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WATER HYACINTHS AND ALLIGATOR WEEDS FOR REMOVAL OF SILVER, COBALT, AND STRONTIUM FROM POLLUTED WATERS

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16. ABSTRACT

Removal of silver, cobalt, and strontium from static water systems, utilizing water hyacinths (Eichhornia crassipes) (Mart.) Solms and alligator weeds (Alternanthera philoxerides) (Mart.) Griesb., was investigated. These aquatic plants demonstrated the ability to rapidly remove heavy metals from an aqueous system by root absorption and concentration. Water hyacinths demonstrated the ability to remove 0.439 mg of silver, 0.568 mg of cobalt, and 0.544 mg of strontium in an ionized form per gram of dry plant material in a 24-hour period. Therefore, one hectare of water hyacinths is potentially capable of removing 263.4 g of silver, 340.8 g of cobalt, and 326.4 g of strontium per day. Alligator weeds removed a maximum of 0.439 mg of silver, 0.130 mg of cobalt, and 0.161 mg of strontium per gram of dry plant material per day.

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WATER HYACINTHS AND ALLIGATOR WEEDS FOR REMOVAL OF SILVER, COBALT, AND STRONTIUM FROM POLLUTED WATERS

INTRODUCTION

The ability of vascular aquatic plants to remove cadmium, nickel, lead, and mercury from waters polluted with these toxic metals has been demonstrated by Wolverton et al (1, 2).

Other metals, such as silver, strontium and cobalt may present water pollution problems under certain conditions.

Strontium, a white metal, is fairly rare on earth, where it exists mainly as a naturally occurring sulphate. The radioactive isotape strontium-90 is man-made through nuclear explosions. Since strontium is mistaken for calcium by body mechanisms, it tends to accumulate in the bone where its radioactivity can hammer bone-marrow cells. Therefore, strontium contamination increases the risk of bone tumors and leukemia.

Silver is an important metal in photography. Large quantities of silver are used annually in the manufacture of photographic plates and films. As a result of this commercial use much silver is permanently lost in waste waters which finds its way into rivers and streams near photographic laboratories.

Cobalt is an essential trace element found on the earth's crust and in man at concentrations of 23 and 0.02 ppm, respectively. Adding cobalt to beer to preserve its foam has contributed to heart disease in heavy beer drinkers (3). Cobalt usually occurs in combination with other metals, including copper, and may contribute to water pollution problems near mining operations.

MATERIALS AND METHODS

Water hyacinths (*Eichhornia crassipes*) (Mart.) Solms were collected in the spring of 1975 in Hancock County, Mississippi. Alligator weeds (*Alternanthera philoxerides*) (Mart.) Griesb were collected in February of 1975 in Pearl River County, Mississippi. All plants were maintained in a greenhouse at 25°C to 30°C in metal troughs filled with tap water.

Five liter glass cylinders were filled with 2-1/2 liters of either distilled water or East Pearl River water. These containers were contaminated with a 1000 mg/l silver nitrate standard solution to produce various initial concentrations of silver ranging from 0.50 ppm to 2.00 ppm. Water hyacinths weighing from 4.8 g to 9.8 g dry weight, were placed in four of the containers. Four other cylinders contained alligator weeds whose total dry weight per container ranged from 1.7 g to 3.8 g.

For monitoring the removal of cobalt from polluted waters, water hyacinths ranging in dry weight from 1.5 g to 4.0 g were placed in one liter glass cylinders filled with either distilled water or East Pearl River water contaminated with different concentrations of cobalt (II) chloride. Alligator weeds, whose total dry weight ranged from 2.9 g to 6.4 g, were placed in Erlenmeyer flasks filled almost to capacity with 575 ml of cobalt contaminated distilled water or river water.

An experimental arrangement similar to the one for cobalt was established using strontium (II) nitrate as the contaminant. All three experiments for the removal of silver, cobalt, and strontium included one plant control free of these metals and one metal control free of plants. The experiments were conducted inside a well-lighted building maintained at 25°C $\pm$ 5°C.

The metal contaminated solutions were prepared by pipetting appropriate amounts of silver, cobalt and strontium from 1000 mg per liter atomic absorption standard solutions obtained from Harleco into known volumes of either distilled water or river water. Initial concentrations and pH of these contaminated solutions were determined prior to plant exposure. After plant exposure, the concentrations were monitored by withdrawing aliquots after 1, 3, 6, and 24 hour exposure times. The pH was again determined after 24 hours. All concentrations were determined by atomic absorption.

