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Removal Of Fluoride Contamination In Waste Water By Using Eichhornia Crassipes

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ABSTRACT

The industrial sector has experienced unprecedented progress in the 21st century not only in India but also across the globe. Loads of wastewaters get generated from industrial, commercial and domestic origins and are discarded. The discharge of wastewater, without any pre-treatment, has always affected the health of human beings, plants and animals. Industrial wastewater contains a toxic chemicals which not even degradable, they are very likely accumulated in the soil and affect plant growth. Phytoremediation is a cost-effective green emerging technology with long-lasting applicability. Eichhornia Crassipes hold steep efficiency for the removal of organic and inorganic pollutants. Eichhornia Crassipes (water hyacinth) was chosen to remediate the problem of fluoride(F) pollution from wastewater. It has been observed that this plant was able to remove 28.3% Fluoride from the wastewater in 10 days.

Keywords- Phytoremediation, Eichhornia Crassipes, Fluoride, Waste Water.

Introduction

Environmental (soil, water and air) pollution is a serious threat to human beings, flora and fauna. Since the beginning of the industrial revolution, pollution of the biosphere with toxic elements has accelerated gradually and dramatically. Rapid development and industrialisation are the main factors responsible for this problem. Contamination of soil and water with metals, metalloids and radionuclei is posing a threat to plant, human and animal health. The primary sources of pollution are the burning of fossil fuels, mining and smelting of metalliferous ores, municipal wastes, fertilizers, pesticides, sewage, transportation and urbanization [1]. The economic, agricultural and industrial expansions are mostly accountable for the pollution caused to the ecosystem. They introduce harmful pollutants into the soil groundwater pollution becomes the main environmental concern, and many contaminated sites have been cleaned up in these two decades by several technologies like soil washing, Nalgonda method, Prasanthi Nilayam method and bioremediation to reduce and remove fluoride concentration in drinking and industrial water. The prominent states, which are severely affected by fluoride in India, are Andhra Pradesh, Rajasthan, Gujarat, Uttar Pradesh and Tamil Nadu[2]. Several conventional methods are available for the treatment of fluoride from industrial effluents like membrane filtration, precipitation, nanofiltration, ion exchange, electrocoagulation flotation, adsorption and phytoremediation [3]. Phytoremediation is an expanding technology that employs higher plants for the clean-up of contaminated environments that has several advantages over physical remediation methods, including lower cost. Phytoremediation involves phytoextraction, rhizofiltration, phytostabilization and phytotransformation/phytodegradation[3]. The present study deals with the removal of fluoride and chromium from industrial wastewater by considering above mentioned factors.

Phytoremediation

Phytoremediation which has been developed by scientists and engineers uses green plants and associated microflora to remove, degrade or stabilize complex environmental contaminants and remediate the polluted areas. It can be loosely defined as the use of plants to improve the environment. Various types of vegetation, including trees, grasses and aquatic plants, are used in situ to decontaminate air, soil and surface and groundwater systems. It refers to the natural ability of certain plants called hyperaccumulators to bioaccumulate, degrade or render harmless contaminants in soils, water or air. Contaminants such as metals, pesticides, solvents, explosives and crude oil and its derivatives, have been mitigated in phytoremediation projects worldwide. It is a cost-effective and affordable technology used to remove inactive metals and metal pollutants from contaminated soil and water.

Phytoremediation is formed with two words “Phyto “a Greek word which refers to plants and the second-word “remediation” which refers to restoring balance. The concept of phytoremediation was first introduced by Rufus Chaney in 1983. Thus, phytoremediation is the technique in which plants are used to clean the environment from pollutants in air, water and soil [5]. Some plants used for the phytoremediation are listed below in table 1[6].

Table 1 Plants used for Phytoremediation

Sr. No.	Plant name	Role in phytoremediation
1	Alyssum	Nickel accumulator
2	Amaranthus retroflexus	Accumulator of 137Cs
3	Armoracia rustica	Hairy-root cultures remove heavy metals
4	Armeria maritime	Lead accumulator
5	Atriplex prostrate	removes salt from the soil
6	Azolla pinnata	Accumulator of lead, copper, cadmium, and iron
7	Brassica canola	Remediates 137Cs- contaminated soil
8	B. juncea	Hyperaccumulator of metals
9	Cannabis sativa	Hyperaccumulator of metals
10	Cardamonopsis gallery	Hyperaccumulator of metals

Techniques/strategies of phytoremediation-

Phytoremediation is done through mainly five mechanisms they are as follows:

1-Phytodegradation.

