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REMOVAL OF HEAVY METALS FROM INDUSTRIAL EFFLUENTS BY ADSORPTION USING WASTE MATERIAL AS AN ADSORBENTS

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Abstract:

In addition to posing major risks to human health, the discharge of industrial effluents that include heavy metals also causes significant risks to the environment. This research endeavours to evaluate the feasibility of employing waste materials as adsorbents for the purpose of removing heavy metals from wastewater produced by industrial processes by means of the adsorption process. Among the goals are the development of a technology that is both economically feasible and ecologically sustainable, the optimisation of the adsorption process, and the evaluation of the potential for widespread industrial use. This research tackles the combined difficulty of effectively removing heavy metals and managing trash by reusing waste materials as adsorbents. Examples of waste materials include agricultural leftovers and industrial by-products. The purpose of the study is to make a contribution to sustainability by providing a solution that is both cost-effective and environmentally friendly, and that is also in line with the principles of sustainable resource management and community health protection. By-products of agricultural and industrial waste, such as rice husk and fly ash, have been utilised for the removal of heavy metals from wastewater. This was done in the context of the treatment of wastewater for electroplating businesses by the EL-AHLIA Company, which served as an actual case study. Rice husk was effective in the simultaneous removal of iron, lead, and nickel, while fly ash was effective in the removal of cadmium and copper. The results showed that low-cost adsorbents can be used fruitfully for the removal of heavy metals with a concentration range of 20–60 mg/l. Additionally, research conducted with real wastewater demonstrated that rice husk was effective in the removal of Cd and Cu.

keywords: *Removal, heavy metals, industrial,adsorbents*

Introduction:

Industrial activities frequently result in the production of wastewater that contains a variety of contaminants, including heavy metals. If this wastewater is released without being properly treated, it can represent significant dangers to both the environment and human health. Lead, cadmium, mercury, and chromium are examples of heavy metals. These are compounds that are persistent and poisonous, and they have the potential to accumulate in the environment. This may have negative effects on aquatic ecosystems as well as on human health. For this reason, it is essential to have efficient procedures for the removal of heavy metals from industrial effluents in order to reduce the severity of these negative impacts. Adsorption, which is a process in which pollutants are attracted and attached to the surface of a solid substance known as an adsorbent, is one method that has the potential to be both ecologically acceptable and promising for the removal of heavy metal residues. Due to the fact that it is both economically and environmentally beneficial, the use of waste materials as adsorbents has garnered a lot of interest. This is because it offers a twofold advantage by simultaneously managing trash and cleaning industrial effluents. The removal of heavy metals from wastewater from industrial processes is the primary emphasis of this study, which focuses on the use of waste materials as adsorbents. Through the process of repurposing waste materials, we want to solve two key environmental challenges: the requirement for efficient removal of heavy metals and the management of trash created by a variety of businesses, either through correct disposal or use.

Environmental Protection:

To develop a cost-effective and sustainable method for the removal of heavy metals from industrial effluents, reducing the environmental impact of metal-contaminated wastewater discharges.

Waste Utilization:

To explore the potential of waste materials, such as agricultural residues, industrial by-products, or discarded materials, as efficient adsorbents for heavy metal removal.

Economic Viability:

To assess the economic feasibility of using waste materials as adsorbents compared to traditional methods, considering both the cost of adsorbent preparation and the overall treatment process.

Optimization of Adsorption Process: To optimize the adsorption process by investigating factors such as adsorbent dosage, contact time, pH, and temperature to enhance the efficiency of heavy metal removal.

Sustainability:

The use of waste materials as adsorbents aligns with the principles of sustainability, offering an eco-friendly solution for waste management and water treatment.

Resource Conservation:

By utilizing waste materials for heavy metal removal, this research contributes to the conservation of natural resources that would otherwise be used in the production of conventional adsorbents.

Industrial Application:

The findings of this study have the potential for practical implementation in various industries, providing them with an affordable and sustainable method for treating their wastewater and meeting environmental regulations.

Community Health:

The reduction of heavy metal discharge into water bodies through effective adsorption can contribute to safeguarding the health of communities living in proximity to industrial areas.

