Removal of heavy metal ions from aqueous solution using *azadirachata indicum (neem) leaves*

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Abstract: This article explores the utilization of Azadirachta Indica leaves as adsorbents for eliminating Lead (II), Nickel (II), Copper (II), and Zinc (II) ions from aqueous solutions. The removal of metal ions was examined through batch adsorption experiments, considering various parameters such as pH, contact time, and concentration, using the Atomic Absorption Spectrometer (AAS). A comparative analysis revealed that the adsorption capacity of the adsorbent decreases as the initial concentration of heavy metals decreases, while the percentage adsorption capacity increases with lower initial values of different parameters. Azadirachta Indica leaves demonstrate high efficiency as adsorbents for the removal of Pb (II), Ni (II), Cu (II), and Zn (II) ions from aqueous solutions.

Keywords: Adsorption, Atomic Absorption Spectrometer, Heavy Metal.

Introduction:

Heavy metals are metallic elements found in both natural and polluted environments. In natural settings, they exist at low concentrations, but in contaminated environments, such as those affected by metal smelting, refining industries, scrap metal, plastic and rubber industries, and the burning of waste, they can reach high concentrations, leading to adverse public health effects. When released into the air, these elements can travel over long distances and deposit onto soil, vegetation, and water based on their density. Once deposited, these metals persist in the environment for many years, posing risks to humans through inhalation, ingestion, and skin absorption.

Heavy metals exist in immobilized form in sediments and as ores in nature[1]. These toxic substances can reach dangerous levels even at low concentrations[2]. Metals like lead, copper, cadmium, zinc, and chromium are toxic even in small amounts, and their nonbiodegradable nature increases their threat through accumulation in the environment via the food chain[3,4]. Common sources of metal pollution include urban industrial aerosols, animal waste, mining activities, agricultural and chemical substances. These metals can enter the water supply through industrial and drinking water or even from acid rain, leading to contamination of rivers, lakes, and groundwater[1]. Despite their industrial applications, the environmental concern surrounding these toxic heavy metals has led to the establishment of discharge limits in most industrialized countries. Consequently, industries are required to treat their industrial effluents before releasing them into the environment[5].

Recent studies have demonstrated the potential of using plant materials, such as palm pressed fibers, coconut husk, water fern (Azolla filiculoidis), peat moss, lignocellulosic substrate from wheat bran, Rhizopus nigricans, cork, yohimbe bark wastes, and leaves of indigenous biomaterials like Tridax procumbens, for the removal of heavy metals. Additionally, chemical modifications of various adsorbents, such as phenol formaldehyde cationic matrices, polyethylonamide modified wood, sulphur-containing modified silica gels, and commercial activated charcoals, have been employed [6-15].

The increasing awareness of the environmental consequences of heavy metal contamination in aquatic environments has led to the demand for treating industrial wastewater before discharge[16]. Conventional methods for removing metals from industrial effluents include chemical precipitation, coagulation, solvent extraction, electrolysis, membrane separation, and ion exchange.

Technologies for removing toxic metals from wastewater have shifted attention to biosorption, a physiochemical process that occurs in certain biomass, allowing it to accumulate and attach contaminants to its cellular structure[17,18]. Biosorption, including the use of activated carbon filters, has been applied for a long time and is considered an alternative economical method for removing heavy toxic substances from wastewater. Biosorption offers advantages over conventional methods, such as low cost, minimization of sludge production, metal recovery, the ability to regenerate the biosorbent, and non-requirement of additional chemicals [19,20].

Different types of biosorbents, including fungi, bacteria, industrial wastes, algae, and agricultural waste, are used for metal removal [21]. Neem tree (Azadirachta indica) is highlighted as a potential biomass due to its widespread availability and proven effectiveness in addressing public health, agricultural, and environmental issues. Neem leaves contain chemical compounds with significant metal binding capacity [22,25]. The objective of this research is to investigate the elimination of toxic heavy metal ions using Neem leaves from aqoues solution and propose this biosorbent as a regional substitute for current commercial adsorbent materials.

