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Green Adsorbents for Heavy Metal Removal: A Study on Zinc Ion Uptake by *Tinospora cordifolia* Biocarbon

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Abstract

Heavy metal pollution in water bodies poses a significant threat to human health. Exposure to heavy metals like lead, mercury, cadmium, and arsenic can lead to severe health issues. To address this pressing environmental concern, this study investigates the potential of Tinospora cordifolia as a low-cost biosorbent for heavy metal removal. By examining the influence of factors like pH (5.0), adsorbent dose (3.0 g), and contact time (150 minutes), the study aims to optimize the biosorption process. The findings demonstrate the effectiveness of Tinospora cordifolia in removing heavy metals from wastewater, highlighting its potential as a sustainable and environmentally friendly solution for water purification. Furthermore, activated carbon derived from Tinospora cordifolia was found to be highly efficient in removing Zn(II) ions from synthetic wastewater. This biosorption technique is not only effective but also straightforward and rapid, offering a powerful approach to mitigate heavy metal contamination. The promising results of this study support the potential for further application of Tinospora cordifolia-based activated carbon in water purification efforts, especially in the treatment of zinc and potentially other heavy metals. The study targeted zinc (Zn II) ions in synthetic wastewater. The results showed that activated carbon derived from Tinospora cordifolia was highly effective in removing zinc, especially under optimal conditions.

Major Findings: *Tinospora cordifolia proved to be an effective and low-cost biosorbent for removing heavy metals from wastewater. Optimal conditions for maximum metal removal were identified, including a pH of 5.0, an adsorbent dose of 3.0 g, and a contact time of 150 minutes. Activated carbon derived from Tinospora cordifolia exhibited high efficiency in removing Zn(II) ions from synthetic wastewater.*

Keywords: *Adsorption, Heavy metals, Pollution, Tinospora cordifolia, Zinc*

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1.0 Introduction

Heavy metals pose a serious environmental threat, representing some of the most persistent pollutants in ecosystems. To protect both environmental and public health, it is essential to develop processes for removing these harmful substances from wastewater. Among the critical heavy metals, zinc serves as a trace element necessary for human health, playing a vital role in numerous physiological processes and regulating various biochemical pathways. Atangana, Ernestine[1] synthesized and characterized Chitosan cross-linked formaldehyde for effective removal of Zn(II) and Pb(II) ions from aqueous solutions, Zinc's prevalence in the environment contributes substantially to heavy metal pollution, underscoring the urgent need for effective removal technologies

However, excessive exposure to zinc can result in significant health problems, including stomach cramps, skin irritations, nausea, vomiting, anaemia, muscle coordination issues, and electrolyte imbalances[2,3].

Several techniques are employed to eliminate heavy metal ions from water systems, including chemical precipitation, ion exchange, adsorption, membrane filtration, and electrochemical treatments[4]. Among these, adsorption stands out as a versatile, eco-friendly, and cost-effective method[5]. This process involves the accumulation of liquid or gas molecules on the surface of a solid or liquid (the adsorbent), forming a thin atomic or molecular layer[6]. Biosorption is a process that utilizes biological materials, like plants, algae, or bacteria, to remove heavy metals from water. *Tinospora cordifolia* is a promising biosorbent due to its abundance, low cost, and the presence of functional groups on its surface that can bind to heavy metal ions. A particular type of adsorption, biosorption, leverages biological materials to bind heavy metals from wastewater via physical and chemical interactions[7].

One promising biosorbent for this purpose is *Tinospora cordifolia*, a climbing, deciduous shrub thriving in the tropical regions of Bangladesh, Myanmar, Sri Lanka, China, and India. Belonging to the Menispermaceae family, this plant contains a rich profile of biologically active compounds, including polysaccharides, alkaloids, glycosides, steroids, sesquiterpenoids, aliphatic molecules, essential oils, and fatty acid mixtures[8]. *Tinospora cordifolia* is renowned for its diverse pharmacological properties, such as anti-diabetic, anti-stress, antimicrobial, anticancer, anti-inflammatory, and antioxidant effects[9-13]. Heavy metals like lead, mercury, cadmium, and arsenic in water can cause severe health issues, including neurological disorders, organ damage, and cancer, posing a significant threat to public health. The aim of this research is to investigate the potential of *Tinospora cordifolia* as a low-cost and eco-friendly biosorbent for the removal of heavy metals, particularly zinc (Zn(II) ions), from wastewater. The primary objective of this study was to explore the potential of *Tinospora cordifolia* as a low-cost and eco-friendly biosorbent for heavy metal removal. Specifically, the research aimed to evaluate the effectiveness of *Tinospora cordifolia* in removing heavy metals from wastewater, optimize the biosorption process by studying the influence of factors like pH, adsorbent dose, and contact time, assess the potential of activated carbon derived from *Tinospora cordifolia* as a highly efficient adsorbent for zinc removal, and ultimately contribute to the development of sustainable and environmentally friendly solutions for water purification.

