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Removal of Cu & Zn from industrial wastewater by using steel industry waste (Slag) as an adsorbent

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Abstract

The removal of two heavy metals Cu and Zn from their aqueous solution, using steel industry slag as an adsorbent was studied as slag consist of calcium oxide, aluminum oxide, magnesium oxide etc. The research is a bench scale experimental type and analysis have performed by using different amount of adsorbent in solution with five different concentration of both metals and also in mixed combination. About 93.6% and 100% Cu removal was achieved by using 1 and 3g adsorbent for solution having concentration of 5 and 10 mg/L Cu. It was also found that adsorption efficiency depend on the amount of adsorbent as adsorption efficiency of Zn was increased from 82% to 100% in the same solution(5 mg/L).It was also observed that adsorption efficiency was decreased about 2% and 4% of Cu and Zn in Mixed metal solution.

Key words: Adsorption, Contact time, Heavy metals, Industrial wastewater, Steel Industry Slag

1. Introduction

Water is a vital resource for agriculture, manufacturing and other human activities. In urban areas, the careless disposal of industrial effluents and other wastes in rivers & lacks may contribute greatly to the poor quality of river water [1-4]. Most of the rivers in the urban areas of the developing countries are the ends of effluents discharged from the industries. African countries and Asian countries experiencing rapid industrial growth and this are making environmental conservation a difficult task [5].

Toxic heavy metals are constantly released into the environment. They are dangerous environmental pollutants due to their toxicity and strong tendency to concentrate in environment and in food chains, [6-7].The source of environmental pollution with heavy metals is mainly industry, i.e. metallurgical, electroplating, metal finishing industries, tanneries, chemical manufacturing, mine drainage and battery manufacturing [8].

Removal of metals from wastewater is achieved principally by the application of several processes such as adsorption [6,10], sedimentation [11], electrochemical processes [12], ion exchange [13], cementation [14], coagulation/flocculation [15], filtration and membrane processes [16],Chemical precipitation and solvent extraction [17-18].Adsorption is the one of the important procedure for the removal of heavy metals from the environment because of strong affinity and high loading capacity [6].

Moradabad also known as brass city of India, having urban population more than 3.7 million and has seen rapid industrialization during last few decades. The city is full of brass, steel & glass cottage industries. The annual turn over of the city is nearly rupees 10,000 million. All these industries are in unorganized sector and thus have unplanned growth leaving to high degree of air, water and soil pollution [19-20]. The most of the industries are dumping their effluents in Gagan River pass from the heart of the city. A large number of small-scale manufacturing units of Steel have been also situated in the heart of the city. During manufacturing process, high temperature coal based furnaces used to melt the metal. After the completion of the process, large amount of slag is produced as a waste. This Slag consists of calcium oxide, magnesium oxide, and other metal oxides and can be used as an adsorbent for the removal of heavy metals in the environmental field. For sorption properties of slag, several researchers reported the removal of heavy metals from wastewaters using slag [21-25]. This give us imputes to extends our work on steel industry slag which is used as an adsorbent for the removal of Cu and Zn from industrial wastewater.

2. Material and Method

2.1 Adsorbent

The steel industry waste (Slag) was collected from the bank of river Gagan River where local small industries generally dump their waste and were sieved to less than 2mm size and its composition was as follows:

CaO – 60.5%

SiO_2 – 20.3%

Al_2O_3 – 8%

MgO – 6%

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2.2 Adsorbate Solution

Stock solution of Copper was prepared (1000mg/L) by dissolving the desired quantity of $CuSO_4.5H_2O$ (Analytical grades), Stock solution of Zinc was prepared (1000mg/L) by dissolving its Chlorides.

2.3 Adsorption Studies

Individual and mixed solutions of Cu and Zn with different concentrations of 5, 10, 20, 40, 100 mg/L were prepared , the experiment were performed using three different amount of adsorbent 1,2,3gm in single solution. 1 gm adsorbent was placed in a conical flask in which 100 ml of solution with known concentration of Cu was added and the mixture was shaken in shaker. The mixture was than filtered after 3 hours contact time and final concentration of metal ion was determined in filtrate by atomic adsorption spectrophotometer (GBC 902). All the Experiments were carried out in triplet and mean concentration was calculated by averaging them. The procedure was repeated by varying the adsorbent dose and concentration of Cu and Zn solution both individual and in mixed solution and the results are summarized in Tables (1-3). On the basis of residual concentrations, the adsorption efficiency of slag is calculated and summarized in
Table (4-6).

