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Removal of heavy metals from Bhangadh water treatment plant Indore wastewater using Multiwalled carbon nanotubes

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Abstract

Because heavy metal pollution has a negative influence on ecosystems and human health, removing it from industrial effluent is a critical environmental concern. Treatment of heavy metal-contaminated wastewater at the Bhangadh Water Treatment Plant in Indore is extremely difficult and requires sophisticated remediation methods. The unique structure and adsorption capabilities of Multiwalled Carbon Nanotubes (MWCNTs) have made them stand out among the others as promising agents for the removal of heavy metals. Lead, cadmium, chromium, and nickel are among the heavy elements that this study looks at how well MWCNTs remove from wastewater at the Bhangadh Water Treatment Plant. MWCNTs are perfect for wastewater treatment because of their many benefits, including a large surface area, variable fictionalizations, and strong adsorption capability. The research holds great importance as it has the potential to improve environmentally friendly and economically viable methods of managing wastewater that contain heavy metal pollution. Through an investigation of MWCNTs' adsorption mechanisms and effectiveness in actual wastewater settings, this work provides insightful information for enhancing water treatment procedures and mitigating environmental hazards related to heavy metal pollution. In this study, lead abortion from wastewater is observed.

Keywords: Heavy metals, Industrial wastewater, Water treatment, Remediation techniques, Adsorption pr Bhangadh Water Treatment Plant's wastewater perties.

Introduction

Because heavy metals have detrimental impacts on ecosystems and human health, removing them from industrial effluent is an important environmental concern. Heavy metal-contaminated wastewater at the Bhangadh Water Treatment Plant in Indore is difficult to handle, requiring sophisticated and effective remediation methods. Because of their special structural and adsorption qualities, Multiwalled Carbon Nanotubes (MWCNTs) have become a viable tool for the removal of heavy metals among these approaches.

The purpose of this research work is to examine the effectiveness of MWCNTs in eliminating heavy metals from wastewater at the Bhangadh Water Treatment Plant, including lead, cadmium, chromium, and nickel. The application of MWCNTs is advantageous due to their strong adsorption capacity, high surface area, and adjustable fictionalizations, which makes them perfect for wastewater cleanup procedures. The research has importance as it has the potential to support ecologically friendly and economically viable approaches to managing water resources by providing a solution to the issue of heavy metal contamination in wastewater.

This study intends to provide important insights for enhancing water treatment procedures and reducing environmental risks related to heavy metal contamination by comprehending the adsorption mechanisms and performance of MWCNTs in actual wastewater circumstances. Known by another name, trace metals, or heavy metals, are metallic elements in the periodic table that have a density greater than 6 grams per cubic centimeter[1,2]. Because they are not biodegradable, they tend to accumulate in living things[3].

Although human metabolism requires trace amounts of several heavy metals, such as iron, copper, and zinc, at excessive concentrations, these elements become extremely poisonous[4,5]. Inhaling dust or fumes, eating tainted food or drink, or coming into touch with skin or eyes can all expose oneself to heavy metals[5,6]. An good chance to assess MWCNTs' performance in wastewater treatment is offered by the Bhangadh Water Treatment Plant in Indore, India. Wastewater from industrial, residential, and commercial areas is received by the plant, resulting in a wide variety of pollutants and toxins.

At the Bhangadh Water Treatment Plant, MWCNTs were added to the wastewater treatment process to test how well they removed certain pollutants, like organic compounds and heavy metals. When their effectiveness was contrasted with traditional treatment techniques, it became clear that MWCNTs were superior to traditional methods in eliminating a variety of contaminants from wastewater, including heavy metals, and in removing them more effectively.

Heavy metals are primarily found in two places: i. Natural Sources: In addition to being naturally occurring in the Earth's crust, heavy metals are also a result of processes including soil erosion and volcanic eruptions[5,7]. ii. Anthropogenic Sources: Sectors including mining activities, glass production, pesticide and fertilizer manufacture, paper manufacturing, electronics manufacturing, battery manufacturing, paint manufacturing, and electronics manufacturing are significant causes of the pollution of water bodies with heavy metals[3,8]. The release of untreated industrial effluent into the environment that contains significant levels of heavy metals has detrimental consequences on aquatic ecosystems, soil, plants, animals, and human health. Animals exposed to heavy metals may experience neurological problems and organ damage as a result of stunted growth and development. Reduced plant development and decreased food production might result from the degradation of soil caused by elevated amounts of heavy metals[6]. Additionally, plants are negatively impacted by heavy metals, which suppress photosynthesis, lower chlorophyll synthesis, impede seed germination, and eventually affect plant growth[9].

