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Heavy metals remediation in stale foundry effluent with Activated Charcoal-250

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Abstract: *The menace of wastewater pollution in the 21st century is becoming alarming. Application of the low-cost adsorbents for wastewater treatment has received more attention this moment in environmental history than never. Therefore, remediating stale foundry wastewater with Activated Carbon, AC-250 is the focus of this study. Wastewater samples were collected from Lamina Foundry, Nitte, Karnataka State, India and were subjected to Atomic Absorption Spectrophotometry (AAS) analysis. The analysis identified the prominent heavy metals (Zn, Cu, Mg, and Pb) present in the stale foundry effluent, determined their respective concentrations and treated them using the commercially sourced activated charcoal, AC-250. Effects of four (4) factors viz: adsorbent dosage, contact time, stirring speed and pH on the adsorption process during the wastewater treatment were studied. Optimum conditions required for the most efficient treatment of the wastewater and the treatment cost estimates were determined. The AC-250 is found as efficient in adsorption of the heavy metals from foundry wastewater. In some of the cases a 100% removal is possible, especially with Pb. The analysis of the major experiments on effects of adsorbent dosage, contact time rotating speed and pH on the adsorption process, gave the optimum conditions for removal under which the most efficient treatment of the wastewater containing studied heavy metals was possible. For the optimum treatment conditions, an adsorbent dosage of 1 g, a contact time of 120 minutes, a rotating/agitation speed of 350 rpm and a pH value of 6 are established. An average cost of treating 1 litre of stale foundry wastewater is Rs 23 or 0.4 USD. This study therefore recommends AC-250 as an efficient adsorbent at the given optimum conditions for stale foundry wastewater. The reuse of AC-250 via the process of thermal reactivation at 800^{0}C is encouraged as a means of waste management.*

Keywords: Activated Carbon-250, remediation, wastewater, heavy metals.

INTRODUCTION

Discharging industrial wastewater containing different pollutants can lead to the contamination of environment and disorder in its ecosystem. Increment and development of the alloy and leather industries, metal galvanizations, laundries, electroplating firms, all result in significant increase of heavy metals ion concentration in the industrial wastewater. Accumulation of these metals ion in human body can lead to severe disorders in the performance of kidneys, liver, sexual organs, brain and nervous systems. Direct discharge of wastewater containing heavy metals into municipal waste water collection system can equally damage biological treatment units and produce active sludge which in turn can destroy the agricultural products. Since heavy metals are non-biodegradable, they are stored in the living tissues and enter the food chain of plants, animals and human beings. Therefore with regard to the numerous disadvantages of heavy metals, their removal from industrial wastewater is an essential environmental requirement.

In recent times, efforts have been made to employ cheaper and more effective organic materials, agricultural wastes, and related compounds as adsorbents [1]. Activated Carbon (AC) is one of the most applicable adsorbents in common use for wastewater

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treatment processes since 1883. AC, also called activated charcoal, activated coal, or *carbo activatus*, is a form of carbon processed to have small, low-volume pores that increase the surface area available for adsorption or chemical reaction [2]. AC is usually derived from charcoal and high-porosity bio-char. Due to its high degree of micro porosity, just one gram of activated carbon has a surface area in excess of 500 m^2, as determined by gas adsorption. An activation level sufficient for useful application may be attained solely from high surface area; however, further chemical treatment often enhances adsorption properties. AC is used as an appropriate adsorbent in removing different pollutants, particularly heavy metals.

Activated charcoal is good at trapping other carbon-based impurities as well as things like chlorine. Many other chemicals are not attracted to carbon at all sodium, nitrates, etc., so they pass right through. This means that an activated charcoal filter will remove certain impurities while ignoring others [3]. Nowadays, activated carbon finds wide application in the treatment of wastewater generated from industries such as food, textile, chemical, pharmaceutical, pesticides and herbicides production, coke plant, munitions factories, petroleum refineries and storage installations, organic pigments and dyes, mineral processing plants, insecticides, pesticides, resins, detergents, explosives, and dyestuffs. It is also employed in the treatment of sanitary and hazardous landfill leachates [4].

