Degradation of some heavy metals in wastewater using aqua plants

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Abstract: The main goal of wastewater treatment is to allow human and industrial effluents to be disposed of without danger to human health or negative impacts to the natural environment. The aim of this study was to evaluate the use of some aquatic plants in terms of the removal of certain chemicals as part of such wastewater treatment. The potential use of the aquatic plant Lemna minor for wastewater purification was thus examined, with Lead, Nickel, Copper, and Cadmium selected as target impurities. The effect of Lemna minor plants on the occurrence of these metals in wastewater for a period of two weeks was thus examined. The results showed that the presence of the plants enhanced the removal of heavy metals: the removal percentage of Lead in the presence of Lemna minor was higher than in the tank with no Lemna minor, with rates of 73% and 47%. In addition, in the presence of Lemna minor, the removal efficiency of Nickel was about 47%, higher than that that without Lemna minor. These results suggest that this plant may decrease the concentrations of some heavy metals and consequently decrease the costs of treating water to remove such metals.

Keywords: Phytoremediation, Degradation, Heavy metals, Wastewater, Lemna minor.

1. Introduction:
One of the main global environment problems is heavy metal pollution. Heavy metals are defined as those metallic elements that have a relatively high density compared to water [1]. There are two main sources of heavy metals in wastewater: natural and human. Natural factors for this include volcanic activities, urban runoff and aerosol particulates, and soil erosion, while human factors include mining extraction operations, textile industries, nuclear power, and metal finishing and electroplating processes.

As heavy metals are non-biodegradable and accumulate at high levels, they can cause serious damage to natural environments [2], and about 20 of these metals are classified as toxic and pose a significant risk to human health [3]. Most heavy metals are phytotoxic at both low and high concentrations, with the former often detected in wastewater. Heavy metal contaminants that are commonly found in the environment are cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), and zinc (Zn), and while some of these metals (Zn, Cu, and Ni ) are necessary for the growth of plants (micronutrients) other metals (Cd and Pb) that have unknown or negative biological functions [4]. If these metals enter the food chain, even in small quantities in some cases, through plants and aquatic animals via occurrence in the sediments, their accumulation may cause chronic or acute toxicity [5,6].
Phytodegradation is the breakdown or degradation of organic pollutants by external and internal metabolic activities as driven by plants. It includes the use of a plant’s tissue to uptake, store and degrade contaminants, reflecting the ways plants metabolise and destroy contaminants within their tissues. For some contaminants, plants can absorb the contaminants, which are then destroyed by the plant’s enzymes [7].

The aim of the current study is to evaluate the use of aquatic plants in the removal of heavy metals as part of wastewater treatment.

2. Material and Method:

2.1. Materials
Appropriate chemicals (CuCl₂, CdSO₄.8H₂O, NiCl₂.6H₂O, (CH₃COO)₂Pb.3H₂O) were obtained with a purity of 99%. Two water tanks with dimensions of 78 x 50 x 50 cm (about 190L) were set up, and an adjustable submersible water pump was installed in each tank with a max flow up to 600LPH and power of 7W in order to keep the systems ventilated and circulating.

2.2. Collection of wastewater
Wastewater was collected from the pump station that located in A-Shamiyah City. About 180 litres was collected from the pump station, and the samples were transferred in large bottles (20 litres each), rinsed before filling, to the College of Engineering. There was no rain on the day of transfer, and the temperature was about 26 ºC.

2.3 Collection of Lemna minor plants
*Lemna minor* is a floating freshwater aquatic plant with oval leaves, each with a single root hanging in the water. *Lemna minor* has distribution and is native throughout most of Africa, Asia (including Iraq), Europe, and North America. It is generally present wherever freshwater ponds and slow-moving streams occur [8, 9]. About 25 Kg of *Lemna minor* plants were collected from a lake located in A-Shamiyah City. These samples were transferred in large plastic bag that was rinsed before filling and then moved to the College of Engineering. There was no rain on the day of transfer, and the temperature was about 26 ºC.

2.4. Methodology
The wastewater collected from the sewerage pump station was added to the two tanks, which were made from Styrofoam and lined with plastic sheets to avoid any unnecessary interfaces. One of the tanks (tank A) was left without any *Lemna minor* while the *Lemna minor* brought from the pond was added to tank B after being cleaned and rinsed with water and being held in clean water for 24 hours for observation of any changes that might happen. Both tanks were spiked with the chemicals under investigation (CuCl₂, CdSO₄.8H₂O, NiCl₂.6H₂O, (CH₃COO)₂Pb.3H₂O) as prepared in the lab to certain concentrations. One litre of each solution with the target metals as prepared was added to each tank to make the total contents about 50 litres per tank.

