Journal of Applied and Natural Science
Special Issue: 14 (SI), 105 - 110 (July, 2022)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Research Article

Suitability of vetiver (*Vetiveria zizanioides*) for removal of Cr (III) from tannery effluent using floating bed and rhizofiltration systems

Ganesan Karthikeyan
Department of Environmental Sciences, Tamil Nadu Agricultural University, Coimbatore- 641003 (Tamil Nadu) India
Kamaludeen Sara Parwin Banu*
Department of Environmental Sciences, Tamil Nadu Agricultural University, Coimbatore- 641003 (Tamil Nadu) India
Muthunalliappan Maheswari
Department of Environmental Sciences, Tamil Nadu Agricultural University, Coimbatore- 641003 (Tamil Nadu) India
Subburamu Karthikeyan
Department of Renewable Energy Engineering, Tamil Nadu Agricultural University, Coimbatore- 641003 (Tamil Nadu), India
Joseph Ezra John
Department of Environmental Sciences, Tamil Nadu Agricultural University, Coimbatore - 641003 (Tamil Nadu), India
Rajarathinam Prabhu
School of Post Graduate Studies, Tamil Nadu Agricultural University, Coimbatore - 641003 (Tamil Nadu), India
Ramesh Poornima
Department of Environmental Sciences, Tamil Nadu Agricultural University, Coimbatore - 641003 (Tamil Nadu), India

*Corresponding author. Email: saraparwinbanu.k@tnau.ac.in

Article Info
https://doi.org/10.31018/jans.v14iSI.3575
Received: March 10, 2022
Revised: April 19, 2022
Accepted: May 30, 2022

How to Cite
Karthikeyan, G. *et al.* (2022). Suitability of vetiver (*Vetiveria zizanioides*) for removal of Cr (III) from tannery effluent using floating bed and rhizofiltration systems. *Journal of Applied and Natural Science*, 14 (SI), 105 - 110. https://doi.org/10.31018/jans.v14iSI.3575

Abstract
Various physico-chemical methods have been employed in remediating heavy metals from wastewater, but most of them are expensive. While phytoremediation, is one cost-effective and eco-friendly technology, proves to be an alternate amongst which Vetiver, a unique tropical plant, is recognized for its large biomass and dense root system and has been proven for various remediation studies. The current research was conducted to assess the potential for Vetiver rhizofiltration of chromium. A pilot study was conducted in rhizobox wherein Vetiver was grown using sand as a medium and samples were collected from rhizobox port 1 and rhizobox port 2. Subsequently, the study was upscaled to a floating bed experiment. In both studies, Vetiver were grown under 500 mg L^{-1} Cr (III) solution and tannery effluent had a chromium concentration of 379 mg L^{-1} and the results were compared to control. Between the samples collected from port 1 and 2, the removal of chromium in port 1 was recorded to be higher than that of port 2. Moreover, the removal of chromium ions from the tannery effluent was relatively higher than the spiked solution. In both the ports, the highest removal of chromium concentration was recorded in T_5 (Sand + Vetiver + Cr (III) @ 500 mg kg^{-1}) with a removal percent of 12.59 and 10.38% in port 1 and 2, respectively. Hence, Vetiver grass has a great potential in removing pollutants like chromium from the wastewater.

Keywords: Chromium, Floating Bed, Rhizobox, Tannery, Vetiver

INTRODUCTION

The concentration of Cr in tannery waste is approximately 20,000 ppm, approximately 1800 ppm in sludge and 200 ppm in composite effluent and these are disposed of without any treatment (Sundaramoorthy *et al.*, 2010; Genawi *et al.*, 2020). The recent findings are still more alarming, as the Cr fractions in the groundwater have increased 10-fold in the same region (maximum of 36.7 mg/L). In the Erode and Coimbatore basins, the impact of tanneries is becoming acute in terms of groundwater and river contamination. Nearly 60 lakh people, including tannery workers, are reported to have severe health impacts in Erode. Various technologies have been under research to remove and recover chromium from contaminated ecosystems through different approaches to reduce adverse environmental impacts.

