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Removal of zinc from industrial wastewater by using sand as adsorbent

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Abstract

Removal of heavy metals from water and wastewater has received a great deal of attention. Adsorption technique is one of the most technologies being used for treatment of polluted water, but seeking for the low cost adsorbent is the objective of this study. This study records lab scale experiments to test efficiency of sand in removing a heavy metal, Zn (II) from wastewater of electroplating industry. Solutions of varying concentrations of Zn (25-100ppm) were prepared and passed through sand column. Leach ate samples collected at different depths of sand column were analyzed for concentration of Zinc ions using atomic absorption spectrophotometer. To study the removal efficiency of sand column pH and influent injection rate were also varied. This method of heavy metals removal proved highly effective as removal efficiency increased with increasing pH while it decreased with increasing metals concentration. The removal efficiency was quite high for Zinc ranging from 71-87% and maximum adsorption occurred at depth 1m as compared to 0.6m & 0.8m depth. Since sand is cheap and easily available, so it can be concluded that the sand filtration, which is efficient and cost effective, has the potential to be used for removal of heavy metals from can successfully be used for removal of heavy metal from water and industrial wastewater.

Keywords: Adsorption, heavy metals, wastewater, zincion

Introduction

Removal of heavy metals from industrial wastewater is of primary importance because they are not only causing contamination of water bodies but are also toxic to many life forms. Industrial processes generate wastewater containing heavy metal contaminants. Since most of heavy metals are non-degradable into non-toxic end products, their concentrations must be reduced to acceptable levels before discharging them into environment. Otherwise these could pose threats to public health and/or affect the aesthetic quality of potable water. According to World Health Organization (WHO) the metals of most immediate concern are chromium, Zinc, zinc, iron, mercury and lead. [1] Electroplating processing industries is one of the most important electroplating sectors of Pakistan with regard to its application and labour force employment. Electroplating wastewater is by far the most important environmental problem faced by the Pakistan electroplating sector. Electroplating processing sector is highly polluting sector utilizes variety of chemicals. Electroplating wastewater is highly polluted in terms of COD, TSS, Cu, Fe and Zn. The value of these parameters is very high as compared to the values in National Environment Quality Standards (NEQS) set by the government of Pakistan (NEQS, 1999) [2]. In advanced countries, removal of heavy metals in wastewater in normally achieved by advance technologies such as ion exchange, chemical precipitation, ultra filtration, or electrochemical deposition do not seem to be economically feasible for such industries because of their relatively high costs. Therefore, there is a need to look into alternatives to investigate a low-cost method, which is effective and economic, and can be used by such industries.

To overcome this difficulty there is strong need to develop economical adsorbents, which can be used in developing countries. Previous removal methods were for heavy metals (Ag, Au, Co & Ni) with economical materials (Kaneco *et al.*, 2000) [3]. Therefore it is desired that simple and economical removal method which could be practiced in developing countries is established. Although precipitation-filtration method is cheap its operation is complicated. On the other hand, adsorption method such as ion exchange is simple for metal removal but chelating and ion exchange resins are expensive. Adsorption is a term commonly used for several different processes involving physical as well as chemical interactions between the solid surfaces of a substance and dissolved metal pieces.

Thus, adsorption in general can be influenced by changes in hydro chemical parameters such as pH and flow rates. Adsorption of the heavy metals form solution has been studied by other using naturally occurring minerals. Pyrolusite has been used for adsorption of Pb, Zn and Mg from their aqueous solution (Ajmal, 1995) [3] zeolites have been used for removal of heavy metals form wastewater (Yuan *et al.* 1999) [5]. Other adsorbents that have been used for the removal of heavy metals include carbonaceous material developed from fertilizer waste slurry (Srivestave *et al.* 1989) [6]. Coffee has been used for the removal of Pb, Cu, Hg, Cd and Zn from drinking water at a rate of 78-90% of the dissolved heavy metals (Strong, 2000) [7]. The aim of this study was to find out the effectiveness of sand for removal of Cu (II) in electroplating wastewater. These materials have large surface areas and are uniform in their physical and chemical properties and easily available.