2.5. Sampling and Data Analysis
Samples were collected from each tank in glass bottles for transfer to the Environment Authority for measurement of the main characteristics of the wastewater and the selected chemicals. Sampling was performed three times across the study, which was of 15 days duration. Standard methods for the examination of water and wastewater were followed to determine the concentration of the selected samples [10].
3. Results and Discussion
This section discusses the results obtained from using *Lemna minor* in the degradation of heavy metals in the wastewater.

3.1. Main Parameters
The concentrations of the main factors measured in this study are shown in Table 1. The dissolved oxygen in the wastewater tank with *Lemna minor* was higher than the dissolved oxygen in the tank with no aquatic plants, possibly due to the presence of the plants in tank B. Figure 2 shows the DO for both wastewater tanks during the period of study.

| Type                      | Date | DO (mg/l) |
|---------------------------|------|-----------|
| Tank A: without Lemna minor | Day 1 | 7.27      |
|                           | Day 5 | 5.47      |
|                           | Day 10| 4.61      |
| Tank B: with Lemna minor   | Day 1 | 8.66      |
|                           | Day 5 | 8.48      |
|                           | Day 10| 6.73      |
3.2. Degradation of heavy metals with Lemna minor

3.2.1. Cadmium (Cd)
The degradation of Cadmium during the two weeks’ observation is shown in Figure 3. Removal efficiency during that period was about 48%.
3.2.2. Nickel (Ni)
The degradation of Nickel during the two weeks of the study is shown in Figure 4; the removal efficiency during that period was about 43%.

3.2.3. Lead (Pb)
The degradation of Lead during the two weeks of the study is shown in Figure 5; the removal efficiency during that period was about 40%.
3.2.4. Copper (Cu)
The degradation of Copper during the two weeks of the study is shown in Figure 6; the removal efficiency during that period was about 88%.
3.3. Degradation of heavy metals without *Lemna minor*

3.3.1. Cadmium (Cd)
The degradation of Cadmium during the two weeks of the study is shown in Figure 7; the removal efficiency during that period was about 32%.

![Figure 7: Concentration of Cd during the study](image)

| Day 1 | Day 5 | Day 10 |
|-------|-------|--------|
| Cd    | 5.74  | 4.64   | 3.88   |

3.3.2. Nickel (Ni)
The degradation of Nickel during the two weeks of the study is shown in Figure 8; the removal efficiency during that period was about 47%.

![Figure 8: Concentration of Ni during the study](image)

| Day 1 | Day 5 | Day 10 |
|-------|-------|--------|
| Ni    | 17.64 | 15.09  | 9.39   |
3.3.3. Lead (Pb)
The degradation of Lead during the two weeks of the study is shown in Figure (9); the removal efficiency during that period was about 73%.

![Figure 9: Concentration of Pb during the study](image)

3.3.4. Copper (Cu)
The degradation of Copper during the two weeks of the study is shown in Figure 10; the removal efficiency during that period was about 80%.

![Figure 10: Concentration of Cu during the study](image)
In phytoremediation, plants play an important role in biological processes by reducing, breaking down, degrade, and removing these contaminants using various parts of their beings, such as the roots, leaves, stomata, cell walls, and shoots [11,12].

Through phytotransformation (phytodegradation), contaminants are destroyed by plants, including aquatic plants, by their transformation into simpler molecules. [13]. Phytostimulation is occasioned by the release of natural substances by plants that supply nutrients to microorganisms, which in turn enhance biological degradation by increasing in the number and activities of microorganisms [3,14].

The nature of heavy metal polluted wastewater effluents means that they may be toxic to humans in acute, chronic, or sub-chronic, carcinogenic, mutagenic, neurotoxic, or teratogenic ways. Some reports have linked skeletal damage in humans to heavy metals such as selenium, for example [15]. Significant efforts must thus be made to minimise the impact of such contaminants by developing sustainable treatments.

4. Conclusions
The removal of heavy metals from wastewater has become a significant factor in water and wastewater treatment systems. The aim of this study was to evaluate the use of certain aquatic plants in the removal of some heavy metals as part of wastewater treatment.

The results obtained show that:

1- The DO was lower in the tank without aquatic plants than in the tank with aquatic plants.
2- The presence of the selected plants enhanced the removal of heavy metals from wastewater.
3- The removal percentage of Lead in the presence of Lemna minor was higher than that in the tank with no Lemna minor, with rates of 73% and 47%.
4- The presence of Lemna minor improved the removal efficiency of Nickel by about 47%.

Removal rates for heavy metals in both with and without aquatic plants were achieved, Lemna minor showed a particular efficiency for the removal of copper, being more efficient in removing it than other metals.

In general, all necessary actions should be taken to reduce the impact of effluent on water bodies, including the removal of the metals responsible for severe damage to such water bodies. This can be achieved by developing environmental awareness and basic environmental knowledge to allow citizens to develop positive environmental behaviours and to effectively play their role in protecting the environment.

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