Rhizofiltration involves the use of root exudates and associated microbes to influence metal availability. The changes in the rhizosphere vary with the plant species growing in each soil biome (Krishnasamy *et al*., 2021). The exudation of organic acids depends on the level of metals in the soil Meier *et al.,* (2012). Rhizofiltration is primarily used to remediate groundwater, surface water and wastewater with low contaminant concentrations (Raskin and Ensley,2000) and can be used for the removal of lead, cadmium, copper, nickel, zinc and chromium (Moosavi and Seghatoleslami, 2013). The main advantage of rhizofiltration is that heavy metals accumulate in the roots instead of transferring them to the shoots.

Vetiver grass has been reported to withstand extreme environmental conditions due to its unique morphological, physiological and ecological characteristics, making it suitable for phytoremediation/rhizofiltration studies (Yeboah *et al.,* 2015; Kafil *et al*., 2019; Masinire *et al*., 2021). It has a massive and deep root system, tolerant to extreme climatic variations such as prolonged drought, flooding, submergence, fire, frost, and heat-waves and a wide range of soil acidity, alkalinity, salinity, sodicity, and elevated levels of Al, Mn, and heavy metals. The vetiver has more potential to remove 77% nickel Mudhiriza *et al.* (2015), 606 mg/L Pb and 23,285 mg/L Zn (Aksorn and Chitsomboon 2013). *Vetiveria zizanioides* (Linn) and *Vetiveria nemoralis* have the capability to remove 89% and 86% of chromium in HRT -constructed wetlands Srisatit and Sengsai (2003). Rhizobox studies using Vetiver sp. resulted in the accumulation of nearly 40% of Cr in roots, followed by Ni and Pb. Hence, the present study aimed to evaluate the performance and potential usefulness of vetivers for the removal of Chromium (III) from tannery effluent.

MATERIALS AND METHODS

Study area

Effluent and water source

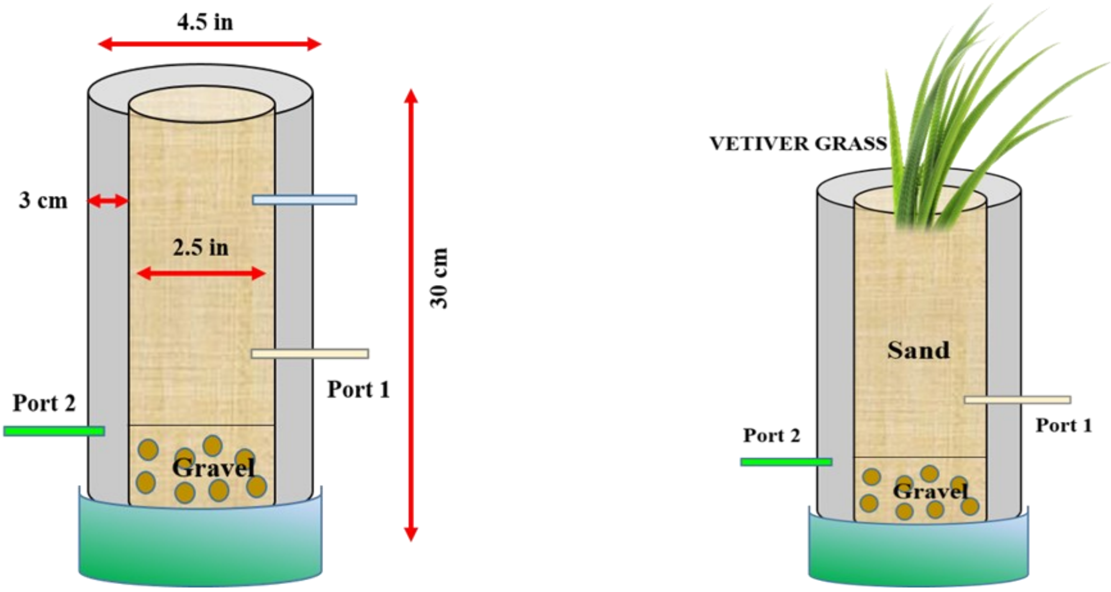
The physico-chemical characteristics of the tannery effluent and water source utilized in the column study were analyzed as per the standard methods. The total dissolved and suspended solid were determined by following the method given by Gupta *et al*. (2000), while pH, electrical conductivity, calcium, magnesium, sodium, chloride, and sulfate were estimated using the protocol given by Jackson (1973). The BOD and COD were determined by the method given by Young *et al*. (1981) and Moore *et al*. (1949) while the carbonate and bicarbonate ions were determined using the procedure given by Piper (1966).