2. Material and Methods

To perform the experiment, working solution of Zinc (II) was prepared by dissolving the respective metal nitrate in distilled water to avoid errors in results. Sand was used as adsorbent for adsorption of Cu (II). Experiment was conducted in lab scale sand filter. The filter had a circular cross section with diameter of 80mm and height of 1.2m. The sand column was filled with the appropriate amounts of each adsorbent up to height of 1m to leave some place for pouring solution. To evaluate the effects of sand bed depth, sampling points were located at 0.6, 0.8 and 1m depth. A peristaltic pump was used to regulate the flow of the influent. Four influent injection rates of 0.25, 0.5, 0.75 and 1 m/hr were considered to study the effects of injection rates on metals removal efficiency (Matin *et al.* 2003) [8]. Before starting experiment, the sand was washed to remove all impurities like clay and silt particles. Sand is first dried in sunlightandtheninovenat 103 ºC. Thesyntheticsamples were passed through filter column and flow rate to filter column was adjusted by using peristaltic pump. Treated samples were collected from all sampling ports at regular time intervals. An atomic absorption spectrophotometer was used to determine the concentrations of heavy metals absorbed by the adsorbents. The definition of removal efficiency is as follows

$$\text{Removal efficince}(\%) = \left[{(C_0 - C_1)}/{C_0} \right] \cdot 100$$

Where C_o and C_1 are the metal concentration in the sample solution before and after treatment, respectively.

3. Results and Discussion

The effect of pH on the removal of heavy metals was examined because the wastewater from plating factory was various pH values. Generally it is considered that wastewater from plating industry is acidic solution. Samples were prepared at pH value of 3 and 7(Gotoda, 1992) [9]. Therefore in this study the effect of pH on removal of heavy metals (Cu) is considered in pH range of 3-7. For a particular injection rate, the effect of pH could then be compared for each and every concentration.

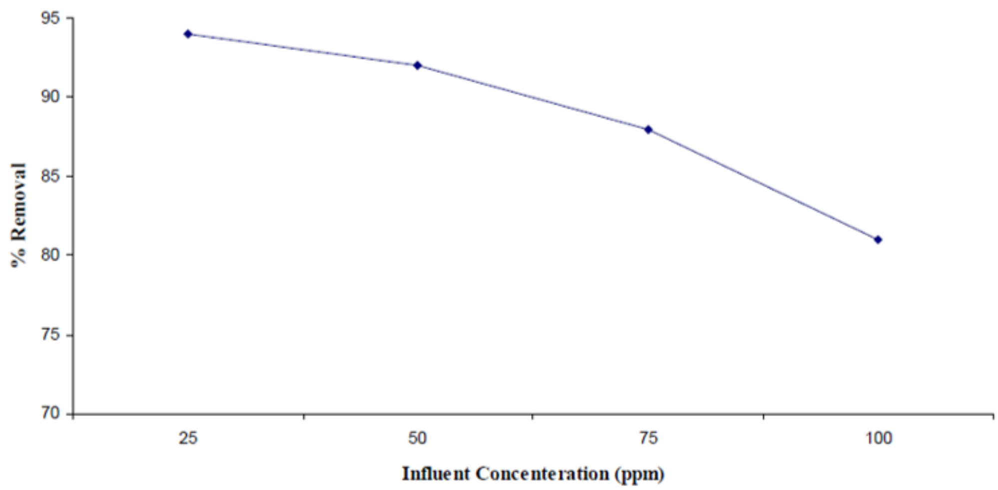

Figure 1(a). Effect of Influent Concentration on the Removal Efficiency at an Injection Rate of $0.1m^3/m^2$-hr and a pH of 3

The effect of pH on the removal of heavy metals showed that the removal of Zinc shows an increasing trend at pH 7 as compared to a pH of 3. This difference goes on increasing with increasing concentration of Cu in the effluent solution e.g. at a flow rate of 0.1m3/m2-hr and an initial concentration of 25ppm, the removal is 94% at pH value 3 and 96% at pH value of 7; whereas at a concentration of 100ppm, 81% of Zinc is removed at pH of 3 and 87% at a solution pH of 7. These results are in accordance with findings of Zeng [10], which shows that the pH does not have a major effect on the removal of Cu^{+2} from solution. The variation in removal efficiency due to the solution pH is attributed to the precipitation of Zinc hydroxide [Zn (OH)] at a higher pH. As the pH increases, there is increasing trend in concentration of hydroxide ions [OH^-] in solution and causing disturbance of equilibrium.

