

Research Article

Sustainable Use of Waste Snail Shell Powder for Water Treatment: A Preliminary Adsorption Study

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Abstract

Water pollution caused due to industrial wastewater discharge has emerged as a crucial environmental concern worldwide. With heavy metals being most hazardous contaminants. Lead (Pb) particularly remains a significant environmental and public health concern. It is a serious treat due to its non-biodegradable nature, environmental persistence and significantly high tendency to bioaccumulate in living organisms. Exposure to lead, even at low concentrations, can cause severe renal, neurological, developmental, and physiological disorders. Thereby making its removal from contaminated water system is an important priority. Conventional methods for lead removal, such as chemical precipitation, ion exchange, and membrane filtration, are often costly, energy-intensive, and may generate secondary pollutants. Therefore, low-cost, sustainable, and environmentally benign alternatives are highly desirable. In this present study the snail shell waste was investigated as an eco-friendly biosorbent for the removal of Pb^{2+} ions from contaminated aqueous systems. Snail shells primarily composed of calcium carbonate ($CaCO_3$) plays a crucial role in their effectiveness as a biosorbent. The $CaCO_3$ can interact with heavy metal ions through adsorption, ion exchange, surface complexation, and precipitation. In this study, collected snail shells were washed, dried, pulverized, and used in normal as well as sintered forms to evaluate their biosorbent potential against contaminated water. The level of contamination was evaluated before and after biosorbent treatment was estimated using a UV-Visible spectrophotometer after colour development and calibration with standard solutions. The experimental groups included lead normal snail shell, sintered snail shell. The results indicated a reduction in impure concentration after treatment with snail shell biosorbent, with sintered snail shell showing comparatively higher removal efficiency than normal snail shell. The improved performance of sintered snail shell may be attributed to increased surface reactivity and enhanced availability of calcium-based active sites. Overall, the findings suggest that snail shell waste can act as an efficient, low-cost, and sustainable biosorbent for reducing lead toxicity in contaminated water systems. The utilization of snail shell waste not only supports heavy metal remediation but also contributes to waste valorisation, circular economy, and environmental sustainability.

Keywords

Lead Toxicity, Snail Shell Waste, Biosorption, Waste Water Treatment, Calcium Carbonate

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1. Introduction

Heavy metal contamination is one of the major environmental problems associated with industrialization, mining, urbanization, and improper waste disposal [1]. Heavy metals such as lead, cadmium, chromium, mercury, arsenic, and copper can enter aquatic ecosystems through industrial effluents, sewage discharge, agricultural runoff, battery waste, paint residues, electroplating waste, and electronic waste [2]. Unlike many organic pollutants, heavy metals do not degrade easily and can remain in the environment for long periods.

Lead (Pb^{2+}) is one of the most toxic heavy metals. It has no known beneficial biological role and can cause harmful effects even at low concentrations. Lead exposure has been associated with bioaccumulation, oxidative stress, neurotoxicity, and immune-related effects in aquatic organisms [3]. In humans and other organisms, lead can interfere with cellular processes, enzyme activity, nervous function, and physiological development [4].

The removal of lead from contaminated water is therefore an important requirement for environmental protection. Conventional methods for lead removal include chemical precipitation, membrane filtration, reverse osmosis, ion exchange, electrochemical treatment, and activated carbon adsorption [5]. Although these methods can be effective, they are often expensive, energy-intensive, and may produce secondary pollutants. This creates the need for low-cost, eco-friendly, and easily available biosorbents.

Biosorption is a process in which biological materials remove pollutants from aqueous solutions through adsorption, ion exchange, complexation, and precipitation [6]. Waste biological materials are especially useful because they are cheap and readily available. Snail shell waste is one such material. Snail shells are mainly composed of calcium carbonate, which can interact with heavy metal ions. Calcium carbonate-based materials, including calcite, have been reported as promising sorbents for Pb^{2+} removal from aqueous solutions, with mechanisms involving surface precipitation, heterogeneous nucleation, and co-precipitation [7].