Table-1: Mean concentration of Residual Cu after Adsorption by Slag (3 hour contact time)

SNo.	Quantity of Slag(gm)	Initial Concentration of Cu (mg/L)				
		5	10	20	40	100
1.	1	0.32	0.9	2.2	6.6	22
2.	2	0.05	0.1	0.9	1.5	3.3
3.	3	0	0	0.4	1	2.8

Table-2: Mean concentration of Residual Zn after Adsorption by Slag
(3 hour contact time)

SNo.	Quantity of Slag(gm)	Initial Concentration of Zn(mg/L)				
		5	10	20	40	100
1.	1	0.9	1.9	4.2	8.6	36.4
2.	2	0.1	0.7	1.9	3.8	19.2
3.	3	0	0	1	2	10.8

Table-3: Mean concentration of Residual Metal in mixed metal solution using 1 g Slag after adsorption
(3 hour contact time)

SNo.	Metal Solution	Initial Concentration (mg/L)				
		5	10	20	40	100
1.	Cu	0.42	1.7	3.4	6.9	24
2.	Zn	1.1	2.2	5.1	10.2	39.2

Table-4: Slag Adsorption Efficiency for Cu at various Concentrations
(3 hour contact time)

SNo.	Quantity of Slag(gm)	Initial Concentration of Cu (mg/L)				
		5	10	20	40	100
		Adsorption Efficiency (%)				

1.	1	93.6	91	89	83.5	78
2.	2	99	99	95.5	96.25	96.7
3.	3	100	100	98	97.5	97.2

Table-5: Slag Adsorption Efficiency for Zn at various Concentrations
(3 hour contact time)

SNo.	Quantity of Slag(gm)	Initial Concentration of Zn (mg/L)				
		5	10	20	40	100
		Adsorption Efficiency (%)				
1.	1	82	81	79	78.5	63.6
2.	2	98	93	90.5	90.5	80.8
3.	3	100	100	95	95	89.2

Table-6: Slag Adsorption Efficiency for Cu and Zn in Mixed Metal solution using 1g Slag
(3 hour contact time)

SNo.	Metal Solution	Initial Concentration (mg/L)				
		5	10	20	40	100
		Adsorption Efficiency (%)				
1.	Cu	91.6	83	83	82.75	76
2.	Zn	78	78	74.5	74.5	60.8

3. Result and Discussions

The data obtain from above analysis indicate that the adsorption efficiency is maximum for Cu (Table- 1and 2). Table-1 shows the residual concentration of Cu in solution after 3 hours contact time and Fig -1 shows the adsorption efficiency for various concentrations of Cu and Zn by 1g slag. It is clear that slag is a good adsorbent for removal of Cu from wastewater. The adsorption rate is dependent on adsorbent amount and initial concentration of metal in synthetic solution. 93.6% removal of Cu from a 5 mg/L solution was possible by applying 1 g slag where as the similar amount of adsorbent was not enough to treat 100mg/L Cu solution to above 78% but by increasing the amount of slag to 3 g it was possible to increase the efficiency of adsorption to about 97.2% for the same solution (100mg/L Cu). It shows that we would have better treatment by using excess slag. As this adsorbent is cheap and available in brass industry waste, there would be no problem to increase its consumption.

Table- 4 & 5 indicate that adsorption efficiency is dependent on the type of metal too , as for Zn we have not more than 82% removal in same condition (1 gm adsorbent in solutions 5,10,20,40,100, mg/L) but for Cu the efficiency is reported to be 93.6%.Table-3 represent the results of adsorption experiments conducted on the mixture of metal solution as mentioned before , the maximum and minimum removal efficiency in the first stage experiments with 1 g of adsorbent was 93.6% and 82% for Cu and Zn . But for the mixture of these metals a decrease of 2% has been observed for Cu whereas Zn adsorption has decreased about 4%. The efficiency of Cu and Zn adsorption by various amounts of slag shown in fig-1 to 3 for individual solution and for mixed solution of Cu and Zn (fig-4) and in comparison to individual solution in fig-5.