Designing vetiver-based wastewater treatment methods for Cr removal

A pilot-study using rhizobox was performed to assess the efficiency of the removal of Cr (III). The study was carried out in a PVC made rhizoboxes with a height of 30 cm and diameter of 4.5 inches. The inner column has a diameter of 2.5 inches and the distance between the outer and inner column was 3 cm. Two different ports were made at different heights to collect the sample (Fig.1). The boxes were loaded with acid washed sand (3.2 kg/box). Vetiver plants containing one tiller with uniform weight (10.0±2.0 g) were planted in the inner layer of rhizobox designed as rhizosphere region. Chromium solutions of 500 ppm concentration and tannery effluent with a chromium concentration of 379 mg L^{-1} were added to the inner layer of each rhizoboxes to based on the water holding capacity of the sand. The experimental setup was incubated for 15 days. The moisture content of the rhizoboxes were maintained by replacing the evaporation loss with deionised water (Kim *et al*., 2010). The wire mesh (0.2mm) and muslin cloth were placed at the bottom of each layer to avoid contact between the amendments. Nine different treatments with three replicates were studied which included T_1 (Sand + water), T_2 (Sand + Cr (III) @ 500 mg L^{-1}), T_3 (Sand + Tannery Effluent), T_4 (Sand + Vetiver + Water), T_5 (Sand + Vetiver+ Cr(III) @ 500 mg L^{-1}), T_6 (Sand + Vetiver+ Tannery Effluent). The soil solution was collected in the bulk sand zone of rhizobox via port 2 and the aqueous solution zone via port 3 (Fig.1). The Cr concentration in the aqueous solution were analyzed using AAS (Perkin Elmer AA400) at regular time intervals.

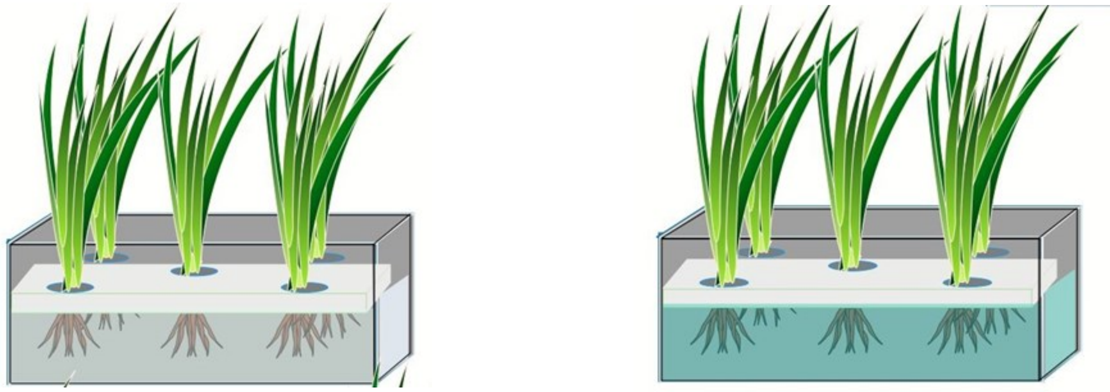
Vetiver floating beds for the removal of Cr in tannery effluent

