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WATER HYACINTHS FOR REMOVAL OF CADMIUM AND NICKEL FROM POLLUTED WATERS

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16. ABSTRACT

Removal of cadmium and nickel from static water systems utilizing water hyacinths (Eichlornia crassipes) (Mart.) Solms was investigated. This aquatic plant demonstrated the ability to rapidly remove heavy metals from aqueous systems by root absorption and concentration. Water hyacinths demonstrated the ability to absorb and concentrate up to 0.67 mg of cadmium and 0.50 mg of nickel per gram of dry plant material when exposed for a 24-hour period to waters polluted with from 0.578 to 2.00 ppm of these toxic metals.

One hectare of water hyacinths has the potential of removing 300 g of cadmium or nickel from 240,000 liters of water polluted with these metals during a 24-hour period.

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INTRODUCTION

The heavy metals in our environment which present the greatest threat to human health are cadmium, mercury, nickel, and lead. Cadmium is probably the most important of these toxic metals because of the many different ways in which man is exposed to this element and the potential hazard to human health. Its concentration in human tissues is increased through contacts with cosmetics, cigarettes, galvanized pipes, burning of diesel and heating oil, residue from automobile tires, smelting industries, foods such as fish, mollusks, crustaceans, and grain [1]. Although cadmium is not always present in food, certain vegetables and grain grown in soil containing large amounts of commercial fertilizer may absorb and concentrate this metal which is associated with the phosphates present.

Beside being a carcinogen, cadmium has been linked to kidney ailments, hypertension, and other cardiovascular conditions [2, 3]. Nickel, like cadmium, can cause cancer in experimental animals and is a potential hazard as an environmental pollutant.

As a result of increased chemical and biological laboratory type operations over the past few years at NASA's National Space Technology Laboratories, Bay St. Louis, Mississippi, a novel water pollution abatement system is being installed to handle waste waters from these operations. This system will utilize vascular aquatic plants grown in a zig-zag canal-type lagoon to remove chemical pollutants from laboratory waste waters. Water hyacinths, (Eichhornia crassipes) (Mart.) Solms, have demonstrated the most promise as a candidate for removing chemicals from polluted waters. This vascular aquatic plant can produce over 240 kg (534 pounds) of dry plant material per 0.40 hectare (acre) per day, which is one of the greatest yields of organic matter ever produced, and appears to be the most productive of all photosynthetic organisms [4, 5]. Water hyacinths in four-tenths of a hectare (one acre) have the potential of removing the average daily nitrogen and phosphorous waste production from over 325 people, absorbing and metabolizing over 68 kg (150 pounds) of phenol every 72 hours from water polluted with this chemical in addition to removing other organic and inorganic toxic chemicals from waste waters [6, 7, 8, 9, 10].

MATERIALS AND METHODS

Water hyacinths, Eichhornia crassipes (Mart.) Solms, were collected in the fall of 1974 from a bayou adjacent to Louisiana Highway 190, approximately 0.40 km north of U.S. 90 intersection in St. Tammany Parish, Louisiana. Adult plants were selected, some of which were in the flowering stage and contained offshoots produced by vegetative reproduction. These plants were transferred to a greenhouse, where they were maintained between 25°C and 30°C. All plants were kept in metal troughs containing tap water and commercial plant food.

Studies to determine the capacity of water hyacinths to remove cadmium and nickel were conducted with four-week and older plants inside a well-lighted building which was maintained at 25°C. Individual plants ranging from 5.6 to 10.5 grams dry weight were exposed to cadmium and nickel concentrations by placing them in 2.5 liter of distilled water or 2.5 liter of water from the East Pearl River at NSTL, contained in 5-liter glass cylinders. Cadmium chloride and nickel nitrate in concentrations from 0.300 to 2.00 ppm were used.

These metals were obtained from Instrumentation Laboratory, Inc. as 1000 mg per liter atomic absorption stock solutions. Water concentrations of cadmium and nickel were determined before plants were added and 1, 3, 6 and 24 hours after exposure. Plant controls free of heavy metals and metal controls free of plants were established for each set of experiments.