Material and Method:

Preparation of Neem leaves:

The Neem leaves underwent a drying process lasting three days, followed by cleaning with distilled water and subsequent air-drying at room temperature. Afterward, the leaves were ground using a grinding mill. The ground Neem leaves was then sieved to achieve a particle size ranging from 0.25 to 0.5 mm. This specific particle size was chosen to facilitate a shorter diffusion path, enabling the adsorbate (Neem leaves) to penetrate the effluent more rapidly, thereby enhancing the rate of adsorption [26].

Preparation of heavy metal ions Solution:

A stock solution of Nickel was created by dissolving 4.9530 g of Nickel nitrate ($Ni(NO_3)_2$) in 1000 ml of deionized water in a volumetric flask, yielding a 1000 ppm nickel solution. To generate a stock solution of copper, 3.930 g of Cu2+ sulphate pentahydrate (CuSO4.5H_2O) was dissolved in 1000 ml of distilled water in a 1000 ml beaker, resulting in a 1000 ppm copper stock solution. 1.000 g of zinc metal underwent dissolution in 30 ml of a 5 M HCl solution, followed by dilution to 1000 ml, resulting in a 1000 ppm zinc solution. For the preparation of a 1000 ppm lead stock solution, 1.60 g of Lead (II) nitrate ($Pb(NO_3)_2$) was dissolved in 20 ml of acid, and the volume was adjusted to 1000 ml with deionized water.

Adsorption Experiment

The experiments were conducted in batch mode to assess adsorption capabilities. Bottles with a 500ml capacity were filled with 50ml of a solution containing heavy metal ions and 1g of ground Neem leaves. The bottles underwent shaking for a predetermined period at room temperature using a reciprocating shaker, operating at 400 rpm for 2.5 hours. Subsequently, the separation of adsorbents and solutions was achieved through filtration using Whatman filter paper No. 42, and the resulting filtrate was stored in sample cans in a refrigerator before analysis. The concentrations of residual metallic ions were determined using an Atomic Absorption Spectrophotometer (AAS) at the Department of Soil, CCS HAU, Hisar.

Results and Discussion

The investigation focused on adsorption studies for the removal of nickel, copper, lead, and zinc from a solution. To formulate an effective adsorption system, the optimization of various operating parameters including different concentrations, pH levels, and contact times, was examined. In alignment with the study's objectives, laboratory adsorption tests were carried out, and the ensuing results are deliberated.

