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Production of NiO/CuO Nanocomposite for the Removal of Cr^{6+}, Fe^{3+}, and Pb^{2+} from Pharmaceutical Wastewater

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Abstract

The rise in the discharge of pharmaceutical wastewater in the form of heavy metals Cr^{6+}, Fe^{3+}, and Pb^{2+} has become an issue of serious concern to the environment and to the general population since these elements are toxic, persistent, and may accumulate in the body. Cr(vi), FE(iii) and Pb(ii) are common toxic contaminants in the Pharma effluents and their quick, effective elimination is paramount in regulation compliance and environmental safety. A simple, scalable synthesis of a bimetallic NiO/CuO nanocomposite was reported in this study through a concurrent coprecipitation-hydrothermal reaction, and then subjected to calcination at 400 ^{0} C. This paper is concerned with synthesis and use of nickel oxide/copper oxide (NiO/CuO) nanocomposites to effectively clean such metal ions that are present in pharmaceutical effluents. NiO/CuO nanocomposite was produced by a slight modification of the sol-gel technique and investigated by X-ray diffraction (XRD), and scanning electron microscopy (SEM) to ascertain the structural, morphological and functional characteristics of the material. The effect of pH, contact time and adsorbent dosage on the adsorption efficiency was studied through batch adsorption. It was found that, at a dosage of 0.8 g, the removal efficiencies increase to 100% for Cr, 96.81% for Fe, and 92.40% for Pb. This demonstrates near-complete removal of Cr and very high removal for Fe and Pb, indicating that the adsorption capacity of the nanocomposite is nearing saturation. Kinetics of the adsorption process was in pseudo-second order and adsorbed monolayers on a homogeneous surface which is pointing to Langmuir isotherm. The regeneration studies indicated the multiple adsorption-desorption cycles of the nanocomposite with its stability and reusability. This report establishes the possibilities of NiO/CuO nanocomposites as a powerful, inexpensive, and ecologically safe adsorbent to treat heavy-metal-contaminated pharmaceutical wastewater to be a part of the sustainability of waste sources and pollution prevention.

Keywords: Adsorption, Efficiency, Heavy, Metal, Pharmaceutical, Pollution, Wastewater.

INTRODUCTION

Heavy metal contamination of water has turned out to be a very serious environmental problem especially in the developing nations where contamination of water by industries and pharmaceutical firms is rapidly growing without equal vigorous growth of waste disposal mechanisms (Adnan *et al.*, 2022). It is established that pharmaceutical wastewater is a combination of toxic metals, organic substances and also any remaining drugs that are extremely dangerous to the aquatic life and human health. Of specific concern among the toxic metals are chromium (Cr^{6+}), iron (Fe^{3+}), and lead (Pb^{2+}) because of their persistence, bioaccumulative and possible carcinogenic, mutagenic, and neurotoxic effects (Okoro *et al.*, 2023). Chromium (VI) is extremely toxic and carcinogenic, high levels of iron (III) may result in organ damage, and lead (II) disrupts the development of the nervous system, particularly in children. Traditional waste water treatment methods like chemical precipitation, ion exchange, and membrane filtration are usually restricted in regards to cost, effectiveness and secondary sludge produced. Thus, there has been an urgent need to develop sustainable low-cost efficient treatment materials that will be used to eliminate these toxic metals in the effluent

of pharmaceutical products (Mathew *et al.*, 2024a; Pandey *et al.*, 2024).

Nanotechnology has been discussed as one of the promising solutions to the water pollution problems by designing better nanomaterials in terms of adsorption and catalysis levels. Of particular interest have been metal oxide nanocomposites, which are easy to tune regarding surface chemistry, have a large specific surface area and are more reactive. Nickel oxide (NiO) and copper oxide (CuO) are the two that are effective adsorbents and catalysts in wastewater treatment due to the combination of chemical stability, thermal resistivity, and strong affinity to the heavy metal ion (Inobeme *et al.*, 2023; Saleh, and Hassan, 2023). Forming a single nanocomposite substance as the NiO + CoO can result in synergies, which can enhance the electron transfer, adsorption capacity, and the redox activity. The following properties demonstrate that NiO/CuO nanocomposites are good candidates to effectually eliminate toxic metal ions in the form of Cr^{6+}, Fe^{3+}, and Pb^{2+} in contaminated water systems. Moreover, NiO/CuO nanocomposites synthesis with the help of environmentally friendly and cost-effective strategies gives a way to the sustainable water purification technologies (Al-Yunus *et al.*, 2024).