Analysis of all heavy metal samples was by atomic absorption spectroscopy. Plant tissue samples were prepared for analysis by the following procedure. Samples were oven dried for 48 hours at 95°C. One gram subsamples were weighed and placed in 100-ml Kjeldal digestion flasks. The samples were then digested with a 1:1 nitric acid distilled water mixture with the addition of 30% hydrogen peroxide in 5 ml increments as required for complete digestion. After digestion, samples were then transferred to volumetric flasks, made to volume with distilled water and analyzed with an IL Model 253 atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

The ability of water hyacinths to remove cadmium and nickel from the two water systems employed in this investigation is presented graphically in Figures 1 and 2. The removal rates are depicted as percent of initial metal concentration remaining as a function of time for the metal control and metal-exposed plant system. pH ranges from 4.3 to 7.3 were evaluated with no apparent influence on the metal absorption. Roots average about 18% of total dry weight and contain approximately 97% of heavy metals found in the plants material after 24 hours of exposure. The exact experimentally determined values used for all plots, in addition to other data, are listed in Tables 1 and 2.

Water hyacinths demonstrated the ability to rapidly remove by root absorption and concentration trace contaminants such as cadmium and nickel from both river and distilled waters in which they were grown. The age and size of plants caused small variations in metal removal rates, but this is to be expected. It is known that mineral uptake rates per unit of dry matter are greater for plants in a rapid growth phase, and decreases as the plant ages [10, 11]. The ages of the water hyacinths used in this investigation were sufficiently variable to contribute somewhat to observed variations in metal removal rates. The health of the control plants was compared to that of those exposed to heavy metals in all experiments; no indication was evident that metal toxicity levels had been exceeded.

The water hyacinths demonstrated the ability to remove a maximum of 0.50 mg of nickel and 0.67 of cadmium from a static water system per gram dry weight of plant material during a 24-hour period. Since one hectare of water hyacinths has an optimum growth rate of approximately 600 kg of dried plant material per day, plants grown in this area could conceivably remove 300 grams of heavy metals per day. This potential removal is based on continually harvesting the metal saturated plant roots.

The ability of water hyacinths to remove other heavy metals such as mercury, lead, silver, etc., from water polluted with these elements are also being evaluated here at the National Space Technology Laboratories. Harvesting of the metal saturated plants with recycling of heavy metals and conversion of plant material into mixed hydrocarbon fuel is also being pursued.

TABLE 1. REMOVAL RATES OF CADMIUM AND NICKEL FROM RIVER WATER SYSTEMS DURING A 24-HOUR PERIOD UTILIZING WATER HYACINTHS AS ABSORPTION FILTERS

RIVER WATER

Heavy Metals (ppm)	pH Range 1 and 24 Hours	1 Hour (ppm)	3 Hours (ppm)	6 Hours (ppm)	24 Hours (ppm)	mg of Metals Removed Per Gram of Dry Plant Material
2.000 Cd	4.3 - 5.7	1.826	1.477	1.020	0.595	0.30
1.905 Cd	4.4 - 5.7	1.782	1.571	1.124	0.611	0.67
1.578 Cd	6.2 - 6.2	1.200	0.847	0.510	0.255	0.30
0.850 Cd	7.3 - 6.7	0.675	0.320	*	0.035	0.28
0.760 Cd	6.9 - 6.9	0.600	0.250	*	0.012	0.27
0.700 Cd	6.7 - 6.5	0.578	0.311	0.120	0.046	0.20
1.939 Ni	7.0 - 6.9	1.477	1.226	0.922	0.538	0.40
1.970 Ni	7.2 - 7.0	1.107	1.100	0.707	0.600	0.50
Background levels of cadmium and nickel in River Water	6.9 - 6.9	$<.005$	$<.005$	$<.005$	$<.005$	
Cadmium controls free of plants 0.340	7.0 - 6.8	0.340	0.351	0.312	0.312	
Nickel control free of plants 1.939	6.7 - 6.9	1.939	2.000	1.900	1.900	

* Not Analyzed

TABLE II. REMOVAL RATES OF CADMIUM AND NICKEL FROM DISTILLED WATER SYSTEMS DURING A 24-HOUR PERIOD UTILIZING WATER HYACINTHS AS ABSORPTION FILTERS