RESULTS AND DISCUSSION

The experimentally determined data organized in Tables 1 through 4 demonstrate the ability of alligator weeds and water hyacinths to rapidly absorb silver, cobalt, and strontium from waters contaminated with these metals. Figures 1 through 10 graphically depict this data as percent of initial metal concentration remaining as a function of time for the metal exposed plant system and for the metal control. Slight fluctuations of metal concentrations in plant free controls are due to evaporation losses and instrument fluctuation.

Based on this experimental data water hyacinths are capable of removing a maximum of 0.439 mg of silver, 0.568 mg of cobalt, and 0.544 mg of strontium in an ionized form from a static water system per gram of dry plant weight in a 24-hour period. The growth rate of water hyacinths is approximately 600 kg of dry plant material per hectare (2.47 acres) per day. Therefore, water hyacinths could potentially remove 263.4 g (0.581 lb) of silver, 340.8 g (0.752 lb) of cobalt, and 326.4 g (0.721 lb) of strontium per hectare (2.47 acres) per day provided that the metal-saturated plants are harvested at regular intervals.

Alligator weeds demonstrated the ability to remove a maximum of 0.439 mg of silver, 0.130 mg of cobalt, and 0.161 mg of strontium from a static water system per gram of dry plant weight per day.

The data for the removal of strontium from river water by water hyacinths and alligator weeds was omitted due to the apparent precipitation of this metal.

Table 1. Removal of Silver, Cobalt, and Strontium from Distilled Water Systems During a 24-Hour Period Utilizing Water Hyacinths as Absorption Filters

Distilled Water

Initial Metal Concentration (ppm)	Dry Plant Material (g)	pH Range 0-24 Hrs.	1 Hour (ppm)	3 Hours (ppm)	6 Hours (ppm)	24 Hours (ppm)	mg of Metals Removed per Gram of Dry Plant Material
0.585 Ag	5.5	7.0-6.7	0.361	0.167	0.116	0.016	0.21
1.044 Ag	5.6	7.6-6.7	0.485	0.293	0.232	0.022	0.40
1.946 Ag	5.8	7.5-6.8	1.415	0.681	0.636	0.064	0.65
* 1.044 Ag		7.4-7.0	0.825	0.930	0.944	1.000	
** $<$0.02 Ag	4.8	7.0-6.5	$<$0.02	$<$0.02	$<$0.02	$<$0.02	
0.488 Co	2.4	6.2-5.9	0.111	0.112	0.087	0.085	0.134
1.000 Co	1.5	6.1-6.4	0.411	0.316	0.279	0.219	0.416
1.905 Co	2.1	5.5-6.4	0.433	0.500	0.500	0.415	0.568
* 1.000 Co		6.1-6.6	0.930	1.067	1.082	0.790	
** $<$0.01 Co	2.3	6.4-6.4	$<$0.01	$<$0.01	$<$0.01	$<$0.01	
0.419 Sr	3.3	6.9-6.5	0.016	$<$0.007	$<$0.007	$<$0.007	0.102
0.932 Sr	4.9	6.6-6.6	0.081	0.032	$<$0.007	0.074	0.140
1.982 Sr	2.7	6.3-6.4	0.177	0.120	0.182	0.147	0.544
* 0.932 Sr		6.6-6.9	0.898	0.963	0.875	0.932	
** $<$0.007 Sr	2.6	6.8-6.4	$<$0.007	$<$0.007	$<$0.007	$<$0.007	

* Metal Control Free of Plants

** Plant Control Free of Metals

Table 2. Removal of Silver and Cobalt from River Water Systems During a 24-Hour Period Utilizing Water Hyacinths as Absorption Filters