Therefore, the system adjusts to terminate this effect (Le Chatelier principle) by more precipitation of hydroxide out of the solution. Precipitate are not permanently adsorbed by the sand particles therefore washing of sand will certainly remove the hydroxide and bring the Zinc into direct contact with the external environment. To prevent reentry of Zinc in the environment, it is recommended to adequately acidify metal containing industrial effluents prior to the removal process.

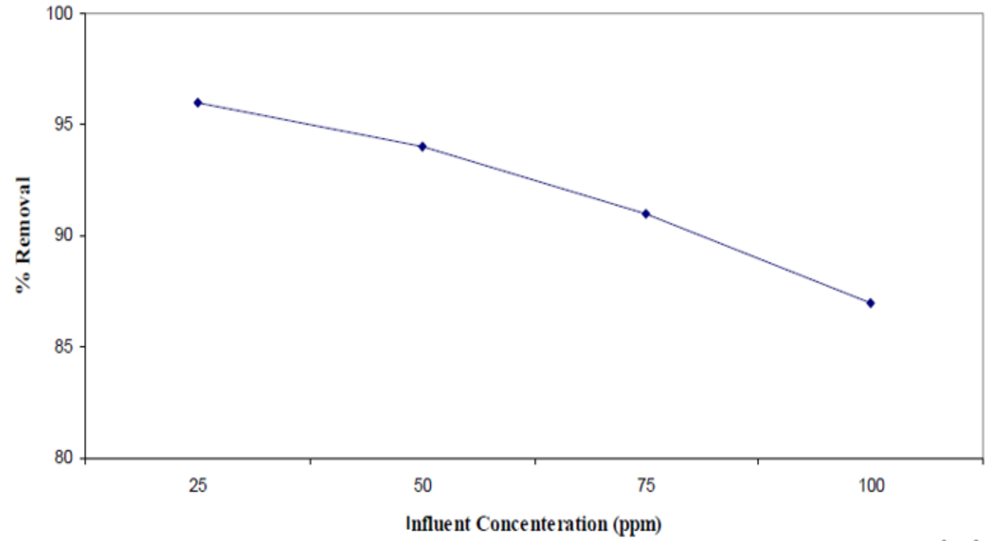

Figure 1(b). Effect of Influent Concentration on the Removal Efficiency at an Injection Rate of $0.1m^3/m^2$-hr and a pH of 7

Fig 1 shows the effect of influent concentration on removal efficiencies for four different concentrations: 25, 50, 75, 100 mg/L. These different influent concentrations were considered to have comparison of sand adsorption behaviour at different pH. Maximum removal was observed for an influent concentration of 25 ppm at all injection rates. Removal efficiency shows a decreasing trend with increasing concentration of Zinc. Even at concentration of 100 ppm removal efficiency rarely falls below 80%. This can be explained by the fact that as the concentration of Zinc ions increases so does the metal loading on the adsorbent. For example, a concentration of 100ppm will have higher surface loading as compared to concentration of 25ppm. Because it causes an equal increase in no of Zinc ions coming in contact with sand increases during same interval of time while on the other hand the no of adsorbing sites available for adsorption are constant for all concentrations. So when influent concentration will be higher, more no of ions will be competing for same adsorption sites and will go through without being adsorbed.

Fig 2 describes the effect of influent injection rates at various column depths. It was observed that the removal efficiency increases with increased column depth and low injection rate and goes on decreasing with increasing injection rate and decreasing sand column depth. This trend is more prominent in shallower columns as compare to the deeper ones. For example, when the column depth is only 0.6m, the removal efficiency decreases from 86% to 63% when injection rate is increased from 0.25 - $1m^3/m^2$-hr. While in case of 1m deep column, the variation is 10% for same injection rates. As usual, the effect of injection rate on the performance of the middle column depth i.e. 08m is somewhere in between.

