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REMOVAL OF CADMIUM, COPPER, LEAD AND ZINC FROM SIMULATED INDUSTRIAL EFFLUENTS USING SILICA POWDER

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Rapid industrial development have led to the recognition and increasing understanding of interrelationship between pollution, public health and environment. Industrial development results in the generation of industrial effluents, and if untreated results in water, sediment and soil pollution. In Pakistan most of the industrial effluents are discharged into surrounding ecosystems without any treatment. Industrial wastes and emission contain toxic and hazardous substances, most of which are detrimental to human health. Extensive efforts are being made around the world for the removal of heavy metal from industrial effluents. A laboratory scale study was designed for removal of Cd, Cu, Pb and Zn from simulated solutions at various weight of silica (0.5gm, 1 g, 2 gm, 3gm and 4 gm), Voltammeter was used to quantify the metals. Maximum removal of all metals was achieved with 4 gm of silica. Absorption of lead onto silica was higher than other metals.

Keywords: Absorbent, Silica, Copper, Lead, Cadmium, Zinc, Industry, Pollution

1. Introduction

Global pollution is increasing everyday due to variations in natural order or activities. Human beings are amongst the primary source of these changes which are leading to degradation of terrestrial and aquatic systems [1,2]. Major source of these pollutants is direct discharge of industrial waste flowing out from industrial activities into surrounding water bodies and land area without any pollution treatment [3]. Industrial waste is generated during many industrial and manufacturing processes such as: metal plating, storage batteries, alloy industries, dying, textile, fertilizers and other chemical. Industrial waste exemplifies major source of metallic pollutants i.e. Cu, Pb, Fe, Cd, Mn, etc. in aquatic systems, natural biota and environment [4]. Metals become harmful when they are consumed in excess amount. In case of living organisms metals can be entered into body via water, food and air inhaling process.

After entering into body these metals come in contact with biomolecules present in organism's body and then are distributed throughout the organism's body resulting in bioaccumulation, biomagnifications and then biotransfer via trophic levels [5].

Pakistan is a developing country and its economy is semi-industrialized. The country's industrial sector constitutes around 20 of the country's gross domestic product. The largest industries of the country are textile, cement, agriculture, fertilizer, steel, tobacco, edible oil, pharmaceuticals, construction materials, shrimp, sugar, food processing, chemicals and machinery. Effluents of these industries are heavily loaded with pollutants with most important heavy metals. Most of these effluents are discharged in surrounding water bodies or lithosphere without any treatment. This leads to many environmental as well as health concerns.

A wide range of technologies such as chemical, biological and physical are available for the removal of heavy metals from industrial effluents. Every technology has its own merits and demerits [6]. Adsorption is separation process where fluid sample containing certain components is transferred to the solid surface of adsorbent [7]. If this mass transfer occurs in opposite direction it is called as 'Desorption' [8]. Adsorption can be applied to both gaseous and liquid separations [9].

Adsorbents are highly porous substances where components of liquid sample adsorb on walls of these pores [8]. Many factors effect rate of adsorption i.e. agitation, characteristics of adsorbent i.e. surface area, particle size, solubility and size of adsorbate, temperature and pH [10,11].

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Silica has been used long times for their chromatographic applications as well removal of heavy metals from wastewaters and industrial effluents.

Various processes and methods such as precipitation, electrochemical treatment, chemical oxidation reduction, membrane separation, solvent extraction, and ion exchange have been employed to remove metal pollutants from aqueous solutions [12], However, most of these methods suffer from low removal efficiency, especially when large volumes of dilute heavy metal solutions are present [13]. Adsorption is one of the most effective and economic techniques for removing heavy metal ions from aqueous solutions. The efficiency of adsorption relies on the capability of the adsorbent to concentrate or adsorb metal ions from solution onto its surfaces and the rate of removing ions from the solution. Different adsorbents such as activated carbon [14], zeolites [15], resins [16], biosorbents [12], hydrogel, and magnetic hydro gel [17] have been used for the removal of heavy metal ions by adsorption. Despite the availability of a number of adsorbents for the removal of low concentrations of heavy metal ions from aqueous solutions, there is still a need for the development of new adsorbent with superior adsorption capacity, facile adsorption-desorption kinetics, high stability and easiness of operation. It has been reported that Silica, silica gel resins [18], silica gel filters [19] and amorphous silicate gels [20, 21] have been used for the removal of heavy metals from certain effluents. Also, for the treatment of nuclear wastes, silica gels are used for the removal of uranyl and neptunyl cations [22].