DISTILLED WATER

Heavy Metals (ppm)	pH Range 1 and 24 Hours	1 Hour (ppm)	3 Hours (ppm)	6 Hours (ppm)	24 Hours (ppm)	mg of Metals Removed Per Gram of Dry Plant Material
1.800 Cd	6.3 - 6.4	0.878	0.609	0.532	0.346	0.52
0.709 Cd	6.4 - 6.6	0.450	0.253	0.154	0.086	0.23
0.688 Cd	6.5 - 6.5	0.394	0.240	0.142	0.077	0.22
0.630 Cd	5.6 - 5.9	0.512	0.441	0.256	0.083	0.21
Cadmium control free of plants 0.300	4.0 - 6.5	0.390	0.290	0.300	0.260	
1.677 Ni	6.9 - 7.0	1.338	0.984	0.753	0.384	0.30
1.600 Ni	6.6 - 6.4	1.350	1.110	0.980	0.680	0.40
Nickel control free of plants 1.540	6.6 - 6.8	1.630	1.650	1.550	1.540	

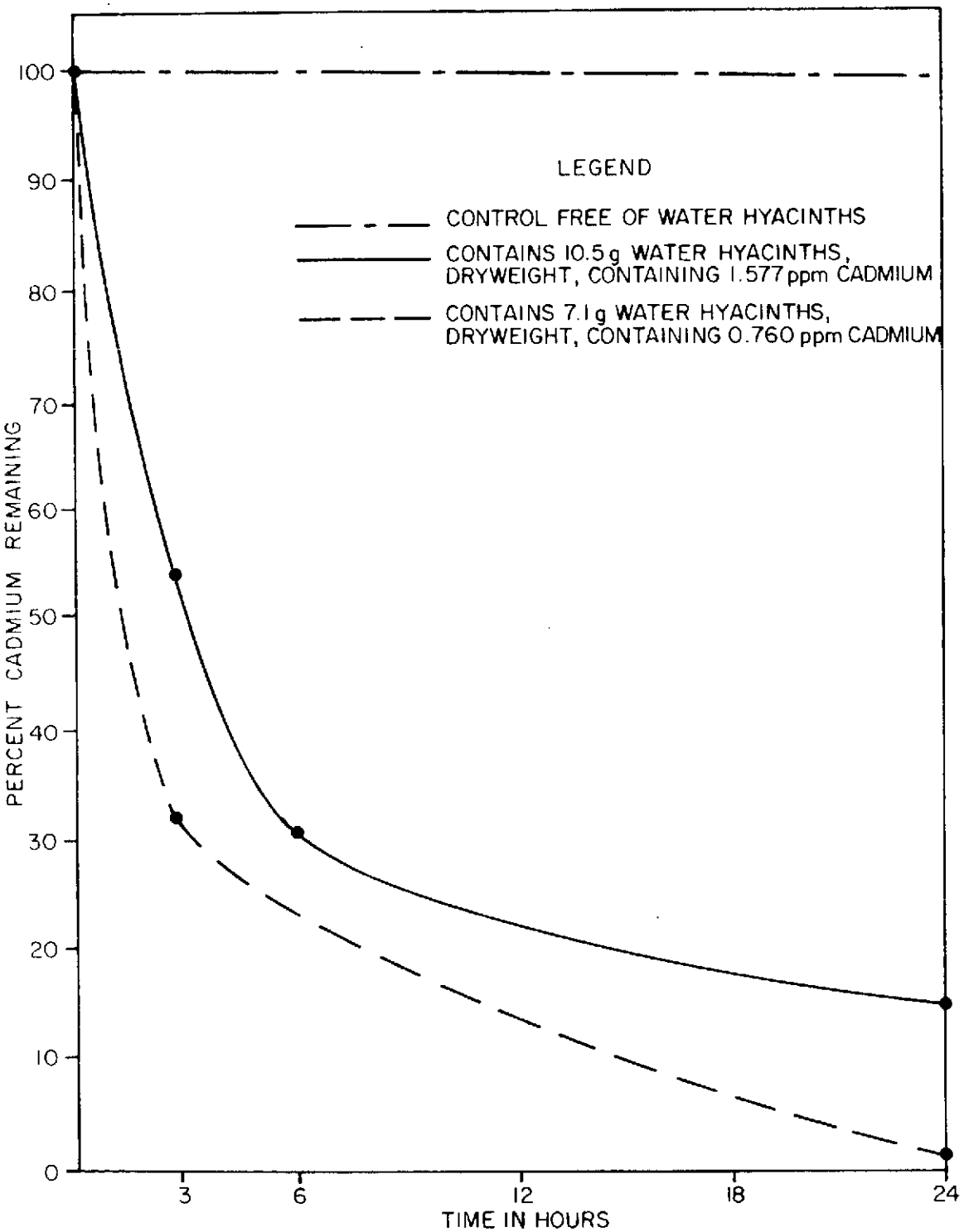

FIGURE 1. Graphic representation of removal rates of cadmium from river water containing water hyacinths and cadmium control free of plants.