Due to their high solubility, heavy metals pose serious risks to aquatic habitats, such as habitat damage, changed water flow patterns, and aquatic species death[6]. Heavy metal exposure in humans mostly happens through the food chain, where it builds up in tissues, damages cells and organs, and in severe situations, may be deadly[5,1]. Lead is a heavy metal that is not biodegradable and is extremely hazardous. It usually enters the human body through tainted drinking water and then travels throughout the body through the bloodstream. The manufacture of paint, pesticides, and mining are common sources of lead pollution[7].

Literature review: Effective remediation strategies are necessary due to the enormous health and environmental dangers posed by heavy metal pollution in wastewater. The significance of eliminating lead from tainted water was underscored by Brooks et al.[4], underscoring the pressing need to tackle heavy metal contamination. Renge et al.'s study[5] of several inexpensive adsorbents for heavy metal removal emphasized the need for economical fixes. Barakat[11] showcased developments in wastewater treatment technologies while talking about new trends in heavy metal removal. Jern[12] emphasized the significance of managing heavy metal contaminants while offering insights into industrial wastewater treatment techniques. Oghenerobor et al.'s investigation[6] into the origins, consequences, and remediation of heavy metal contamination in wastewater emphasized the complex nature of the issue. In their thorough analysis of heavy metal ion removal procedures, Fu and Wang[3] emphasized the need for effective and long-lasting solutions.

The use of improved carbon nanotubes for heavy metal removal was examined critically by Ihsanullah et al.[10], who emphasized the potential uses of these materials for adsorption. Salem et al.'s[1] discussion of the effects of heavy metals in drinking water on the ecosystem emphasized how crucial it is to maintain water safety. Srivastava and Majumder[2] investigated and suggested unique biofiltration techniques for the treatment of heavy metals. Ecological problems were highlighted by Fernandez and Olalla's[7] study on the toxicity and bioaccumulation of lead and cadmium in marine protozoan communities. Gardea-Torresdey et al.'s study[8] highlighted the potential advantages of phytoremediation as a sustainable heavy metal removal method. In their discussion of the effects of nickel on health, Duda-Chodak and Blaszczyk[9] emphasized the necessity of mitigating actions.

Reviewing the impact of heavy metals in drinking water on human health, Mohod and Dhote[13] emphasized the significance of water quality standards. Paulino et al.[14] presented novel materials for wastewater treatment and proposed a unique adsorbent for heavy metal removal. The biotoxic effects of heavy metal pollution on human health were emphasized by Duruibe et al.[15], who advocated for efficient pollution control methods. In their global study of heavy metal pollution in drinking water, Luqueño et al.[16] emphasized the pervasive risk to human health. Regulations are guided by the World Health Organization's recommendations[17], which establish requirements for the quality of drinking water. Naseem and Tahir[18] investigated Pb(II) removal by adsorption techniques, demonstrating the capability of adsorbents such as bentonite. The US Environmental Protection Agency[19] listed the inorganic pollutants, such as heavy metals, that are regulated in drinking water. The removal of chromium (VI) from activated carbons was studied by Khezami and Capart[20], who focused on adsorption kinetics and equilibrium studies. As we indicated in the introduction, a lot of study has been done on the removal of heavy metal contaminants from polluted water.

Methodology

Sampling: Samples of wastewater were taken from the Indore Bhangadh Water Treatment Plant. To record variations in the amounts of heavy metals, samples were taken at various points during the treatment procedure. Using accepted techniques, the wastewater's physicochemical parameters—pH, conductivity, total dissolved solids (TDS), and turbidity—were measured. concentrations of heavy metals, such as lead (Pb). Multiwall carbon nanotubes (MWCNTs), which are readily available in the market, were chosen as the adsorbent for the removal of heavy metals.

To improve their adsorption capabilities and get rid of contaminants, the MWCNTs underwent acid and demonized water pretreatments. The adsorption capacity of MWCNTs for heavy metals was assessed by batch adsorption tests. In each experiment, a specified quantity of pretreated MWCNTs was combined with a known volume of wastewater sample in glass beakers. After that, the beakers were kept on a shaker with continuous agitation for a predetermined amount of time. Over time, samples were analyzed at regular intervals to study the kinetics of adsorption.

The MWCNTs' equilibrium adsorption capacity for every heavy metal was ascertained by charting the adsorption kinetics data and fitting it to various kinetic models, including intra-particle diffusion, pseudo-first-order, and pseudo-second-order models. By altering the starting amounts of heavy metals while holding other factors constant, adsorption isotherms were created. To find adsorption capacities and affinities, the equilibrium adsorption data were fitted to isotherm models such Langmuir, Freundlich, and Temkin.