A floating bed experiment was performed to assess the efficiency of the removal of Cr (III). The study was carried out in 15-litre water tubs filled with an aqueous solution. A chromium solution of 500 ppm was prepared using deionized water. Either 8 liters of Chromium solution or tannery effluent was added to each water tub. Five vetiver plants containing one tiller with uniform weight (10.0±2.0 g) were inserted into the polystyrene sheets and allowed to float freely on the surface of the solution. A schematic illustration of the floating vetiver system is depicted in Fig. 2. The treatment details include T_1 (water), T_2 (Cr III @500 mg L^{-1}), T_3 (Tannery Effluent), T_4 (Water + Vetiver), T_5 (Cr III @500 mg L^{-1} + Vetiver), T_6 (Tannery Effluent + Vetiver). The experimental setup was incubated for 7 days. After seven



Rhizobox setup **Column packed with sand alone**

Fig. 1. *Schematic illustration of vetiver Rhizobox experiment*



Vetiver Plants in water **Vetiver Plants in aqueous chromium Solution**

Fig. 2. *Schematic illustration of floating vetiver experiment*

days from the tubs, water samples were collected and analyzed using AAS (Perkin Elmer AA400) to determine the Chromium concentration.

Data analysis

Statistical analysis of experimental data from the experiment was carried out to determine the effect of treatments and other factors through ANOVA for a completely randomized design (batch experiment) by the statistical software SPSS. The interpretation of data was performed using the critical difference (CD) value calculated at the 0.05 probability level by ANOVA. Analysis of variance was calculated as suggested by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

Characterization of tannery effluent

The characteristics of tannery effluent used for the study are presented in Table1. Apparently, the pH, EC, TDS and TSS values were 4.53, 20.9 dS m^{-1}, 14000 mg L^{-1} and 4200 mg L^{-1}, respectively. The BOD and COD values of the effluent were found to be 36.0 mg L^{-1} and 276 mg L^{-1}. The values of calcium, magnesium, sodium, chloride and sulphate were 4.02 meq L^{-1}, 7.01 meq L^{-1}, 206 meq L^{-1}, 143 meq L^{-1} and 50.40 meq L^{-1}, respectively. The heavy metal total chromium content was 379 mg L^{-1}, which was higher than the permissible limit to discharge into the inland surfaces or river. The tannery effluent is acidic (4.53). This might be due to the utilization of concentrated acids for tanning process. Divya and Vidya (2016) reported the use of salts such as calcium carbonate, sodium chloride and sodium dichromate in the transformation of animal skin to hide. Other effluent characteristics like BOD, COD, TSS, TDS, Na, Cl, SO_4^{2-} were also high which coincides with the evidences of several researchers Dilaconi *et al.* (2002); Louhab *et al.* (2008). Adding this, Cr concentration was found to be high, which might be due fact that only 60-70% of chromium salts utilized in

Table 1. Characterization of tannery effluent (TE)

S.No.	Parameters	Values
1	pH	4.53
2	Electrical conductivity (dS m^{-1})	20.9
3	Biological Oxygen Demand (mg L^{-1})	36.0
4	Chemical Oxygen Demand (mg L^{-1})	276
5	Total Dissolved Solids (mg L^{-1})	14,000
6	Total Suspended Solids (mg L^{-1})	4200
7	Calcium (meq L^{-1})	4.02
8	Magnesium (meq L^{-1})	7.01
9	Sodium (meq L^{-1})	206
10	Chloride (meq L^{-1})	143
11	Sulphate (meq L^{-1})	50.40
12	Total chromium (mg L^{-1})	379

the tanning process retaliate with the skins and the remnant amount of 30-40% left in the exhaust bath to be discharged.