Overview of adsorption process

Surface phenomena known as adsorption take place when an adsorbate-containing solution is adsorbed onto the surface of an adsorbtive substance. There are two main ways in which adsorption occurs: physiosorption, in which the adsorbate physically binds to the adsorbent through the action of van der Waals forces, and chemisorption, in which the adsorbate and adsorbent interact chemically. Physiosorption is a weaker process that frequently consumes endothermic energy; in contrast, chemisorption is irreversible, selective, and exothermic.

Adsorption isotherm and models

The amount of the solute adsorbed on the surface of the adsorbent per unit weight may be estimated using adsorption isotherms, which are representations that depend on equilibrium concentration at a constant temperature. Finding the adsorbed quantity of the solute accomplishes this. The Freundlich and Langmuir isotherms are the most commonly used to describe the adsorption process. In addition to these models, we also use Redlich and Peterson Radke, Prausnitz Sips Toth, and Koble and Corrigan.

Types of adsorbents

The most common way to classify adsorbents is by their source, which can be either naturally occurring or artificially produced. As an illustration, zeolites, clays, minerals, charcoal, and ores are all forms of naturally occurring adsorbents. In contrast, synthetic adsorbents are produced from many types of waste, including those originating from factories, farms, and other comparable sources.

Removal of heavy metals from wastewater by adsorption

It is widely believed that adsorption is the most efficient and cost-effective method currently available for removing heavy metals from wastewater. As its main advantage, this technique allows for the production of high-quality effluent. Advantageously compared to other heavy metal removal technologies, adsorption is a more cost-effective option. The majority of the time, the adsorbent can still be recycled and used again. The fact that adsorption is both easy to implement and emits zero hazardous emissions makes it an environmentally friendly technology. Adsorbents should be chosen based on their polarity, distribution of functional groups, cost-effectiveness, high surface area and porosity, and other relevant properties. Conventional and commercial adsorbents are composed of chemicals such activated carbon, zeolites, graphenes, fullerenes, and carbon nanotubes. The great adsorption effectiveness of carbons and their derivatives makes them the most used adsorbents. Because of their structural features, which give them a large surface area and make simple chemical changes possible, they are very capable. Because of this, a wide spectrum of pollutants may tolerate them. There are several limitations to the use of activated carbons due to their negative characteristics. Because of the high production cost, the difficulty in disposing of spent activated carbon, and the time and effort required for regeneration, they are not cost-effective. Consequently, there was a flurry of activity on the topic of affordable adsorbents. Because they have a range of structures that bind the pollutant ions, the non-conventional adsorbents are easily available, cheap, and possess a high complexing capacity. These garbage items include agricultural waste, industrial waste sludge, and wasted slurry.

Activated carbon adsorbents

Active carbon (AC) is one of the most widely used adsorbents due to its huge surface area, high efficiency, and porosity. It is expensive and has limited uses as it is mass-produced in a factory by carbonising resources like coal and wood. Their principal production process involves the pyrolysis of carbonaceous materials at temperatures below 1000 degrees Celsius. The raw material undergoes carbonisation in an oxygen-free atmosphere at temperatures below 800 degrees Celsius. Activation, the second step in making activated carbon, involves heating the finished product to temperatures between 950 and 1000 degrees Celsius. Consequently, most carbonaceous materials may be used to make activated carbon; however, the characteristics of the final product will depend on the materials used and the conditions it is made under. Activated carbon adsorbent mostly consists of carbon, but it also contains other elements including hydrogen, oxygen, sulphur, and nitrogen. Depending on the situation, they can be made either granular or powdered. When compared side by side, the granular one has a large interior surface area but few holes, whereas the powdered one is much smaller but has more pores. What makes activated carbon so effective as an adsorptive is not just its chemical make-up but also its high porosity and surface area. As a result, the cost-effectiveness of activated carbon synthesis is being enhanced by exploring additional low-cost raw sources, such as agricultural output waste.