In summary, tackling the problem of heavy metal pollution requires innovative and sustainable approaches. The potential of biosorption, especially through plants like *Tinospora cordifolia*, offers a promising path forward in eco-friendly heavy metal remediation. *Tinospora cordifolia* was chosen because it is widely available, inexpensive, and known for its medicinal properties. Its high adsorption capacity makes it suitable for removing heavy metals from water. The plant part as shown in Figure 1.



Figure 1. Plant part of *Tinospora cordifolia.*

2.0 Materials and Methods

2.1 Preparation of Synthetic Wastewater

1000-ppm Zn(II) stock solution was prepared by dissolving AR grade $ZnCl_2$ in deionised water. Standard solution of 100 ppm Zn (II) prepared from the stock solution[14].

UV-Visible spectrometer was used to measure absorbance of solution before and after adsorption[15-17].

Percentage of metal ion removal is calculated by:

$$\% \text{ removal of metal ion} = Co\text{-}Ct \times 100/Co$$

Where, C_o is initial concentration of metal ion,
C_t is concentration of metal ion after adsorption.

2.2 Preparation of Biocarbon

Stems of *Tinospora cordifolia* were collected and washed with deionised water to removedust and dirt. Stems were sundried for 8-10 days. Sundried biomass crushed using mortar and pestel and sieved to get fine powder and then treated with 1:1 HCl solution. The activated material was washed with deionised water for several times to remove excess of acid and again dried in oven. The resultant black coloured product was stored in airtight container for further studies[18].

3.0 Observations and Result

3.1 Effect of pH

The pH of the solution has significant impact on the adsorption of metal ions as the ionic activity plays the vital role in metal uptake[19]. It is a key parameter in the adsorption of heavy metals because it regulates the functional group and electrostatic interaction between biocarbon and heavy metals[20]. Maximum adsorption was found to be at 5 as you can see in Figure 2.

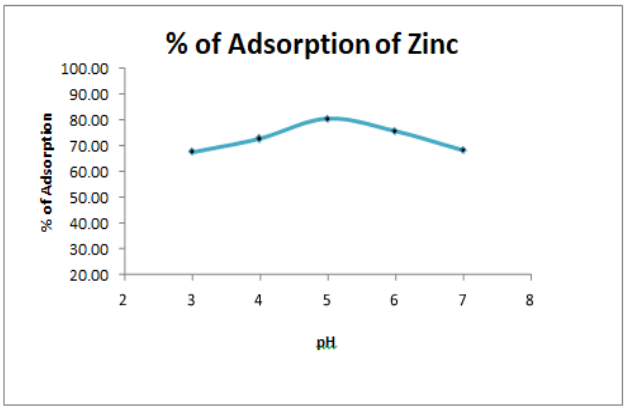


Figure 2. Percentage of Adsorption of Zinc on *Tinospora cordifolia* at different pH.

3.2 Effect of Adsorbent Dose

As the adsorbent quantity increases, adsorption rises due tothe larger surface area, more biosorption sites and ion exchange site ability[21]. Maximum adsorption was observed at 3.0 g/100 ml as shown in Figure 3.

