

## Lead Removal from Industrial Waters by Water Hyacinth

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### *Abstract.*

*This is a preliminary study intended to develop a method for treating industrial waters that are contaminated with lead. Lead uptake caused by hydroponics feeding into water hyacinth (*Eichhornia crassipes*) was monitored by atomic absorption spectroscopy AAS. Uptake, excretion and oscillation processes were observed.*

*At lower concentrations of 0.001 M, high lead accumulation was observed in the roots and leaves. At higher concentrations of 0.01 M, the lead from roots and leaves drained into the petiole.*

**Keywords:** *lead, industrial wastewater, hydroponics feeding, water hyacinth, *Eichhornia crassipes*, atomic absorption spectroscopy AAS*

### Introduction

Lead occurs naturally in the earth's crust, in ores such as galena, lead (II) sulfide and PbS. However, human activity has resulted in atmospheric lead, mainly as PbSO<sub>4</sub> and PbCO<sub>3</sub>. Lead is generally resistant to corrosion, but will dissolve in low pH, acid water. Beside such weak solutions, a significant fraction may be present in an undissolved form, colloidal particles, or larger particles of lead (II) carbonate, lead (II) oxide, and lead (II) hydroxide. Lead may be leached out, or washed out in suspension from pipes or from soil after heavy rains or flooding especially in acid conditions. Hence, lead contaminated waters may be found near foundries producing metal alloys containing lead, such as brass and bronze; and also near petroleum refineries, where leaded gasoline is produced. Tetraethyl lead (TEL), an organic alkyl compound, is used to increase the gasoline grade, measured in "Octane Number" and thus prevents 'knocking' in petrol engines.

Environmental pathways for lead transportation may be via air, water and soil (Beverland and Agius 2002). The atmosphere path includes lead particles emitted from

vehicles as halides (e.g. PbBrCl, PbBrCl, NH<sub>4</sub>Cl), and lead particles emitted from mines and smelters primarily in the form of PbSO<sub>4</sub>, PbO.PbSO<sub>4</sub>, and PbS. In the atmosphere, lead exists primarily in the form of PbSO<sub>4</sub> and PbCO<sub>3</sub>.

The water path includes significant fraction in the form of colloidal or larger undissolved particles of lead (II) carbonate, lead (II) oxide and lead (II) hydroxide, resulting from lead's tendency to form compounds of low solubility, with the major anions found in natural water. The ratio of lead in suspended solids to lead in dissolved form has been found to vary from 4:1 in rural streams, to 27:1 in urban streams.

The soil pathway includes paint, dry and wet deposition of atmospheric lead; industrial contamination (sparingly soluble solid phases with long residence times) and relatively stable chelates (organo-metal complexes) with the organic matter in soil. Evidence of rapid conversion to lead (II) sulfate at the soil surface exists.

In soils with a pH greater or equal to 5, and with at least 5% organic matter, atmospheric lead is retained in the upper 2-5 cm of undisturbed soil. Mobilization as soil particles in run off feeding surface waters during heavy rains, and mobilization from soil

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to atmosphere, where smaller lead-containing soil particles are carried in the prevailing wind are especially important around contaminated sites. Downwards leaching is less important as it is very slow under most natural conditions

Lead can be absorbed through ingestion into the gut, through inhalation and through the skin. Ingestion usually involves inorganic lead, e.g. ingestion of paint in infants or children, or drinking of lead containing water. Inhalation may be occupationally or environmentally of either inorganic or organic forms. Absorption through the skin especially involves organic lead compounds (**Beverland and Agius 2002**).

Lead is absorbed into the bloodstream and is distributed in blood, soft tissue, bones, and teeth (95% in bones and teeth). Organic forms of lead being fat-soluble have a particular tendency to drain into the brain. Half lives for blood; soft tissue and bone are approximately 25 days, 40 days and 25 years respectively. Thus, lead can accumulate over a lifetime, and if it is released very slowly it can cause anaemia.