The paper will synthesize, characterize, and assess the adsorption capacity of NiO /CuO nanocomposites in the elimination of Cr^{6+}, Fe^{3+}, and Pb^{2+} in pharmaceutical wastewater. To identify the crystal structure, surface morphology and functional groups of the synthesized nanocomposite, the use of X-ray diffraction (XRD), fourier-transform infrared spectroscopy (FTIR), and scanning electron microscopy (SEM) will be applied to characterize it. The experiments on adsorption will determine the effect of important variables including pH, contact time, dosage of adsorbent and the concentration of initial metal ion on the removal efficiency. It is expected that the NiO/CuO nanocomposite will have a high sorption capacity, reusability, and stability and is an effective wastewater remover (Etsuyankpa *et al.*, 2024). Finally, the study can enhance the further development of nanotecnology-related environmental remediation strategies, which will be an effective and environmentally friendly way to reduce heavy metal contamination to the environment by pharmaceutical companies and obtain healthier water resources of the population and nature.

MATERIALS AND METHODS

Nickel(II) nitrate hexahydrate [$Ni(NO_3)_2{\cdot}6H_2O$], copper(II) nitrate trihydrate [$Cu(NO_3)_2{\cdot}3H_2O$], sodium hydroxide (NaOH), and ethanol were procured from Sigma-Aldrich (analytical grade) and used without further purification. Distilled water was used for all preparations and rinsing processes. Standard solutions of Cr^{6+}, Fe^{3+}, and Pb^{2+} ions were prepared from potassium dichromate ($K_2Cr_2O_7$), ferric chloride ($FeCl_3$), and lead nitrate [$Pb(NO_3)_2$], respectively. The pharmaceutical wastewater samples were collected from an effluent discharge point of a local drug manufacturing facility.

Synthesis of NiO/CuO Nanocomposite

The NiO/CuO nanocomposite was synthesized via a co-precipitation method due to its simplicity, cost-effectiveness, and control over particle size.0.1 M aqueous solutions of $Ni(NO_3)_2{\cdot}6H_2O$ and $Cu(NO_3)_2{\cdot}3H_2O$ were prepared separately and then mixed in a 1:1 molar ratio under continuous magnetic stirring for 30 minutes at room temperature to obtain a homogeneous mixture. A 1.0 M NaOH solution was added dropwise to the mixed nitrate solution under vigorous stirring until the pH reached approximately 10 (Mathew *et al.*, 2023a). The formation of a dark precipitate indicated the co-precipitation of nickel and copper hydroxides. The resulting suspension was aged for 12 hours at room temperature to allow for complete precipitation and particle growth. The precipitate was then filtered and repeatedly washed with distilled water and ethanol to remove residual ions and impurities. The washed precipitate was dried in an oven at 100 °C for 6 hours. The dried sample was ground into a fine powder and subsequently calcined at 500 °C for 3 hours in a muffle furnace to convert the hydroxides into their corresponding oxides (NiO and CuO) and enhance crystallinity. The obtained black powder was stored in airtight containers for further analysis (Idris *et al.*, 2024; Mathew *et al.*, 2025).

Characterization of Nanoadsorbents

NiO-CuO nanocomposite were analyzed using a range of advanced characterization techniques, including X-ray diffraction (XRD), high-resolution scanning electron microscopy (HRSEM), high-resolution transmission electron microscopy (HRTEM) combined with energy-dispersive X-ray spectroscopy (EDS), and Brunauer–Emmett–Teller (BET) surface area analysis (Musa *et al.*, 2024; Musah *et al.*, 2025).

Batch Adsorption Process

Batch adsorption experiments, including the investigation of contact time, adsorbent dosage, and temperature effects, were conducted following the standard procedures outlined by Mathew *et al.*, (2024c).

Adsorption Isotherms

The isothermal experimental data were evaluated using the Langmuir and Freundlich adsorption models, as described by Mathew *et al.*, (2024b) and Muhammad *et al.*, (2024).

Adsorption Kinetics

The adsorption kinetics of metal ions onto the nanocomposites from wastewater were analyzed using the pseudo-first-order and pseudo-second-order kinetic models (Mathew *et al.*, 2023b; Abdulkadir *et al.*, 2025).

RESULTS AND DISCUSION

The XRD spectrum of NiO-CuO nanocomposite in Fig. 1 exhibits distinct diffraction peaks corresponding to the crystalline planes of NiO and CuO phases. For NiO, the prominent peaks are observed at 2θ values around 37.2°, 43.3°, 62.8°, 75.4°, and 79.4°, which correspond to the (111), (200), (220), (311), and (222) planes, respectively. These peaks are indicative of the face-centered cubic (FCC) structure of NiO. For CuO, the characteristic peaks are found at 2θ values of approximately 38.7° and 66.3° corresponding to the (111) and (311) planes, respectively. These peaks reflect the monoclinic crystal structure of CuO. These peaks in the XRD spectrum confirm the successful synthesis of NiO-CuO nanocomposite, indicating the coexistence of NiO and CuO phases within the composite material. The sharp and well-defined peaks suggest good crystallinity, while the shifts or changes in peak intensity provide insight on the interaction between NiO and CuO in the nanocomposite. Al-Yunus (2024) investigated CuO-NiO nanocomposites and identified monoclinic and cubic phases via XRD analysis. These studies confirm the presence of specific phases in nanocomposite materials, validating the synthesis and characterization of NiO-CuO nanocomposites.