This study identified the heavy metals present in the stale foundry effluent, determined their respective amounts and treated them using the commercially sourced activated charcoal, AC-250. Also examined were the effects of various factors such as adsorbent dosage, contact time, stirring speed and pH on the adsorption process during the treatment of the wastewater. And finally it established the optimum conditions required for the most efficient treatment of the wastewater. The sampling station was the outlet sump of the Lamina Foundry, Nitte, Karnataka State, India. The effluent was kept at room temperature for 4 weeks before the commencement of the study to ensure it was stale.

Methodology

(a) AAS analysis for initial concentration of foundry effluent: The untreated Lamina Foundry effluent sample was subjected to AAS (Atomic Absorption Spectroscopy) analysis conducted in the Flame atomic absorption spectroscope of the Department of Biotechnology Engineering, NMAM Institute of Technology, Nitte, Karnataka State, India. The AAS experiment on the untreated lamina foundry effluent gave information regarding the heavy metals present in them and their amount.

Figure 1: AAS Analysis of the untreated Effluent

One-factor-at-a-time (OFAT) treatment experiments: The effluent was treated using the purified AC. Four different types of experiments were conducted in order to determine the effect of contact time, pH, adsorbent dosage and rotating/stirring speed on the adsorption of heavy metals by the AC-250.

(i) Experimental study of the adsorbent dosage effect on the treatment process: Five conical flasks of 100ml volume were taken and were labelled from 1 to 5.Then in each of the flasks 50ml of the untreated foundry effluent were put. After this 0.2, 0.4, 0.6, 0.8 and 1.0 g of the AC were added to the 5 respective conical flasks.

Figure 2. Foundry effluent being treated with different adsorbent dosages

The flasks were then placed in a rotary incubator shaker and agitated at a speed of 150 rpm for 1 hour at a room temperature of 32^0C. The filtrate from each flask was collected in a test tube and the mouth of the test tube and subjected to AAS analysis.

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Figure 3. Foundry effluent being rotated at 150 rpm in mechanical shaker

(ii) Experimental study of the contact time effect on the treatment process: Six conical flasks had 50 ml of the untreated foundry effluent added to each of them, and with 0.2g of AC-250. The flasks were placed in a mechanical shaker one after the other and were agitated at 150 rpm for different selected contact times of 20, 40, 60, 80, 100 and 120 min. The filtrate from the content of each flask was collected and subjected to AAS analysis.

(iii) Experimental study of the rotating speed effect on the treatment process: 1 g each of the AC was added 5 conical flasks of 50 ml wastewater. The conical flasks were placed in a mechanical shaker in turns and rotated at the desired speed ranging from 150 to 350 rpm.

Figure 4: Foundry effluent being rotated at different speed

(iv) **Experimental study of pH effect on the treatment process:** The effect of pH on the adsorption of metal ions was studied over a pH range of 2 to 6. Three conical flasks were filled with 50 ml of the untreated foundry effluent. 1 g of the AC-250 was added to each of them. The pH of the contents in the three conical flasks was adjusted and maintained at 2, 4 and 6 respectively. The flasks contents were agitated in a mechanical shaker at 150 rpm for an hour. The filtrate of each flask was then subjected to AAS analysis.

Results and Discussion

The results of laboratory experiments/analyses are as presented and discussed below:

Untreated foundry effluent:

The AAS analysis conducted on the untreated Lamina foundry effluent showed the presence of Zn, Cu, Mg and Pb. The concentration levels of these metals obtained are presented in Table 1. Figure 5 shows that Mg is dominant while the presence of Pb is at the minimum level.

Adsorption study on the wastewater

Table 2 and Figure 6 contain the results and graphical representation respectively, of the adsorption.

In all the dosage concentrations Cu was totally adsorbed by AC-250. At the 0.2 g dosage, 100% of Cu was removed while the complete adsorption of Pb commenced from 0.6 g dosage. Zn and Mg were equally removed with Mg having the least removal efficiency of 60% in all concentrations. The maximum efficiency in AC-250 treatment of the stale foundry effluent was obtained at an adsorbent dosage of 1 g. The efficiency of treatment increases with the adsorbent dosage.

Effect of contact time on the treatment process

The pattern of treatment based on the effect of contact time of the adsorbent with wastewater is as shown on Table 3 and Figure 7.

It is observed that in virtually all the treatment cases the removal efficiencies increase with the contact time. Pb however had 100% removal right from the 60 mins contact time. The maximum efficiency in the treatment was obtained at a contact time of 120 minutes for all the studied metals.