Lead at 500 ppm in soil or solid waste qualifies the substance as "hazardous waste". Maximum allowable level of lead in drinking water is 0.05 mg L<sup>-1</sup>. Twenty-fifty per cent of the total lead content found in children is attributable to the drinking water. Thus, lead contamination is extremely dangerous, and lead polluted waters need to be cleansed.

An article on use of aquatic plants for wastewater treatment (Wolverton 1988) induced an interest in the use of aquatic plants for removal of lead from industrial waters. Hence, it was decided to make a preliminary study of lead uptake by water hyacinth (*Eichhornia crassipes*), similar to that done with copper uptake (Aung and Win 1994).

Biological monitoring of ion uptakes had been examined (Little and Martin 1988), but it was decided to use chemical monitoring and follow the uptake via the lead content in various plant segments by AAS (Atomic Absorption Spectroscopy) measurements.

Heavy metal tolerance in plants, studied previously, showed that plants have tolerance mechanisms that involved excretion of excess cations (Antonovics *et al.* 1971). Thus, the water hyacinth would probably have high

tolerance and should be capable of removing large amounts of lead (Sutcliffe 1962).

Some water treatment facilities using water hyacinth exists. The San Pasqual Aquatic Treatment Facility, located just south of Escondido, California USA, operated by the City of San Diego, is an example. (Soderman 1996).

## Experimental

### Equipment.

The Atomic Absorption Spectrometer, AAS, used was as described before (Aung and Win 1994; Than 1990; and Tun 1990).

### Chemicals.

Lead (II) Nitrate. BDH – AR

### Procedure.

Test solutions containing various concentrations of Lead (II) Nitrate were prepared. Appropriate fixed volumes of the test solutions were placed in a plastic bucket. Water hyacinth plants were immersed for various times of 1, 2, 3 and 4 days. The plants were taken out washed with de-ionized water and cut into three segments: roots, petiole and leaves. The segments were air-dried, ashed and lead was extracted with de-ionized water. Samples for AAS measurements were prepared. The detailed procedure was as described in the copper uptake study (Aung and Win 1994).

## Results and Discussion

Conceivably, uptake of ions by aquatic plants should involve both biological and physical processes (Than 1990). Diffusion, osmosis, ion exchange, complex formation, etc. may be identified as some of the physical processes. Diffusion would shift cations into the plant cells. Osmosis would move water in the opposite direction and would hinder the cation uptake. Since both diffusion and osmosis were across the cell wall, cell membrane permeability should greatly influence cation

uptake. Ion exchange would modify the uptake rates and formation of large complex ions would prevent  $Pb^{2+}$  ions from entering the plant cell. Biological processes could encourage, hinder or even push out the cations, depending on the degree of plant need for  $Pb^{2+}$  ion. Thus, generally two classes of processes could be identified: uptake processes that shift  $Pb^{2+}$  into the cells and hindering processes that prevent uptake, or even push out the  $Pb^{2+}$  ions.

Because of these two classes of opposing processes, three main types of temporal lead uptake traces were expected: (1) An initial fast rising trace showing the predominance of uptake processes. (2) Falling traces showing saturation of the cells with  $Pb^{2+}$ , reflecting domination of hindering processes. These traces could sharply fall if over-saturation occurred. Hindering mechanisms would become completely dominant and  $Pb^{2+}$  excretion would occur. (3) Slightly oscillating traces showing the two classes of processes becoming about equal (Than 1990).

These curves were substantiated in Figs. 1 and 2, with associated data in table 1. In Fig. 1, where the test solution was 0.001 M,  $Pb^{2+}$  content of the roots showed an oscillating type, with average contents very much higher than those of leaves and petiole.

For example, at the four-day immersion, the root  $Pb^{2+}$  content was 438 ppm and the leaf and petiole contents were only 24 ppm and 7 ppm respectively. The leaf curve showed an initial decrease followed by a rise after the third day. This probably indicated an initial drainage of leaf  $Pb^{2+}$  into the roots. This could be observed more clearly on an expanded scale in Fig. 3. The petiole  $Pb^{2+}$  content was more or less constant.