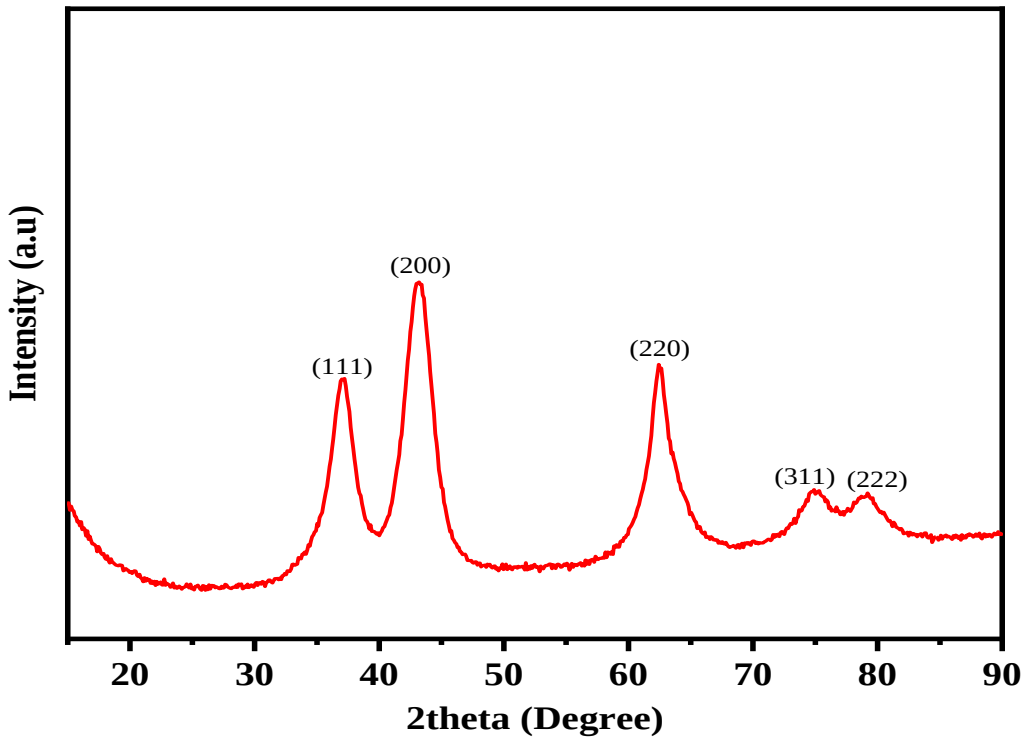

Figure 1: XRD pattern of NiO-CuO nanocomposite

4.1.2 HRSEM/EDS analysis

The HRSEM image of the synthesized NiO-CuO nanocomposite (Fig. 2a) reveals the morphology and surface characteristics of the material, showing a homogenous distribution of the nanoparticles. The image displays spherical or irregularly shaped particles, indicating the successful formation of the nanocomposite. Byeon (2023) studied CuO/rGO nanocomposites, highlighting a well-defined structure and homogeneous distribution of CuO nanoparticles within the nanocomposite. The EDS spectrum provides the elemental composition of the NiO-CuO nanocomposite (Fig. 2b). It typically shows distinct peaks corresponding to nickel (Ni), copper (Cu), and oxygen (O), confirming the presence of these elements in the sample. The relative intensity of the peaks helps understand the elemental distribution and stoichiometry within the nanocomposite, supporting the successful synthesis and composition of NiO-CuO nanostructures. The absence of significant impurities peaks suggests the synthesized nanocomposite's high purity.

