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WATER HYACINTHS AND ALLIGATOR WEEDS FOR REMOVAL OF LEAD AND MERCURY FROM POLLUTED WATERS

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16. ABSTRACT

Removal of lead and mercury by water hyacinths (Eichhornia crassipes) (Mart.) Solms and alligator weeds (Alternanthera philoxeroides) (Mart.) Griesb. was investigated. Water hyacinths demonstrated the ability to remove 0.176 mg of lead and 0.150 mg of mercury per gram of dry plant material from distilled water and river water in a 24-hour period. Therefore, one acre of water hyacinths is potentially capable of removing 105.6 grams of lead and 90.0 grams of mercury per day. Alligator weeds removed 0.101 mg of lead per gram of dry plant material in a 24-hour period. This same plant also demonstrated the ability to remove a minimum of 0.153 mg of mercury per gram of dry plant material in a six hour period.

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INTRODUCTION

The ability of vascular plants to absorb and concentrate toxic elements from soils in which these plants are grown was recognized as early as 1937 (1). Recently, Wolverton demonstrated the ability of water hyacinths (Eichhornia crassipes) (Mart.) Solms, a floating aquatic plant, to rapidly remove cadmium and nickel from waters polluted with these two important toxic metals (2). This work demonstrated the potential of vascular aquatic plants in removing other toxic elements from waters in which these plants are grown by means of root absorption and concentration. Another floating aquatic plant which is a promising candidate for removing chemical pollutants from waste waters is alligator weeds (Alternanthera philoxeroides)(Mart.) Griesb. This plant is highly prolific and can tolerate higher levels of salinity than water hyacinths (3, 4).

Lead and mercury are two other very important toxic metals that are found in trace quantities throughout the terrestrial and aquatic environment (5, 6). Lead is one of the most abundant pollutants of the human environment and contaminant of the human body. The uptake of lead by terrestrial plants has been the subject of numerous studies in recent years (7, 8, 9, 10, 11, 12). Its principle source today is tetra-ethyl lead, an anti-knocking chemical added to gasoline (13). Lead oxide has been the principle white pigment of paint for over 2,000 years.

Lead and mercury are both normal soil constituents with lead ranging from 1 to 200 ppm and mercury up to 0.8 ppm (12, 13). Unlike lead, inorganic mercury does not accumulate in the body, but organic mercury is deposited in fat and nerve tissue where it is less mobile.

Environmental pollution by toxic metals can be a much more serious and insidious problem than pollution by organic substances. Unlike most organic substances, metals are not degradable by natural processes.

Both the chemical behavior and the toxicity of mercury are further complicated by the ability of microorganisms to convert inorganic mercury to a highly toxic organic form, which enters the food chain of fish and other aquatic life. The seriousness of water pollution by mercury in industrial effluent was accentuated by the occurrence of Minamata disease from 1953 to 1960 in Japan, caused by methyl mercury poisoning (13).

MATERIALS AND METHODS

Water hyacinths (Eichhornia crassipes) (Mart.) Solms, were grown by vegetative reproduction from parent stock collected in February of 1975 from nearby bayous. Alligator weed (Alternanthera philoxeroides) (Mart.) Griesb. were also grown by vegetative reproduction from parent stock collected in Pearl River County, Mississippi. All plants were transferred to a greenhouse and maintained between 25°C and 30°C in metal troughs filled with tap water. Commercial plant food was added every two weeks.

One liter glass cylinders containing either 800 ml of distilled water or East Pearl River NSTL water were contaminated with mercuric chloride and lead nitrate and used as containers for individual water hyacinths ranging from 2.2 to 4.6 grams dry weight. Five hundred milliliter glass Erlenmeyer flasks filled almost to capacity with 575 ml of distilled water or East Pearl River NSTL water contaminated with the same two metals were used as containers for two to four alligator weeds whose total dry weight per container ranged from 3.0 to 3.6 grams. Each experimental arrangement included one plant control free of heavy metals and one metal control free of plants. Slight fluctuations in controls occurred due to evaporation and resulting volumetric adjustments with distilled water. This may cause concentration curves to be slightly more or less than the originally prepared concentrations. These studies were conducted simultaneously inside a well lighted building which was maintained at 25°C $\pm$ 5°C.

