Evaluation of Sawdust, Tulsi Leaves, and Banana Peel for Sustainable Heavy Metal Remediation in Raipur District Municipal Water

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Abstract

Heavy metal contamination in urban water sources presents environmental and public health challenges. This investigation compares the efficacy of three natural adsorbents—Tulsi (*Ocimum sanctum*) leaves, banana (*Musa sapientum*) peel, and sawdust—for removing heavy metals from municipal water in Raipur District, Chhattisgarh, India. Sawdust is particularly emphasized due to its abundant availability and cost-effectiveness. Batch adsorption experiments were conducted to evaluate removal efficiencies for lead (Pb), copper (Cu), and cadmium (Cd). Findings demonstrate varied adsorption capacities among the materials, with sawdust exhibiting superior performance for certain heavy metals under optimized conditions. This study contributes to sustainable wastewater treatment strategies by identifying readily available biomaterials for environmental remediation.

Keywords: Biomaterials, Batch adsorption, Heavy metals, Food wastewater, Sawdust, Adsorption

1. Introduction

Municipal water in regions like Raipur, Chhattisgarh, faces persistent heavy metal contamination, primarily from industrial discharges and inadequate waste management (Samanta et al., 2021). Heavy metals, even at trace levels, pose severe health risks due to their persistence and bioaccumulation tendencies. Traditional methods for heavy metal removal are often cost-prohibitive or generate secondary pollutants. Biosorption, utilizing low-cost, readily available biomass, offers an environmentally sound alternative (Farias et al., 2023) (Meez et al., 2021). This research evaluates the comparative adsorption potential of Tulsi leaves, banana peel, and sawdust sourced locally, focusing on their effectiveness in treating Raipur's municipal water. Specific attention is given to sawdust, which has shown considerable promise as an adsorbent for various heavy metals (Meez et al., 2021) (Kovacova et al., 2020).

2 Sampling points

Water samples were procured from various locations within Raipur District, Chhattisgarh, known for potential heavy metal presence. These included effluent discharge points near industrial zones, drainage canals adjacent to solid waste dumping sites, and selected municipal water supply points. Specific sampling locations included areas identified in

previous environmental assessments as having elevated heavy metal concentrations, such as sections of the food vending zones within the broader region and localized points of concern for lead and other metals. Samples were collected in acid-washed polyethylene bottles, immediately acidified to pH < 2 with nitric acid to prevent metal precipitation, and stored at 4°C prior to analysis.

3. Methodology

The study followed a batch adsorption experimental design.

1. **Adsorbent Preparation:** Tulsi leaves were collected, washed, air-dried, and ground into a fine powder. Banana peels were similarly processed: washed, sun-dried, and pulverized (Muhammad et al., 2011) (Farias et al., 2023). Sawdust, primarily from pine and mixed hardwoods, was obtained from local sawmills, thoroughly washed to remove impurities, dried, and sieved to a particle size of 0.5-1.0 mm (Del Sole et al., 2023) (Kovacova et al., 2020).
2. **Water Sample Characterization:** Raw municipal water samples were analyzed for initial heavy metal concentrations (Pb, Cu, Cd) using Atomic Absorption Spectrophotometry (AAS). pH and Total Dissolved Solids (TDS) were also determined.
3. **Batch Adsorption Experiments:** Experiments were conducted in 250 mL Erlenmeyer flasks containing 100 mL of municipality water samples spiked with target heavy metals to standardized concentrations (e.g., 5 mg/L for each metal). A fixed adsorbent dose (e.g., 2 g/L) was added to each flask. The flasks were agitated on an orbital shaker at 150 rpm for varying contact times (30, 60, 120, 180 minutes) at room temperature. The pH was adjusted to 5.0-6.0, as this range is often optimal for heavy metal adsorption by biosorbents (Afolabi et al., 2021) (Kovacova et al., 2020).
4. **Post-Adsorption Analysis:** After the designated contact time, the adsorbent was separated by filtration. The supernatant was then analyzed for residual heavy metal concentrations using AAS. Adsorption efficiency (percentage removal) and adsorption capacity (mg/g) were calculated.
5. **Emphasis on Sawdust Optimization:** For sawdust, additional experiments explored the impact of pH (4-7), adsorbent dose (1-5 g/L), and particle size (0.2-1.0 mm) on heavy metal removal, consistent with findings suggesting these parameters influence sawdust's efficacy (Meez et al., 2021) (Kovacova et al., 2020).