Study area: The Bhangarh Water Treatment Plant, located in Indore, Madhya Pradesh, India, is a significant facility responsible for purifying water for consumption in the city. Its main objective is to provide clean and safe water using cutting-edge technologies and procedures for Indore's expanding population. The treatment process includes stages like screening, coagulation, flocculation, sedimentation, filtration, and disinfection to eliminate impurities, contaminants, and pollutants from raw water. The treated water is then distributed to residential, commercial, and industrial areas through a network of pipelines. Efficient operation and maintenance of the Bhangarh Water Treatment Plant are crucial to provide continuous access to safe drinking water for Indore's residents. Regular monitoring and quality control measures are implemented to uphold performance and meet established water quality standards.

Samples of wastewater are taken at several points during the treatment process, such as influent, primary, secondary, and effluent, in order to do additional analysis and determine the amounts of pollutants. Filtration Unit it effluent from the sedimentation unit has further treated using filtration techniques. Various filter media, such as sand, activated carbon, or MWCNTs, has employed to remove smaller suspended particles and residual pollutants. MWCNTs have incorporated as a filtration media to assess their efficiency in adsorbing contaminants.

Adsorption Experiments: Batch adsorption experiments have conducted using the synthesized MWCNTs to evaluate their adsorption capacity for specific pollutants present in the wastewater samples. The MWCNTs has added to the wastewater samples in sealed containers and agitated for a specific contact time to allow for adsorption equilibrium. The concentrations of targeted pollutants before and after adsorption have analyzed using appropriate analytical techniques.

Analytical Techniques: The concentrations of pollutants in the wastewater samples, both before and after treatment, have determined using suitable analytical techniques. Depending on the particular pollutants of interest, methods like spectrophotometers, high-performance liquid chromatography, and atomic absorption spectroscopy (AAS) have been used. Quantitative information about the effectiveness of MWCNTs in eliminating contaminants from wastewater has been made available by these analyses.

Assessment of Performance: Based on factors including pollutant removal efficiency, adsorption capacity, and overall treatment process efficiency, the efficacy of MWCNTs in wastewater treatment has been evaluated. The obtained data has compared with results obtained from conventional treatment methods to evaluate the effectiveness of MWCNTs.

Statistical Analysis: Statistical analysis has performed on the data collected from the experimental setup to determine the significance of the results and identify any trends or correlations. This analysis has aid in the interpretation of the experimental findings and provides meaningful conclusions. The laboratory-scale wastewater treatment setup provides a controlled environment to assess the efficiency of MWCNTs in pollutant removal. By integrating MWCNTs into the treatment process and evaluating their performance using appropriate analytical techniques, the effectiveness of MWCNTs as nonmaterial's for wastewater treatment has observed and quantified.

Results and Discussion

Lead Removal Kinetics Using Raw-MWCNTs: At the Bhangarh Water Treatment Plant, two adsorption kinetics models—pseudo-first order and pseudo-second order—were used to evaluate the effectiveness of lead removal using raw-MWCNTs. Table-1 displays the parameters and goodness of fit (R2) for every model.

Model of pseudo-first order: The pseudo-first order model's rate constant (k1) was found to be 0.037 min-1, and its related R2 value was 0.91. According to this model, lead removal using raw-MWCNTs largely follows a first-order kinetic process and shows a strong fit to the experimental results.

Pseudo-second order model: The model produced an excellent fit with an R2 value of 1, and its rate constant (k2) was determined to be 0.108 g/mg.min.

This suggests that a pseudo-second order kinetic model would be a better fit for the adsorption of lead onto raw-MWCNTs, emphasizing the importance of surface complexity and chemical interactions in the adsorption process. Overall, the findings imply that the Bhangarh Water Treatment Plant's wastewater can effectively be treated for lead using both raw and modified MWCNTs.

A more realistic depiction of the adsorption process is given by the pseudo-second order kinetic model, which also emphasizes the significance of surface changes and chemical interactions in raising lead removal efficiency.

These results provide important new information for maximizing lead removal techniques in water treatment procedures, which will eventually guarantee that Indore's citizens have access to clean and safe drinking water.

Table-1: The parameters of two models of adsorption kinetics for the elimination of lead using raw-MWCNTs.

Kinetics of Adsorption Model	Parameters	R^2
First order- Pseudo	k_1=0.037min^{-1}	0.91
Second order- Pseudo	k_2=0.108g/mg.min	1

Lead Removal Kinetics Using Modified MWCNTs: Similarly, the pseudo-first order and pseudo-second order models were used to assess the lead removal kinetics at the Bhangarh Water Treatment Plant utilizing modified MWCNTs. Table-2 summarizes the associated parameters and quality of fit (R2). Model of pseudo-first order: With updated MWCNTs, the pseudo-first order model's rate constant (k1) was determined to be 0.059 min-1, yielding an R2 value of 0.91. Additionally, this model fits the experimental data well, suggesting that the removal of lead using modified MWCNTs is a first-order kinetic process.

