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Application Of Flax Pod As Bio-Adsorbent For Removal Of Nitrate From Water

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Abstract

This study aims to remove nitrate ions from synthetic water using pristine Flax pod bio-adsorbent. The bio-adsorbent was synthesized at 500 °C using a muffle furnace. Adsorption experiments were performed with an initial nitrate concentration of 45 mg/L, an adsorbent dose of 2 g/L, a contact time of 240 minutes, and agitation at 100 rpm at room temperature. The highest observed nitrate adsorption percentage was 18.97%. These results indicate that the adsorbent has potential for nitrate removal from water. Further research is necessary to characterize the adsorbent and optimize its synthesis method to enhance nitrate removal efficiency.

Keywords: nitrate; Flax, bio-adsorbent; agricultural waste, adsorption

1. Introduction:

Nitrates are compounds of considerable importance and complexity, playing pivotal roles in both natural ecosystems and human activities. Chemically represented as NO_3^-, nitrates are the oxidized form of nitrogen, a fundamental element essential for life. These compounds are ubiquitous in the environment, present in soil, water, and a variety of foods (Snider, 2011). The central role of nitrates in the nitrogen cycle, their contributions to agricultural productivity, and their potential to cause environmental and health problems make them a subject of extensive scientific study and regulatory focus (Subbarao, et. al., 2006). In natural settings, nitrates are formed through the microbial processes of nitrification, where ammonia is oxidized to nitrite and then to nitrate (Tiso & Schechter, 2015). These processes are vital for the recycling of nitrogen in ecosystems, facilitating the growth of plants by providing them with an essential nutrient. Plants assimilate nitrates through their root systems, incorporating the nitrogen into amino acids, proteins, and other crucial biomolecules (Zayed, et. al., 2023). Consequently, nitrates are fundamental to the global food supply and agricultural practices. The agricultural significance of nitrates is underscored by their inclusion in fertilizers, which are applied to crops to enhance growth and yield (Hepperly, et. al., 2009). The widespread use of nitrogen-based fertilizers has revolutionized agriculture, enabling increased food production to support growing populations. However, this intensive use also introduces significant quantities of nitrates into the environment. Leaching of nitrates from agricultural fields into groundwater and surface water bodies is a major environmental concern (Craswell, 2021). Elevated nitrate levels in water can lead to eutrophication, a phenomenon characterized by excessive nutrient enrichment, resulting in algal blooms, hypoxia, and the degradation of aquatic ecosystems (Akinnawo, 2023). From a public health perspective, nitrates in drinking water pose various risks. The most well-documented health issue is methemoglobinemia, or "blue baby syndrome," a condition that affects infants and reduces the blood's ability to carry oxygen (Churchill, 2007). Additionally, there are concerns about the long-term exposure to high levels of nitrates and their potential role in forming carcinogenic compounds such as nitrosamines (Karwowska, & Kononiuk, 2020). These health risks necessitate strict regulatory measures to control nitrate levels in water supplies and ensure public safety. The dual nature of nitrates as both essential nutrients and potential contaminants presents a complex challenge. Effective management strategies must balance the need for agricultural productivity with the imperative to protect environmental and human health. This requires a multifaceted approach, encompassing advanced agricultural practices, improved wastewater treatment, and robust monitoring and regulatory frameworks. This paper aims to provide a comprehensive analysis of nitrates, exploring their sources, functions, environmental impacts, and health implications (Shah, & Wu, 2019). We will examine the biochemical processes involving nitrates, their role in agricultural systems, and the pathways through which they enter and affect natural water bodies. Furthermore, we will discuss current regulatory standards and innovative practices designed to mitigate nitrate pollution. By synthesizing existing research and highlighting emerging trends, this paper seeks to contribute to a deeper understanding of nitrates and inform effective policy and management decisions.

2.0 Materials and equipment used

Anhydrous Sodium Nitrate ($NaNO_3$) was procured from Sigma Aldrich. Ionic Strength Adjustment Buffer (ISAB) solution was obtained for adjusting the nitrate strength.

2.1 Selection of raw materials for the development of bio-adsorbents

Flax (Linum usitatissimum) pod waste was sourced from agricultural regions close to Dr. Rammanohar Lohia Avadh University, Ayodhya, Uttar Pradesh, India, for the purpose of preparing a biosorbent. This particular agro-waste was selected due to its negligible environmental impact. The gathered waste was thoroughly washed multiple times with distilled water to remove any dust and impurities. After cleaning, it was dried in an oven at 80°C until a consistent weight was reached. The dried material was then ground into a fine powder using a mixer grinder. This powder was passed through a 250 µm sieve and stored in airtight containers, ready for use as a bio-adsorbent.