Silica coating has attractive properties including: biocompatibility [23], high adsorption capacity, acid-base properties, insolubility in most solvents, and chemical and thermal stability [24]. Being hydrophilic in nature, silica-coated core-shell MNPs can be easily dispersed in aqueous solutions. Furthermore, since SiO_2 is stable under acidic conditions, iron oxide-SiO_2 MNPs can be used as adsorbent in acidic solutions. The surface of silica is dominated by hydroxyl or silanol groups.

In this study silica has been used as adsorbent for removal of Cd, Cu, Zn and Pb present in known simulated solution of respective metals.

2. Material and Methods

Commercially available Silica powder was used as adsorbent. Known solutions of Zn, Cd, Pb and Cu of varying concentrations (10-60 ppm) were prepared as sculpt of industrial effluents.

2.1. Standard Solution

Standard solutions were prepared from 1000 pm commercially available pure solution of Zn, Cu, Pb (5 ppm) and Cd (2.5 ppm) by taking 0.5 ml of Zn, Cu, Pb whereas 0.25ml of Cd and dissolving it in distilled water and making volume upto 100 ml.

2.2. Stock Solution

Known solution of 250 ppm of 4 salts i.e Copper nitrate, Zinc acetate, Cadmium nitrate and Lead nitrate were prepared by taking 0.475g, 0.35g, 0.26g and 0.199g of these salts respectively and dissolving them with distilled water by making volume upto 500 ml.

2.3. Buffer Solution

Buffer solution of pH 4.6 was prepared by dissolving 18.9 ml of concentrated acetic acid with 27.75 g of sodium acetate in distilled water and making volume upto 250 ml.

Metals concentrations ranging from 10ppm-60 ppm for different experiments were prepared from 250ppm stock solution.

Five absorbent dose (weight of silica) 0.5 gm, 1gm, 2 gm, 3 gm and 4 gm, was added in 50 ml plastic vial which contained 20 ml of each concentration (10-60 ppm) solution in this way total treatments were 42. The pH of solution was adjusted to 5. The vials were shaken at room temperature for one. Subsequently shaked samples were filtered through 3 layer filter paper (whatman 42). Metal concentration in the filtrate was then measured to determine the left amount of metals that depicted adsorption rate of these metals on the silica by Polarograph 797 Computrace by VA-83.

Samples for voltammeter were prepared by taking 1 ml of diluted sample, 9ml distilled water and 0.5 ml of buffer solution in volumetric cells followed by 3 standard additions of standard solution. Measured values presented by polarograph were first multiplied by dilution factor and then compared with original stock solution values to find out percentage removal of tested metals.

The removal efficiency of the contaminants (Pb, Cd, Cu and Zn) was calculated by using the following formula.

$$\text{Removal efficiency} = \frac{(\text{Cf} - \text{Ci})}{\text{Cf}} \times 100$$