The mercury and lead contaminated solutions were prepared by diluting separate 1000 mg per liter atomic absorption standard solutions obtained from Fisher Scientific Company. Initial pH's and mercury and lead concentrations of the contaminated distilled water and river water and of the metal free controls were determined before the plants were added. The concentrations were again monitored after 3, 6, and 24 hours exposure to the plants. The pH's were monitored after 24 hours exposure.

The lead concentrations were monitored by atomic absorption spectroscopy after each sample was acidified to pH 3 with concentrated nitric acid. All mercury analyses were determined by a flameless atomic absorption technique (14).

RESULTS AND DISCUSSION

Alligator weeds and water hyacinths demonstrated their ability to rapidly absorb mercury and lead from contaminated river and distilled waters. These results are depicted in Figures 1 through 8 as percent of initial metal concentration remaining as a function of time for the metal control and metal-exposed plant system. Tables 1 through 4 include the experimentally determined values used in all plots, as well as the pH values and dry plant weights. pH measurements ranged from 6.2 to 6.7.

In a 24-hour period, the water hyacinths removed a maximum of 0.176 mg of lead and 0.150 mg of mercury from a static water system per gram of dry plant material. Based on this optimum removal rate of lead and mercury and on an optimum growth rate of approximately 600 Kg of dry plant material per hectare per day, one hectare of water hyacinths could potentially remove 105.6 grams of lead and 90.0 grams of mercury per day. This heavy metal removal rate is based on continually harvesting the metal saturated plants.

Alligator weeds removed a maximum of 0.101 mg of lead per gram of dry plant material from a static water system in a 24-hour period. These plants also reduced the initial mercury levels of 0.875 ppm in river water and 0.920 ppm in distilled water below the detection limit of 1.0 ppb after 6 hours. Based on this data, alligator weeds can remove a minimum of 0.153 mg of mercury per gram of dry plant material in a 6-hour period.

Further laboratory experiments are also being conducted at the National Space Technology Laboratories to evaluate the abilities of water hyacinths and alligator weeds to remove other heavy metals, as well as organic pollutants and nutrients.

Table 1. Removal of Lead and Mercury from River Water Systems During a 24-Hour Period Utilizing Water Hyacinths as Absorption Filters

River Water

Initial Hg and Pb (ppm)	Dry Plant Material (g)	pH Range 0-24 Hrs.	3 Hours (ppm)	6 Hours (ppm)	24 Hours (ppm)	mg of Metals Removed per Gram of Dry Plant Material
1.091 Pb	4.3	6.5-6.5	0.221	0.176	0.058	0.192
1.091 Pb	3.5	6.5-6.35	0.279	0.324	0.147	0.216
0.875 Hg	4.3	6.5-6.5	0.402	0.259	0.071	0.150
0.875 Hg	3.5	6.5-6.35	0.464	0.393	0.205	0.153
Background levels of Pb in River H_2O	2.8	6.2-6.1	<0.008	<0.008	<0.008	
Background levels of Hg in River H_2O	2.8	6.2-6.1	<0.001	<0.001	<0.001	
Pb concentration in Pb-Hg Controls free of plants Initial: 1.091 ppm		6.5-6.7	1.055	1.073	1.127	
Hg concentration in Pb-Hg Controls free of plants Initial: 0.875 Hg		6.5-6.7	0.821	0.813	0.723	

Table 2. Removal of Lead and Mercury from Distilled Water Systems During a 24-Hour Period Utilizing Water Hyacinths as Absorption Filters