In Fig. 2, where the test solution was 0.01 M, the root  $Pb^{2+}$  content was still relatively high. Up to the third day, the petiole contents were comparable to those of the roots, while the leaf contents remained low. For example, at the three-day immersion, the  $Pb^{2+}$  contents for leaf, petiole and root were 52 ppm, 227 ppm and 339 ppm respectively. The very low leaf contents probably showed that the plant was trying to prevent  $Pb^{2+}$  influx.

On the fourth day, the root content had dropped to 281 ppm from 339 ppm for day three, as shown in Fig. 2 and more clearly on an expanded scale in Fig. 4. This indicated that the roots were already saturated and emitting  $Pb^{2+}$ . The leaf contents increased and became close to 50% those of root and petiole: 148 ppm as compared to 224 ppm for petiole and 281 ppm for root. This leaf content of 148 ppm on the fourth day as compared to 17 ppm on day one, is a 770% increase. It indicated a huge influx of  $Pb^{2+}$  that could not be prevented any more by the plant. It was interesting to note that the plant still thrived even under these conditions.

## Conclusion

Uptake and hindrance processes cause three types of traces: uptakes, excretion and oscillation, reflecting predominance of uptake processes, hindrance processes and competition between the two processes, when they have about equal strength.

$Pb^{2+}$  accumulated mainly in the roots and the petiole contents became comparable at high concentrations and prolonged immersion. The relatively low leaf contents, until drastic conditions were used, indicated the presence of a prevention mechanism to inhibit  $Pb^{2+}$  uptake.

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Table 1. Lead (II) contents of plant segments

[Lead (II)]/M	Plant segment	Immersion time/day	Lead (II)/ppm	
0.01	Leaf	1	17	
	Leaf	2	45	
	Leaf	3	52	
	Leaf	4	148	
	Petiole	1	83	
	Petiole	2	191	
	Petiole	3	227	
	Petiole	4	224	
	Root	1	180	
	Root	2	254	
	Root	3	339	
	Root	4	281	
	0.001	Leaf	1	24
		Leaf	2	15
		Leaf	3	11
		Leaf	4	24
Petiole		1	10	
Petiole		2	8	
Petiole		3	6	
Petiole		4	7	
Root		1	165	
Root		2	274	
Root		3	280	
Root		4	438	