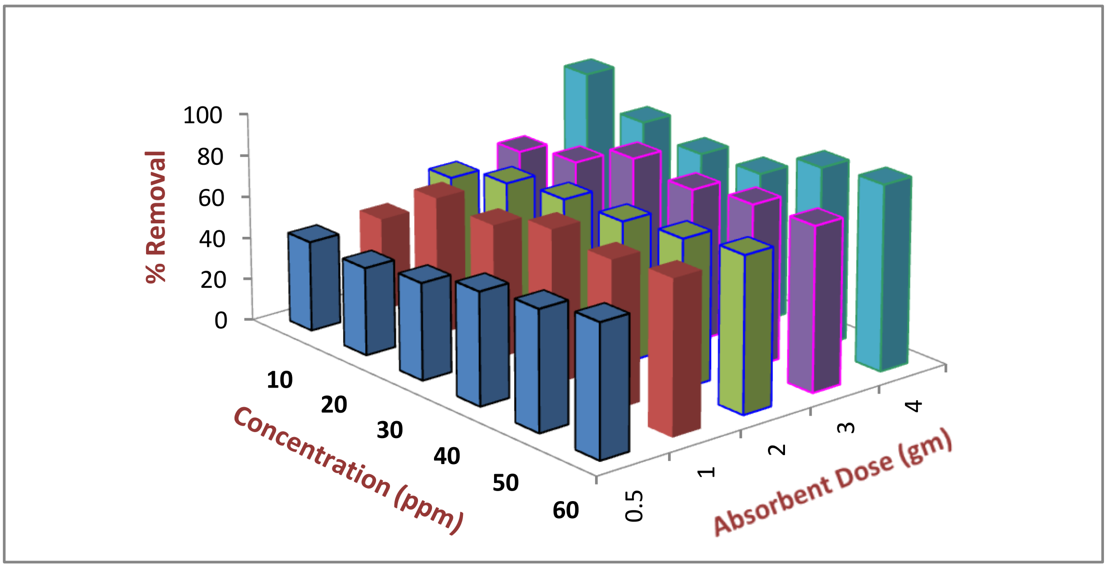

Figure 1. Effect of adsorbent dose on removal efficiency of Cu on to SiO_2 powder.

Where

Cf = Quantity of metals before adsorption experiment

Ci = Quantity of metals after adsorption experiment

3. Results and Discussions

Removal efficiencies of metals studied at different doses are presented in following section:

3.1 Removal Efficiency of SiO_2 Powder for Cu

Figure 1 shows adsorption of Cu on silica powder at different adsorbent dose i.e weight of silica powder. In general increase in absorbent dose enhanced absortption of Cu on the silica. The absorption of Cu also enhanced with increasing concentration of metals at 0.5 and 1 gm absorbent dose (weight of silica) whereas absorption of Cu was almost constant with 2 gm silica at all concentration levels. However, Cu removal was found to be irregular at 3 and 4 gm of silca, here the adsorption of Cu was higher at lowe concentration of Cu. Maximum Copper removal (89 %) occurred at 10 ppm concentration level using 4 gm of silica.

3.2 Removal Efficiency of SiO_2 Powder for Pb

Figure 2 illustrates removal efficiencies of SiO_2 powder for Pb at different concentration with different absorbent weight. A systematic trend was observed at different adsorbent dose. In general the absorption of lead on silica increased as the weight of silca is increased at each concentration level. Highest removal efficiency was recorded at 60 ppm level using 4g of silica powder which was 81 %. Strong adsorption ability towards of silica Pb metal ions is observed.

3.3 Removal Efficiency of SiO_2 Powder for Cd

The overall course of removal efficiency increased as the weight of silica powder increased with some exceptions. Figure 3 demonstrates adsorption of Cd on to silica powder. However 4g showed highest removal efficiencies at 60 ppm level of concentrations. Maximum absorption is recorded at 60 ppm level when 3 gm silca is used (89 %) and it decreased to 81 % at 4 gm of silca.

3.4 Removal Efficiency of SiO_2 Powder for Zn

Figure 4 presents the effect of varrying silica powder weight on adsorption of Zn at different concentration levels. A systematic pattern of Zn adsorption was observed at various adsorbent doses. 0.5gm showed steady increase in adsorption with increasing concentration levels. Removal efficiency of silica powder increased upto 40 ppm when 1 gm silica is used followed by decrement at 50 ppm concentration and then increased. Absorption of Zn at diffent concentration levels was almost the same at 2 gm , 3 gm and 4gm of adsorbent. However, maximum removal was recorded at 60 ppm at all dose rate which was found in the range of 71- 74 %.