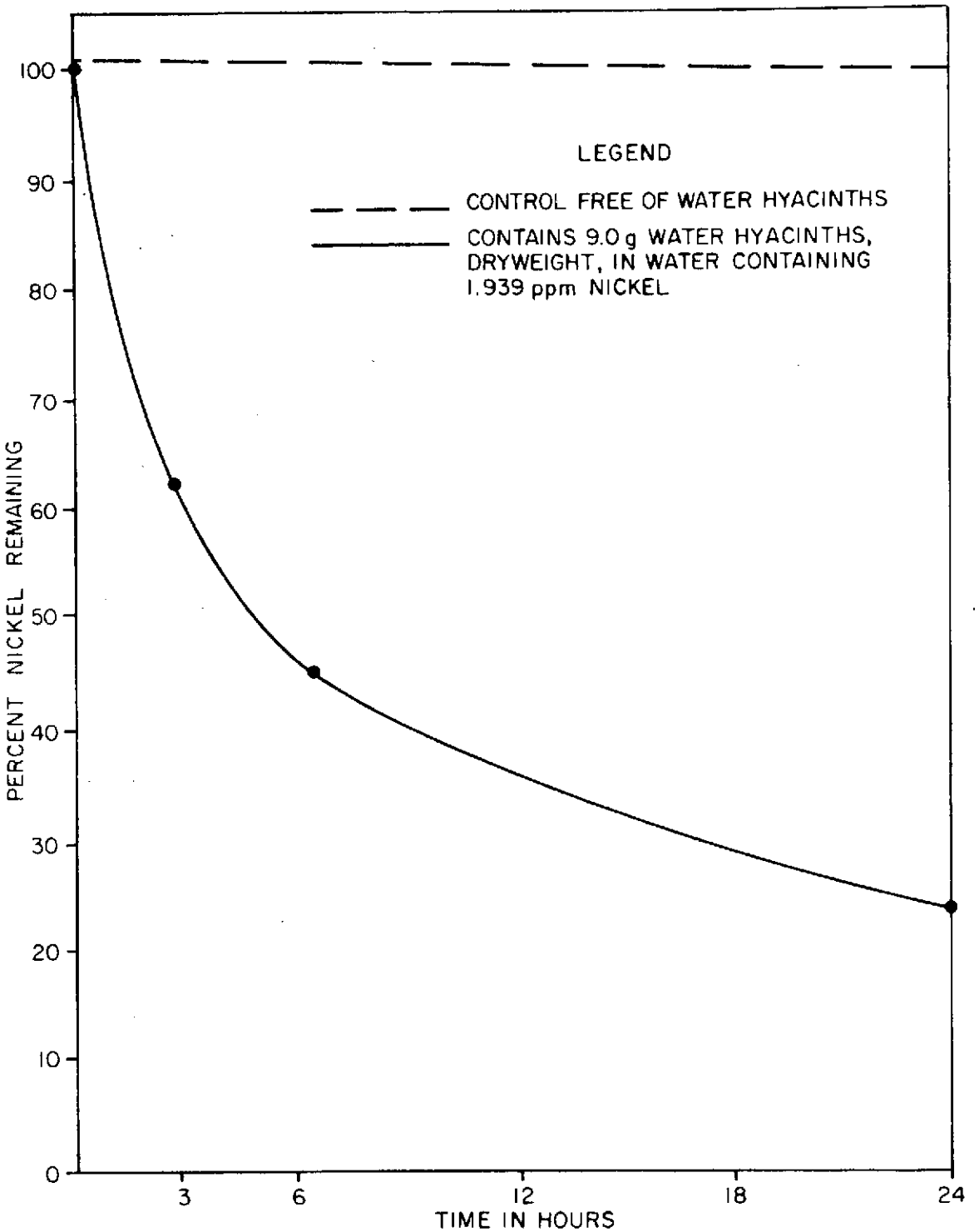

FIGURE 2. Graphic representation of removal rate of nickel from river water containing water hyacinths and nickel control free of plants.

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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 Officer. This report, in its entirety, has been determined to be unclassified.

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

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