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Effect of rotating/stirring speed on the treatment process:
Results of the rotating speed and the metal remediation are presented on Table 4 and Figure 8. Pb was totally removed right from 200 rpm while other metals show percent increase in removal with the agitation increase. Mg was however least removed with increasing stirring speed.

Effect of pH on the treatment process
The effects of pH on the adsoption process using AC-250 are presented on Table 6 and in Figure 9. The metal removal efficiency is observed to increase with pH increase except in the case of Pb where the pattern appears undefined.

Optimum foundry wastewater treatment conditions for the AC-250
The activated charcoal-250 is found as an efficient adsorbent in treating the stale foundry wastewater. The optimum conditions in required for the most efficient treatment of 50mL of the studied Lamina foundry effluent containing Zn, Cu, Mg and Pb present in 0.552, 1.283, 2.647 and 0.068 mg/L respectively are:

1. An adsorbent dosage of 1 gram
2. A contact time of 120 minutes
3. A rotating/agitation speed of 350 rpm

and

4. A pH value of 6.

Cost Estimate for the treatment process:
For 50ml foundry effluent, the dosage quantity required is 1gm of activated charcoal-250.

Therefore, 1ml = 1/50 g,

And 1000ml = 1000/ 50g,

Therefore for treating 1 Litre of foundry wastewater containing heavy metals we require 20g of activated carbon-250

Cost of 500 g = Rs 572/-

Cost of 1 g of AC-250 = Rs (572/500)
= Rs 1.144

Therefore, the average cost of treating 1 litre of foundry wastewater = Rs 1.144x20

= Rs 22.88

or 0.38 USD

Conclusion and Recommendation

The Activated Charcoal (AC-250) was found as efficient in adsorption of the heavy metals consisting of Zn, Cu, Mg and Pb from foundry wastewater. In some of the cases a 100% removal is possible, especially with Pb. The analysis of the major experiments on effects of adsorbent dosage, contact time rotating speed and pH on the adsorption process, gave the optimum conditions for removal under which the most efficient treatment of the wastewater containing studied heavy metals was possible. For the optimum treatment conditions, an adsorbent dosage of 1 g, a contact time of 120 minutes, a rotating/agitation speed of 350 rpm and a pH value of 6 are established. An average cost of treating 1 litre of stale foundry wastewater is Rs 23 or 0.4 USD. This study therefore recommends AC-250 as an efficient adsorbent at the given optimum conditions for stale foundry wastewater. The reuse of AC-250 via the process of thermal reactivation at 800^0C is encouraged as a means of waste management.

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Table 1: Concentration levels of the heavy metals in untreated wastewater

Metals	*Zn*	*Cu*	*Mg*	*Pb*
Concentration (mg/L)	0.552	1.283	2.647	0.068

Table 2: Results obtained from the absorbent dosage study

Adsorbent dosage used in treatment (in grams)	*Concentration of metals present after treatment (in mg/L)*			
	Zn	***Cu***	***Mg***	***Pb***
0.2	0.101	0.00	1.106	0.008
0.4	0.072	0.00	1.101	0.007
0.6	0.060	0.00	1.069	0.00
0.8	0.023	0.00	0.843	0.00
1.0	0.019	0.00	0.806	0.00

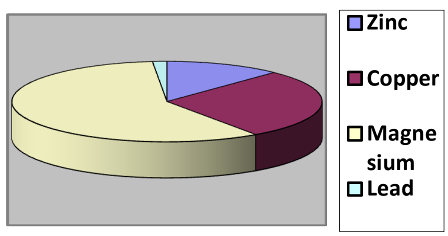

Figure 5: Representation of the heavy metals in the untreated wastewater

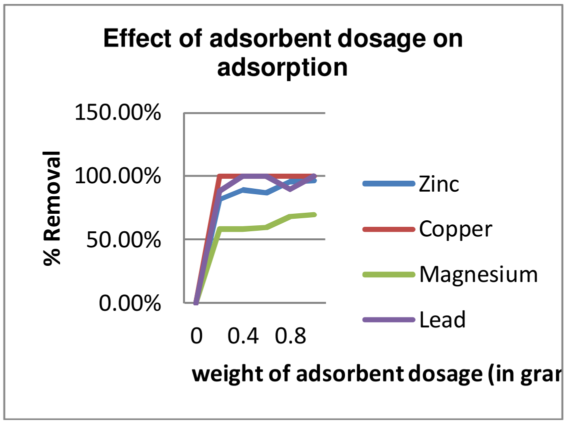

Figure 6: The removal percentage based on the adsorbent dosage

Table 3: Results of the effect of contact time on the treatment

Contact time (in minutes)	*Concentration of metals after treatment (in mg/L)*			
	Zn	*Cu*	*Mg*	*Pb*
20	0.079	0.222	1.063	0.026
40	0.043	0.186	1.101	0.116
60	0.072	0.318	0.954	0.00
80	0.024	0.084	0.364	0.00
100	0.024	0.00	0.287	0.00
120	0.00	0.00	0.044	0.010