2.2 Preparation of pristine bio-adsorbents

The ground and sieved flax pod waste was placed into 100 ml crucibles, covered with lids, and subjected to pyrolysis in a muffle furnace at 500°C for 2 hours. The resulting bio-adsorbent was then extensively washed with distilled water to eliminate any remaining carbon residues. After washing, the material was dried in an oven for 12 hours. The pristine bio-adsorbent thus prepared was used to adsorb nitrate ions from water.

2.3 Batch experiment

A stock solution with a nitrate concentration of 1000 mg/L was prepared by dissolving 1.63 grams of $NaNO_3$ in 1000 milliliters of distilled water. This stock solution was then serially diluted to obtain a working concentration of 45 mg/L. The residual nitrate concentration in the solutions was determined using the ion-selective electrode method, following the standard procedure outlined by APHA, and employing an Ion Meter (LMION-04, Labman, India). All solutions were maintained at room temperature. Before use, all glassware was meticulously washed with distilled water and dried. Each experiment was performed in triplicate to minimize errors, and the average values were recorded.

The adsorption efficiency and adsorption capacity were calculated using the following equations;

$$\text{Adsorption efficiency (\%R)} = \frac{(C_0 - C_e)}{C_0} * 100 \qquad (2.1)$$

Where, C_0 and C_e are the initial and equilibrium concentrations of nitrate ions, respectively (mg/L), V is the volume of the solution (L) and M is the adsorbent mass (g).

3.0 Result and Discussion

The adsorption of nitrate from water was investigated at room temperature using an initial nitrate concentration of 45 mg/L, an adsorbent dose of 2 g/L, and a contact time of 240 minutes, with a shaking speed of 100 rpm. The experiments were carried out in 50 ml conical flasks, each containing a working volume of 25 ml. Pristine Flax pod bio-adsorbent (FBC) was employed throughout the study. Samples were collected at various time intervals—5, 15, 30, 60, 90, 120, 150, 180, 210, and 240 minutes—to determine the remaining nitrate concentration using an Ion Meter.

The removal percentage was calculated using equation (2.1), and the resulting data were plotted in Figure 1.

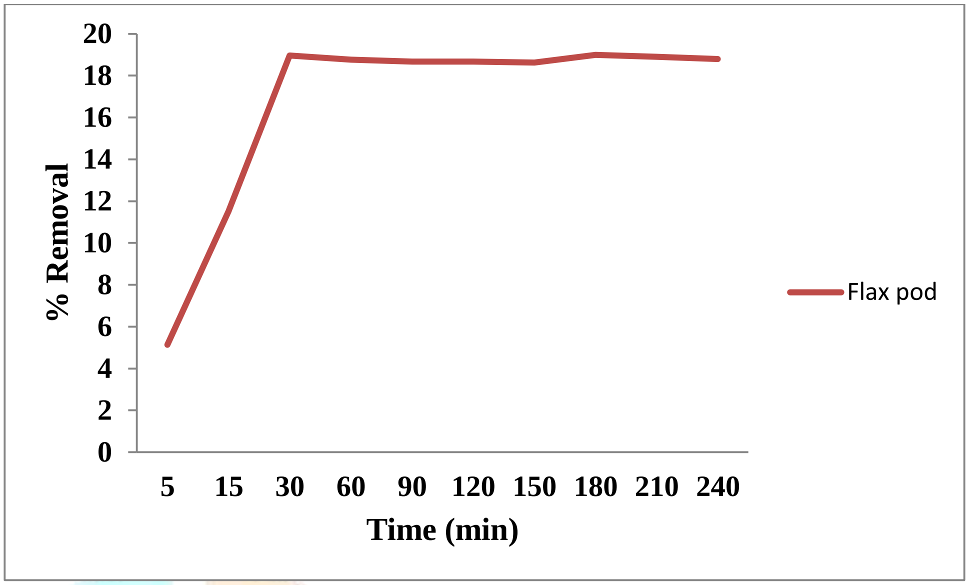

Figure-1: Nitrate removal using pristine Flax pod bio-adsorbent

The graph illustrates that as the contact time of the bio-adsorbent increased, the efficiency of nitrate adsorption rose until reaching a contact time of 30 minutes, after which no significant change was noted. The highest removal efficiency of 18.97% was achieved using the flax pod bio-adsorbent at a contact time of 30 minutes. Hence, it can be noted that pristine flax bio-adsorbent can be effective for nitrate removal from water.

4. Conclusion

This study describes the preparation of a pristine bio-adsorbent derived from Flax pods at 500°C and evaluates its effectiveness in removing nitrate from water. The nitrate adsorption experiments were conducted with an initial nitrate concentration of 45 mg/L, an adsorbent dose of 2 g/L, a contact time of 240 minutes, and agitation at 100 rpm at room temperature. The highest removal efficiency observed was 18.97% at a contact time of 30 minutes, suggesting that adsorption equilibrium was reached within this period.

5. Acknowledgement

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