In recent years, the use of waste-derived biosorbents has gained attention because it combines pollution control with waste valorisation [8]. Materials such as eggshell, coconut shell, rice husk, fruit peels, fish scales, and molluscan shells have been investigated for heavy metal removal [9]. Among these, snail shell waste is particularly promising because it is inexpensive, naturally abundant, and usually discarded without proper utilization. Converting snail shell waste into a biosorbent provides a sustainable approach that reduces solid waste while producing a useful material for wastewater treatment. The adsorption potential of snail shell is mainly associated with its calcium carbonate-rich structure. Calcium carbonate provides active sites for binding metal ions and can also participate in ion exchange and precipitation reactions

[10]. In the case of lead, Pb^{2+} ions may interact with carbonate groups and form poorly soluble lead carbonate, thereby reducing the dissolved concentration and bioavailability of lead in water. This makes snail shell powder a suitable material for lead immobilization.

Thermal treatment or sintering of snail shell powder may further improve its biosorbent properties. During sintering, structural and chemical changes may occur in the shell material, leading to increased surface roughness, porosity, and reactivity [11]. At higher temperatures, calcium carbonate may partially convert into more reactive calcium-based compounds such as calcium oxide [12]. These changes can enhance the interaction between the biosorbent surface and Pb^{2+} ions. Therefore, comparing normal and sintered snail shell powder can help determine whether thermal modification improves lead removal efficiency.

The present study aims to evaluate the potential of waste snail shell powder as a sustainable adsorbent for the treatment of industrial wastewater using a simple batch adsorption approach.

2. Materials and Methods

2.1. Collection and Preparation of Adsorbent

Discarded shells of *Pila globosa* were collected from local freshwater sources and cleaned thoroughly with tap water followed by distilled water to remove adhering impurities. The cleaned shells were dried in a hot air oven at 60 °C for 24 h. Dried shells were crushed manually and ground into fine powder using a laboratory grinder. The powder was sieved through a fine mesh ($\leq 250 \mu m$) to obtain uniform particle size and stored in airtight containers for further use [13].

2.2. Preparation of Sintered Shell

Some amount of prepared shell powder was subjected to thermal treatment in muffle furnace (horizontal shape chamber type muffle furnace max. temp 1050, Narcas) at high temperature (200°C) to obtain sintered shell powder.

2.3. Collection and Preparation of Industrial Wastewater

Industrial wastewater samples were collected from a local discharge site in clean polyethylene containers. The samples were transported to the laboratory and stored at 4 °C. Prior to experimentation, the wastewater was filtered using Whatman filter paper to remove suspended particles and brought to room temperature.

2.4. Batch Adsorption Experiment

Batch adsorption experiments were carried out by adding 1 g of snail shell powder to 100 mL of wastewater in conical flasks. The mixture was maintained at room temperature and gently agitated. Samples were withdrawn at regular intervals (0, 15, 30, 45, 60, 90, and 120 minutes), filtered, and analyzed.

2.5. Spectroscopic Analysis

The optical density (OD) of the wastewater samples was measured using a UV–Visible spectrophotometer (Model 119, Systronics, India) at 660 nm wavelength. Distilled water was used as a blank. Reduction in OD values indicated removal of

pollutants.

2.6. Calculation of Removal Efficiency

$$\% \text{ Removal} = \frac{OD_0 - OD_t}{OD_0} \times 100$$

Where:

OD_0 = initial optical density

OD_t = optical density at time t

2.7. Scheme

The overall experimental workflow followed in this study is illustrated in [Scheme 1](#).



Scheme 1. Preparation of snail shell powder and its application.

Table 1. Optical Density and percentage Removal of During the treatment.

Time (min)	OD Value (Normal)	% Removal	OD (Sintered)	% Removal
0	1.00	0	1.00	0
15	0.86	14	0.78	22
30	0.74	26	0.63	37
45	0.65	35	0.52	48
60	0.56	44	0.41	59
90	0.45	55	0.30	70
120	0.36	64	0.22	78

3. Results

The adsorption performance of snail shell powder for the

treatment of industrial wastewater was evaluated by monitoring the reduction in optical density (OD) over time. A gradual decrease in OD values was observed with increasing contact time, indicating effective removal of pollutants.