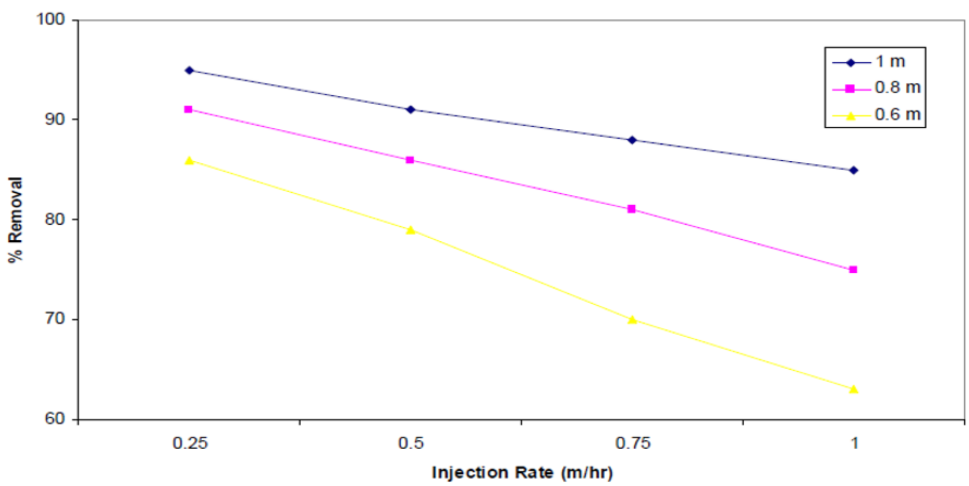

Figure 2. Effect of Influent Injection Rate and Column Depth on Removal Efficiencies

Fig. 3 illustrates the deviation in Zinc removal efficiency with depth of sand column at a specific injection rate. The results show that Zinc removal efficiency increases as the depth of sand column increases. At depth of 1 m the Zinc removal efficiency remains 87% after passing of 8 litres of the influent solution. Conversely, the efficiency of 0.6m sand column drops to 74% after passing an identical volume of Zinc sulphate. Alike results were obtained for actual industrial wastewater sample, which had a concentration of 245 ppm and a pH of 6.8.

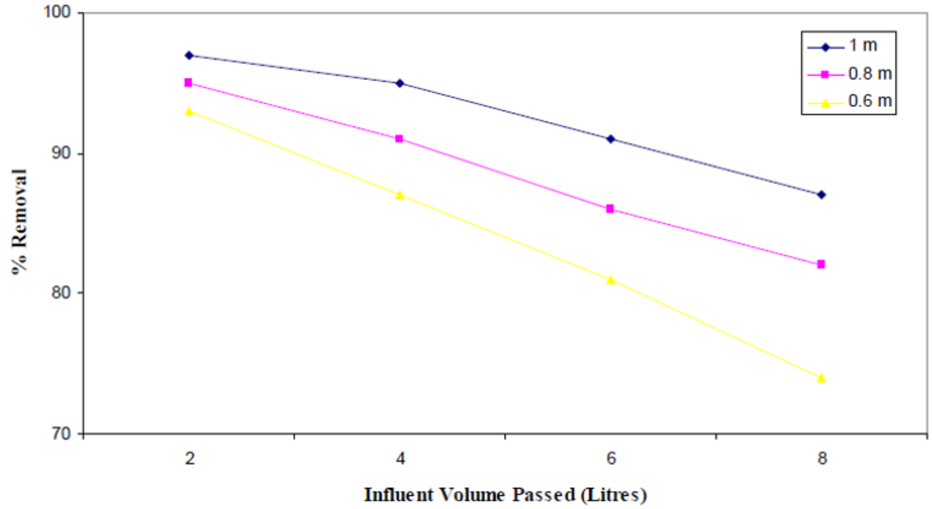

Figure 3. Removal of Zinc Form Industrial Effluent at Different Column Depths

This performance of sand column is attributed to adsorption of Zinc in shallower column. Smaller amount of sand means availability of lesser adsorption sites for Zinc and therefore less removal efficiency of sand column. Passage of smaller volume of effluent sample will cause the fill up of adsorption sites and exhaust the removal capacity of sand.