Model pseudo-second order: Using modified MWCNTs, the model pseudo-second order's rate constant (k2) was found to be 0.053 g/mg.min. An R2 value of 1 indicated an excellent fit. This demonstrates that modified MWCNTs are effective in adsorbing lead, and a pseudo-second order kinetic model describes the adsorption process well.

Table-2: Parameters for two models of adsorption kinetics that use modified MWCNTs to remove lead.

Kinetics of Adsorption Model	Parameters	R^2
First order- Pseudo	k_1 = 0.059 min-1	0.91
Second order- Pseudo	k_2 = 0.053 g/ mg.min	1

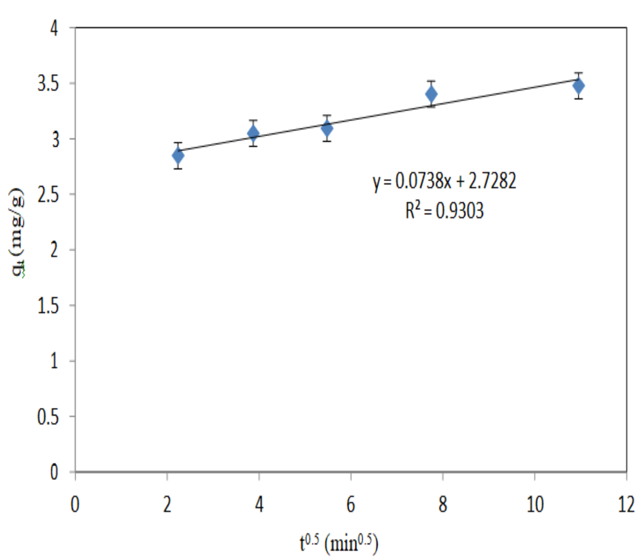

Figure-1: Adsorption kinetics models with raw-MWCNTs for the elimination of lead.

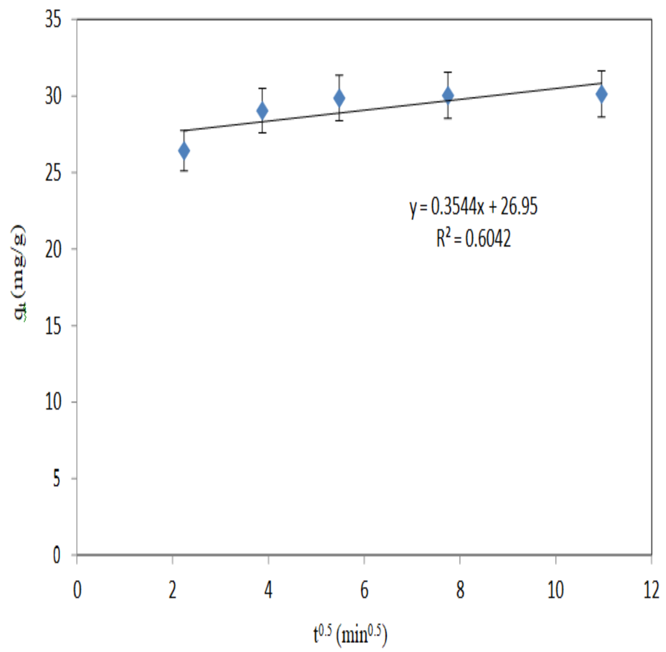

Figure-2: Models of adsorption kinetics for the elimination of lead using modified MWCNTs.

Conclusion

Multiwalled Carbon Nanotubes (MWCNTs) were utilized in a study at the Bhangarh Water Treatment Plant in Indore, Madhya Pradesh, India, to determine how well they removed lead from wastewater. Both raw and adjusted MWCNT adsorption kinetics modeling findings have yielded insightful information regarding the lead removal process. The results show that MWCNTs, both modified and raw, have excellent lead removal capabilities from wastewater, as demonstrated by the good fit of experimental data using pseudo-second order and pseudo-first order kinetics models. With an R2 value of 1, the pseudo-second order kinetic model in particular showed a good fit and suggested that lead is adsorbed onto MWCNTs through a chemically regulated process.

The adsorption effectiveness of MWCNTs is reflected in the rate constants (k1 and k2) derived from the kinetic models; modified MWCNTs exhibit marginally higher values than raw MWCNTs. This demonstrates the possible improvement in lead removal efficiency attained by carbon nanotube surface modification. Overall, the study shows how well MWCNTs remove lead from wastewater and offers insightful data for improving lead removal tactics in water treatment operations. Applying MWCNTs especially when modified can make a big difference in ensuring that Indore's citizens have access to clean, safe drinking water. In the future, improvements in water treatment technologies could result from more study and development of surface modification methods and adsorption kinetics modeling, which would ultimately improve environmental sustainability and public health results.

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