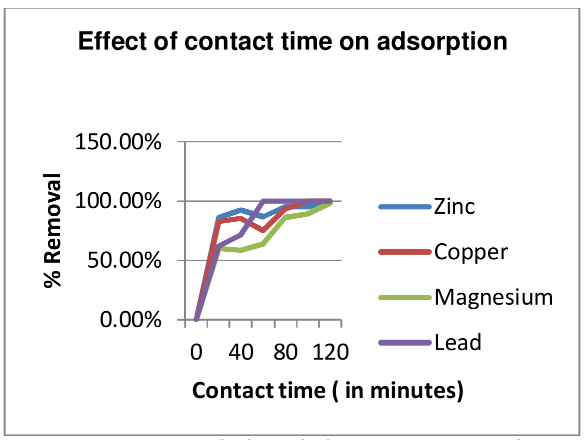

Figure 7: Percent removal of metals due to contact time of AC-250

Table 4: Results on effect of the rotating speed on the treatment

Rotating/Stirring speed (in RPM)	*Concentration of metals after treatment (in mg/L)*			
	Zn	*Cu*	*Mg*	*Pb*
150	0.045	0.243	1.560	0.031
200	0.029	0.222	1.682	0.00
250	0.063	0.364	1.854	0.00
300	0.040	0.255	1.669	0.00
350	0.047	0.159	1.182	0.00

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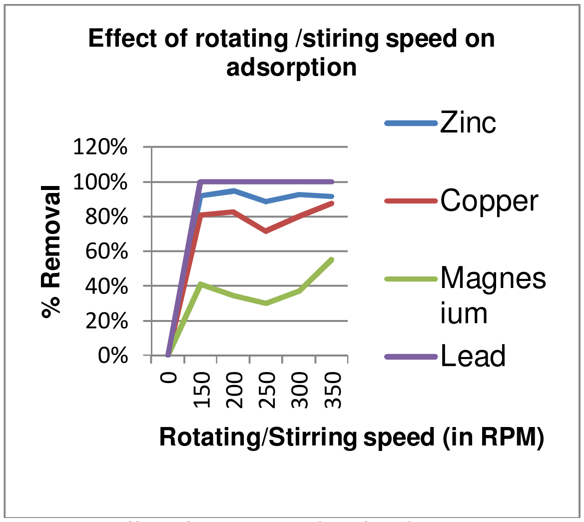

Figure 8: Effect of rotating speed on the adsorption process

Table 6: Effect of pH on the treatment

pH value maintained	*Concentration of metals after treatment (in mg/L)*			
	Zn	***Cu***	***Mg***	***Pb***
2	0.344	0.318	3.708	0.00
4	0.054	0.177	3.281	0.057
6	0.084	0.404	2.148	0.00

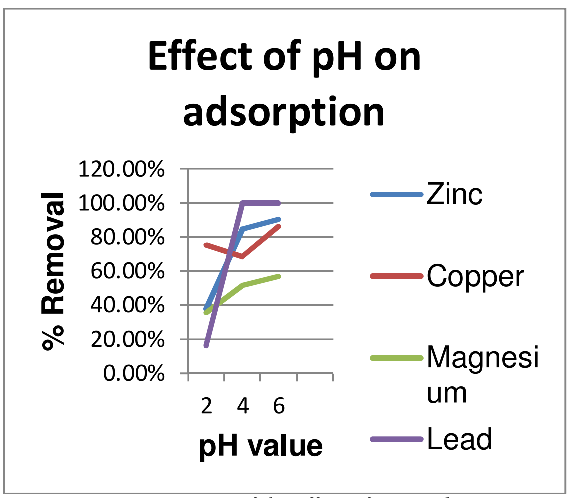

Figure 9: Representation of the effect of pH on the treatment

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