Rhizobox study and Floating bed technology to evaluate the potential of vetiver in Cr removal

The removal of chromium by Vetiver based biofilter is presented in Table 2 (Port 1). After two weeks of incubation, the concentration varied between 370.80 (T_6) and 495.15 mg L^{-1} (T_2), respectively. As the days progressed, a reduction in the concentration was observed. At the end of four and six weeks, the lowest concentration was recorded in T_6 (Sand + Vetiver+ Tannery Effluent (379 mg/L)) with a reduction percent of 0.02 and 2.16 %, respectively. The role of Vetiver based biofilter system in removing chromium from port 2 is presented in Table 3 (Port 2). Generally, it was observed that in all treatments, the removal was significantly higher in port 1 than in port 2. During the second week, the chromium concentration ranged between 373.68 (T_6) and 497.64 mg L^{-1} (T_2), respectively. As like in port 1, the chromium concentration gradually declined as days progressed. At the sixth week, the highest removal percent of 1.40 % was observed in T_6 (Sand + Vetiver+ Tannery Effluent (379 mg/L)). Furthermore, during both 4^{th} and 6^{th} week, the highest concentration was recorded in T_2 (Control (Sand + Cr (III) @ 500 mg L^{-1}) as 492.64 and 489.36 mg L^{-1} in port 1; while in port 2, the concentration was found to be 490.82 and 487.41 mg L^{-1} respectively.

A hydroponic study conducted using Vetiver in the removal of chromium exhibited the superior nature of Vetiver in remediation (Table 4). Initially, the chromium concentration ranged from 377.38 (T_6) to 499.34 mg L^{-1} (T_2), respectively. After one week, a progressive decline in all treatments were observed with the highest reduction of 1.50 % in T_5 (Sand + Vetiver+ Cr (III) @ 500 mg L^{-1}) followed by T_6 (Sand + Vetiver+ Tannery Effluent (379 mg L^{-1}) with a reduction percent of 1.46 %. Nevertheless, no significant difference was observed between T_5 and T_6. The chromium removal during different weeks is presented in Fig.3. In T_5 and T_6, the maximum removal was observed only after six weeks. Vetiver must have taken time to acclimatize to the condition initially, which could be the reason for lesser reduction during the second and fourth week. Vetiver is reported to be an efficacious hydroponic material for remediation (Davamani *et al.,* 2021; Panja *et al.*, 2021). In the tannery wastewater analysis, previous

Table 2. Removal of Cr (III) by biochar based Vetiver biofilter system - Port 1

Treatments	2 Week	4 week	6 week
T1- Control (Sand + water)	0.00	0.00	0.00
T2- Control (Sand + Cr (III) @ 500 mg/L)	495.15	492.64	489.36
T3- Control (Sand + Tannery Effluent (379 mg/L))	377.65	375.69	368.21
T4- Sand + Vetiver + Water	0.00	0.00	0.00
T5- Sand + Vetiver+ Cr(III) @ 500 mg/L	494.16	489.36	476.21
T6- Sand + Vetiver+ Tannery Effluent (379 mg/L)	370.80	366.75	348.45

Table 3. Removal of Cr (III) by biochar based Vetiver biofilter system - Port 2

Treatments	2 Week	4 week	6 week
T1- Control (Sand + water)	0.02	0.02	0.01
T2- Control (Sand + Cr (III) @ 500 mg/L)	497.64	494.37	491.72
T3- Control (Sand + Tannery Effluent (379 mg/L))	378.38	375.72	371.39
T4- Sand + Vetiver + Water	0.02	0.01	0.03
T5- Sand + Vetiver+ Cr(III) @ 500 mg/L	495.72	490.82	487.41
T6- Sand + Vetiver+ Tannery Effluent (379 mg/L)	373.68	370.54	367.95

