

Assessment of agro-industrial and bacterial surfactant based bio-adsorbent columns for heavy metal removal from industrial wastewater

SUMMARY OF Thesis

SUBMITTED TO
BABASAHEB BHIMRAO AMBEDKAR UNIVERSITY
LUCKNOW

BABASAHEB
BHIMRAO
AMBEDKAR
UNIVERSITY



प्रज्ञा शील करुणा
ESTABLISHED 1996

FOR THE DEGREE OF

Doctor of Philosophy IN ENVIRONMENTAL MICROBIOLOGY

Submitted By

Swati Rastogi

(Enrolment no. 1380/16)

Under the Supervision of

Dr. Rajesh Kumar

Professor

DEPARTMENT OF ENVIRONMENTAL MICROBIOLOGY
SCHOOL FOR ENVIRONMENTAL SCIENCES
BABASAHEB BHIMRAO AMBEDKAR UNIVERSITY
(A CENTRAL UNIVERSITY)
VIDYA VIHAR, RAEBARELI ROAD, LUCKNOW-226 025
UTTAR PRADESH, INDIA

2021

Some of the common industries that generate heavy metal containing effluent include tanneries, mining, electroplating, fertilizer, smelting plants, etc. On account of various industrial operations, copious measures of wastewater are produced and are being dismissed nonchalantly into the water bodies affecting its environment (Agarwal et al., 2020; Ahmed et al., 2021). Such wastewaters contain toxic, carcinogenic, indelible heavy metal ions therefore, it requires their efficient treatment before dumping into the ecosystem (Gupta et al., 2020). Lead, Cadmium, Mercury, Arsenic, Chromium, Copper, etc. are most common heavy metal ions found in such industrial effluents that has high binding affinity for biological macromolecules composed of oxygen, nitrogen, etc. thereby, exerts interference towards the normal functioning of different organ systems by exhibiting their harmful effects such as diseases like Itai-Itai in Japan due to cadmium toxicity, etc. (Calabrò et al., 2021; Saini et al., 2020).

Numerous conventional treatment techniques such as chemical precipitation, flotation, coagulation, etc., are available for heavy metal remediation but all are associated with certain advantages and disadvantages. Major drawback includes high operational costs and generation of secondary toxic by-products (Vo et al., 2020). However, adsorption seems to be a promising, an economically feasible, environmental friendly process that involves flexible process factors (Sheth et al., 2021). Some of the conventional materials such as zeolites, commercial activated carbon are widely explored adsorbents but has limitations like difficult regeneration, and are expensive (Bagchi & Behera, 2020; Qasem et al., 2021; Wadhawan et al., 2020). Therefore, their limitations has shifted the direction in search of an economical alternative that poses less or no threat to the environment as well. The extensive usage of agro-industrial based bio-adsorbents have given rise to greener non-conventional remediation technology that are low cost, have numerous binding sites containing rich functional groups, and give good bioadsorption capacities comparable to the conventional adsorbents (Chai et al., 2021; Sabir et al., 2021; Vo et al., 2020). Further, their (bio-adsorbents) modification with suitable agents enhances their performance ability for a particular pollutant in study (Gupta et al., 2020; Surgutskaia et al., 2020).

Keeping in view of background of this problem, the present study was designed to assess the potential of low cost and efficient bioadsorption system for the removal of Pb^{2+} and Cd^{2+} from aqueous solutions and real effluents through batch and column based experiments. To fulfil the objectives of the present study, economical agro/biowastes i.e., rice husk powder (RHP), *Eucalyptus* saw dust powder (SDP), orange peel powder (OPP), banana peel powder (BPP), activated carbon from orange and banana fruit peel wastes (AcOPP and AcBPP) were prepared. The activated banana peel powder performed (AcBPP) well in the batch adsorption process and hence, it was fabricated with bacterial metabolite i.e., surfactin to be used in the column adsorption process for heavy metal removal. To prepare biosurfactant modified activated banana peel powder (BSBP); bacterial isolates from hydrocarbon contaminated sites were screened for their biosurfactant production. The potential bacterial strains were further subjected to the mass production of biosurfactant and extraction. The evaluation of the prepared bio-adsorbents were done in terms of their characterization, effect of process conditions, regeneration and desorption percentages by utilizing Pb^{2+} and Cd^{2+} as primary pollutants in aqueous solutions and in a multi metal wastewater system.

Salient findings of the present study entitled “Assessment of agro-industrial and bacterial surfactant based bioadsorbent column for heavy metal removal from industrial wastewater” are summarised below:

1. All the bio-adsorbents that were used in the study i.e., activated orange peel powder (AcOPP), activated banana peel powder (AcBPP) and biosurfactant modified activated banana peel powder (BSBP) illustrated the presence of microporous particles in their asymmetric structures and pores which contributed towards the affinity for high binding of the pollutants (heavy metals such as Pb^{2+} and Cd^{2+}).
2. Prepared bio-adsorbent surfaces represented diverse functional moieties such as anionic oxygen containing functional groups as carboxylic, phenolics, hydroxyls and amines that served as high binding sites for positively charged heavy metal ions.