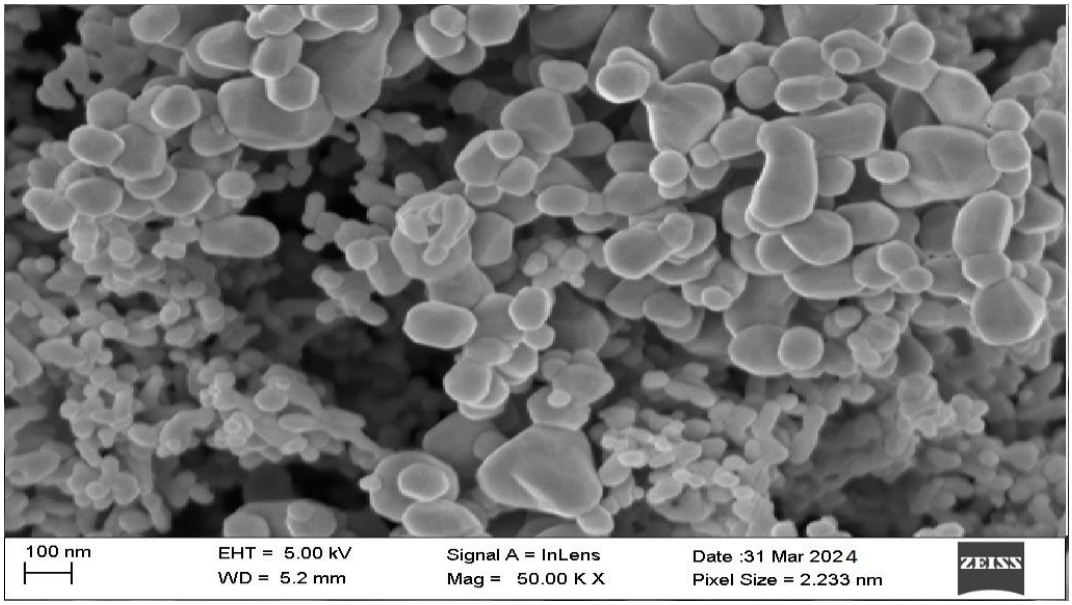

Figure 2(a): HRSEM image of NiO-CuO nanocomposite

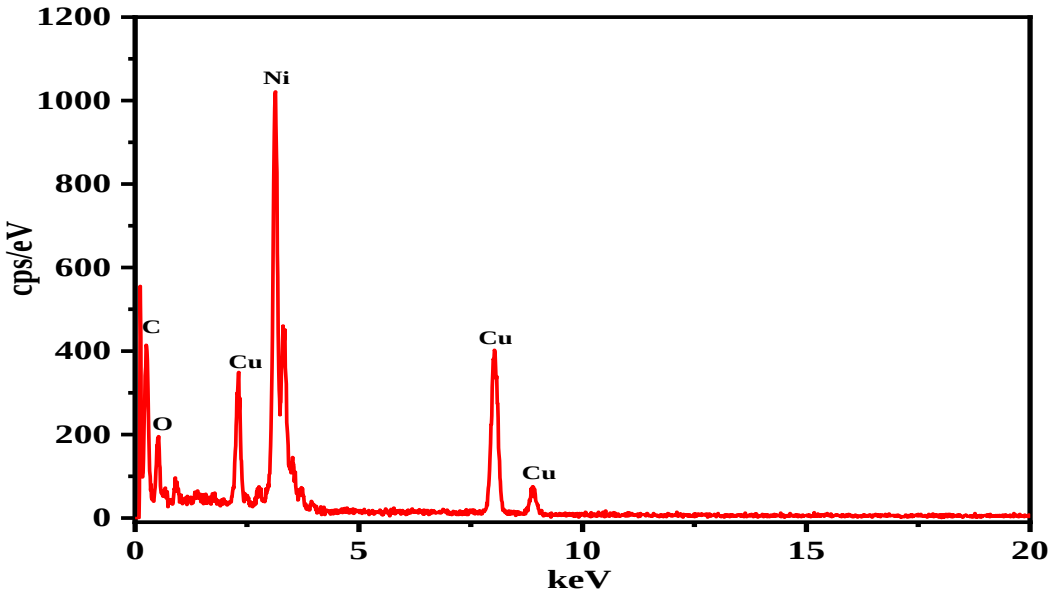

Figure 2(b): EDS spectrum of NiO-CuO nanocomposite

The HRSEM image of the synthesized NiO-CuO nanocomposite reveals a well-defined and uniform morphology (Fig. 3). The nanocomposite consists of closely packed nanostructures with a distinct and homogeneous distribution of nickel oxide (NiO) and copper oxide (CuO) phases. The high resolution of the SEM image highlights the fine details of the surface texture and particle shape, showing that the nanocomposite has a relatively smooth surface with minimal agglomeration. This indicates a successful synthesis process, where the NiO and CuO components potentially increase the material's surface area and reactivity (Ali *et al.*, 2023). The SAED pattern of the synthesized NiO-CuO nanocomposite exhibits distinct diffraction rings, confirming the crystalline nature of the material (Fig. 3). The sharp spots in the pattern indicate high crystallinity of both NiO and CuO phases (Lv and Sun, 2020; Tangcharoen *et al.*, 2022). These diffraction patterns correspond to specific crystallographic planes consistent with the known crystal structures of NiO and CuO (Chakraborty *et al.*, 2018). Sharp and well-defined spots in the SAED pattern suggest that both NiO and CuO phases are highly crystalline. The diffraction rings correspond to specific crystallographic planes, which can be indexed to the known crystal structures of NiO and CuO. The SAED image demonstrates the successful formation of a nanocomposite, where the individual crystalline domains of NiO and CuO are coherently integrated, potentially enhancing the composite's overall physical and chemical properties.

