SWORD FERNS FOR PHYTOREMEDIATION OF CHROMIUM CONTAMINATED WATERS

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ABSTRACT

Chromium is a highly soluble transition metal of vital industrial importance. It occurs in both trivalent and hexavalent forms. Due to many well identified adverse impacts of chromium to human health and natural ecosystems, treatment of chromium contaminated waters has become a major concern and challenge for environmental engineers. The currently practiced conventional mechano-chemical treatment systems for remediation of chromium contaminated waters have high operational costs, especially when the concentrations are low. Therefore alternative natural attenuation systems are becoming the focus of modern research. This paper presents a research to asses the applicability of Common Sword Ferns in phytoremediation of water contaminated with low or medium concentration of bot trivalent and hexavalent chromium.

Saword ferns (*N. Exaltata)* showed very high removal rates (about 99%) in a Hydroponic medium upto 50 ppmcontamination of T-Cr. The mass balance shows that most of the Cr taken up by the plant is retained in the roots (about 75 % or 3500 mg/kg). Little is translocated to above-ground tissues (4% or 120 mg/kg). Therefore the mechanism of removal is mainly Rizofiltration. The mechanism of uptake may be Bio-sorption or Active uptake by root cells. *N. Exaltata* hardly shows any symptoms of Phyto-toxic affects upto 50 ppm of Cr^{+3}, and 15 ppm of Cr^{+6}. But in a Soil water system mass balances show that most of water soluble Cr^{+3} is sorbed to soil (about 90%). *N. exaltata* is poor in de-mineralizing, mobilizing and uptake of soil bound Cr^{+3}. Sand has a remarkable capacity to immobilize Cr^{+3} in water.

KEYWORDS

Plant base systems, Root zone, Treatmen

INTRODUCTION

Chromium is a highly soluble transition metal, available as ions of different valances, out of which the trivalent (Cr^{+3}) and hexavalent (Cr^{+6}) forms are relatively stable and widely found than others. Because of the excellent hardness properties and the bright colours of chromium compounds they are widely used in industries such as alloy making , electroplating, paint manufacturing, textile dying, tanning etc.

There are many well identified effects of Cr^{+3} and Cr^{+6} on human health. Cr^{+6} is known to be highly toxic and proven to be 100 times more toxic than Cr^{+3}. Chromium compounds can be absorbed by the lungs, skin or intestines.

There are several well established environmental engineering techniques to remove chromium from wastewater and contaminated sites such as; 1) Chemical precipitation, 2) Ion exchange 3) Chemical reduction etc. Due to high operational costs and exhaustive nature of these systems, towards the latter part of the last century attempts were made to commercially apply natural attenuation methods to treat heavy metal contaminated sites and wastewater in the US and some parts of Europe (Sudaresan, 2001).

Phyto remediation can be grossly defined as the use of vegetation (macro-flora) for in situ treatment of soils, sediments and water. Plants may actively take-up the contaminant and store it in the above ground tissues or transform the contaminant

chemically (Phyto-accumilation, Phyto-transformation and Phyto-volatalizaton). Another type of plant may adsorb the contaminant in the root zone or the contaminant will get degraded within the plant root zone due to microbial action (Rhyzo-filtration, Root-zone biodegradation). The most favored method in phytoremediation is use of *hyper accumulator* plants for fast uptake and removal of certain contaminants from a site. Some plants such as Common reed (*Pragmities austrilus*) although not hyper accumulators have been proven to uptake or remediate several types of contaminants, these plants are easily grown and needs less care than most hyper accumulators (Sutharesan, 2002).

This paper investigates in detail about the applicability of abundantly found type of fern *Nepholepis Exaltata* for phytoremediation of Chromium contaminated waters as a tertiary treatment method for industrial wastewater or remediation of contaminated aquatic systems. *Nephrolepis exaltata* is a dependable easy to grow fern which produces large masses of narrow pale green leaves. It has a high growth rate and resists high degree of moisture and soil acidity (University of Florida Fact Sheet FPS-427, 1998)

METHADOLOGY

The tests were carried out in three groups (Group A, Group B and GroupC). For group A tests, a fixed fresh plant weight of 100g was tested under following conditions; 1)varying chromium concentrations (15ppm, 30ppm, 50ppm and 100ppm) 2) 2)varying pH and 3)varying salinity levels. The plants were kept in a hydroponic system. Group B test was carried out by varying the plant weight while keeping the chromium concentrations fixed at 50ppm. Group C test was carried out in a soil water system (gravel bed with small sand culture), where a fixed plant weight was (500g) was replenished daily with 1l of 50 ppm chromium solution continuously for 12 days. For all the above tests potable water artificially contaminated with $Cr_2(SO_4)_3$ was used. A separate experiment was carried out with varying concentrations of CrO_3 (5ppm, 15ppm, 30 ppm and 50ppm) to understand the behavior of sword ferns with Cr^{+6} compounds. All the experiments were done in triplicate.

The chromium concentrations in water were measured by collecting samples initially and at required intervals. Samples were then analyzed using Atomic Absorption Spectrometry (AAS). The chromium levels in the plant tissues were measured by digesting the plant matter by Micro-wave digestion and analyzing with AAS.