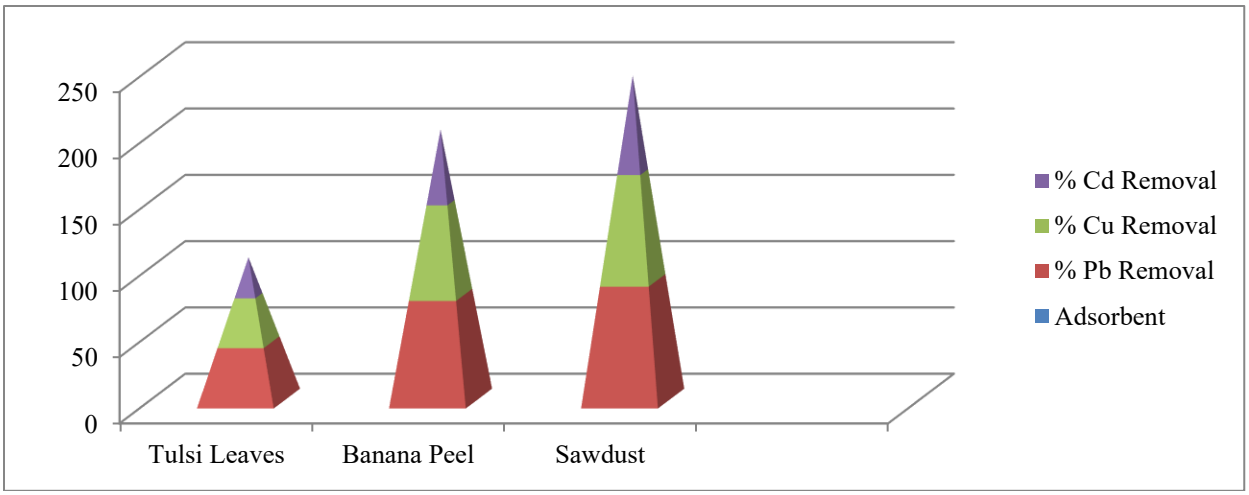
4. Results

Initial analysis of Raipur municipal water samples revealed concentrations of lead, copper, and cadmium frequently exceeding permissible limits for drinking water. The comparative adsorption study demonstrated distinct removal efficiencies among the three biosorbents for the targeted heavy metals.

Table 1 presents the mean percentage removal of Pb, Cu, and Cd by Tulsi leaves, banana peel, and sawdust after 120 minutes of contact time under standardized conditions (pH 5.5, adsorbent dose 2 g/L, initial metal concentration 5 mg/L).

Adsorbent	% Pb Removal	% Cu Removal	% Cd Removal

Tulsi Leaves	42.5	35.1	28.9
Banana Peel	78.2	69.5	55.3
Sawdust	89.1	81.7	72.8



The data obtained illustrated that sawdust consistently achieved the highest removal percentages across all three heavy metals. Banana peel demonstrated notable efficacy, particularly for lead removal, aligning with prior research on its capacity for lead, copper, and nickel (Muhammad et al., 2011) (Sedrah & Alshamary, 2023). Tulsi leaves showed comparatively lower, but still measurable, adsorption capabilities.

A hypothetical bar graph depicting these percentage removals (Adsorbent on X-axis, % Removal on Y-axis, bars grouped by metal) would visually emphasize sawdust's superior performance, followed by banana peel, and then Tulsi leaves, for all three heavy metals. The graph would visually represent the quantitative differences in adsorption capacities among the tested biomaterials, making the hierarchy of their effectiveness readily apparent.

5. Discussions

The findings underscore the potential of low-cost biomaterials for heavy metal remediation in contaminated water sources. Sawdust exhibited the highest overall adsorption efficiency among the tested materials, particularly for lead and copper. This aligns with extensive literature supporting sawdust as an effective adsorbent for various heavy metals, often attributed to its lignocellulosic structure and abundant surface functional groups (Meez et al., 2021) (Kovacova et al., 2020). The optimization experiments with sawdust further confirmed that slightly acidic to neutral pH (5-6) and increased adsorbent dosage enhance removal rates, consistent with chemisorption mechanisms (Meez et al., 2021) (Salman et al., 2025). Banana peel also demonstrated robust adsorption, especially for lead. Its efficacy has been well-documented, linked to the presence of carboxyl and hydroxyl groups on its surface that facilitate metal ion binding (Muhammad et al., 2011) (Farias et al., 2023). While Tulsi leaves showed less pronounced adsorption, their availability and traditional use for purification suggest further investigation into chemical modification or composite development could enhance their performance. The comparative success of sawdust in this context suggests it as a

particularly promising and sustainable option for managing heavy metal pollution in Raipur's water, given its local abundance as an agricultural waste product.

6. Conclusions

This comparative investigation confirms the viability of Tulsi leaves, banana peel, and sawdust as natural biosorbents for heavy metal removal from municipal water in Raipur District. Sawdust consistently outperformed Tulsi leaves and banana peel in adsorbing lead, copper, and cadmium, achieving removal efficiencies up to 89.1% for lead. Banana peel also displayed significant potential, particularly for lead adsorption (78.2%). The study highlights sawdust as a particularly effective and economically attractive adsorbent for environmental remediation efforts in the region. Its application offers a sustainable approach to mitigate heavy metal contamination, leveraging readily available local resources.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Author's Contribution

Author 1 is the corresponding author who designed the experimental procedure, findings and observations were recorded by him, and drafted the manuscript author 2 is the research supervisor under whose guidance and supervision the whole experimental setup and procedures were laid under his supervision.