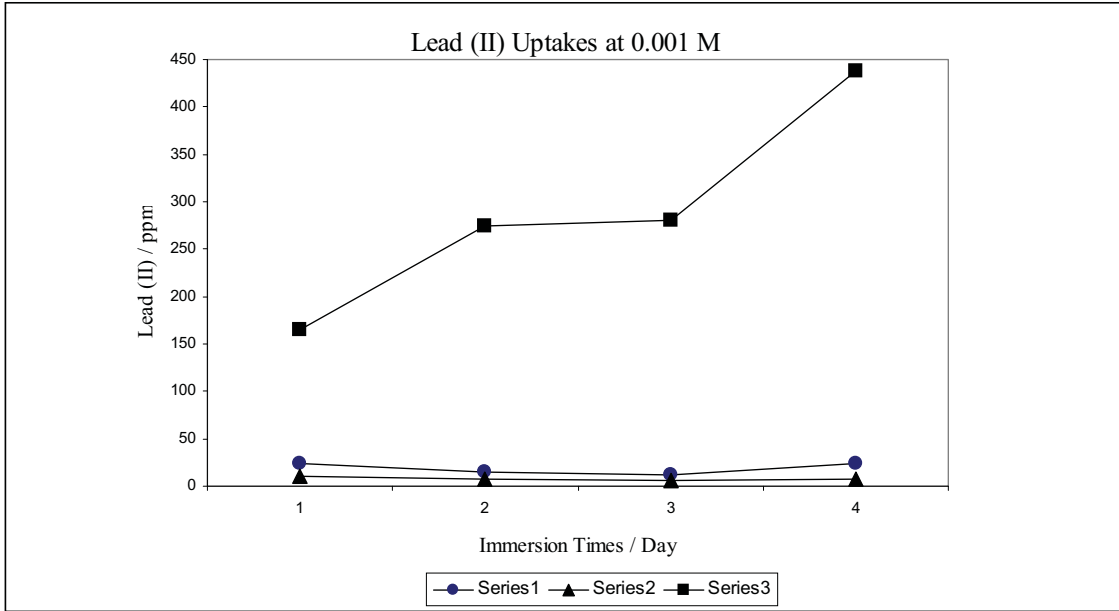


Fig. 1. Lead (II) Uptakes at 0.001 M Test Solution Concentration  
Series 1 = Leaf, Series 2 = Petiole, Series 3 = Roots

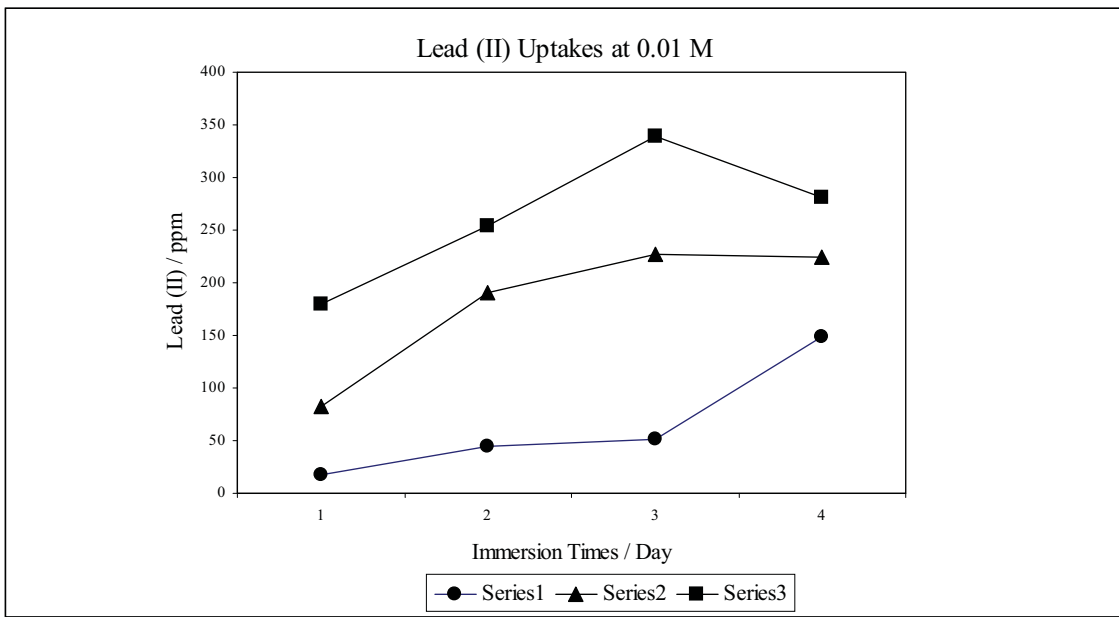


Fig. 2. Lead (II) Uptakes at 0.01 M Test Solution Concentration  
Series 1 = Leaf, Series 2 = Petiole, Series 3 = Roots