River Water

Initial Metal Concentration (ppm)	Dry Plant Material (g)	pH Range 0-24 Hrs.	1 Hour (ppm)	3 Hours (ppm)	6 Hours (ppm)	24 Hours (ppm)	mg of Metals Removed per Gram of Dry Plant Material
0.690 Ag	9.8	6.6-6.7	0.571	0.293	0.275	0.129	0.14
1.280 Ag	7.2	6.5-6.7	1.193	1.074	1.016	0.629	0.32
2.380 Ag	7.3	6.6-6.8	2.035	1.784	1.606	1.094	0.44
* 1.303 Ag		6.5-6.9	1.200	1.296	1.290	1.156	
** $<$0.02 Ag	9.7	6.7-6.5	$<$0.02	$<$0.02	$<$0.02	$<$0.02	
0.488 Co	3.2	6.5-6.5	0.267	0.235	0.192	0.134	0.089
1.027 Co	4.0	6.5-6.5	0.656	0.571	0.433	0.317	0.144
1.976 Co	2.7	6.4-6.5	1.302	1.278	1.122	0.780	0.354
* 1.027 Co		6.5-6.6	1.081	1.122	1.153	0.951	
** $<$0.01 Co	2.1	6.5-6.7	$<$0.01	$<$0.01	$<$0.01	$<$0.01	

* Metal Control Free of Plants

** Plant Control Free of Metals

Table 3. Removal of Silver, Cobalt, and Strontium from Distilled Water Systems During a 24-Hour Period Utilizing Alligator Weeds as Absorption Filters

Distilled Water

Initial Metal Concentration (ppm)	Dry Plant Material (g)	pH Range 0-24 Hrs.	1 Hour (ppm)	3 Hours (ppm)	6 Hours (ppm)	24 Hours (ppm)	mg of Metals Removed per Gram of Dry Plant Material
0.586 Ag	1.7	7.2-6.8	0.273	0.220	0.214	0.176	0.139
1.076 Ag	3.8	7.2-7.1	0.891	0.729	0.714	0.611	0.070
2.148 Ag	2.9	7.3-6.8	0.750	0.500	0.411	0.380	0.351
*1.181 Ag		7.2-6.9	0.953	0.913	0.873	1.014	
** $<$0.02 Ag	2.8	6.9-6.7	$<$0.02	$<$0.02	$<$0.02	$<$0.02	
0.488 Co	6.7	6.2-6.7	0.189	0.051	0.077	0.061	0.037
1.000 Co	5.2	6.1-6.4	0.267	0.133	0.211	0.195	0.089
1.905 Co	7.0	5.5-6.3	1.081	0.633	0.567	0.536	0.112
*1.000 Co		6.1-6.6	0.930	1.067	1.082	0.790	
** $<$0.01 Co	2.9	6.4-6.4	$<$0.01	$<$0.01	$<$0.01	$<$0.01	
0.419 Sr	4.5	6.9-6.4	0.048	0.032	$<$0.007	0.088	0.042
0.932 Sr	6.2	6.6-6.3	0.194	0.081	$<$0.007	0.132	0.074
1.982 Sr	6.4	6.3-6.4	0.210	0.145	0.045	0.191	0.161
*0.932 Sr		6.6-6.9	0.898	0.963	0.875	0.932	
** $<$0.007 Sr	5.6	6.8-6.5	$<$0.007	$<$0.007	$<$0.007	$<$0.007	

* Metal Control Free of Plants
** Plant Control Free of Metals

Table 4. Removal of Silver and Cobalt from River Water Systems During a 24-Hour Period Utilizing Alligator Weeds as Absorption Filters

River Water

Initial Metal Concentration (ppm)	Dry Plant Material (g)	pH Range 0–24 Hrs.	1 Hour (ppm)	3 Hours (ppm)	6 Hours (ppm)	24 Hours (ppm)	mg of Metals Removed per Gram of Dry Plant Material
0.904 Ag	3.1	6.5–6.7	0.418	0.336	0.295	0.213	0.128
1.311 Ag	2.2	6.6–6.8	0.891	0.492	0.455	0.241	0.280
2.408 Ag	2.8	6.5–6.8	1.756	1.047	0.880	0.435	0.405
* 1.348 Ag		6.7–6.8	1.223	1.195	1.157	1.207	
** $<$0.02 Ag	3.9	6.6–6.7	$<$0.02	$<$0.02	$<$0.02	$<$0.02	
0.488 Co	4.0	6.5–6.5	0.278	0.224	0.192	0.134	0.051
1.037 Co	6.4	6.4–6.4	0.544	0.388	0.308	0.317	0.065
1.976 Co	5.1	6.3–6.4	1.330	1.233	1.000	0.827	0.130
* 1.037 Co		6.4–6.6	1.081	1.122	1.153	0.951	
** $<$0.01 Co	3.5	6.5–6.6	$<$0.01	$<$0.01	$<$0.01	$<$0.01	