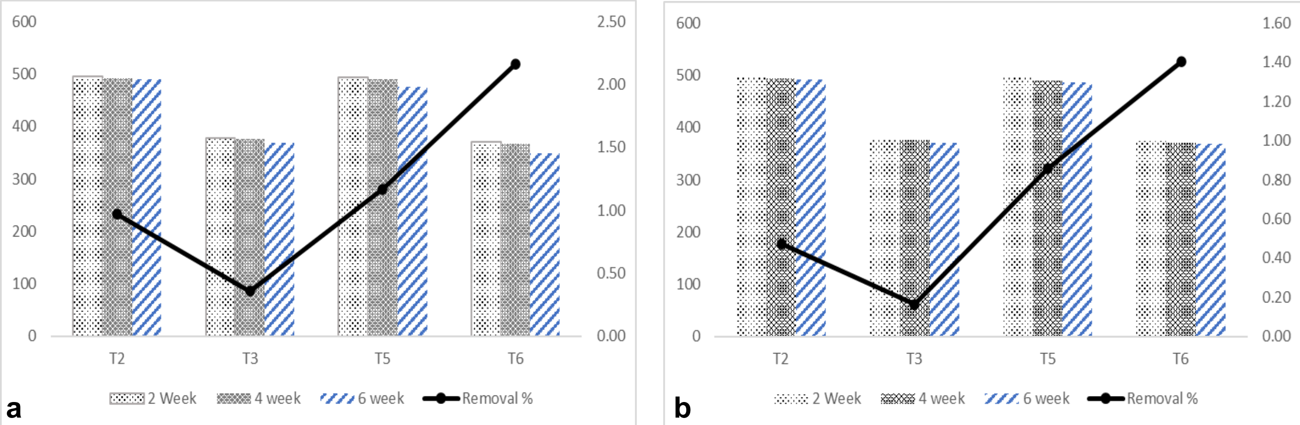


Fig. 3. *Effect of vetiver in chromium removal during different weeks a) Port 1 and b) Port 2*

Table 4. Removal of Cr (III) by vetiver hydroponic system

Treatments	Initial	7th Day
T_1- Control (water)	0.00	0.00
T_2- Control (Cr (III) @500 mg/L)	499.34	497.77
T_3- Control (Tannery Effluent (379 mg/L))	378.58	375.82
T_4- Water + Vetiver	0.00	0.00
T_5- Cr (III) @500 mg/L + Vetiver	497.12	489.62
T_6- Tannery Effluent (379 mg/L) +	377.38	371.84

study findings by Amenu (2015) indicated that total chromium was decreased up to 99.3% for an inlet average total chromium loading rate of 40mg/L. The difference in results between the planted and unplanted beds might be due to the Vetiver grass's ability to absorb metal. The most vital reaction zone for chromium removal is the root zone (rhizosphere), wherein physicochemical and biological processes happen (Stottmeister *et al*., 2003). The removal efficiency of chromium is achieved due to the uptake potential of Vetiver. Various researches and studies were conducted at both lab – and full scale on the removal efficiency of chromium by Vetiver (Aregu *et al*., 2021; Darajeh *et al*., 2019; Jayanthi *et al*., 2020 and Rajendran *et al*., 2019).

Conclusion

Chromium (Cr) poisoning of soil and water was caused by the indiscriminate dumping of wastes from tanning factories. The biofilter employing Vetiver was used with the intention of eliminating Cr (III) from the tannery effluent. Plants that can accumulate metal ions in their tissues are known as hyperaccumulators. The findings suggest that Vetiver may accumulate higher levels of chromium. As a result, the hydroponic Vetiver system may be employed as one of the wastewater treatment solutions for heavy metal-laden industrial effluents. This is a pilot-scale study being conducted for a shorter period. To fully maximise Vetiver's potential, more long-term and large-scale trials and research into the process of heavy metal removal by Vetiver are required.

ACKNOWLEDGEMENTS

The authors wish to express their profound gratitude to Tamil Nadu Agricultural University for conducting experiments.

Conflict of interest
The authors declare that they have no conflict of interest.