Using AC derived from hazelnut shell, Kobya was able to adsorpt Cr4+ from water-based solutions to a maximum of 170 mg/g, even at a pH of 1.0. Other adsorbents, such wood AC and coconut shell, removed 58.5 and 87.6 mg/g of the material, respectively, but this one removed more. Karthikeyan and colleagues looked into the possibility of using activated carbon made from wood saw dust to remove Cr6+ from wastewater. The maximum adsorption capacity of Cr6+, 44 mg/g, was achieved when the pH was at 2.0. Compared to other adsorbents, such as sugarcane bagasse, processed sawdust from Indian rose wood, carbon recovered from coconut shells, and sawdust from coconut trees, these findings were significantly better. The maximum amounts of adsorption that were found in four separate studies were 10.88, 10.3, 3.60, and 13.40 mg/g, respectively. The AC that Kongsuwan et al. developed for the removal of copper and lead ions from weakly acidic wastewater included eucalyptus bark. In contrast, Cu2+ and Pb2+ both have their maximum adsorption capacities at 0.45 and 0.53 mmol/g, respectively. The use of AC derived from pomegranate peel for the removal of Cu2+ and Pb2+ from water-based solutions was studied by El-Ashtoukhy and colleagues. To learn about the connection between adsorbent dosage, contact duration, and pH, batch adsorption experiments were conducted. After 120 minutes, the removal of both metals reached a saturation point, with Cu2+ and Pb2+ requiring an ideal pH of 5.8 and 5.6, respectively. A study was carried out by Kavand et al. about the adsorptive removal of lead, cadmium, and nickel from water solutions using granulated activated carbon. The removal was performed in the following numerical order: Pb2+ > Cd2+ > Ni2+, at an ideal pH of 2, with an adsorbent dose of 2g/L and a contact duration of 80 minutes. Kim et al. conducted a study to determine the efficacy of decontaminating electroplating effluent for Zn2+, Ni2+, and Cr2+ removal. For this study, we used both the original AC powder and a modified version of it. When the pH was neutral, the two adsorbents had a removal effectiveness of about 90%.

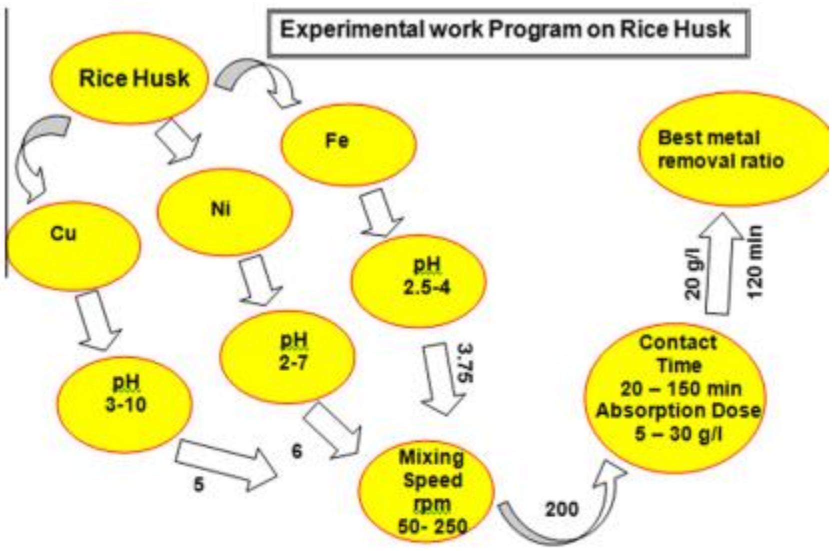

Fig. 1 Rice husk is the subject of an experimental work programme.