* Metal Control Free of Plants

** Plant Control Free of Metals

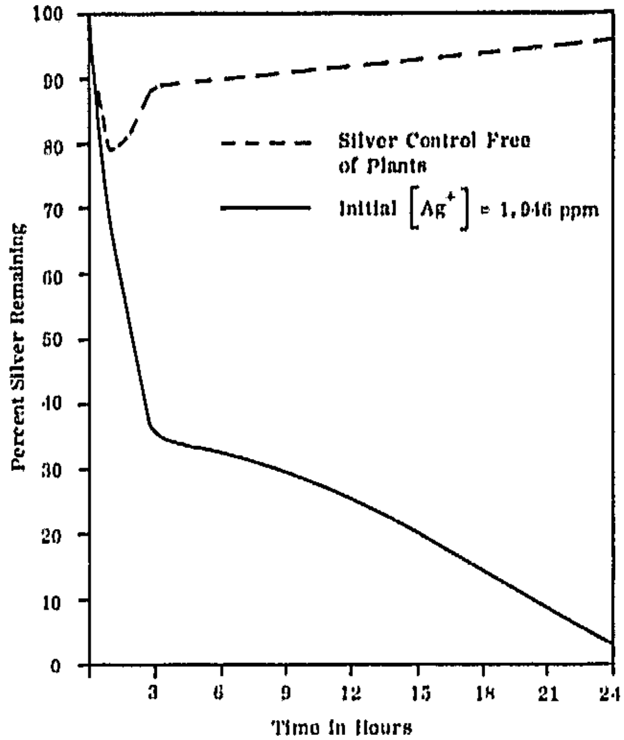

Figure 1. Graphic Representation of Removal Rates of Silver from Distilled Water Containing Water Hyacinths and Silver Control Free of Plants

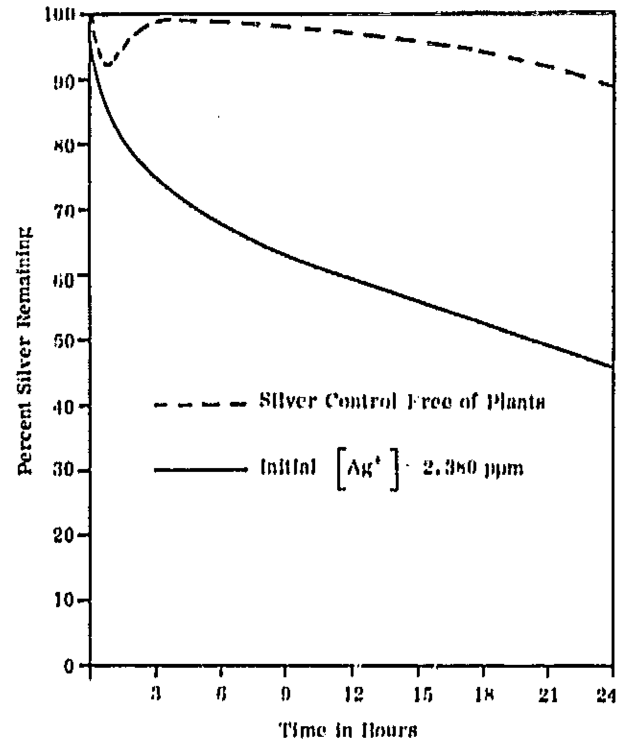

Figure 2. Graphic Representation of Removal Rates of Silver from River Water Containing Water Hyacinths and Silver Control Free of Plants