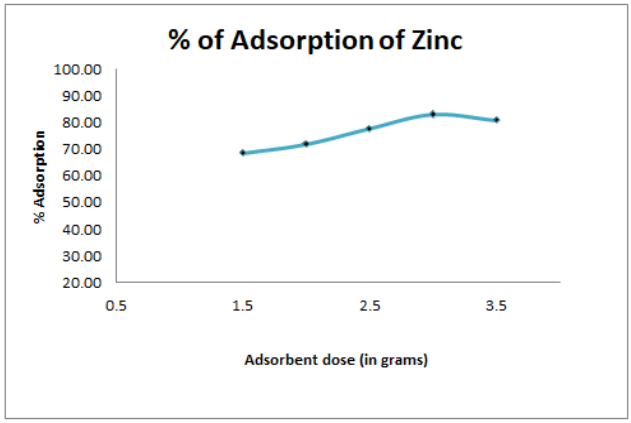


Figure 3. Percentage of adsorption of Zinc on *Tinospora cordifolia* at different adsorbent dose.

3.3 Effect of Contact Time

Contact time is the time required for biosorption process to attain equilibrium when no more changes were

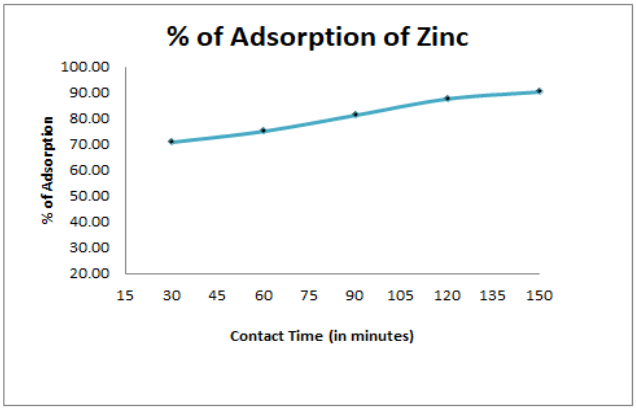


Figure 2. Percentage of adsorption of Zinc on *Tinospora cordifolia* at different contact time.

observed in concentration after a certain period of time. Maximum adsorption found at 150 minutes as shown in Figure 4.

4.0 Conclusion

Tinospora cordifolia, a widely accessible and adaptable herb found abundantly in nature, is known for its extensive medicinal properties and holds promise for various therapeutic applications. Beyond its health benefits, *Tinospora cordifolia* demonstrates remarkable potential in environmental applications, specifically in biosorption - a method used to extract heavy metals from polluted water sources. In this study, *Tinospora cordifolia*-derived activated carbon was utilized to remove Zn (II) ions from synthetic wastewater effectively. The study determined optimal conditions for maximum zinc removal, including a pH level of 5.0, an adsorbent dosage of 3.0 grams, and a contact time of 150 minutes. Under these conditions, the activated carbon derived from *Tinospora cordifolia* proved to be an efficient and environmentally sustainable bio-adsorbent for treating zinc-laden wastewater. This biosorption technique is not only effective but also straightforward and rapid, offering a powerful approach to mitigate heavy metal contamination. The promising results from this study support the potential for further application of *Tinospora cordifolia*-based activated carbon in water purification efforts, especially in the treatment of zinc and potentially other heavy metals. Beyond zinc, this study suggests that *Tinospora cordifolia*-based activated carbon could potentially be used to treat other heavy metals in contaminated water, supporting a wide range of water purification needs. The study highlights the promising role of natural materials like *Tinospora cordifolia* in addressing environmental issues, demonstrating that biological resources can be harnessed effectively for sustainable water treatment solutions.