			Distilled Water			
Initial Hg and Pb (ppm)	Dry Plant Material (g)	pH Range 0-24 Hrs.	3 Hours (ppm)	6 Hours (ppm)	24 Hours (ppm)	mg of Metals Removed per Gram of Dry Plant Material
0.529 Pb	2.2	6.40-6.15	0.103	0.074	0.044	0.176
0.529 Pb	4.0	6.40-6.10	0.103	0.059	0.029	0.100
0.920 Hg	2.2	6.40-6.15	0.188	0.107	0.054	0.315
0.920 Hg	4.0	6.40-6.10	0.152	0.080	0.054	0.173
Background levels of Pb in Distilled Water	4.6	6.70-6.20	<0.008	<0.008	<0.008	
Background levels of Hg in Distilled Water	4.6	6.70-6.20	<0.001	<0.001	<0.001	
Pb concentration in Pb-Hg Controls free of plants Initial: 0.529 ppm		6.40-6.75	0.544	0.588	0.485	
Hg concentration in Pb-Hg Controls free of plants Initial: 0.920 ppm		6.40-6.75	0.848	0.768	0.804	

Table 3. Removal Rates of Lead and Mercury from River Water Systems During a 24-Hour Period Utilizing Alligator Weeds as Absorption Filters

			River Water			
Initial Hg and Pb (ppm)	Dry Plant Material (g)	pH Range 0-24 Hrs.	3 Hours (ppm)	6 Hours (ppm)	24 Hours (ppm)	mg of Metals Removed per Gram of Dry Plant Material
0.968 Pb	3.3	6.3-6.35	0.839	0.706	0.471	0.087
0.968 Pb	3.5	6.3-6.2	0.559	0.676	0.353	0.101
0.875 Hg	3.3	6.3-6.35	0.045	<0.001	<0.001	0.153
0.875 Hg	3.5	6.3-6.2	0.026	<0.001	<0.001	0.144
Background levels of Pb in River Water	3.4	6.2-6.15	<0.008	<0.008	<0.008	
Background levels of Hg in River Water	3.4	6.2-6.15	<0.008	<0.008	<0.008	
Pb concentration in Pb-Hg Controls free of plants Initial: 0.968 ppm		6.3-6.45	0.903	0.968	0.821	
Hg concentration in Pb-Hg Controls free of plants Initial: 0.875 ppm		6.3-6.45	0.777	0.875	0.813	

Table 4. Removal Rates of Lead and Mercury from Distilled Water Systems During a 24-Hour Period Utilizing Alligator Weeds as Absorption Filters

Initial Hg and Pb (ppm)	Dry Plant Material (g)	pH Range 0-24 Hrs.	Distilled Water 3 Hours (ppm)	6 Hours (ppm)	24 Hours (ppm)	mg of Metals Removed per Gram of Dry Plant Material
0.529 Pb	3.6	6.4-5.8	0.266	0.206	0.125	0.065
0.529 Pb	3.6	6.4-6.0	0.265	0.206	0.143	0.062
0.920 Hg	3.6	6.4-5.8	0.018	<0.001	<0.001	0.147
0.920 Hg	3.6	6.4-6.0	0.018	<0.001	<0.001	0.147
Background levels of Pb in Distilled Water	3.0	6.7-6.2	<0.008	<0.008	<0.008	
Background levels of Hg in Distilled Water	3.0	6.7-6.2	<0.001	<0.001	<0.001	
Pb concentration in Pb-Hg Controls free of plants Initial: 0.529 ppm		6.4-6.6	0.456	0.529	0.554	
Hg concentration in Pb-Hg Controls free of plants Initial: 0.920 ppm		6.4-6.6	0.786	0.813	0.848	

