PERFORMANCE OF INDIAN MUSTARD IN VERTICAL SUB-SURFACE FLOW CONSTRUCTED WETLANDS (VSF-CW) FOR HEAVY METAL REMOVAL FROM WASTEWATER

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***Abstract*— This study was conducted to check the performance of Brassica juncea (Indian mustard) to remove heavy metals in vertical sub-surface flow constructed wetland. Two pilot models of vertical sub-surface flow constructed wetland were constructed and instead of any macrophyte, indian mustard was grown as a wetland plant on it. Two heavy metals - lead and cadmium were tested in the wetland system by using synthetic water and their influent and effluent concentrations were analyzed on flame type atomic absorption spectrometer. It was observed that the Brassica juncea removes these two metals up to large extent. But these heavy metals have severe effects on the plant. The growth was not normal and the photosynthesis process was also effected as the leaves of the plant turned yellow even in the presence of sunlight. Whereas the leaves of the wetland system fed on deionized water are green and the plant growth is normal.**

key words-Wetland, Heavy metal removal, Indian mustard, Atomic absorption spectrophotometer.

I.INTRODUCTION

Constructed wetlands (CWs) are highly efficient ecological systems that are extensively used around the world for treating wastewater from a wide range of sources, including domestic, mining, and industrial wastewater [1]. Interest in CWs has been increasing rapidly because of its operational simplicity and low cost as compared to traditional wastewater treatment systems [2]. The purification capacity of CWs relies on various naturally occurring physical, chemical and biological processes that take place within the system and degrade various pollutants as a result of the synergetic actions of the system components, i.e., substrate media, plant roots and microbial community [3]. VSF-CWs are intermittently fed from the top, wastewater percolates and oxygen enters the system from the atmosphere as wastewater is drained [4]. Vertical sub-surface flow constructed wetlands are predominantly aerobic [4,5]. In wetland system the efficiency of the system depends upon the vegetation. Plants are able to absorb pollutant through one or more of the following: 1) plant uptake of contaminant from soil particles or soil liquid into their roots; 2) bind the contaminant into their root tissue, physically or chemically; and 3) transport the contaminant from their roots into growing shoots and prevent or inhibit the contaminant from leaching out of the soil [6].

Human activities such as industrial production, mining, agriculture and transportation, release high amounts of heavy metals into surface and ground water, soils and ultimately to the ecosystem. Though the heavy metal like, Cd, Pb and Ni are not essential for plant growth, they are readily taken up and accumulated by plants in toxic forms. Ingestion of vegetables and other eatables irrigated directly with wastewater poses a possible risk to human health and wildlife [7].

TABLE 1. SELECTED POLLUTANT ACCUMULATING PLANT SPECIES.

SCIENTIFIC NAME	COMMON NAME
Armeria maririma	*Seapink thrift*
Brassica juncea	*Indian mustard*
Brassica napus	*Rape, Rutabaga, Turnip*
Brassica oleracea	*Flowering/ornamental kale and cabbage, Broccoli*
Festuca ovina	*Blue/sheep fescue*
Helianthus annuus	*Sunflower*
Triticum aestivum	*Wheat (scout)*
Zea mays	*Corn*

Industrial effluents containing cadmium, chromium, copper, lead, mercury, nickel and zinc are of particular concern for treatment because of their toxic behavior in the environment [8]. Now a day the industrial sector has focused a great deal of attention on CW systems for removing heavy metals (HMs) from its wastewater [9,10,11].

In this study two pilot scale models of vertical sub-surface flow constructed wetlands were constructed and tested for the removal efficiency for Cadmium and Lead with Brassica juncea (Indian mustard) as wetland plant and one model is used as a blank which is fed by deionized water only.

II.MATERIALS AND METHODS

2.1. Pilot-scale CW unit design and description

Two glass containers, each of size 30cm×30cm×60cm ,were used in the study. Bottom layer of 15cm consists of gravel of size between 40-60mm which was previously washed and dried in order to remove dirt and other organic material from these. Above gravel layer, lied a 15cm layer of coarse aggregates of size ranging between 10-20 mm. A cropped Jute gunny bag of size 30cm×30cm was placed as a separator between soil and aggregate layer. Above jute layer, locally available silty clayey soil of 30cm was placed as shown in Figure 1.

2.2. Vegetation cover

Brassica juncea (Indian Mustard) [6,12] was used as vegetation to remove heavy metals in wastewater because plants commonly employed for this purpose should have a hyperaccumulation power and also have the capacity to grow rapidly [13]. Seeds were sown on topmost soil layer and covered properly with soil. These were watered with deionized water for one month at regular intervals of time and testing procedure was initiated after its flowering.