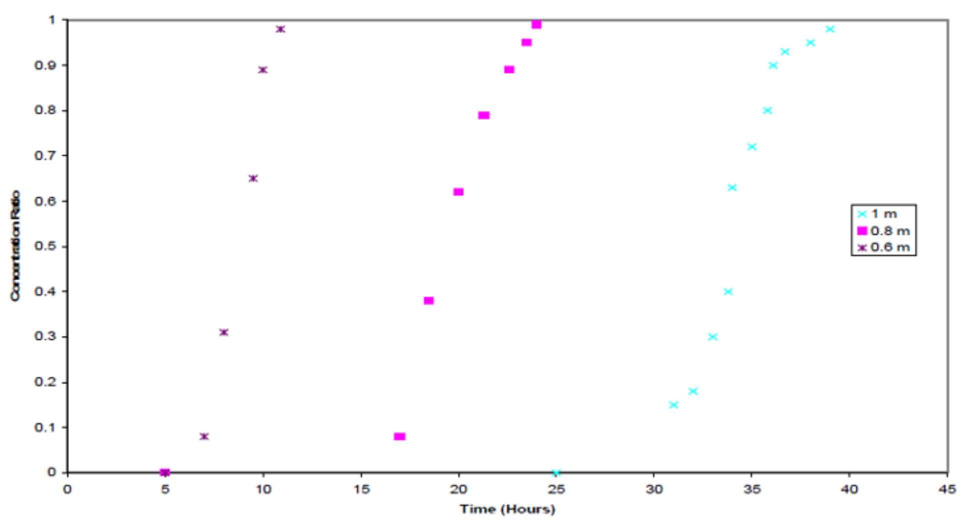

Figure 4. Zinc Removal Capacity at Various Depths Concentration Ratio is Effluent to Influent

To estimate the adsorption capacity of sand, the solution of 200ppm was filtered through the sand column until the Zinc concentration in the effluent becomes equal to influent concentration. This is the point when all the adsorption sites of sand are occupied and no more sites are available.

The total adsorption capacity of sand in sand column was calculated as follows:

Influent concentration = 200 mg/L
Number of runs(2L/run) = 73
Amount of Zinc passed = 200 * 73 = 29200mg = 29.2g
Total weight of sand in column = 3.5 Kg = 3500g
Adsorption capacity of sand = Zinc passed / weight of sand
Adsorption capacity of sand = 29200/3500 = 8.342 mg of Zinc/g of sand

After sand adsorption the sand becomes saturated with the Zinc metal. One feasible method of this sand disposal is by making it as component of concrete used in construction (Vallejo *et al.* 1999) [11].

4. Conclusions

A simple and cost effective treatment procedure was proposed for the removal of heavy metals through the adsorption on sand. Adsorption is a strong choice for removal of heavy metals as it is operationally simple and can adapt to changing wastewater flow rates and compositions. The solution pH does not have a significant effect on the removal efficiency. As higher pH results in precipitation of Zinc instead of permanent adsorption, it is recommended that to acidify the influent solution prior to treatment. Sand has showed very high adsorption capacities and can be successfully be used for treatment of electroplating wastewater. Since this method involves less capital cost and is highly efficient it is practicably feasible for developing countries. The results of investigation will be useful for the removal of metals from industrial effluents.

5. Acknowledgements
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Biography

Dr. Sachin Madhavrao Kanawade was born in 11 March 1978 at Nashik, Maharashtra, India. His native place is Nimgaonpaga, Tal-Sangamneer, Dist-A'Nagar, Maharashtra, India. He received his Bachelor's Degree in Chemical Engineering from Pravara Rural Education Society's Pravara Rural Engineering College, Pravaranagar (Loni) which is affiliated to Pune University in India in Nov.2001.Then he worked as a Production Officer in different Multinational Chemical Industries in India (2001 to 2008) like M/S Watson Pharma Ltd, Ambernath, MIDC, Mumbai, MS,M/S Glenmark Pharmaceuticals Ltd, Mohol, Dist. Solapur, MS, M/S Sun Pharmaceutical Industries Ltd, A. Nagar, MIDC,MS for 7 years.
Then he changes his field. He joined K. K. Wagh College, Nasik, MS, India in 2008 & worked as Lecturer for 2 years. At the same time he received his Master of Engineering in Environmental Engineering from Pravara Rural Education Society's Pravara Rural Engineering College, Loni in Dec.2010. Then he joined Pravara Rural Education Society's Sir Visvesvaraya Institute of Technology, Chincholi, Tal-Sinnar, Dist-Nasik, MS. India in 2010 & worked as Assistant Professor in Chemical Engineering Department for 5 years.
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His research topic includes & interested in Chemical Engineering, Environmental Engineering, Wastewater Treatment by Adsorption, Advanced Separation Process, Chemical Engineering Design, Mass Transfer, Chemical Process Synthesis, Chemical Engineering Thermodynamics etc.