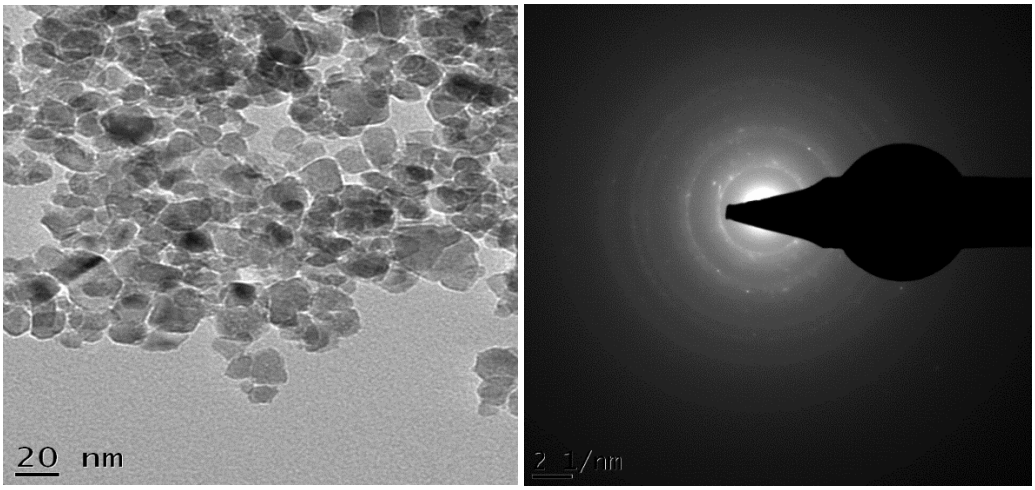

Figure 3: HRTEM and SAED images of NiO-CuO nanocomposite

The effect of contact time on the removal of Cr, Fe, and Pb ions using NiO-CuO nanoparticles from dyeing wastewater is illustrated in Fig. 4. The removal of chromium ions increases steadily from 0% at 0 min to 75.45% at 25 min, indicating that the NiO-CuO nanoparticles are highly effective in adsorbing Cr ions from the wastewater initially. The increase in removal percentage with time suggests that Cr ions occupy more adsorption sites on the nanoparticles as the contact time increases.

Similarly, the removal of iron ions increases from 0% to 68.10% within the same time frame. This trend demonstrates that Fe ions are also effectively adsorbed by the nanoparticles, with more Fe ions being removed as contact time increases, indicating that the adsorption sites are progressively utilized. The removal of lead ions follows the same trend, rising from 0% to 59.30% in 25 min. The increasing removal rate over time shows that Pb ions are successfully adsorbed onto the nanoparticles, utilizing the available adsorption sites. For instance, Ali *et al.* (2023) demonstrated the effectiveness of GO/CuO nanocomposites in adsorbing Ni^{2+} ions. Additionally, Hashem *et al.* (2022) investigated NiO-CuO/Activated Carbon nanocomposites to remove lead and cadmium ions from water, highlighting the potential of such materials for adsorption applications. After reaching a peak removal of 75.45% at 25 min, the removal percentage of Cr ions slightly decreases to 72.30% at 30 min. This decrease could be due to desorption, where Cr ions start detaching from the nanoparticles as the adsorption sites become saturated, or due to equilibrium being reached. For Fe ions, the removal percentage also decreases from 68.10% at 25 min to 63.21% at 30 min. This reduction might be attributed to the same reasons as Cr, where desorption or equilibrium limits further adsorption. Pb ions show a similar trend, decreasing from 59.30% at 25 min to 56.40% at 30 min. The slight reduction indicates that equilibrium is likely being approached, and the available adsorption sites on the nanoparticles are nearly saturated.

Initially, the high availability of active adsorption sites on the NiO-CuO nanoparticles facilitates rapid adsorption of metal ions. As time progresses, these sites get occupied, leading to a slower adsorption rate. The system approaches adsorption equilibrium, where the adsorption rate equals the desorption rate, causing a plateau or slight decrease in removal efficiency. Over time, some adsorbed ions might desorb from the nanoparticles, especially if the adsorption is not strong, leading to the decline in the removal percentage.