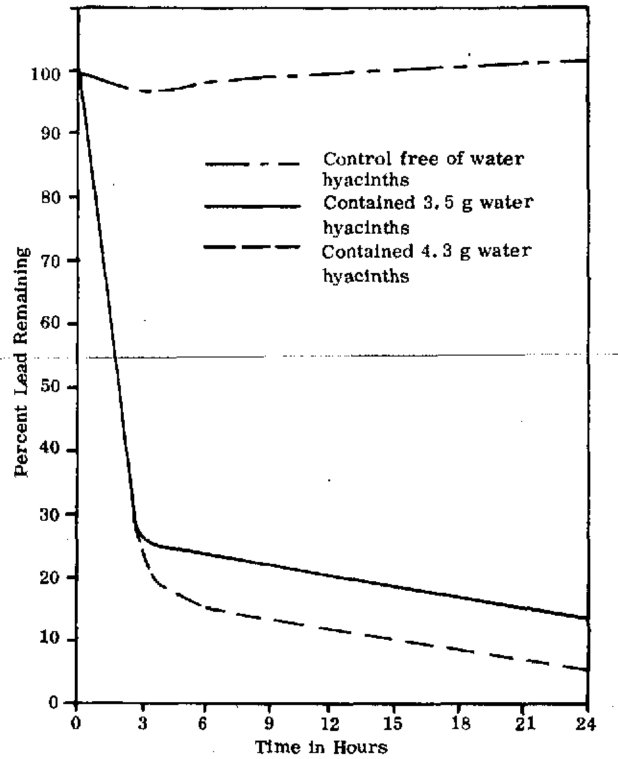

Figure 1. Graphic Representation of Removal Rates of Lead from River Water Containing Water Hyacinths and Lead-Mercury Control Free of Plants

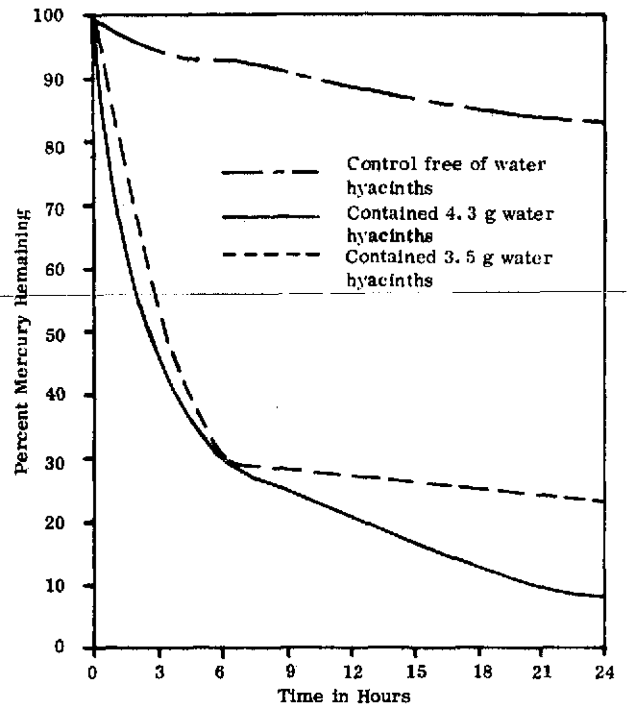

Figure 2. Graphic Representation of Removal Rates of Mercury From River Water Containing Water Hyacinths and Lead-Mercury Control Free of Plants

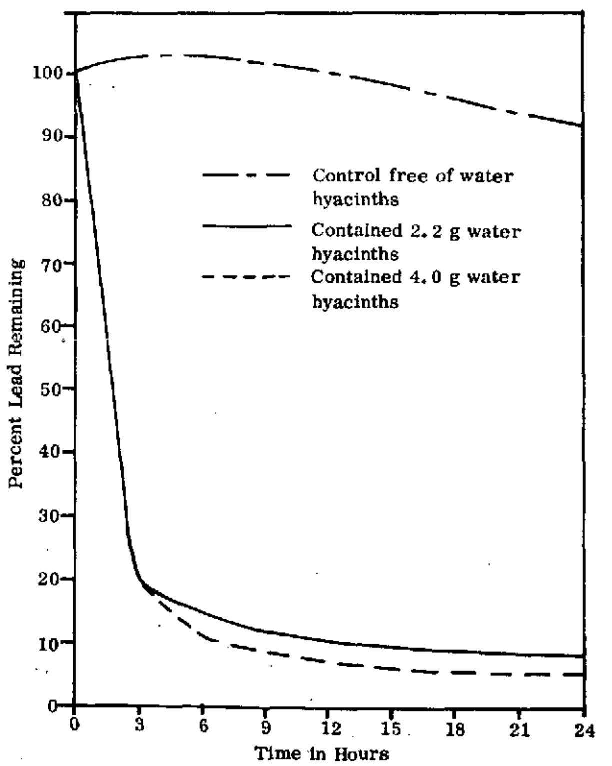

Figure 3. Graphic Representation of Removal Rates of Lead from Distilled Water Containing Water Hyacinths and Lead-Mercury Control Free of Plants