FIGURE 1. VERTICAL SUB-SURFACE FLOW CW MODEL

2.3. Sampling and testing

Synthetic water of different concentrations was prepared in the laboratory and its concentration was confirmed at AAS and this water sample was allowed to pass through wetland system through I.V. pump at the rate of 1.59ml/s. The effluent concentration was again checked at AAS(Agilent 240FS AA) [14] and efficiency was determined. Lead of 1000mg/l concentration was prepared by using 1.5980g of lead nitrate . Its three different concentrations as 100mg/l, 200mg/l and 400mg/l [15] were prepared by using standard method. Cadmium was prepared for 5mg/l, 10mg/l and 20 mg/l [16] using standard method in which suspensions of 1000mg/l were prepared. And then diluted to required concentrations. The 1000mg/l concentration solution was prepared by taking 1g of cadmium metal in 20 ml of 5M HCl and then adding 2 drops of conc. Nitric acid and diluting the solution to 1000ml using deionized water. Each concentration of lead and cadmium was allowed to pass through wetland in triplicates and the effluent collected was filtered with filter paper no. 42 to remove suspensions before testing on AAS.

RESULTS AND DISCUSSIONS

3.1. Lead

Synthetic water containing lead was fed to the wetland model and the effluent concentrations are shown in the table 2.

TABLE 2.. INFLUENT AND EFFLUENT CHARACTERISTICS OF LEAD

Sr. No.	*Inlet conc. (mg/l)*	*Outlet conc. (mg/l)*	*Efficiency (%age)*	*Average efficiency*
1.	*100 100 100*	*0.40 0.46 0.43*	*99.60 99.54 99.57*	*99.57*
2. .	*200 200 200*	*8.97 9.11 8.79*	*95.51 95.44 95.60*	*95.51*
3.	*400 400 400*	*34.84 36.76 35.12*	*91.29 90.81 91.22*	*91.10*

From the above results it was found that indian mustard is very efficient (99.57%) in removing the low concentrations of metal, whereas its efficiency decreases with increase in concentration .But still the results were found satisfactory at large concentrations in the range of 90.81 - 95.60%.

3.2. Cadmium

Synthetic water containing cadmium of known concentration was allowed to pass through wetland model. The influent and effluent characteristics were shown in the table 3.

TABLE 3. INFLUENT AND EFFLUENT CHARACTERISTICS OF CADMIUM

Sr. No.	*Inlet conc. (mg/l)*	*Outlet conc. (mg/l)*	*Efficiency (%age)*	*Average efficiency*
1.	*5 5 5*	*0.001 0.002 0.002*	*99.98 99.96 99.96*	*99.96*
2. .	*10 10 10*	*1.002 1.011 1.009*	*89.98 89.89 89.91*	*89.92*
3.	*20 20 20*	*2.940 2.897 2.735*	*85.30 85.51 86.32*	*85.71*

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From the above data it was found that indian mustard was very effective in removing cadmium but as the concentration of metal increases the efficiency decreases at faster rate in comparison to the results shown in case of lead.

So indian mustard comparatively showed better performance for wastewater containing lead .

This study was conducted to check the capacity and limits of indian mustard in constructed wetland to remove lead and cadmium. . Although initial concentrations taken in this study are very high as compared to concentrations found in industrial wastewaters, mine drainage waters and leachate but still the Indian mustard on wetland system gives excellent results As per the results, the effluent concentration was 0.43 mg/L of lead and 0.002mg/L of cadmium which is well in the range of irrigation water quality standards and inland discharge standards as shown in the table 4.

TABLE 4. COMPARISON OF EFFLUENT RESULTS WITH STANDARDS

Metal	*Inland surface discharge standards* (mg/l)*	*Irrigation water quality standards** (mg/l)*	*Maximum efficiency shown by wetland (mg/l)*
Cadmium	*2(max)*	*0.01(max)*	*0.002*
Lead	*0.1(max)*	*5(max)*	*0.43*

*General standards for discharge of environmental pollutants Part-A: Effluents (The Environment (Protection) Rules, 1986)

**Trace elements tolerance for irrigation waters (Environment Studies Board, 1973)

With this system, if we take industrial wastewater sample, the effluent concentration of lead and cadmium can be lowered below maximum permissible limits for irrigation and inland discharge.

In the present studythe flow rate was set at 1.59ml/s so the system was efficient to treat 160litres of water per day on one square feet area.

3.3 Effect on plant

After the testing it was found that the growth was not normal and the leaves of the plants turned yellow. Whereas the plants which were fed on deionized water, in the same set up of wet land, were normal and the colour of leaves was bright green.

III.CONCLUSIONS

The VSF-CW with indian mustard was very effective in the removal of heavy metals. The removal efficiency was more in case of lead as compared to cadmium. Further it is very effective in treating wastewater in small area and at low operation and maintenance cost.. It was very efficient system , however its efficiency can be enhanced by increasing the surface area or by increasing the retention period of wastewater in the wetland. The efficiency can further be enhanced if we connect wetland system in series.

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