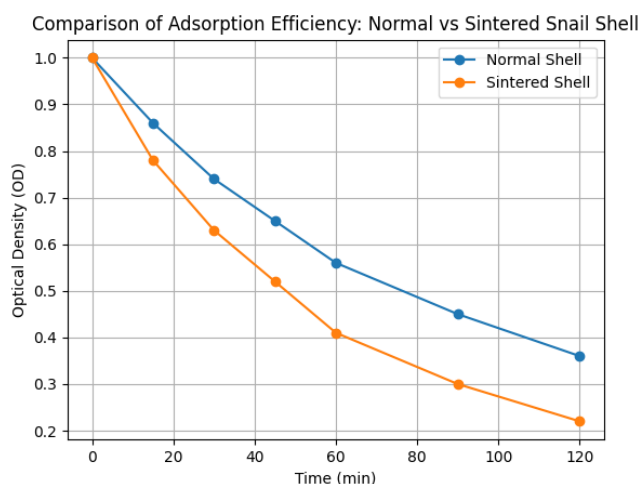


Figure 1. Comparative reduction in OD of wastewater using normal and sintered snail shell over time.

The results indicate a gradual decrease in OD with increasing time, as shown in Figure 1, sintered snail shell powder exhibited consistently lower OD values compared to normal shell powder, indicating enhanced adsorption efficiency.

4. Discussion

The present study demonstrates that waste snail shell powder can serve as an effective biosorbent for the treatment of industrial wastewater, as evidenced by the progressive decrease in optical density with increasing contact time. The reduction in OD indicates removal of dissolved and suspended pollutants from the wastewater, confirming the adsorption capability of the material [14]. The initial rapid decrease in OD observed during the early stages of treatment (0–60 min) can be attributed to the availability of a large number of active adsorption sites on the surface of the shell powder. As the process continued, the rate of removal gradually decreased, suggesting partial saturation of these active sites and the establishment of adsorption equilibrium. This behavior is consistent with typical adsorption kinetics reported for low-cost biosorbents. The improved performance of sintered snail shell powder compared to normal shell powder highlights the importance of surface modification. Thermal treatment likely enhances the surface area, porosity, and reactivity of the material, thereby increasing the number of available binding sites. This leads to higher adsorption efficiency and faster removal of pollutants. The structural transformation of calcium carbonate during sintering may also contribute to improved adsorption behavior.

Snail shells are predominantly composed of calcium carbonate, which plays a crucial role in pollutant removal [15]. The adsorption process may involve multiple mechanisms, including surface adsorption, ion exchange, and precipitation [16]. These mechanisms collectively contribute to the reduction in pollutant concentration in the wastewater. The use of

real industrial wastewater in this study adds practical significance to the findings, as such wastewater contains a complex mixture of contaminants rather than a single model pollutant. This demonstrates the potential applicability of snail shell powder in real-world environmental conditions. Compared to conventional treatment methods, the use of snail shell waste offers advantages such as low cost, easy availability, minimal processing requirements, and environmental sustainability [17]. However, the present study is preliminary in nature and has certain limitations. Parameters such as pH, adsorbent dosage, initial pollutant concentration, and temperature were not extensively varied. Additionally, detailed adsorption isotherm and kinetic modelling were not performed. Future studies should focus on optimizing these parameters and investigating the regeneration and reuse potential of the adsorbent. Overall, the findings indicate that snail shell powder is a promising, eco-friendly material for wastewater treatment and can contribute to sustainable waste management and environmental protection [18].

6. Conclusions

Waste snail shell powder is an efficient, low-cost, and eco-friendly adsorbent for lead removal from wastewater. Sintered shell exhibits higher efficiency due to improved surface properties. This study supports the use of biological waste for sustainable environmental remediation.

Abbreviations

Pb ²⁺	Lead Ion
OD	Optical Density
UV–Vis	Ultraviolet Visible

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Author Contributions

Ghanishtha Prusty: Conceptualization, Resources, Writing – review & editing

Bodroth Rabi Prasad: Formal Analysis, Investigation, Supervision

Suman Polaki: Formal Analysis, Investigation, Supervision

Tapas Ranjan Guru: Data curation, Methodology, Writing – original draft

Abhipsa Pradhan: Data curation, Methodology, Writing – original draft

Sushree Yugma Senapati: Data curation, Methodology, Writing – original draft

Snehalata Pradhan: Data curation, Methodology, Writing – original draft

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Data Availability Statement

The data supporting the outcome of this research work has been reported in this manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography



Ghanishtha Prusty is a PhD scholar in Toxicology at GIET University, Odisha, Gunupur, India. She holds a Master's degree in Life Sciences and has research expertise in environmental toxicology, heavy metal stress, and microbial analysis. Her work focuses on the impact of pollutants such as lead on aquatic organisms and the application of sustainable remediation strategies. She has experience in metagenomics, spectroscopic techniques, and biosensor-based approaches. She has published research on lead toxicity and enzymatic responses and is actively engaged in interdisciplinary research integrating environmental science with biotechnology.



Bodroth Rabi Prasad is an Assistant Professor in the Department of Biotechnology at GIET University, Odisha, India. He holds a Ph.D. in Biotechnology and has extensive experience in environmental biotechnology and wastewater treatment. His research focuses on microbial applications, biosorption, and sustainable approaches for pollution control. He has contributed to several research publications and academic projects related to environmental remediation and biological treatment technologies. He is actively involved in teaching, mentoring students, and guiding research in applied biological sciences.



Suman Polaki is an academic and researcher associated with Centurion University, Odisha, India. He holds a Ph.D. in Biotechnology and specializes in environmental microbiology and bioprocess technology. His research interests include wastewater treatment, microbial biotechnology, and sustainable environmental solutions. He has been involved in interdisciplinary research projects and has contributed to academic development through teaching and student mentorship. His work focuses on applying biological systems for environmental and industrial applications.



Tapas Ranjan Guru is a postgraduate student pursuing an M.Sc. in Life Sciences (Batch 2023–2025) at GIET University, Odisha, India. His academic interests include environmental science, biotechnology, and wastewater treatment. He is actively involved in research on low-cost biosorbents and their application in pollutant removal from industrial wastewater. His work focuses on developing sustainable and eco-friendly approaches for environmental remediation. He is gaining hands-on laboratory experience and contributing to applied research projects under academic supervision.



Abhipsa Pradhan is an M.Sc. Life Sciences student (Batch 2023–2025) at GIET University, Odisha, India. Her academic focus related to wastewater treatment using natural biosorbents. Her work emphasizes developing cost-effective and eco-friendly solutions for pollution control. She is actively building laboratory skills and participating in research activities under faculty guidance. includes environmental biotechnology, microbiology, and sustainable waste management. She is engaged in research



Sushree Yugma Senapati is a postgraduate student pursuing an M.Sc. in Life Sciences (Batch: 2023–2025) at GIET University, Odisha, India. Her academic interests lie in environmental science and applied biotechnology. She is involved in experimental research on wastewater treatment and biosorption techniques using natural materials. Her work focuses on sustainable environmental solutions and practical laboratory-based applications. She is developing strong research and analytical skills through active participation in academic projects



Snehlata Pradhan is an M.Sc. Life Sciences student (Batch 2023–2025) at GIET University, Odisha, India. Her academic interests include environmental science, microbiology, and biotechnological applications in pollution control. She is currently engaged in research on wastewater treatment using low-cost biosorbents. Her work contributes to sustainable environmental management and waste utilization strategies. She is gaining practical experience in laboratory techniques and research methodologies.

Research Field

Ghanishtha Prusty: Environmental Toxicology, Heavy Metal Toxicity, Microbial Ecology and Metagenomics.

Bodroth Rabi Prasad: Environmental Biotechnology, Bio-based Adsorbents for Wastewater Treatment, Lignocellulosic Biomass Processing and Valorization, Microbial Applications in Pollution Control.

Suman Polaki: Proteomics and Functional Biology, Molecular Analysis of Stress Responses, Environmental Microbiology, Wastewater Treatment and Environmental Applications.

Tapas Ranjan Guru: Lifescience, Animal Science, Biosorption Techniques, Microbiology, Environmental Science.

Abhipsa Pradhan: Environmental Science, Animal Science, Waste Management, Lifescience, Microbiology.

Sushree Yugma Senapati: Water treatment, Lifescience, Animal Science, Microbiology, Environmental Biotechnology

Snehalata Pradhan: Microbiology, Environmental Science, Animal Science, Waste Management, Bio absorption.