REFERENCES

1. Aksorn, E. & Chitsomboon, B. (2013). Bioaccumulation of heavy metal uptake by two different Vetiver grass (Vetiveria zizanioides and Vetiveria nemoralis) species. *African Journal of Agricultural Research*, *8*(24), 3166-3171. http://doi.org/ 10.5897/AJAR12.2066
2. Amenu D. (2015). Evaluation of selected wetland plants for the removal efficiency of pollutants from wastewater. *Int J Adv Multidiscip Res., 2,* 63-66.
3. Aregu, M. B., Soboksa, N. E. & Kanno, G. G. (2021). High Strength Wastewater Reclamation Capacity of Vetiver Grass in Tropics: The Case of Ethiopia. *Environmental Health Insights*, 15, 11786302211060162. http://doi.org/ 10.1177/11786302211060162
4. Darajeh, N., Truong, P., Rezania, S., Alizadeh, H. & Leung, D. W. M. (2019). Effectiveness of vetiver grass versus other plants for phytoremediation of contaminated water.
5. Davamani V., Parameshwari, C. I., Arulmani, S., John, J. E. & Poornima, R. (2021). Hydroponic phytoremediation of paperboard mill wastewater by using vetiver (Chrysopogon zizanioides). *Journal of Environmental Chemical Engineering*, *9*(4), 105528. http://doi.org/ 10.1016/j.jece.2021.105528
6. Dilaconi, C., Lopez, A., Ramadori, R., Di Pinto, A. & Passino, R. (2002). Combined chemical and biological degradation of tannery wastewater by a periodic submerged filter. *Water Res.*, 36(9), 2205-2214. http://doi.org/ 10.1016/ s0043-1354(01)00445-6.