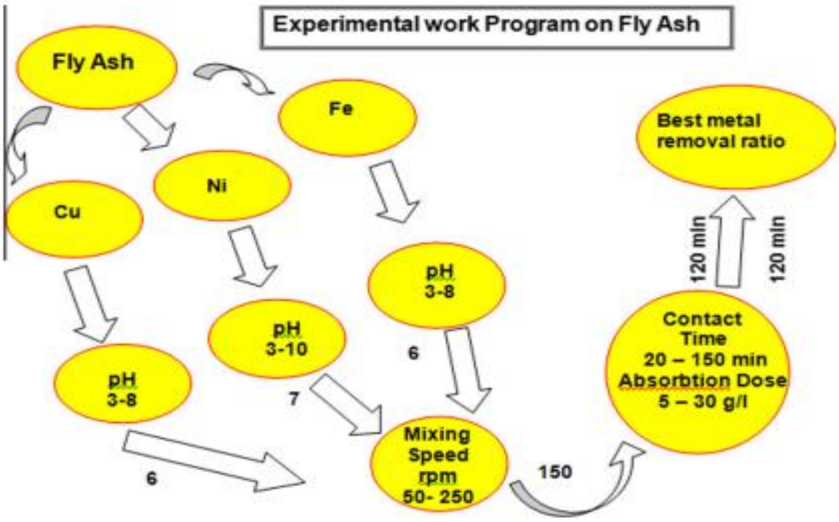

Fig. 2 The experimental work programme for fly ash.

Materials

To examine the adsorption of heavy metal ions by low-cost adsorbents under a range of conditions, including pH, heavy metal concentration, mixing speed, and adsorbent dose, studies were conducted using kinetic and isotherm techniques. These methods were utilised to conduct the research. In addition to this, the ideal removal condition for every metal ion was identified and analysed. Table 1 provides an overview of the major consistent, primary source, physical structure, chemical characterization, and primary function of low-cost adsorbents such as rice husk and fly ash. Additional information is also included in the table. Please see Figures 1 and 2 for any further information that you may want.

Batch study (synthetic wastewater)

The procedure for making solutions of copper, nickel, and iron involved dissolving the following in double-distilled water: copper sulphate (CuSO4Æ5H2O), nickel nitrate (NiNO3)2Æ6H2O, and iron sulphate (FeSO4Æ7H2O). In doing so, we were able to produce synthetic wastewater with the correct amounts of metal ions. All of the investigations were conducted in triplicate and managed to obtain a relative standard deviation of less than 5%. The standard operating procedure for the sorption process called for an agitation speed of 200 rpm and a dose of 20 mg/l of adsorbent in a solution containing 10 mg/l of a concentration metal (Cu, Ni, Fe). I kept the adsorbent in the solution for 20 minutes at a temperature of 25 ± 3 degrees Celsius.To study how pH affects sorption, the pH of the solution containing metal ions was adjusted to a range of 2–10. The solution was pre-experimented with CuSO4.5H2O, (NiNO3)2Æ6-H2O, and FeSO2.7H2O to achieve this. The Langmuir isotherms were generated by bringing metal ion solutions to equilibrium with different adsorbent doses (from 5 to 30 mg/l) at equilibrium pH and rpm for different durations (from 20 to 150 minutes). At room temperature, the metal content was maintained at 10 mg/l. An experiment was conducted to study the effect of agitation rate on metal ion absorption. The adsorbent dose was 20 mg/l, and the experiment was run at equilibrium pH and rpm for 20 minutes. The concentration of the adsorbent was 5-30 mg/l, and the room temperature was maintained throughout. There was a range of 50 to 200 rpm for the agitation rate.

Case of study: wastewater treatment in the electroplating industry at EL-AHLIA Company

Daily, the EL-AHLIA Company is believed to produce 750 cubic metres of wastewater, which is then discharged into the Abozabal sewage system via the Ismailia canal. The electroplating department's 250 cubic metres of effluent per day is the main source of pollution in this company. The rinse water that has not been treated has high concentrations of nickel, copper, iron, lead, and cadmium. Figure 3 shows that the corresponding values were as high as 11.78, 1.17, 0.48, 5.43, and 1.74 mg/l.

Results and discussion

Various absorbent weights for Fe removal

In Table 3, the influence of the quantity of adsorbent on the removal of Fe ions by rice husk is depicted for a variety of adsorbent doses, including 20, 30, 40, 50, and 60 mg/l. This allows for a more comprehensive understanding of the relationship between the two. This shows that the quantity of absorbent concentration increased, as evidenced by the fact that the elimination of iron through the utilisation of rice husk rose from 68.59% to 99.25%. On the other hand, the removal of iron by the use of fly ash varied from 46.18 percent to 86.75 percent.