2-Phytoaccumulation/Phytoextraction,

3-Phytostablization,

4-Phytofiltration/Rhizofiltration,

S-Phytovolatization.

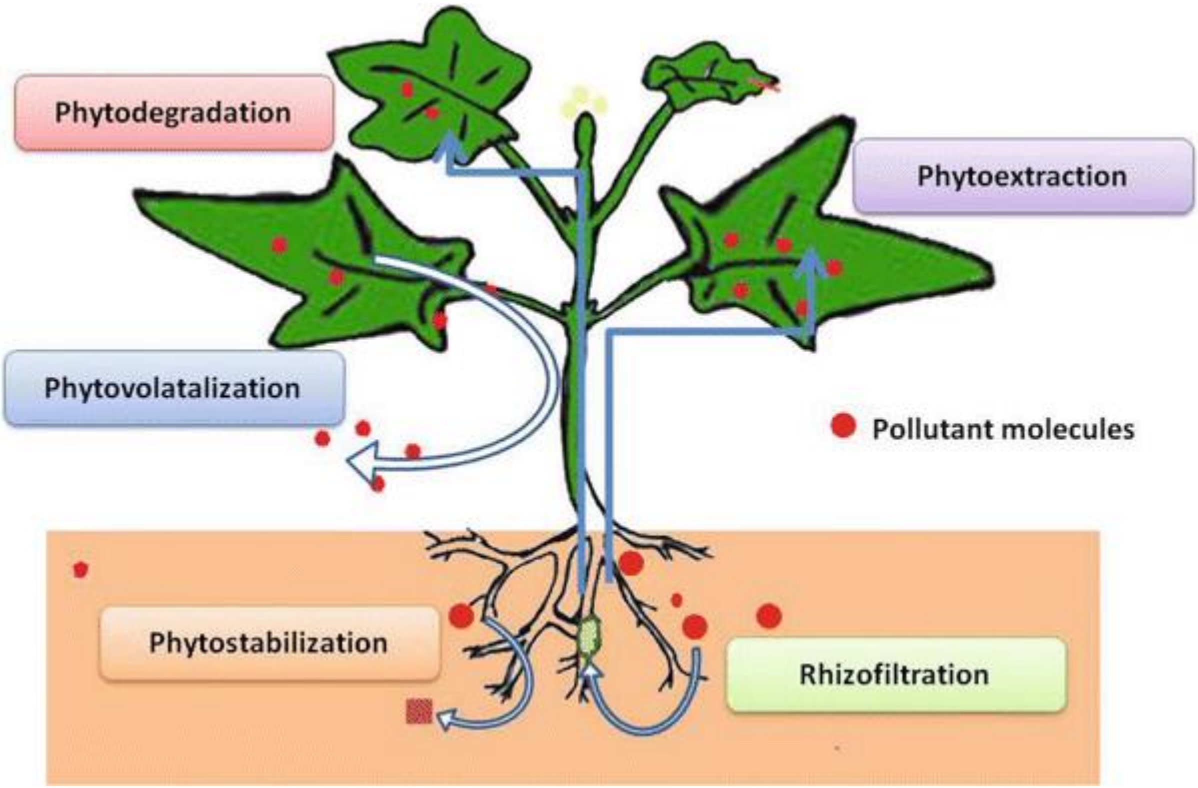


Figure 1: Mechanism of phytoremediation (source-link.springer.com)

Phytodegradation: Phytodegradation is the process of decomposition of organic pollutants by the action of enzymes produced by plants such as oxygenase, dehalogenase etc. Green plants act as "green liver" for the biosphere. The Phytodegradation mechanism is limited to the organic pollutant; heavy metals are not degraded by this mechanism.

Phytoaccumulation/Phytoextraction: Phytoaccumulation is the process in which heavy metals are taken from the soil by roots and transferred to parts of the plant above the ground like steam, leaves etc.