7. Divya, K. & Vidya, R. (2016). A Review on Tannery Pollution in Vellore District, Tamil Nadu, India. *Research Journal Of Pharmaceutical Biological And Chemical Sciences,* 7(3), 1380-1384.
8. Genawi, N. M., Ibrahim, M. H., El-Naas, M. H. & Alshaik, A. E. (2020). Chromium removal from tannery wastewater by electrocoagulation: optimization and sludge characterization. *Water*, 12(5), 1374. https://doi.org/10.3390/w12051374
9. Jayanthi, N., Subramanian, S. & Hema, J. (2020, October). A hydroponic vetiver system to remove cadmium and chromium from contaminated water. In: 7 th International Conference on Vetiver, Chiang Mai, Thailand (pp. 1-12).
10. Kafil, M., Boroomand Nasab, S., Moazed, H. & Bhatnagar, A. (2019). Phytoremediation potential of vetiver grass irrigated with wastewater for treatment of metal contaminated soil. *International Journal of Phytoremediation*, 21(2), 92-100. http://doi.org/ 10.1080/15226514.201 8.147 4443
11. Kim, K.-R., Owens, G. & Kwon, S.-L. (2010). Influence of Indian mustard (Brassica juncea) on rhizosphere soil solution chemistry in long-term contaminated soils: a rhizobox study. *Journal of Environmental Sciences*, 22(1), 98-105. https://doi.org/10.1016/S1001-0742(09)60080-2
12. Krishnasamy, S., Lakshmanan, R. & Ravichandran, M. (2021). Phytoremediatiation of Metal and Metalloid Pollutants from Farmland: An In-Situ Soil Conservation. In *Biodegradation*. Intech Open. http://doi.org/ 10.5772/intechopen.98659
13. Louhab, K., Sahmoune, N., Addad, J. & Barr, S. (2008). Quality Improvement of Recycled Chromium in the Tanning Operation by Fermentation Waste. Paper presented at the 12th International Water Technology Conference, IWTC12.
14. Lovell, S. C., Davis, I. W., Arendall Iii, W. B., De Bakker, P. I., Word, J. M., Prisant, M. G., Richardson, J. S. & Richardson, D. C. (2003). Structure validation by Cα geometry: ϕ, ψ and Cβ deviation. *Proteins: Structure, Function, and Bioinformatics*, 50(3), 437-450. https://doi.org/10.1002/prot.10286
15. Masinire, F., Adenuga, D. O., Tichapondwa, S. M., & Chirwa, E. M. (2021). Phytoremediation of Cr (VI) in wastewater using the vetiver grass (Chrysopogon zizanioides). *Minerals Engineering,* 172, 107141.
16. Mathew, M., Sebastian, M. & Cherian, S. M. J. P. T. (2016). Effectiveness of vetiver system for the treatment of wastewater from an institutional kitchen. 24:203-209. http://doi.org/ 10.1016/j.protcy.2016.05.028
17. Meier, S., Alvear, M., Borie, F., Aguilera, P., Ginocchio, R. & Cornejo, P. (2012). Influence of copper on root exudate patterns in some metallophytes and agricultural plants. *Ecotoxicology and Environmental Safety*, 75, 8-15.
18. Mccoy, W. F. & Olson, B. H. (1986). Relationship among turbidity, particle counts and bacteriological quality within water distribution lines. *Water Research*, 20(8), 1023-1029. https://doi.org/10.1016/0043-1354(86)90045
19. XMeier, S., Borie, F., Bolan, N. & Cornejo, P. (2012). Phytoremediation of metal-polluted soils by arbuscular mycorrhizal fungi. *Critical Reviews in Environmental Science and Technology*, 42(7), 741-775. http://doi.org/ 10.1080/10643389.2010.528518
20. Mohan, D. & Pittman Jr, C. U. (2006). Activated carbons and low cost adsorbents for remediation of tri-and hexavalent chromium from water. *Journal of Hazardous Materials,* 137(2), 762-811. http://doi.org/ 10.1016/j.jhazmat.2006.06.060.
21. Moosavi, S. G. & Seghatoleslami, M. J. (2013). Phytoremediation: a review. *Advance in Agriculture and Biology,* 1 (1), 5-11.
22. Mudhiriza, T., Mapanda, F., Mvumi, B. & Wuta, M. (2015). Removal of nutrient and heavy metal loads from sewage effluent using vetiver grass, *Chrysopogon zizanioides* (L.) Roberty. *Water SA*, 41(4), 457-493. http://doi.org/10.4314/wsa.v41i4.04
23. Panja, S., Sarkar, D., Zhang, Z. & Datta, R. (2021). Removal of antibiotics and nutrients by vetiver grass (*Chrysopogon zizanioides*) from a plug flow reactor based constructed wetland model. *Toxics,* 9(4), 84. http://doi.org/10.3390/toxics9040084
24. Panse, V. G. & Sukhatme, P. V. (1967). Statistical methods of agricultural workers. 2nd Endorsement. ICAR Publication, New Delhi, India, 381.
25. Piper, C. S. (1966). Soil and plant analysis: Hans Publishers; Bombay.
26. Rajendran, M., An, W. H., Li, W. C., Perumal, V., Wu, C., Sahi, S. V. & Sarkar, S. K. (2019). Chromium detoxification mechanism induced growth and antioxidant responses in vetiver (*Chrysopogon zizanioides* (L.) Roberty). *Journal of Central South University*, 26(2), 489-500.
27. Raskin, I. & Ensley, B. D. (2000). Phytoremediation of toxic metals: John Wiley and Sons.
28. Srisatit, T. & Sengsai, W. (2003). Chromium removal efficiency by *Vetiveria zizanioides* and *Vetiveria nemoralis* in constructed wetlands for tannery post-treatment wastewater. Paper presented at the Proceedings of the Third International Conference on Vetiver and Exhibition, Guangzhou, China.
29. Stottmeister, U., Wießner, A., Kuschk, P., Kappelmeyer, U., Kästner, M., Bederski, O. .... & Moormann, H. (2003). Effects of plants and microorganisms in constructed wetlands for wastewater treatment. *Biotechnology Advances*, 22(1-2), 93-117.
30. Sundaramoorthy, P., Chidambaram, A., Ganesh, K. S., Unnikannan, P. & Baskaran, L. (2010). Chromium stress in paddy:(i) nutrient status of paddy under chromium stress;(ii) phytoremediation of chromium by aquatic and terrestrial weeds. *Comptes Rendus Biologies,* 333(8), 597-607. http://doi.org/ 10.1016/j.crvi.2010.03.002
31. Yeboah, S. A., Allotey, A. N. M. & Biney, E. (2015). Purification of industrial wastewater with vetiver grasses (*Vetiveria zizanioides*): the case of food and beverages wastewater in Ghana. *Asian Journal of Basic and Applied Sciences,* 2(2).1 - 40.