RESULTS

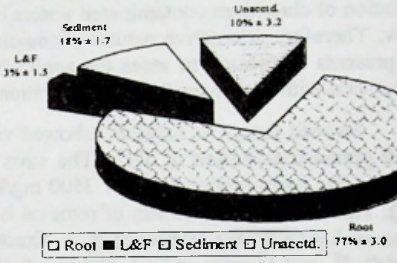

Figure 1: Final mass balance of T-Cr in plants kept at 50ppm $Cr_2(SO_4)_3$ solution in the hydroponic system

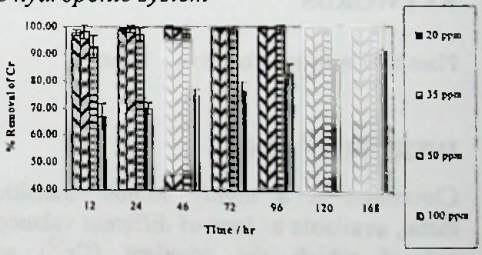

Figure 2: Variation of percentage removal of T-Cr with time in the $Cr_2(SO_4)_3$ solution in the hydroponic system

Chromium removal characteristics of sword ferns were studied under different conditions. Fig. 2 shows that common sward ferns can remove T-Cr at percentage removal rates as high as 98% within less than 24 hours. Plants in 100ppm T-Cr concentration showed a significantly lesser removal rate of 65% initially. Although the percentage removal increased up to 87% in the end of 168 hrs, these plants clearly showed signs of toxication. It's notable that up to 50ppm

concentration of T-Cr plants didn't show any form of phyto-toxicity or discoloration due the presence of chromium.

According to fig. 1 which is the final mass balance of a 100g plant kept in 50ppm solution, 77% percent of T-Cr is accumulated in the roots. An excellent bio accumulation rate of 3358 mg of Cr/kg of dry biomass of plant was identified, but translocation of chromium to above ground tissues was found to be very low in sword ferns. T-Cr concentration in the leaves and fronds were only 122 mg of T-Cr/kg of dry biomass.

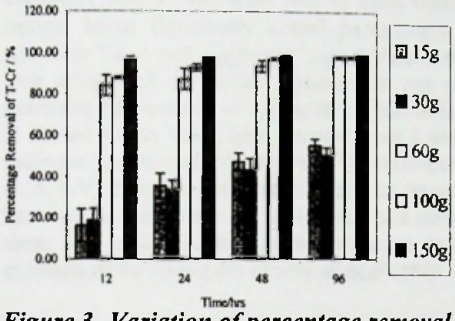

Figure 3- Variation of percentage removal of T-Cr with time in the $Cr_2(SO_4)_3$ solution with different plant weights

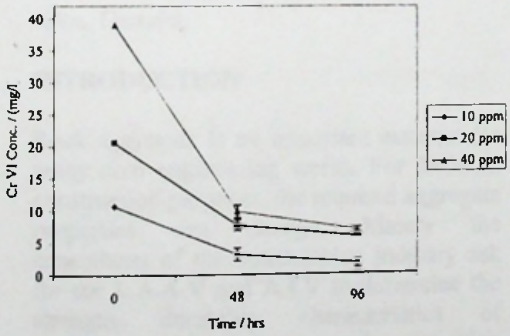

Figure 4 -Variation of concentration of T-Cr with time in CrO3 solution with N. exaltata

Fixed plant weights of *N. exaltata* were tested for the percentage removal of T-Cr from a CrO_3 solution by *N. exaltata* in a hydroponic system. The percentage removal achieved in various concentrations of CrO_3 is given by the fig 4. Although the percentage removal rates were impressive, plant which were kept in concentrations above 15 ppm of Cr^{-6}concetrations showed explicit symptoms of toxicity.

DISCUSSION

It was observed that even a *N. exalatata* bush of 60g plant weight can be used to achieve above 85% removal of T-Cr in 1 liter of 50 ppm $Cr_2(SO_4)_3$ solution within 12 hrs. But the percentage removal of T-Cr is not proportionate to the weights when the when the plan weights become smaller. This might be due to the fact that root surface area reduces rapidly not proportionately with the reduction of plant weight. The observation also supports the assumption that major mechanism of chromium intake by the roots is sorption rather than active cell uptake.

In a soil water system sward ferns could accumulate T-Cr up to 2421 mg of T-Cr/kg of dry biomass in roots and 135 mg of T-Cr/kg of dry biomass in a 50ppm solution of $Cr_2(SO_4)_3$. These values are substantially lower than the accumulation concentration showen by the plants kept in the hydroponic system. From fig.3 it's clear that gravel/sand media has sorbed more than 94% of Chromium applied to the system, It is a known fact that the sorption between a certain sorbate and a sorbant can be affected by the presence of another competitive sorbant media (Sutharesan, 2001). This particular phenomenon tempted the authors to investigate more in to the possibilities of using sand or gravel in treatment of chromium contaminated waters.

CONCLUSIONS

From the experiments it's evident that *N. exaltata* could effectively accumulate Cr^{+3} in its root zone in moderate concentrations without showing any symptoms of phyto-toxicity. It can also effectively remove Cr^{+6} in an aqueous medium but only in low concentrations.

Mass balances show that the Major mechanism of contaminant removal in both cases seems to be root zone adsorption rather

than active cell uptake. Therefore N. exaltata is not a hyper accumulator.

But engineered beds of N. exaltata in hydroponic or soil-water systems can be used for non-rapid tertiary treatment of water contaminated with moderate concentrations of Cr^{+3}.

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