Phytostablization: In Phytostablization the heavy metals in the soil or water are stabilized. By this mechanism, pollutants are stabilized near the roots through sorption. comlexation, precipitation etc. Pollutants having high toxicity are converted into less toxic substances and get accumulated in plants by which they are immobilized and out of the food chain.

Rhizofiltration: This mechanism involves the removal of the pollutants floating on the surface of the water. Certain plants have very dense roots which act as the filtration media for the water and the pollutant floating on the surface are getting trapped in it.

Phytovolatization: Phytovolatization is the process in which the pollutants are taken from soil and water through roots and via tree, it is releasedd in atmosphere. In this mechanism, the pollutants are only transferred from one place to another. The liberation of contaminants through phytovolatization converts a ground problem into an air problem.

Material & Methods

Eichhornia Crassipes (Water hyacinth) as phytoremediation plant

It is native to tropical and subtropical South America and is now widespread in all tropic climates. It is a free-floating, perennial aquatic fern belonging to the family Pontederiaceae. It forms dense mats in the water and mud. It is also referred to as 'bull hyacinths'. It flourishes and reproduces floating freely on the surface of water or it can also be anchored in mud. It grows in ponds, canals, freshwater and coastal marshes and lakes. Eichhornia crassipes attracted considerable attention because of their ability to grow well in polluted water together with their capacity of accumulating heavy metal ions.

Plants absorb depending upon their affinity towards the particular metal. Based on absorption and accumulation mechanisms, Eichhornia crassipes render services of cleaning water bodies, sewage and sludge ponds from heavy metal and nutrient contamination. Eichhornia crassipes possess the capacity to treat industrial and municipal waters contaminated with Pb, As, Hg, Zn, Se, Cr, Cd, Ni and Cu. Eichhornia crassipes supports Phytofiltaration mechanism of phytoremediation. Phytofiltaration is also known as Rhizofiltration[7].

Figure 2: Eichhornia crassipes

Location- This study was conducted at Bundelkhand Institute of Engineering and Technology, Jhansi, Uttar Pradesh, India.

Sample collection- Eichhornia crassipes were collected in a pond located in Shivaji Nagar, Jhansi,284128, Utter Pradesh, India. The plant was collected at suitable sizes of clumps and leaves. After collection, they were cleaned with tap water to remove any epiphytes and insect-like larvae grown on plants. After then the plants of the same size were selected for our experiment.

Figure 3:collecting Eichhornia crassipes (image taken by Lavakush Kumar)

Preparation of Hoagland solution

Hoagland solution is a hydroponic nutrient solution that was developed by D.R. Hoagland and D.R. Arnon in 1938. It is the most popular solution in which plants can grow without soil, which was later revised by D.R. Arnon in 1950. The Hoagland solution provides every nutrient necessary for plant growth and is appropriate for the growth of a large variety of plant species. The solution consists of three main constituents as follows:

- Macronutrients
- Micronutrients
- Phosphates

To make Hoagland's solution first we weigh the exact amount of given compounds in the weighing machine. After which we make a stock solution of these compounds and kept them in different vessels. After which 16628approx.. 800 ml of distilled water is added to each component such that it fills up to 1 litre of volumetric flask. Shake and mix all the solutions after which the solution is ready to use. Hoagland Solution is a useful component to grow plants which require fewer amounts of nutrients. Generally, for Eichhornia crassipes 10 to 20% of this solution is used. Here we used 10% of this solution for our investigations. Table 2 shows various constituents and their concentrations in the Hoagland's solution.