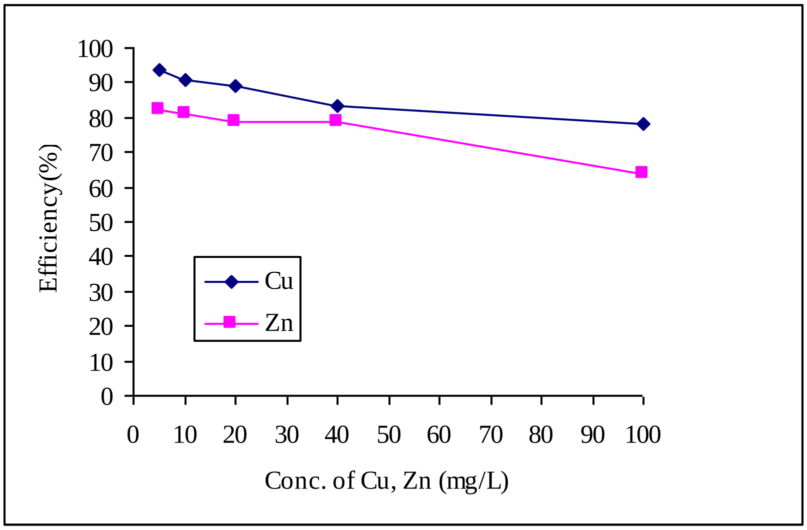

Fig. 1: % Adsorption of Cu and Zn by 1 g Slag

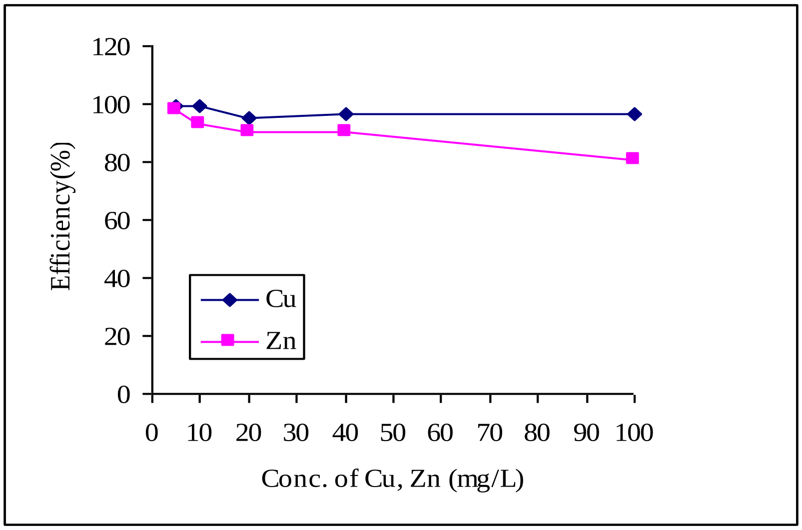

Fig. 2: % Adsorption of Cu and Zn by 2 g Slag

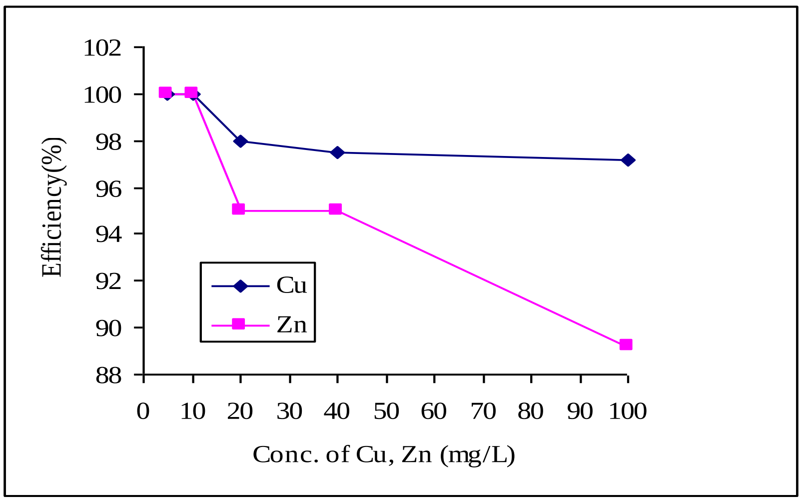

Fig. 3: % Adsorption of Cu and Zn by 3 g Slag

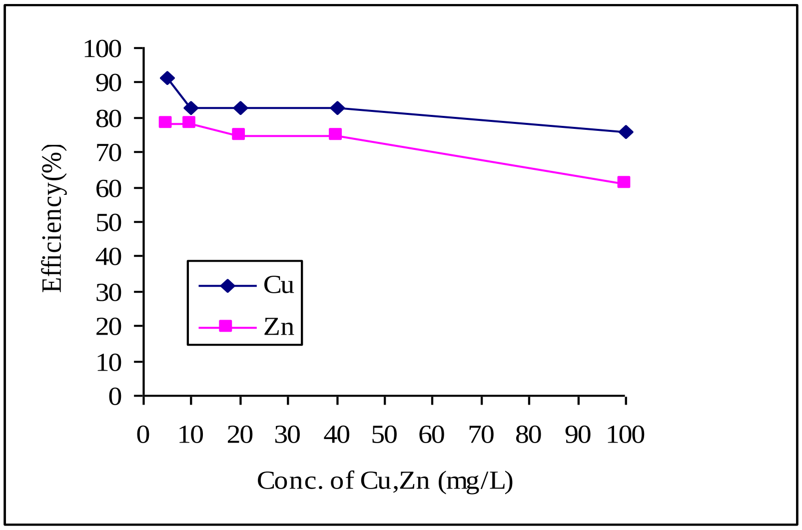

Fig. 4: % Adsorption of Cu and Zn in Mixed Metal Solution by using 1 Slag

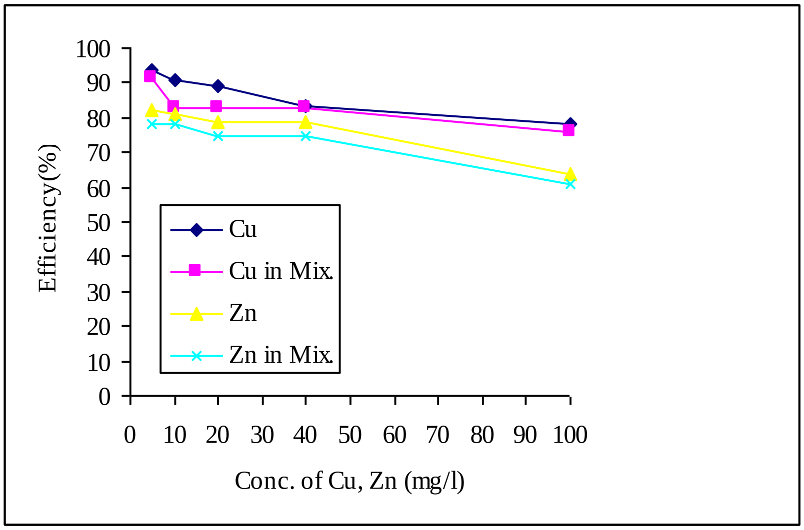

Fig.5: A Comparison Between % Adsorption of Cu and Zn in individual and Mixed Metal Solution by 1 g Slag

4. Conclusions

The above results shows that steel industry slag like the most other natural adsorbents can be used in the treatment process of heavy metals and the treatment efficiency may be as high as 100% by precise choosing of adsorbent amount. It was also found that the concentration of heavy metals has an important effect on the result of this treatment. Slag is a waste material and can be conveniently used for the treatment of industrial wastewater, it is like the industrial waste is utilizing for the treatment of industrial wastewater. Further it is recommended that the industries should developed pretreatment process by using slag as an adsorbent before mixing the industrial wastewater into the river.

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