Pb removal by different weights of absorbents

Within the context of the removal of lead ions by rice husk, Table 4 indicates the impact that the quantity of adsorbent has on the process. A wide range of adsorbent doses, including 20, 30, 40, 50, and 60 mg/l concentrations, are included in the table. The proportion of lead that was eliminated by the utilisation of rice husk increased from 22.22 percent to 87.17 percent, which is indicative of an increase in the amount of absorbent concentration. On the other hand, the number of lead atoms that were eliminated by the use of fly ash varied from 21.79% to 76.06%.

Cd removal by different weights of absorbents

Table 5 indicates how the quantity of adsorbent impacts the removal of Cd ions by rice husk at different doses of 20, 30, 40, 50, and 60 mg/l. These dosages are shown in the data shown in the table. A record of the outcomes of the experiment is also included in the table. The amount of cadmium that was removed by the utilisation of rice husk increased from 26.04% to 67.917%, which implies that the quantity of absorbent concentration saw an increase. In contrast, the removal of cadmium by the utilisation of fly ash ranged from 25.21 percent to 73.5 percent throughout the board.

Cu removal by different weights of absorbents

Within the context of the removal of copper ions by rice husk, Table 5 indicates the impact that the quantity of adsorbent has on the process. The following adsorbent doses are included in the table: 20, 30, 40, 50, and 60 mg/l. The chart also includes all relevant information. The level of copper removal achieved by the utilisation of rice husk went from 24.49% to 98.177%, which is indicative of an increase in the quantity of absorbent concentration. The removal of copper by the use of fly ash, on the other hand, ranged from 37.38 percent to 98.45 percent (according to Table 6).

Ni removal by different weights of absorbents

The data presented in Table 5 illustrates how the quantity of adsorbent affects the removal of nickel ions by rice husk at various concentrations of 20, 30, 40, 50, and 60 mg/l. There are additional doses of adsorbent that are included in the chart as well. In addition, the table contains a record of the results of the experiment that was carried out. The elimination of nickel increased from 94.885% to 96.954% as a result of the utilisation of rice husk, which is indicative of an increase in the quantity of absorbent concentration that was accomplished. On the other hand, the removal of nickel by the use of fly ash ranged from 94.540% to 96.034% (for more information, please refer to Figures 4–7 and Table 6).

Table1 Programmer of work that is experimental(syntheticwater).

Lowcostadsorption	Run	Metals	pH	Mixingspeed(rpm)	Contacttime(min)	Adsorbentdose(g/l)
Ricehusk	1	Cu	3:10	200	20	10
	2		5	50:250	20	10
	3		5	200	20:150	5:30
	4		5	200	120	20
	5	Ni	2:7	200	20	10
	6		6	50:250	20	10
	7		6	200	20:150	5:30
	8		6	200	120	20
	9	Fe	2.5:4	200	20	10
	10		3.75	50:250	20	10
	11		3.75	200	20:150	5:30
	12		3.75	200	120	20
Flyash	13	Cu	3:8	200	20	10
	14		6	50:250	20	10
	15		6	150	20:150	5:40
	16		6	150	120	20
	17	Ni	3:10	200	20	10
	18		7	50–250	20	10
	19		7	150	20:150	5:40
	20		7	150	120	20

	21	Fe	3:8	200	20	10
	22		6	50:250	20	10
	23		6	150	20:150	5:40
	24		6	150	120	20

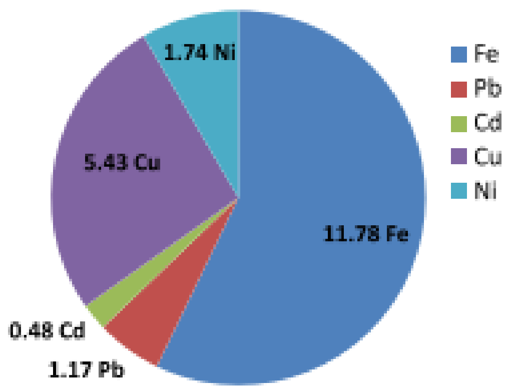

Fig. 3 El-AHLIA wastewater contains a high proportion of heavy metals.