Table 2 Hoagland solution constituents

Components	Stock solution	ML stock solution per litre

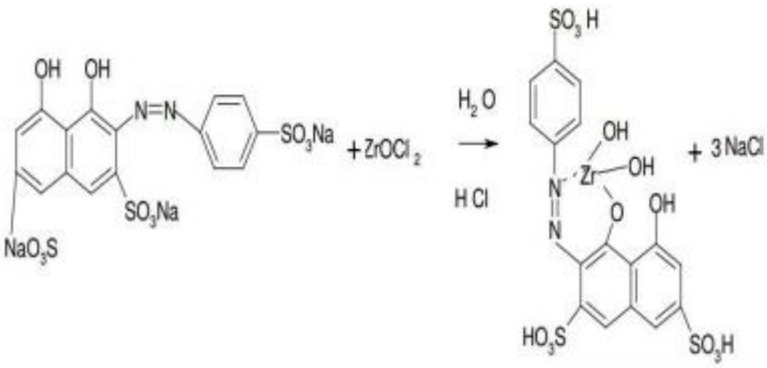
Macronutrients		
2M KNO_2	202 g/L	2.5
1M $Ca[NO_3]_2•4H_2O$	472g/L	2.5
Iron [Sprint 138 iron chelate]	15 g/L	1.5
2M $MgSO_4•7H_2O$	493 g/L	1
1M NH_4NO_3	80 g/L	1
Micronutrients		
H_3BO_3	2.86g/L	1
$MnCl_2•4H_2O$	1.81g/L	1
$ZnSO_4•7H_2O$	0.22g/L	1
$CuSO_4•5H_2O$	0.051g/L	1
$H_3MoO_4•H_2O$	0.09g/L	1
$Na_2MoO_4•2H_2O$	0.12g/L	1
Phosphate		
1M KH_2PO_4	136g/L	0.5

Experimental Setup- The 100mg/l stock solution of fluoride was prepared by dissolving 221mg of anhydrous sodium fluoride (NaF) in one litre of distilled water. The test solution of 20mg/l fluoride concentration was prepared from the stock solution. The selected concentration is the normal fluoride concentration in industrial wastewater.

All the experiments were carried out in 250 ml round bottom flasks, with 50 ml test solution at (29+1)°C in the round bottom flask. Analysed for fluoride concentration by SPADNS method, described in the standard method of examination of wastewater and water[8].

Figure 4: Eichhornia crassipes after cleaning

Spectrophotometric methods-

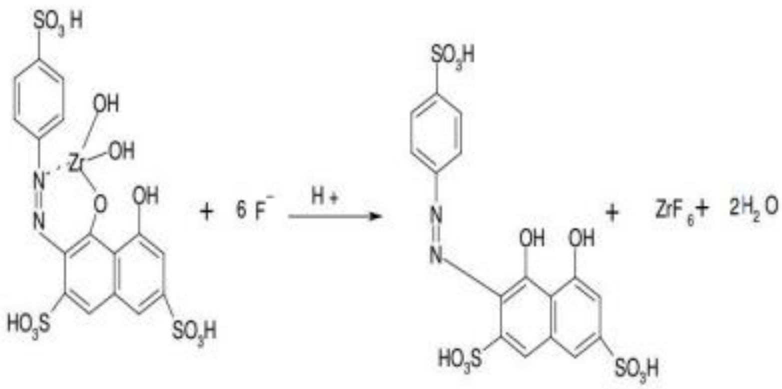


In this technique, a compound of a metal such as aluminium, iron, thorium, zirconium, lanthanum or cerium reacts with an indicator dye to build a complex of small dissociation constant. This complex reacts with fluoride to give a new complex. Because of the transformation in the configuration of the complex, the surface assimilation spectrum also shifts relative to the spectrum for the fluoride-free reagent solutions.

This alteration can be observed by using a spectrophotometer. One of the essential dyes employed is trisodium 2- (parasulfophenylazo)-1, 8-dihydroxy-3, and 6- naphthalene disulfonate, generally recognized as SPADNS. Erichrome Cyanine R is one most commonly used dyes.

The dye reacts with metal ions to give a coloured complex. In the SPADNS method, zirconium reacts with SPADNS to build a red coloured complex. Fluoride discolours the red colour of the complex and therefore the alteration in absorbance can be calculated using a spectrophotometer.

Formation of the SPADNS – ZrOCl2 complex-



The reaction of the complex with fluoride ions

Recipe for SPADNS Solution

$$\frac{\text{Mg of fluoride}}{\text{litre}} = \frac{\text{A}}{\text{sample(ml)}} \times \frac{\text{B}}{\text{C}}$$

Where

A represents Fluoride obtained by Curve (mg)

B represents diluted sample final volume (mL)

C represents diluted sample volume worn for the development of colour.