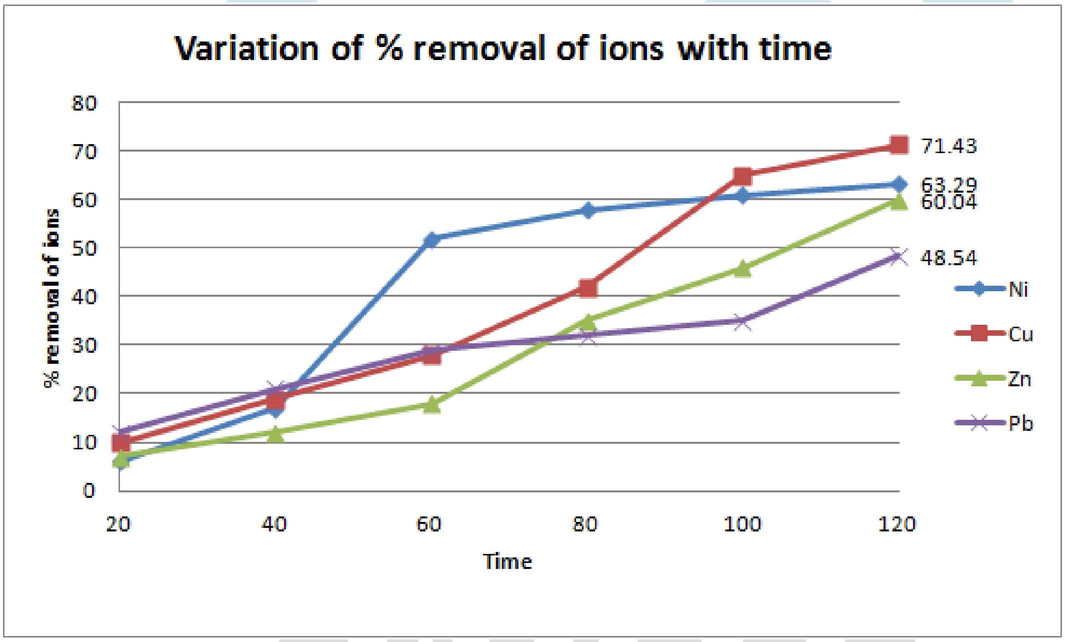

Figure-1

Figure 1 Illustrates the percentage removal of various metal ions by the Neem leaves adsorbent. Over time, there was a consistent increase in the percentage removal of metal ions from aqueous solution for all types of metal ions. According to the adsorption experiment results, Cu^{2+} ions exhibited the highest percent removal at 71.43% after 120 minutes, followed by Ni^{2+} ions, Zn^{2+} ions and Pb^{2+} ions at 63.29%, 60.04%, and 48.54%, respectively.

In the case of Neem leaves, the rate of adsorption displayed a non-linear progression at various time intervals. Figure 1 indicates that the adsorption rate of Neem leaves increased with prolonged contact time. Notably, there was a significant increase in the adsorption rate for certain metal ions in aqueous solution between 80 and 100 minutes of contact time. This finding holds importance, as the equilibrium time is a crucial parameter in establishing an economically viable wastewater treatment system.

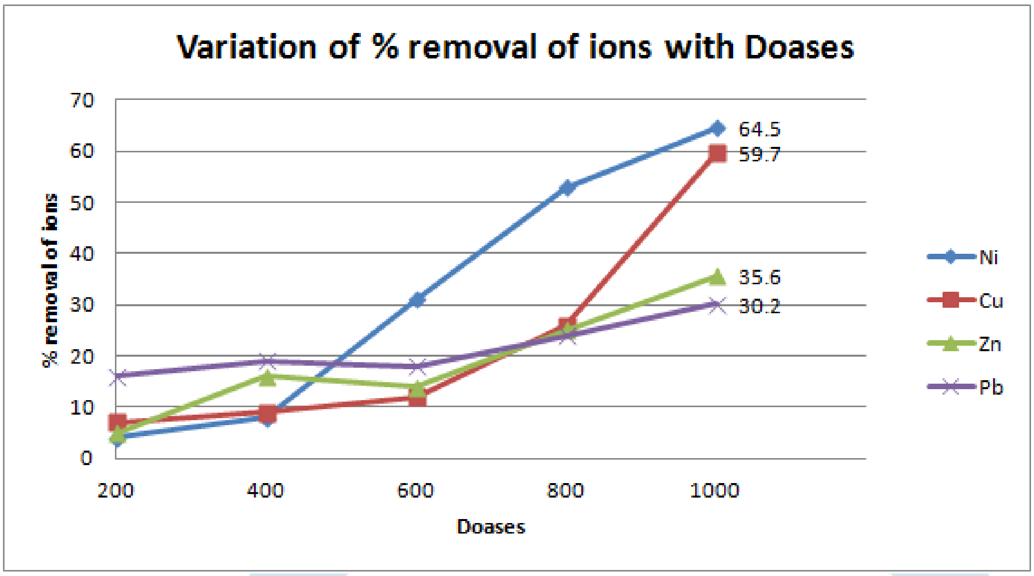

Figure- 2

Figure 2 Illustrates that, at an adsorbent dose of 1.0g, there was an observed increase in the adsorption rate. The greater the surface area, the more metal ions were adsorbed. This phenomenon is likely attributed to the increased availability of binding sites in the biomass for the complexation of heavy metals. This higher availability of binding sites could explain the notable percentage removal of heavy metals. Specifically, the Neem leaves achieved a percentage removal of 64.59%, 59.70%, 35.60%, and 30.20% for Ni^{2+}, Cu^{2+}, Zn^{2+}, and Pb^{2+} ions, respectively.