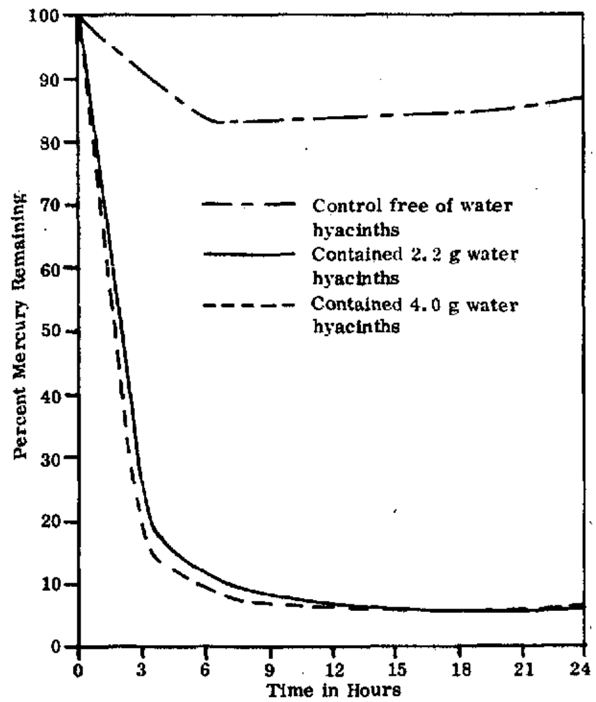

Figure 4. Graphic Representation of Removal Rates of Mercury From Distilled Water Containing Water Hyacinths and Lead-Mercury Control Free of Plants

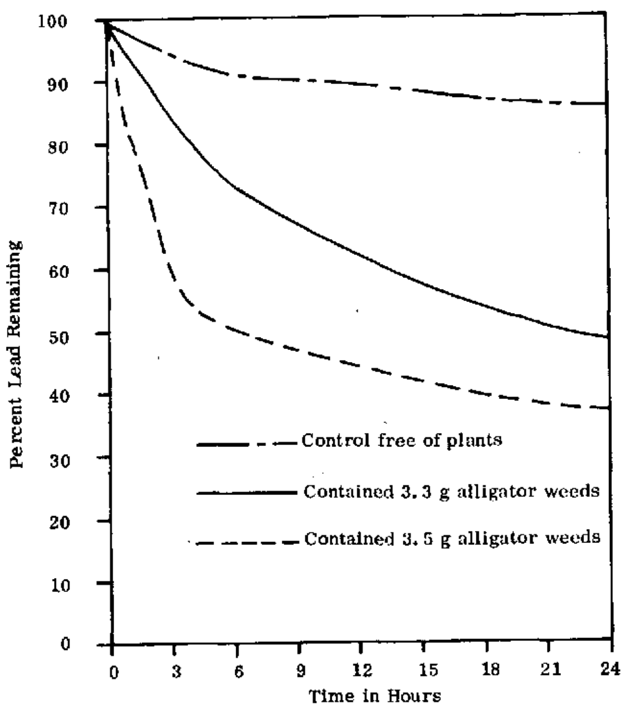

Figure 5. Graphic Representation of Removal Rates of Lead From River Water Containing Alligator Weeds and Lead-Mercury Control Free of Plants