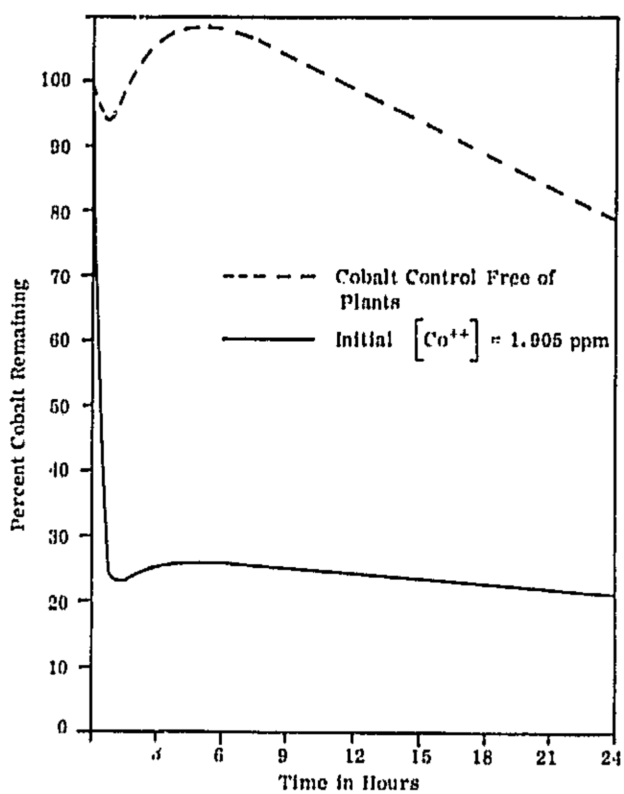

Figure 3. Graphic Representation of Removal Rates of Cobalt from Distilled Water Containing Water Hyacinths and Silver Control Free of Plants

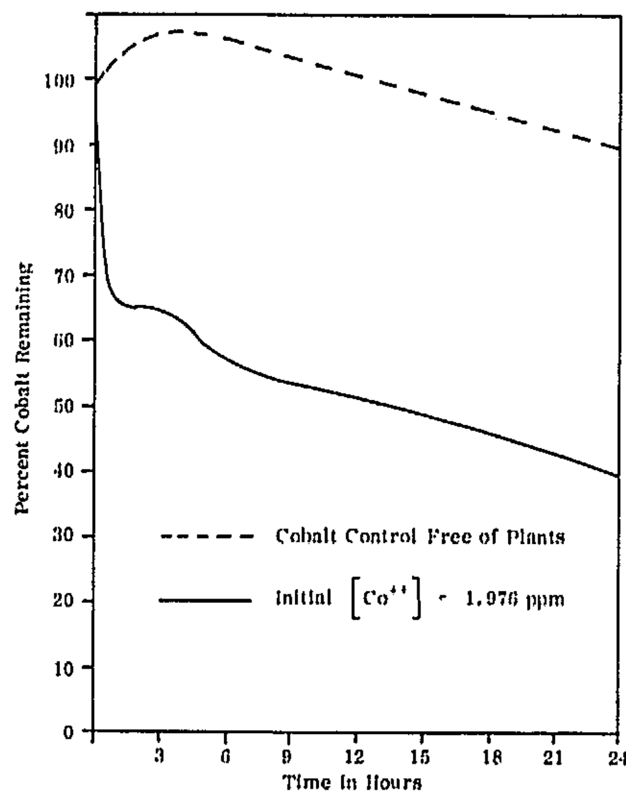

Figure 4. Graphic Representation of Removal Rates of Cobalt from River Water Containing Water Hyacinths and Cobalt Control Free of Plants

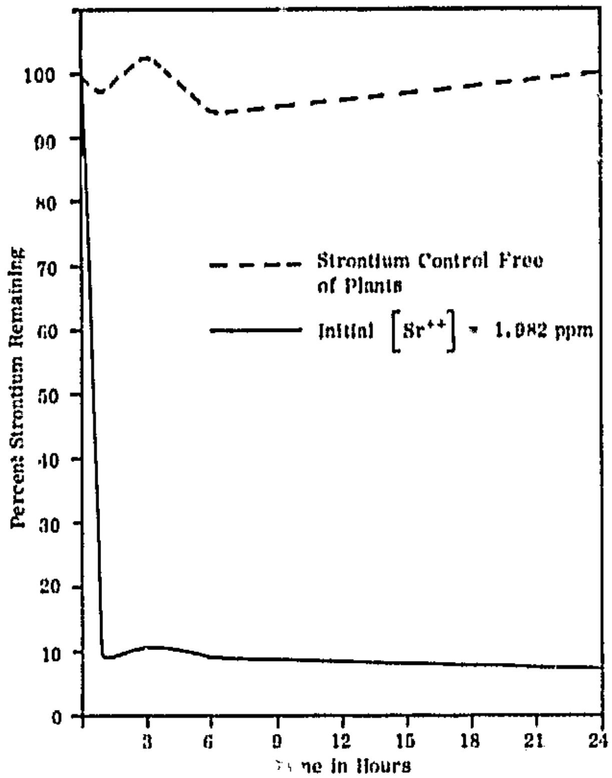

Figure 5. Graphic Represe..ation of Removal Rates of Strontium from Distilled Water Containing Water Hyacinths and Strontium Control Free of Plants