3. BET (Brunauer-Emmett-Teller) analysis revealed that orange peel powder (OPP) possessed highest while rice husk powder (RHP) had lowest surface area, respectively.
4. The bioadsorption process was affected by change in the experimental conditions such as pH, contact time, bio-adsorbent dose, and initial metal ion concentration. Bio-adsorbents were best regenerated using 0.1N HNO₃ and were reusable up to 3 times with little loss in the efficiency.
5. The Langmuir adsorption isotherm model showed best fit as regression coefficient i.e., R² value ranging between 0.97 to 0.99 than the other two Freundlich and Temkin model for the removal of Pb²⁺ and Cd²⁺ ions from aqueous solutions having maximum bioadsorption capacities (q_m) of 96.15 and 93.46 mg/g respectively with activated orange peel powder (AcOPP) while 111.11 and 54.05 mg/g, respectively using activated banana peel powder (AcBPP).
6. The Langmuir isotherm model behaviour depicted performance of activated orange peel powder (AcOPP) to be better than activated banana peel powder (AcBPP) in terms of regression coefficient value in comparison to the experimental results where AcBPP performed better than AcOPP for Pb²⁺ and Cd²⁺ removal. However, according to the overall batch adsorption results obtained, AcBPP presented better bioadsorption potential than AcOPP in the order Pb²⁺ > Cd²⁺.
7. The pseudo-second-order kinetic model was found to be in agreement with the bioadsorption process for both the bio-adsorbents with bioadsorption capacity values of 85.47 mg/g at 50 ppm Pb²⁺, 119.05 mg/g at 100 ppm Pb²⁺, 96.15 mg/g at 50 ppm Cd²⁺ and 103.09 mg/g at 100 ppm Cd²⁺ using AcOPP.
8. The AcBPP depicted adsorption 62.5 mg/g at 50 ppm Pb²⁺, 100 mg/g at 100 ppm Pb²⁺, 60.61 mg/g at 50 ppm Cd²⁺ and 91.74 mg/g at 100 ppm Cd²⁺ which was quite similar to the experimental results indicating the role of physico- and chemisorption processes.
9. The biosurfactant producing bacterial strains were reported to yield ~3.7 g/L surfactin biosurfactant and ~2.4 g/L rhamnolipid biosurfactant using raw

orange peel extract wastes as carbon substrates with *Bacillus haynesii* E1 and *Pseudomonas aeruginosa* F5 respectively.

10. On account of high yield of surfactin from *Bacillus haynesii* E1, it was utilised to modify the activated banana peel powder (AcBPP) to make biosurfactant modified activated banana peel powder (BSBP) for column mode study.
11. Fixed-bed column experiments explained better removal of Pb^{2+} and Cd^{2+} ions at parameters such as higher feed concentrations, higher feed flow rate, and higher bio-adsorbent bed height giving uptake (bioadsorption) capacity of 130.65 and 130.05 mg/g for Pb^{2+} and Cd^{2+} removal from aqueous solutions.
12. The removal of metal ions from an electroplating effluent depicted bioadsorption percentage of 92.19 and 92.24 % for Pb^{2+} and Cd^{2+} , respectively.

7.1 Conclusion:

The continuous column mode study showed better results than the batch process. The modification of activated banana peel powder with surfactin biosurfactant presented an economical aspect of bio-adsorbent preparation having good heavy metal removal efficiency giving it an equal weightage among its other representatives. This recommends its application at industrial scale as biofilter material for the treatment of effluents and their discharge into natural bodies of water.

7.2 Recommendations

The prepared bio-adsorbents showed good metal removal efficiencies and could be regenerated multiple times without significant loss in their efficiency. These could also be applied in continuous mode for industrial effluents/wastewater. Based on the experimental investigation, following recommendations are provided for the future study:

1. A pilot-scale bio-adsorbent column containing prepared bio-adsorbent could be utilised for other industrial effluents.
2. Fabrication of the bio-adsorbent with surfactin biosurfactant showed promising results in metal removal, the tailoring of the bio-adsorbent with

other biosurfactant molecules of other class or in combination could be explored in the removal of metals from concomitant (organic/inorganic) systems.

3. A desirable modification (and/or statistical optimisation) of the methodology employed in the preparation of the bio-adsorbent can be explored to achieve higher metal removal efficiencies.
4. A bioreactor based study could be conducted to remove organic pollutants and nutrients such as organic carbon that are being added on account of dissolving bio-adsorbent in aqueous solutions.

These recommendations will be helpful for future research for exploring more alternates with different types of wastewater and their subsequent application in Industrial wastewater treatment having metals other than lead and cadmium.