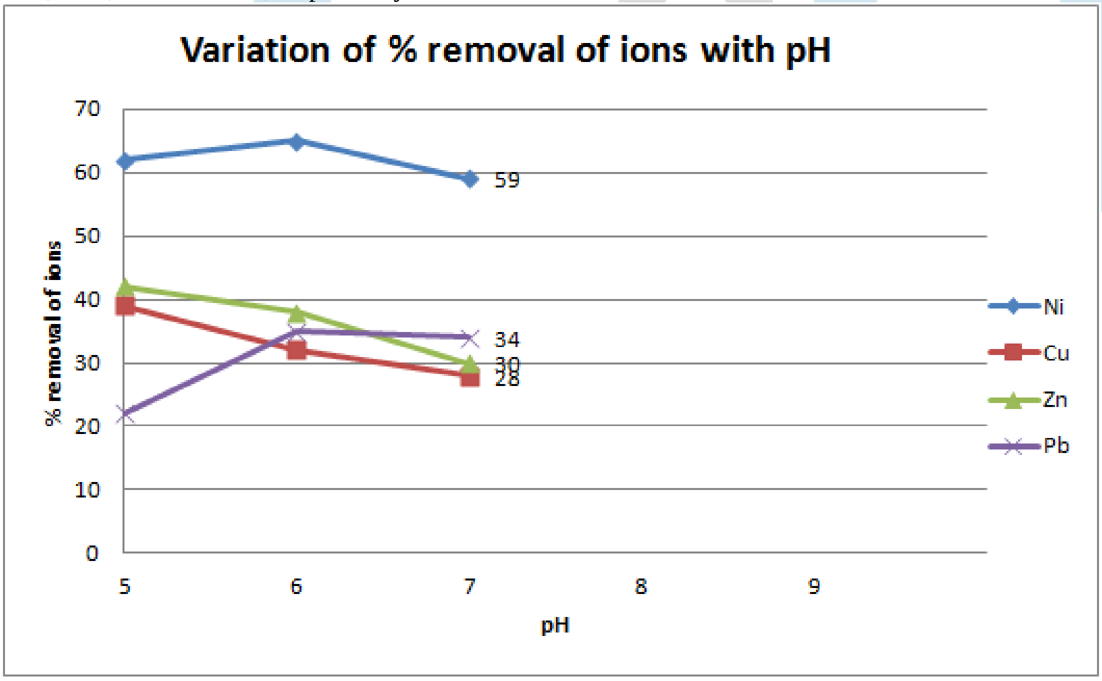

Figure-3

Figure 3 indicates that Neem leaves exhibited a decrease in the adsorption rate for Cu^{2+} and Zn^{2+} ions, along with an increase in the adsorption rate for Pb^{2+} and Ni^{2+} ions when the pH of the aqueous solution ranged between 4 and 7. As alkalinity increased, moving from a pH value of 7 to 9, there was a further decline in the adsorption rate by Neem leaves for Cu^{2+}, Zn^{2+}, Pb^{2+}, and Ni^{2+} ions in the aqueous solution.

The adsorption experiment results highlight that the highest rate of adsorption by Neem leaves was a 65% removal for Ni ions in aqueous solution at a pH value of 7. The increase in pH from 4 to 9 led to a gradual decrease in the degree of protonation of the adsorbent functional group, resulting in reduced removal. A correlation between the surface basicity of the adsorbents and the anions is evident, aligning with the findings of others. The primary adsorption mechanisms involve the interaction between oxygen-free Lewis basic sites and the free electrons of the anions, as well as electrostatic interactions between the anions and the protonated sites of the adsorbent.

Conclusion

The study of metal ion removal from solution using biosorption technology yielded several key conclusions. Ground Neem leaves proved highly effective in removing Ni^{2+} ions from the aqueous solution, achieving percentage removals of 71.43%, 63.29%, 60.04%, and 48.54% for Cu^{2+}, Zn^{2+}, Pb^{2+}, and Ni2+ ions, respectively, after 120 minutes of contact. Neem leaves emerged as efficient biomaterials for removing certain heavy metals from aqueous solutions, demonstrating a 64.59% removal of Ni^{2+} ions with an effective dose of 1.0 g of bioadsorbent (Neem leaves). The capacity of Neem leaves to absorb metal ions presents an opportunity for the development of an efficient and cost-effective technology for effluent treatment, particularly in the removal of heavy metals from wastewater.

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