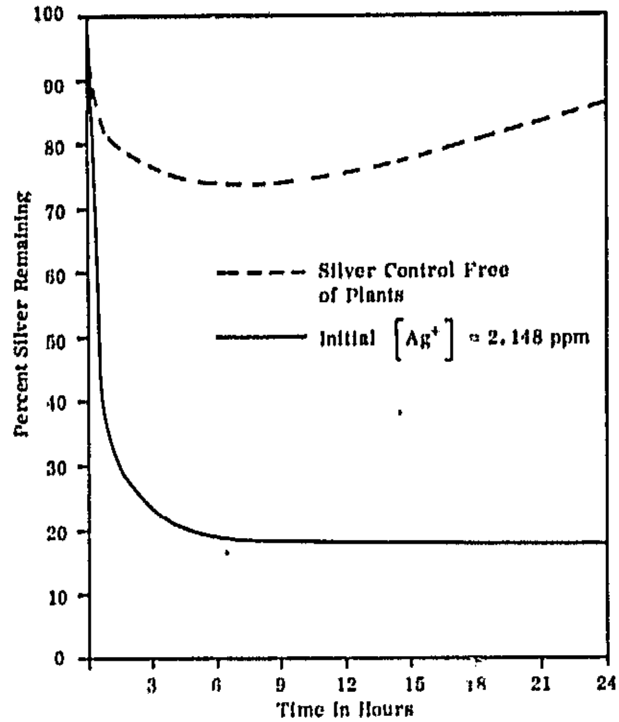

Figure 6. Graphic Representation of Removal Rates of Silver from Distilled Water Containing Alligator Weeds and Silver Control Free of Plants

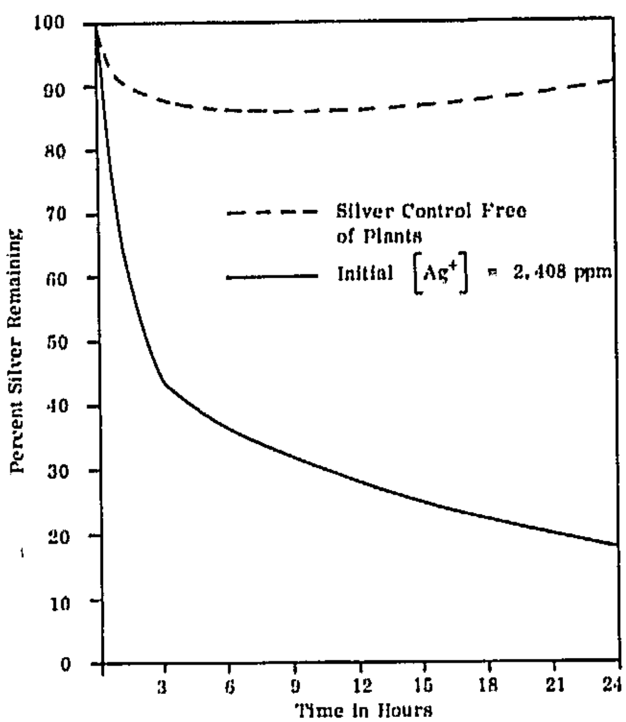

Figure 7. Graphic Representation of Removal Rates of Silver from River Water Containing Alligator Weeds and Silver Control Free of Plants