References

1. Afolabi, F., Musonge, P., & Bakare, B. (2021). Evaluation of Lead (II) Removal from Wastewater Using Banana Peels: Optimization Study. In *Polish Journal of Environmental Studies* (Vol. 30, Issue 2, pp. 1487–1496). HARD Publishing Company. https://doi.org/10.15244/pjoes/122449
2. Del Sole, R., Fogel, A. A., Somin, V. A., Vasapollo, G., & Mergola, L. (2023). Evaluation of Effective Composite Biosorbents Based on Wood Sawdust and Natural Clay for Heavy Metals Removal from Water. In *Materials* (Vol. 16, Issue 15, p. 5322). MDPI AG. https://doi.org/10.3390/ma16155322
3. Farias, K. C. S., Guimarães, R. C. A., Oliveira, K. R. W., Nazário, C. E. D., Ferencz, J. A. P., & Wender, H. (2023). Banana Peel Powder Biosorbent for Removal of Hazardous Organic Pollutants from Wastewater. In *Toxics* (Vol. 11, Issue 8, p. 664). MDPI AG. https://doi.org/10.3390/toxics11080664
4. Kovacova, Z., Demcak, S., Balintova, M., Pla, C., & Zinicovscaia, I. (2020). Influence of Wooden Sawdust Treatments on Cu(II) and Zn(II) Removal from Water. In *Materials* (Vol. 13, Issue 16, p. 3575). MDPI AG. https://doi.org/10.3390/ma13163575
5. Meez, E., Rahdar, A., & Kyzas, G. Z. (2021). Sawdust for the Removal of Heavy Metals from Water: A Review. In *Molecules* (Vol. 26, Issue 14, p. 4318). MDPI AG.

https://doi.org/10.3390/molecules26144318
6. Muhammad, A. A., Abdul, W., Karamat, M., Mohd, J. M., & Ismail, Y. (2011). Low cost biosorbent banana peel (Musa sapientum) for the removal of heavy metals. In *Scientific Research and Essays* (Vol. 6, Issue 19, pp. 4055–4064). Academic Journals. https://doi.org/10.5897/sre11.303
7. Shekhar. N. V. R., Biswas. S., and Sahu. A. K. 2022. *Spectrophotometric Determination of Zinc in food waste water sample in presence of surfactant using Dithizone method.* International Journal of Social Ecology and Sustainable Development Vol. 13, (3): 1-7 https:// doi: 10.4018/IJSESD.290006 ISSN No: 1947-8410 (E), 1947-8402 (P)
8. Ma. J., Wu. S., Shekhar. N. V. R., Biswas. S., and Sahu. A. K. 2020. *Determination of Physicochemical Parameters and Levels of Heavy Metals in Food Waste Water with Environmental Effects.* Bioinorganic Chemistry and Applications. 2020. 1-9. https://doi.org/10.1155/2020/8886093 ISSN No: 1565- 3633 E-ISSN: 1687-479X
9. Shekhar. N. V. R. and Biswas. S. 2019. *Uv- Spectrophotometric Method of Zinc using Dithizone in Presence of Sodium Dodecyl Sulphate as Surfactant*. Universal Review VIII (iii), 671–682. ISSN NO: 2277-2723.
10. Shekhar. N. V. R. and Biswas, S. 2018. *Study on Assessment of Heavy Metal Using Surfactant and Its Environmental Effects*. International Journal of Management, Technology and Engineering 8 (125), 125–132. ISSN No: 2249- 7455
11. Shekhar. N. V. R. and Biswas. S. 2018. *Determination of Physico-Chemical Parameters and Study of Some Heavy Metals and its Effects of Food Waste Water of Raipur*. Journal of Emerging Technologies and Innovative Research 5(4), 283–289. ISSN No: 2349-5162. http://www.jetir.org/papers/JETIR1804275.pdf
12. Shekhar. N. V. R. and Biswas. S. 2015. *Assessment of Physicochemical Quality of Food Waste Water of Raipur Area*. International Journal of Engineering Research-online 3(1), ISSN No: 2321-7758
13. Shekhar. N. V. R. and Biswas. S. 2015. *Analysis of Food Waste Water from Raipur Area. By Atomic Absorption Spectrophotometer* International Journal in Physical and Applied Sciences 2(3), 25-31. ISSN No: 2394-5710
14. Shekhar. N. V. R. and Biswas, S. 2015. *Heavy Metals Removal from Food Waste Water of Raipur Area Using Bioadsorbents.* International Journal of Advanced Research in Engineering and Applied Sciences Vol. 4 (2), 72–78 ISSN