HA/ L of wastewater. Similar results were achieved by El-Kassas *et al* (2002) and El-Ghozoli (2003).

The depression percentage in Cd concentration due to humic application were 65.5, 75.7 and 77.0% corresponding to Cd addition rates of 2,4 and 8 mg CdL^{-1}, respectively.

Data in Table (4) reveal the relationship between Ni concentration in wastewater and each of HA and Ni addition rate. The concentration of Ni increased with increasing rates of Ni addition. The average value of Ni were 1.21, 1.46 and 2.10 mgL^{-1} corresponding to Ni rates of 2,4 and 8 mgL^{-1}, respectively.

With respect to the effect of H.A on the concentration of Ni, results indicated that Ni was negatively and significantly affected with increasing rates of H.A application. The average values of Ni were 2.60, 1.72, 1.26 and 0.80 mgL^{-1} corresponding to added rates of H.A of 100, 200, 400 and 800 mgL^{-1}. The percentage decreases in Ni concentration due to H.A application corresponding Ni levels of 2, 4 and 8 mgL^{-1} were 39.5, 63.5 and 73.8%, respectively. Organic matter, particularly the humic and fulvic acids, plays an important role in the chemical behavior of several metal ions through their functional groups which have the ability to retain the metal in complex or chelate from (Stevenson, 1981).

It can be deduced from the above-mentioned results that humic acid was the most efficient methods for decreasing the concentration of heavy metals which according to the descending order: Cd > Ni > Pb.

Results in Table (5) show concentration of Pb, Cd and Ni in the secondary treated wastewater enriched with Pb, Cd and Ni at concentrations of 2, 4, and 8 mgL^{-1}. Humic acid was applied at rates of 100, 200, 400 and 800 mgL^{-1}. Data indicated that the concentrations of heavy metals under study increased with increasing rate of heavy metals addition. The average values were 1.17, 2.26 and 3.63 mgL^{-1} for Pb, 0.80, 1.54 and 1.86 mgL^{-1} for Cd, 1.05, 2.32 and 3.19 mgL^{-1} for Ni corresponding to addition rates of 2, 4 and 8 mgL^{-1}, respectively.

As for the effect of humic acid on the mixed concentrations of Pb, Cd and Ni, results listed in Table (5) indicate that heavy metal concentrations were decreased with increasing rate of the applied humic acid. The average values of amounts heavy metals by humic acid corresponding to the studied different rates i.e 100, 200, 400 and 800 mgL^{-1} were 2.82, 2.59. 2.23 and 1.78 mgL^{-1} for Pb, 1.91, 1.66, 1.17 and 0.88 mgL^{-1} for Cd and 2.55, 2.36, 2.12 and 1.72 mgL^{-} for Ni, respectively.

Table (5): Effect of different rates of humic acid as well as Pb, Cd and Ni applied combined together on heavy metal concentrations in the studied wastewater.

Rate of applied humic acid (mgL^{-1})	Pb			Cd			Ni			Mean		
	Initial concentration (mgL^{-1})											
	2	4	8	2	4	8	2	4	8	Pb	Cd	Ni
100	1.33	2.60	4.54	1.47	1.96	2.30	1.15	2.76	3.75	2.82	1.91	2.55
200	1.21	2.55	4.02	1.21	1.75	2.01	1.10	2.52	3.47	2.59	1.66	2.36
400	1.14	2.07	3.50	0.39	1.41	1.72	1.04	2.13	3.20	2.23	1.17	2.12
800	1.02	1.85	2.48	0.15	1.05	1.43	0.91	1.88	2.37	1.78	0.88	1.72
Mean	1.17	2.26	3.63	0.80	1.54	1.86	1.05	2.32	3.19	2.35	1.40	2.19

L.S.D0.01: Pb = 0.19 Cd = 0.17 Ni = 0.21

On the other hand, humic acid seemed to be more efficient for removing Pb, Cd and Ni the sequence Cd > Ni > Pb.

Practically every aspect of the chemistry of heavy metals is related to the formation of complexes with organic matter. Whereas multivalent cations have potentialities for forming coordinate linkages with organic molecules.

The complexing ability of humic and fulvic acids results largely from their content of oxygen containing functional groups, such as COOH, phenolic OH and C= O groups of various types. (Stevenson, 1981)

It can be deduced from the above-mentioned results that cyanobacteria was the most efficient for heavy metals (Pb- Cd- Ni) removal from wastewater as compared with Azolla or humic acid.

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دراسة مقارنة بين السيانوباكتريا والأزولا وحامض الهيومك لإزالة بعض العناصر الثقيلة من الماء العادم

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أجريت تجربه معمليه لتقدير قدرة كل من سيانوبكتريا والأزولا وحامض الهيومك على إزالة العناصر الثقيلة مثل الرصاص والكادميوم والنيكل المضافة إلى ماء ملوث بتركيز ٨،٤،٢ ملليجرام / لتر، كما تم بحث أثر حامض الهيوميك المضاف بمعدلات، ١٠٠، ٢٠٠ ٤٠٠، ٨٠٠ ملليجرام/ لتر في إزالة مثل هذه العناصر. وقد أوضحت النتائج أن كل من سيانو بكتريا والأزولا وحامض الهيومك كانت لها القدرة على إزالة العناصر الثقيلة بدرجات متفاوتة ويرتبط ذلك بتركيز العنصر. كما أشارت النتائج أنه بزيادة معدل إضافة حامض الهيومك تزداد كفاءة إزالته للعناصر الثقيلة. كما ازداد كذلك معدل تراكم العناصر الثقيلة بزيادة تركيزها. وقد أوضحت النتائج كفاءة عالية سيانو بكتريا على إزالة العناصر الثقيلة تحت الدراسة أكثر من كل من الأزولا او حامض الهيوميك. بالنظر إلى تأثير كل من السيانوباكتريا والأزولا على الحد من تراكم العناصر الثقيلة فانه يمكن ترتيب تاثيرهما كما يلى : الرصاص > الكادميوم > النيكل . بينما فى حالة حامض الهيومك فانه يمكن ترتيبها كما يلى :الكادميوم > الرصاص > النيكل.