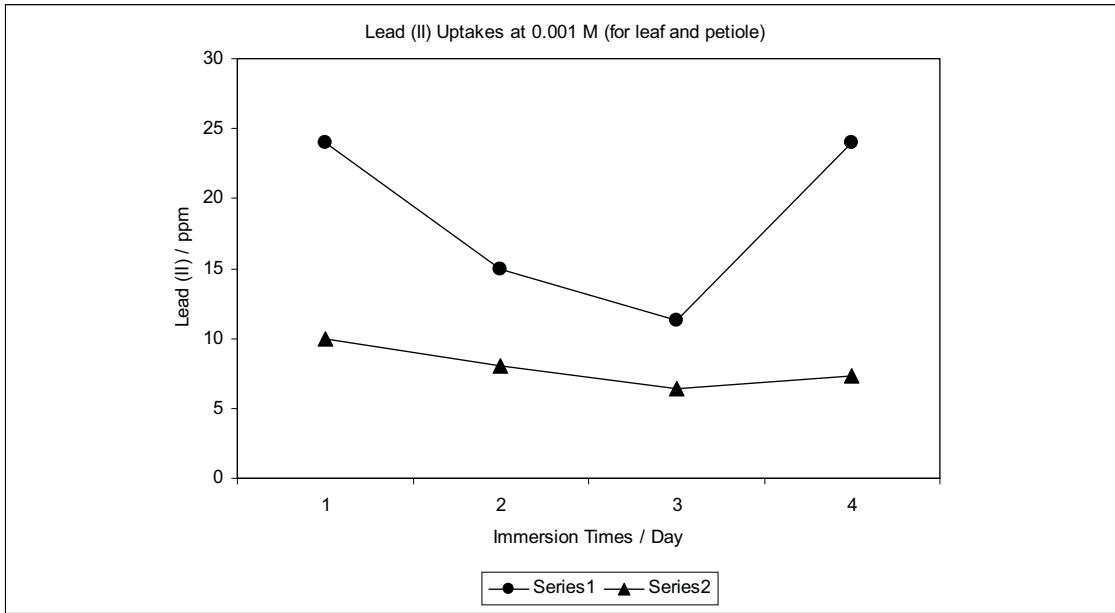


Fig.3. Lead (II) Uptakes at 0.001 M Test Solution Concentration [Expanded Scale]  
Series 1 = Leaf, Series 2 = Petiole

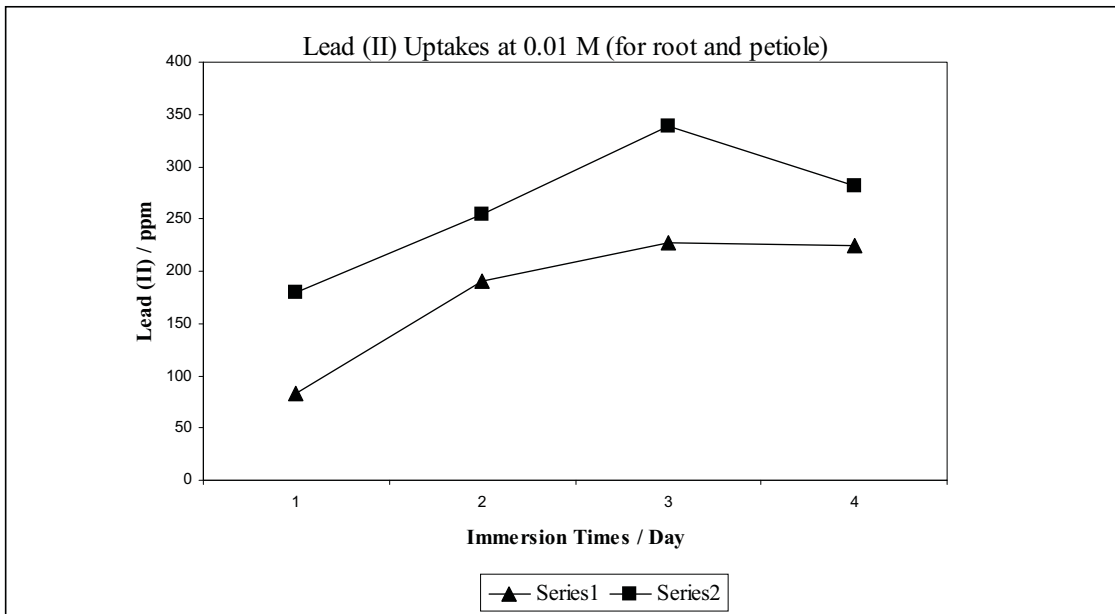


Fig. 4. Lead (II) Uptakes at 0.01 M Test Solution Concentration [Expanded Scale]  
Series 1 = Petiole, Series 2 = Root