Table 2Looking at how different absorbent doses remove iron

Heavymetal	Adsorbent dose	In-Femg/l	Ricehusk			Flyash	
			Outlet-Femg/l	Removal ratio%		Outlet-Femg/l	Removalratio%
Fe	20	11.78	3.7	68.59		6.34	46.18
	30	11.78	2.1	82.17		4.9	58.4
	40	11.78	1.2	89.81		4.1	65.2
	50	11.78	0.09	99.236		2.97	74.788
	60	11.78	0.088	99.253		1.56	86.757

Table 3Dosage of absorbents and their impact on lead removal effectiveness.

Heavy metal	Adsorbent dose	In-Pbmg/l	Ricehusk			Flyash	
			Outlet-Pbmg/l	Removal ratio%		Outlet-Pbmg/l	Removalratio%

Pb	20	1.17	0.91	22.22		0.92	21.79
	30	1.17	0.66	43.59		0.7	40.17
	40	1.17	0.38	67.52		0.46	60.68
	50	1.17	0.28	76.068		0.33	71.795
	60	1.17	0.15	87.179		0.28	76.068

Table 4How well does cadmium removal work with different absorbent doses?

Heavy metal	Adsorbent dose	In-Cdmg/l	Ricehusk			Flyash	
			Outlet-Cdmg/l	Removal ratio%		Outlet-Cdmg/l	Removalr atio%
Cd	20	0.48	0.36	26.04		0.36	25.21
	30	0.48	0.31	35.42		0.30	37.50
	40	0.48	0.24	50.00		0.23	52.08
	50	0.48	0.190	60.417		0.180	62.500
	60	0.48	0.154	67.917		0.127	73.542

Table 5Copper removal efficiency across different absorbent doses.

Heavym etal	Adsorbentd ose	In-Cumg/l	Ricehusk			Flyash	
			Outlet-Cumg/l	Removalra tio%		Outlet-Cumg/l	Removalrat io%
Cu	20	5.43	4.10	24.49		3.40	37.38
	30	5.43	2.84	47.70		1.81	66.67
	40	5.43	1.83	66.30		1.01	81.40
	50	5.43	1.210	77.716		0.089	98.361
	60	5.43	0.099	98.177		0.079	98.545

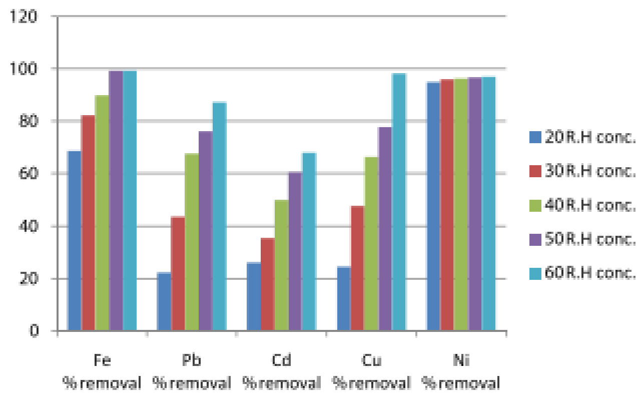

Fig. 4 The husk of rice is an efficient solvent for removing several heavy metals.

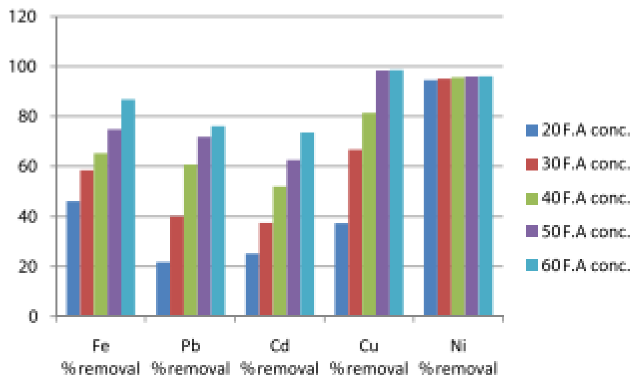

Fig. 5 Efficiency of removal of a variety of heavy metals by the use of fly ash.