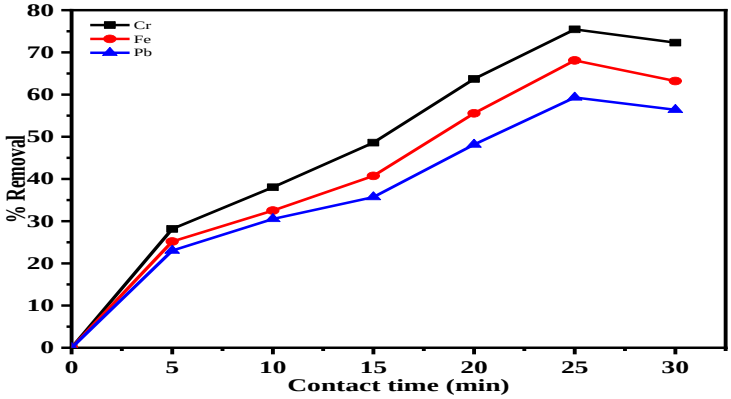

Figure 4: The effect of contact time on the removal of some metal ions using NiO-CuO nanocomposite

The effect of dosage on the removal of Cr, Fe, and Pb ions using NiO-CuO nanocomposite from dyeing wastewater is presented in Fig. 5. As the mass of the nanocomposite increases, the removal efficiency for all three metal ions improves significantly. At a dosage of 0.4 g, the removal efficiencies are 82.15% for Cr, 75.01% for Fe, and 73.11% for Pb, indicating a moderate removal efficiency at the lowest dosage. When the dosage is increased to 0.6 g, the removal efficiencies rise to 92.07% for Cr, 89.65% for Fe, and 88.72% for Pb, suggesting a substantial improvement likely due to the increased availability of active adsorption sites.

At a dosage of 0.8 g, the removal efficiencies increase to 100% for Cr, 96.81% for Fe, and 92.40% for Pb. This demonstrates near-complete removal of Cr and very high removal for Fe and Pb, indicating that the adsorption capacity of the nanocomposite is nearing saturation. At a dosage of 1.0 g, the removal efficiencies reach 100% for all three metal ions, confirming complete removal. This suggests that the NiO-CuO nanocomposite provides sufficient active sites to adsorb all the metal ions in the wastewater at this dosage. The increasing removal efficiencies with higher dosages can be attributed to the greater number of active sites available for adsorption, which enhances the interaction between the metal ions and the nanocomposite. Ahsan *et al.* (2022) demonstrated that NiO/CuO nanocomposites had higher degradation rates for various dyes than individual NiO and CuO nanoparticles, indicating enhanced interaction and adsorption capabilities. Weldekirstos *et al.* (2022) found that NiO/CuO nanocomposites exhibited superior performance in the photocatalytic degradation of methylene blue, further supporting the idea of increased active sites and enhanced metal ion interaction.

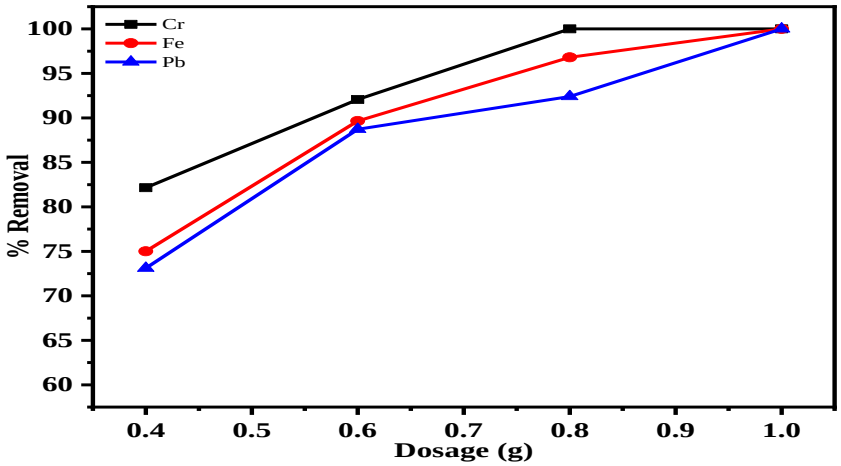

Figure 5: The effect of dosage on the removal of some metal ions using NiO-CuO nanocomposite

The effect of pH on the removal of Cr, Fe, and Pb ions using NiO-CuO nanoparticles from dyeing wastewater is presented in Fig. 6. At pH 2, the removal efficiency of Cr is 50.01%. As the pH increases to 4, the removal efficiency improves to 60.20%. The efficiency continues to increase, reaching 65.14% at pH 6 and peaking at 70.25% at pH 8. However, at pH 10, there is a slight decline to 68.10%. The optimal removal of chromium occurs in slightly basic conditions, likely due to the formation of various chromium species at different pH levels. At higher pH levels, the increased presence of negatively charged hydroxyl ions enhances the adsorption of positively charged chromium ions on the nanocomposite (Sarojini *et al.*, 2021). Beyond a certain pH, the removal efficiency might decrease due to the possible formation of less adsorbable chromium hydroxide precipitates.