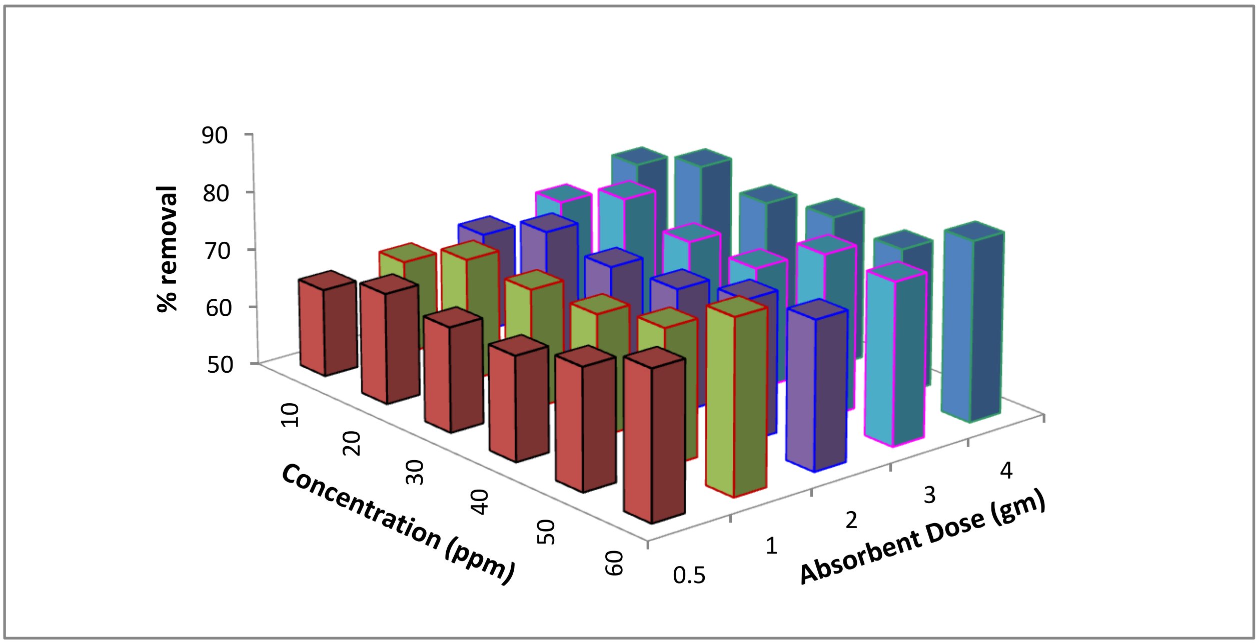

Figure 2. Effect of adsorbent dose on removal efficiency of Pb on to SiO_2 powder.

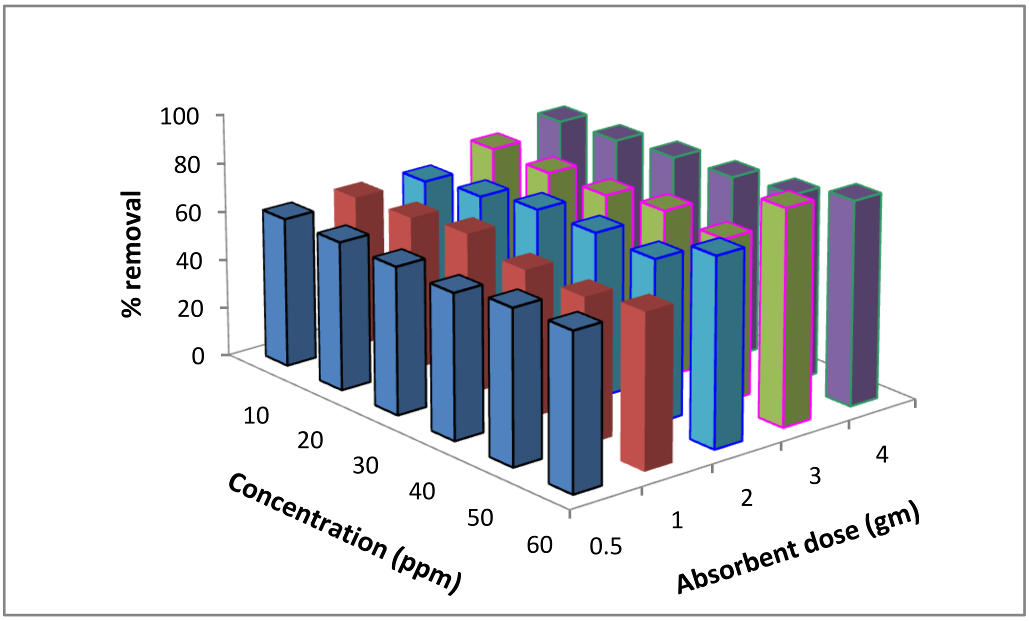

Figure 3. Effect of adsorbent dose on removal efficiency of Cd on to SiO_2 powder.