$$\frac{\text{Mg of fluoride}}{\text{Litre}} = \frac{A_0 - A_x}{A_0 - A_1}$$

Where

A_0 represents Absorbance at Zero Fluoride Concentration

A_1 represents Absorbance at Fluoride Concentration of 1 mg/L

A_x represents the Absorbance of a sample prepared

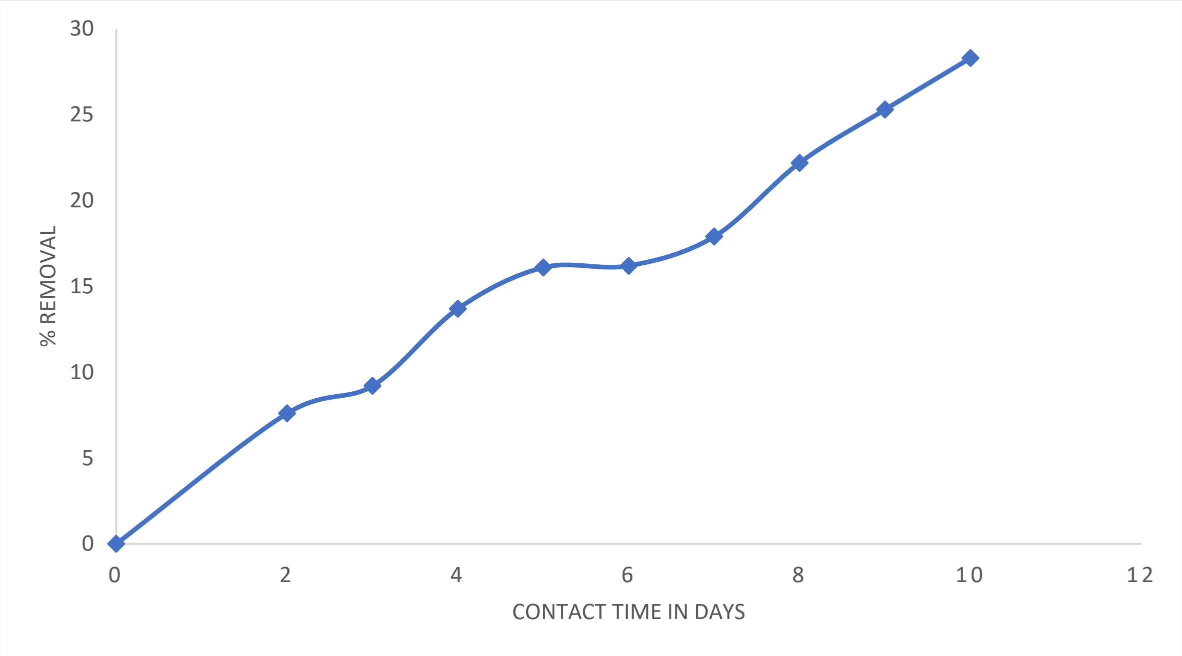
Result and discussion-

Table 3: Variation of contact time on removal of fluoride

Contact time (days)	Initial concentration of fluoride(mg/l)	Absorbance Of sample prepared (A_x)	Final concentration of fluoride (mg/l)	Amount adsorbed by Eichhornia crassipes (mg/l)	% Removal
1	10	0.351	0	0	0
2	10	0.275	9.24	0.76	7.6
3	10	0.263	9.08	0.92	9.2
4	10	0.214	8.63	1.37	13.7
5	10	0.192	8.39	1.61	16.1

6	10	0.184	8.38	1.62	16.2
7	10	0.172	8.21	1.79	17.9
8	10	0.129	7.78	2.22	22.2
9	10	0.099	7.47	2.53	25.3
10	10	0.068	7.17	2.83	28.3

Figure-05: Effect of contact time on the removal of Fluoride



The initial concentration of fluoride is 10 mg/l. The concentration of samples after 10 days is 7.17 mg/l. The amount of fluoride removed from wastewater 2.83 mg/l in 10 days. The percentage removal of fluoride is 28.3% in 10 days.

Conclusion – Water being the source of life has become a scarce resource in this century. The water is continuously contaminated due to various kinds of human activities, consequently, it would be a direct threat to the survival of all living forms. The present study has successfully addressed the phytoremediation method of removal of fluoride contaminants in wastewater by plants. It has positively indicated that the Eichhornia crassipes plants have potential in the abatement of fluoride pollution to some extent in aquatic ecosystems receiving industrial effluents and municipal wastewater. The present study proved Eichhornia Crassipes as a good accumulator of fluoride. This plant has successfully removed up to 28.3% of Fluoride.

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