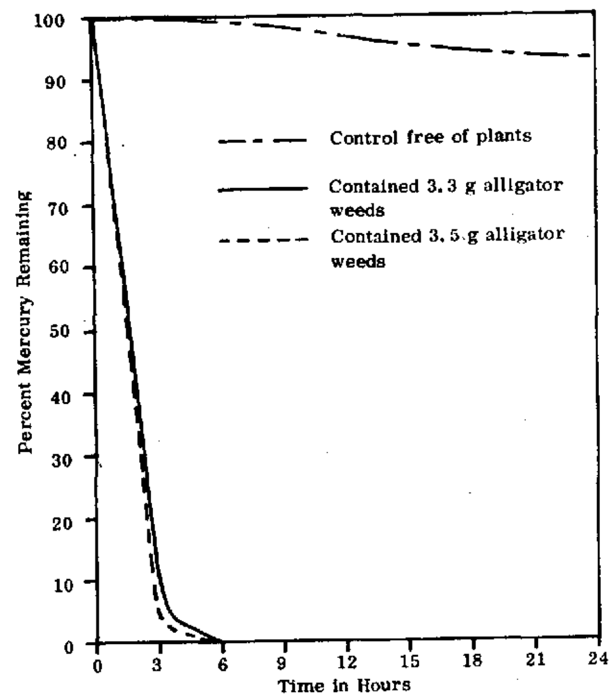

Figure 6. Graphic Representation of Removal Rates of Mercury from River Water Containing Alligator Weeds and Lead-Mercury Control Free of Plants

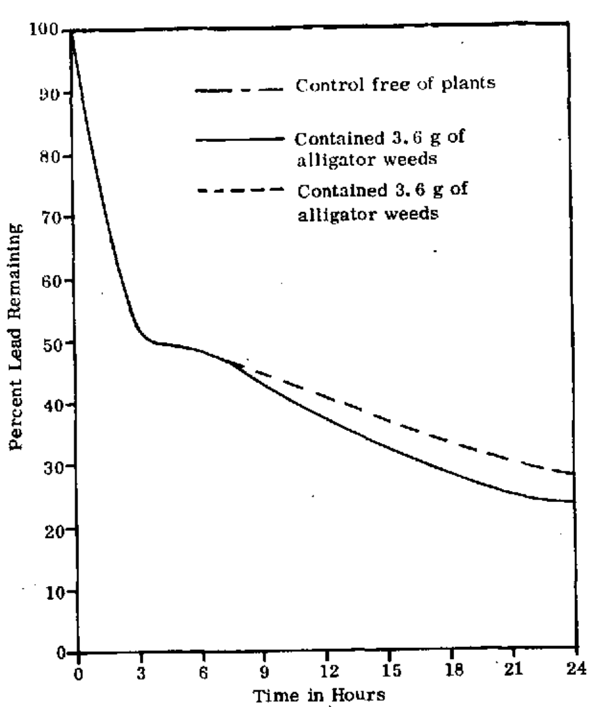

Figure 7. Graphic Representation of Removal Rates of Lead from Distilled Water Containing Alligator Weeds and Lead-Mercury Control Free of Plants

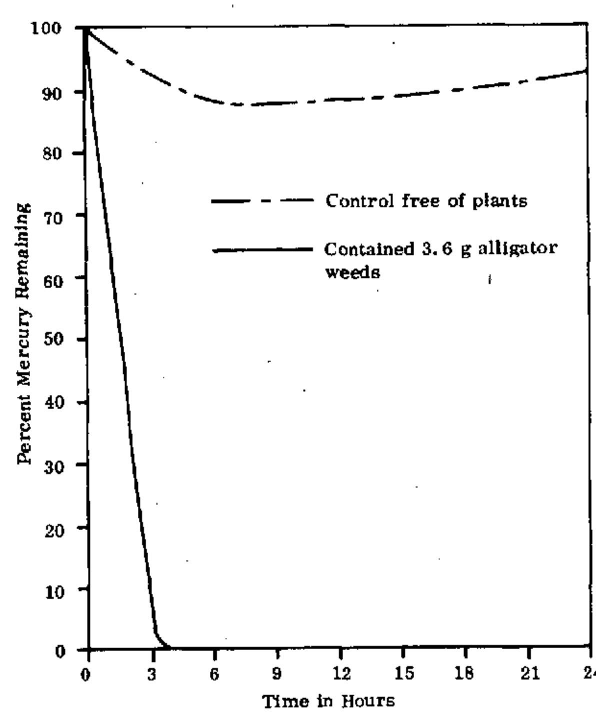

Figure 8. Graphic Representation of Removal Rates of Mercury from Distilled Water Containing Alligator Weeds and Lead-Mercury Control Free of Plants

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APPROVAL

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The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the NSTL Security Classification Offier. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

Henry F. Auter

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