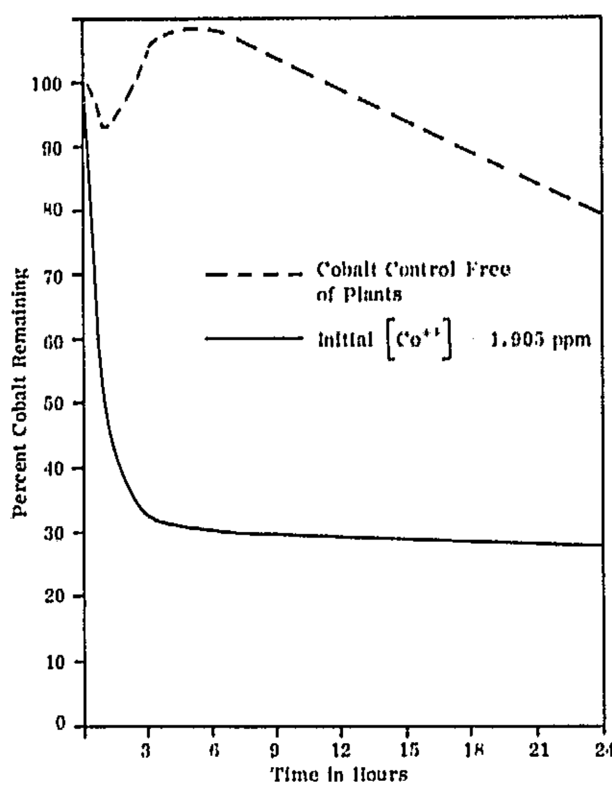

Figure 8. Graphic Representation of Removal Rates of Cobalt from Distilled Water Containing Alligator Weeds and Cobalt Control Free of Plants

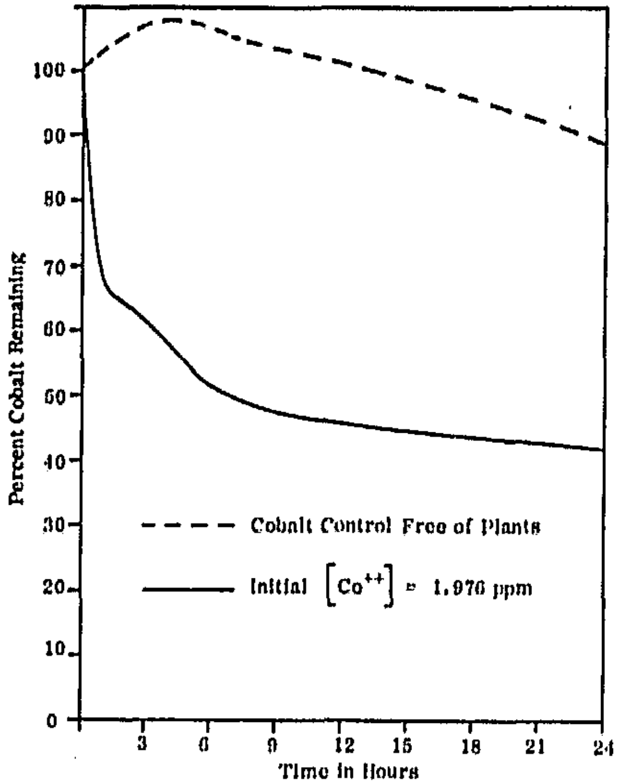

Figure 9. Graphic Representation of Removal Rates of Cobalt from River Water Containing Alligator Weeds and Cobalt Control Free of Plants

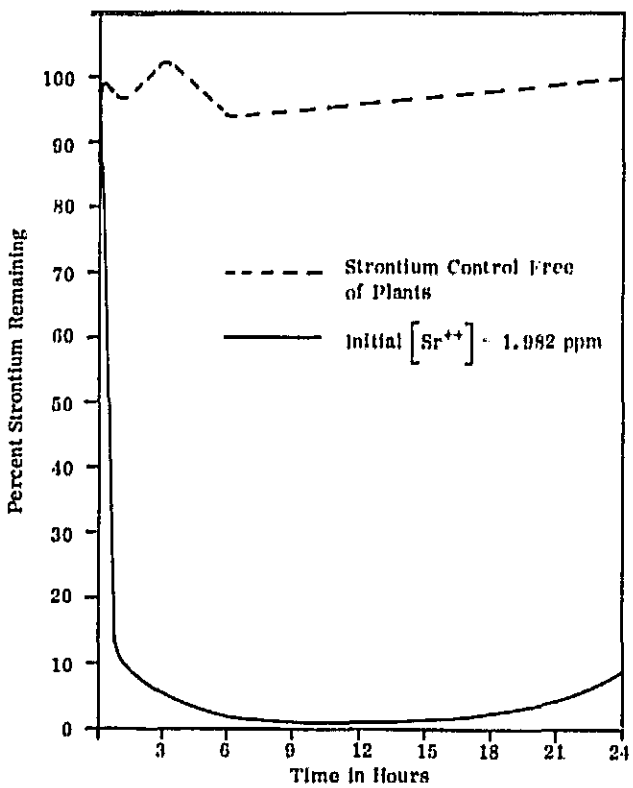

Figure 10. Graphic Representation of Removal Rates of Strontium from Distilled Water Containing Alligator Weeds and Strontium Control Free of Plants

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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 of 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 accruacy.

Henry F. Auter

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