5.0 References

1. Ernestine A. Adsorption of Zn(II) and Pb(II) ions from aqueous solution using chitosan cross-linked formaldehyde adsorbent to protect the environment. J Environ Polym Degrad. 2019; 27. https://doi.org/10.1007/s10924-019-01523-x
2. Jain CK, Singhal DC, Sharma MK. Adsorption of zinc on bed sediment of River Hindon: Adsorption models and kinetics. Journal of Hazardous Materials. 2004; 114(1-3):231-9. https://doi.org/10.1016/j.jhazmat.2004.09.001 PMid:15511595
3. Oyaro N, Juddy O, Murago ENM, Gitonga E. The contents of Pb, Cu, Zn and Cd in meat in Nairobi, Kenya. Int J Food Agric Environ. 2007; 5:119-21.
4. Fu F, Wang Q. Removal of heavy metal ions from wastewaters: A review. J Environ Manag. 2011; 92:407-18. https://doi.org/10.1016/j.jenvman.2010.11.011 PMid:21138785
5. Rao BH, Dalinaidu A, Singh DN. Accelerated diffusion test on the intact rock mass. J Test Eval, ASTM. 2007; 35(2):111-7. https://doi.org/10.1520/JTE100184
6. Matos GD, Arruda MAZ. Vermi-compost as natural adsorbent for removing metal ions from laboratory effluents. Process Biochem. 2003; 39(1):81-8. https://doi.org/10.1016/S0032-9592(02)00315-1
7. Raut P, Gotmare S. Cynodon dactylon- A cost effective, Eco-friendly adsorbent for removal of lead. IARJSET. 2021; 8(2):113-5.
8. Khan MM, dul Haque MS, Chowdhury MS. Medicinal use of the unique plant *Tinospora cordifolia*: Evidence from the traditional medicine and recent research. Asian J Med Biol Res. 2016; 2:508-512. https://doi.org/10.3329/ajmbr.v2i4.30989
9. Vishvakarma P, Mandal S, Pandey J, Bhatt AK, Banerjee VB, Gupta JK. An analysis of the most recent trends in flavoring herbal medicines in today's market. J Pharm Negat Results. 2022; 31:9189-98.
10. Maurya R, Manhas LR, Gupta P, Mishra PK, Singh G, Yadav PP. Amritosides A, B, C and D: Clerodane furano diterpene glucosides from *Tinospora cordifolia*. Phytochemistry. 2004; 5:2051-5. https://doi.org/10.1016/j.phytochem.2004.05.017 PMid:15279971
11. Mishra A, Sharma K, Pandey J, Dev K, Kadan S, Sahai M. Tinosporaside from *Tinospora cordifolia* encourages skeletal muscle glucose transport through both PI-3- kinase-and AMPK-dependent mechanisms. Molecules; 2023; 28(2):483. https://doi.org/10.3390/molecules28020483 PMid:36677541 PMCid:PMC9864719
12. Kumar BP, Jacob J, Augustine J. Dual inhibition of lipoxygenase/cyclooxygenase by an ayurvedic herb, *Tinospora cordifolia* (Willd.): Possible explanation for anti-inflammatory activity. J Pharm Res. 2011; 4:1779-80.

13. Maya N, Dewan J, Rashid N, Uddin M, Tabassum H. Protective and curative effects of ethanol extract of *Tinospora Cordifolia* on gentamicin-induced nephrotoxicity in rats. Mymensingh Med J. 2022; 31:437-42.
14. Raut PN, Gotmare S. Adsorption of Cd (II) ions on biocarbon prepared from Tridaxprocumbens. International Advanced Research Journal in Science, Engineering and Technology. 2022; 9(11):15-7.
15. Jadav JN, Maind SD, Bhalerao SA. Competitive biosorption of lead (Ii) ions from aqueous solution onto *Terminalia catappa* L. leaves as a cost effective biosorbent. Oct Jour Env Res. 2015; 3(1):067-79.
16. Bhalerao1 SA, *et al.* Removal of zinc (II) ions using peanut hulls (*Arachis hypogaea* Linn.) from aqueous solutions in a batch system. Int J Adv Res Biol Sci. 2015; 2(4):136-50.
17. Pragathiswaran C, *et al.* Studies on the removal of hexavalent chromium from synthetic waste water by using activated biocarbon. J Appl Chem. 2015; 4(6):1811-20.
18. Raut PN, Gotmare SR. Use of activated biocarbon for water treatment- adsorption process. Int J Innov Res Sci Eng Technol. 2019; 8(10):10539-43.
19. Singanan M. Removal of Pb(II) and Cd(II) ions from waste water using activated biocarbon. Sci Asia. 2011; 37:115-9.
20. Karthika T, Thirunavukkarasu A, Ramesh S. Biosorption of copper from aqueous solutions using *Tridax procumbens*. Recent Research in Science and Technology. 2010; 2(3):86-91.
21. Naiya TK, Das SK, Bhattacharya AK. Adsorption of Cd (II) & Pb (II) from aqueous solution on activated alumina. J Coll Inter Sci. 2009; 21:434-51.