The removal efficiency of Fe is 43.70% at pH 2. At pH 4, the efficiency increases to 55.65%. Further increasing the pH to 6 results in 61.40% removal efficiency, with the highest removal efficiency being 63.82% at pH 8. At pH 10, the efficiency slightly drops to 60.31%. Like chromium, removing iron ions is more effective in slightly basic conditions. The enhanced adsorption at higher pH levels is due to the reduced competition between hydrogen ions and metal ions for the active sites on the nanocomposite, leading to better ion exchange and adsorption processes (Zhang *et al.*, 2021). The slight decline at very high pH might be attributed to the formation of iron hydroxides, which are less adsorbable. At pH 2, the removal efficiency of Pb ions is 40.80%. This efficiency increases to 51.65% at pH 4 and rises to 58.12% at pH 6, where the maximum removal efficiency is observed. At pH 8, the efficiency is 57.41%, slightly decreasing to 55.03% at pH 10. The removal of lead ions is influenced by the pH of the solution, with the highest removal efficiency occurring in slightly acidic to neutral conditions (pH 6-8). The reduced efficiency at very low pH can be attributed to the competition between hydrogen and lead ions for adsorption sites (Ghorbani *et al.*, 2020). At very high pH levels, the precipitation of lead as lead hydroxide might reduce the effectiveness of the adsorption process.

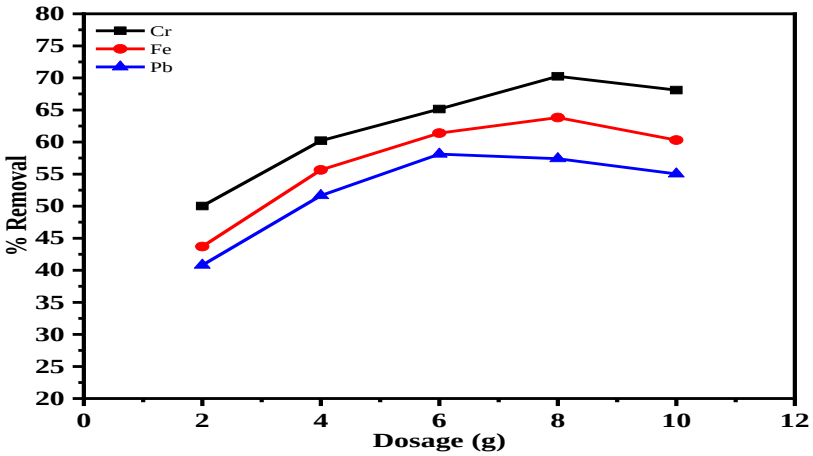

Figure 6: The effect of pH on the removal of some metal ions using NiO-CuO nanocomposite

The adsorption isotherm model for removing Cr, Fe, and Pb ions using NiO-MgO nanoparticles from dyeing wastewater is presented in Table 1. The Freundlich constants (K_F) for Cr, Fe, and Pb are 2.18, 2.04, and 1.97, respectively. This indicates that the adsorption capacity of the NiO-CuO nanocomposite is highest for Cr ions, followed by Fe and Pb. The higher K_F value for Cr suggests a stronger interaction and higher affinity between Cr ions and the nanocomposite surface. The values of 1/n for Cr, Fe, and Pb are 0.35, 0.56, and 0.63, respectively. A lower 1/n value indicates more favorable adsorption, meaning Cr ions are more adsorbed than Fe and Pb ions. The lower 1/n for Cr also implies a more heterogeneous surface for Cr adsorption. The R^2 values for Cr, Fe, and Pb are 0.9518, 0.9430, and 0.9262, respectively. Although all R^2 values are high, indicating a good fit to the Freundlich model, the fit is better for Cr and Fe than Pb, suggesting that the Freundlich model adequately describes the adsorption process for these ions. The maximum adsorption capacities (q_e) for Cr, Fe, and Pb are 43.96 mg/g, 32.50 mg/g, and 27.42 mg/g, respectively. This shows that the nanocomposite has the highest capacity to adsorb Cr ions, followed by Fe and Pb. The significant difference in q_e values suggests that Cr ions have the greatest affinity and saturation capacity on the NiO-CuO nanocomposite. The Langmuir constants (K_L) for Cr, Fe, and Pb are 0.95, 0.80, and 0.67, respectively. Higher K_L values indicate stronger binding affinities, and thus, Cr ions have a higher binding affinity to the adsorbent surface than Fe and Pb ions. The R^2 values for the Langmuir isotherm are 0.9972, 0.9951, and 0.9935 for Cr, Fe, and Pb, respectively. The very high R^2 values indicate an excellent fit of the experimental data to the Langmuir model, suggesting that the adsorption process is monolayer and occurs on a homogeneous surface with finite identical sites (Fagundez *et al.*, 2021). The Langmuir isotherm provides a better fit for all three metal ions, as indicated by the higher R^2 values than the Freundlich isotherm. This suggests that the adsorption of metal ions onto the NiO-CuO nanocomposite occurs predominantly on a homogeneous surface with uniform adsorption sites, leading to monolayer coverage. Cr ions have the highest adsorption capacity and affinity, as shown by the highest q_e and K_F values and the lowest 1/n value. This could be due to the size, charge, or specific interactions between Cr ions and the functional groups on the NiO-CuO nanocomposite. Fe and Pb ions follow a decreasing order of adsorption performance, which can be attributed to their lower affinities and capacities as indicated by their respective isotherm parameters.