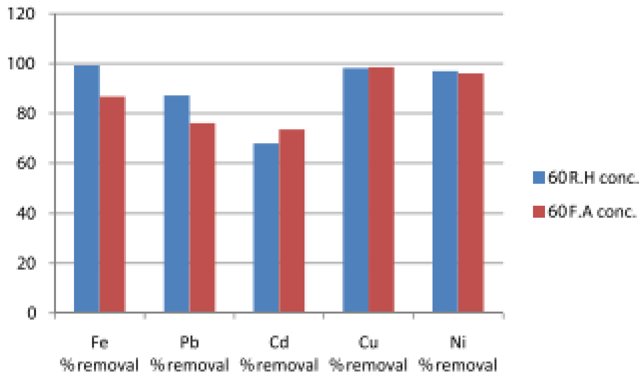

Fig. 6 Comparative analysis of the removal effectiveness of rice husk and fly ash at an absorbent concentration of sixty milligrammes per litre.

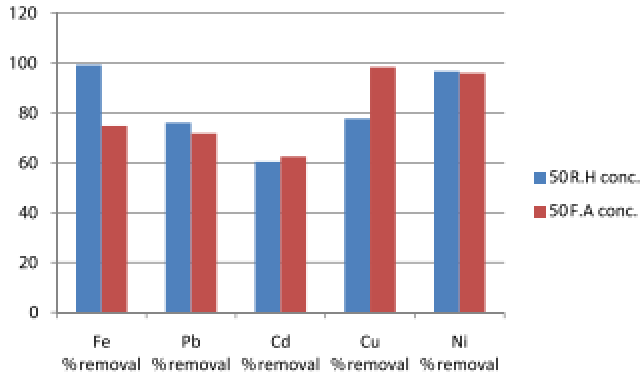

Fig. 7 When the absorbent concentration was 50 mg/l, a comparison was made between the removal effectiveness of rice husk and fly ash.

Adsorption batch experiments

In order to carry out adsorption batch tests, a series of bottles containing various quantities of each of the compounds were shaken in succession.

Table 6 Raising the efficacy of Ni removal across doses of absorbent.

Heavymetal	Adsorbent dose	In-Nimg/l	Ricehusk			Flyash	
			Outlet-Nimg/l	Removal ratio%		Outlet-Nimg/l	Removalratio%
Ni	20	1.74	0.089	94.885		0.095	94.540
	30	1.74	0.071	95.920		0.085	95.115
	40	1.74	0.065	96.264		0.076	95.632
	50	1.74	0.058	96.667		0.070	95.977
	60	1.74	0.053	96.954		0.069	96.034

There are several different adsorbents and heavy metal ions with different pH levels. The slurry was subjected to agitation in a shaking bath at a temperature of 25 ± 3 degrees Celsius for twenty minutes until its pH was stabilised after its pH had been adjusted to an ideal range of 2-10. Copper ions ($CuSO_4.5H_2O$), iron ions ($(NiNO_3)_2.6H_2O$), and copper ions ($FeSO_4.7H_2O$) were subsequently added to the bottles. The goal was to determine starting concentrations between 5 and 30 mg/L. Once balance was reached, the bottles were agitated for another two to three hours. For the purpose of determining the sample's residual heavy metal concentration, an atomic absorption spectrometer was employed. Along with adsorption testing, we also conducted a battery of inexpensive blank experiments to see how well metal hydroxide precipitation removed contaminants at different pH levels. Details of the experimental work programme, including the adsorbent dose, contact duration, and mixing speed, are shown in Table 2.

Conclusion

Ultimately, this project aims to explore and validate the potential of using waste materials as adsorbents to extract heavy metals from industrial effluents. Finding a long-term solution to water purification that doesn't harm the environment is the main goal of this research. The research concluded that low-cost adsorbents might be useful for heavy metal removal from solutions with concentrations between 20 and 60 mg/l. The results of the experiment using real wastewater showed that rice husk worked well for the simultaneous removal of Fe, Pb, and Ni, whereas fly ash worked well for the removal of Cd and Cu. It was found that the percentage of heavy metals eliminated depended on the concentration of the adsorbent as well as the quantity of the affordable adsorbent.

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