Table 1: Adsorption isotherm parameters for the removal of some metal ions in wastewater using NiO-CuO nanocomposite

Isotherm	Parameter	Cr	Fe	Pb
Freundlich	K_F	2.18	2.04	1.97
	$\frac{1}{n}$	0.35	0.56	0.63
	R^2	0.9518	0.9430	0.9262
Langmuir	q_e	43.96	32.50	27.42
	K_L	0.95	0.80	0.67
	R^2	0.9972	0.9951	0.9935

The adsorption kinetic model on removing Cr, Fe, and Pb ions using NiO-CuO nanocomposite from dyeing wastewater is presented in Table 2. The pseudo-first-order model for Cr ions showed the equilibrium adsorption capacity (q_e) is 28.06 mg/g, with a rate constant (k_1) of 0.176 min^{-1} and a correlation coefficient (R^2) of 0.9245. For Fe ions, the qe is 21.42 mg/g, k_1 is 0.105 min^{-1}, and R^2 is 0.9106. For Pb ions, the qe is

15.72 mg/g, k_1 is 0.096 min^{-1}, and R^2 is 0.9037. The R^2 values for all three ions in the pseudo-first-order model are relatively high but not close to 1, suggesting a moderate fit of this model to the experimental data. The pseudo-second-order model for Cr ions indicated the q_e is 40.56 mg/g, with a rate constant (k_2) of 1.19 g/mg/min and a R^2 of 0.9981. For Fe ions, the qe is 30.91 mg/g, k_2 is 1.02 g/mg/min, and R^2 is 0.9972. For Pb ions, the q_e is 25.13 mg/g, k_2 is 0.093 g/mg/min, and R^2 is 0.9961. The R^2 values for all three ions in the pseudo-second-order model are very close to 1, indicating an excellent fit of this model to the experimental data. The pseudo-second-order model typically assumes that the rate-limiting step is chemisorption, involving valence forces through the sharing or exchanging electrons between adsorbent and adsorbate. The high R^2 values for Cr, Fe, and Pb ions suggest that chemisorption is the dominant mechanism for the adsorption process. The higher equilibrium adsorption capacities (q_e) obtained from the pseudo-second-order model compared to the pseudo-first-order model further support the notion that the interaction between NiO-MgO nanoparticles and the metal ions is more accurately described by the former. The rate constants (k_2) in the pseudo-second-order model are significantly higher for Cr and Fe ions, indicating faster adsorption rates, consistent with the high R^2 values. Therefore, the pseudo-second-order kinetic model better describes the adsorption of Cr, Fe, and Pb ions onto NiO-MgO nanoparticles from dyeing wastewater, suggesting that chemisorption primarily controls the process (Chatla *et al.*, 2022).

Table 2: Adsorption kinetic parameters for the removal of some metal ions in wastewater using NiO-CuO nanocomposite

Kinetic	Parameter	Cr	Fe	Pb
Pseudo-first-order	q_e	28.06	21.42	15.72
	k_1	0.176	0.105	0.096
	R^2	0.9245	0.9106	0.9037
Pseudo-second-order	q_e	40.56	30.91	25.13
	k_2	1.19	1.02	0.093
	R^2	0.9981	0.9972	0.9961

CONCLUSION

The experiment showed that the prepared NiO/CuO nanocomposite is a very efficient and viable adsorbent in the purification of pharmaceutical wastewater of toxic heavy metals- Cr^{6+}, Fe^{3+}, and Pb^{2+}. The results of the characterization showed that a well-defined nanocomposite with a high surface area, homogenous morphology and the presence of functional groups which increase the metal ion binding were successfully formed. PH, contact time and adsorbent dosage were the most important parameters that affected adsorption performance of NiO/CuO nanocomposite, and the optimum removal was observed at moderately acidic conditions. The kinetics of adsorption were well described by a pseudo-second-order model, which suggests that predominantly the chemisorption was involved in the removal, and the equilibrium data were consistent with the Langmuir isotherm, which is indicative of monolayer adsorption. In addition, the reuse experiments indicated that the nanocomposite retained high removal capacity in multiple regeneration cycles, thus, highlighting its stability and its possible application at a large scale. All in all, this study shows that NiO/CuO nanocomposites have a potential to become a cost-effective, environmentally friendly, and efficient media in treating wastewater of heavy-metals in pharmaceutical effluents and thus lead to cleaner water production and practices that are sustainable and environmental friendly

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