Average percent metal removal at different concentration levels using different weight of silica used is presented in Table 1. It is obvious from the table that maximum absorption was recorded at 4 gm of silica (71- 80 %). There is an increasing trend of removal when the increase of absorbent dose for all the metals. The adsorption ability of SiO_2 towards the four kinds of metal ions follows the order Pb > Cd) > Cu>Zn. Percent removal of lead was higher than other metals at all the treatment except for 4 gm of silica, whereas, Zn adsorption was lower as compared to other metals at the absorbent dose.

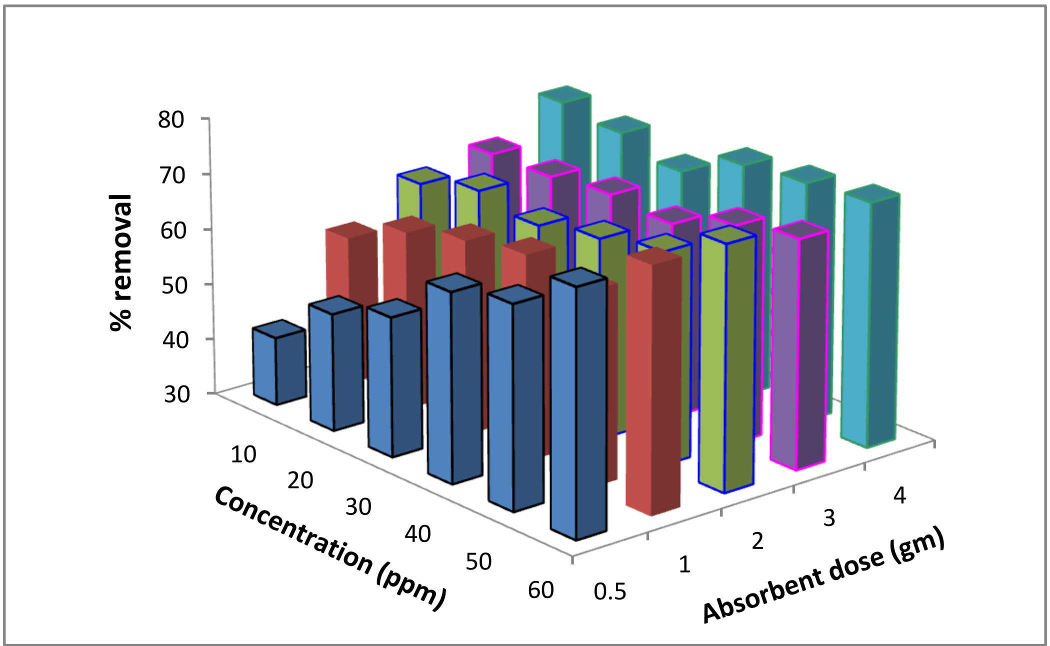

Figure 4. Effect of adsorbent dose on removal efficiency of Zn on to SiO_2 powder.

Table 1. Average percent removal of metals at different adsorbent dose.

Metals	Absorbent Dose (gm)					Average
	0.5	1	2	3	4	
Cu	51	66	67	72	80	67.2
Pb	69	72	72	74	76	72.6
Cd	62	63	68	71	75	67.8
Zn	59	65	67	67	71	65.8

4. Conclusion

A laboratory scale study was designed for removal of Cd, Cu, Pb and Zn from simulated solutions (artificially contaminated) using different weight of silica at different metals concentrations. The following conclusion can be drawn from present investigation:

- Silica powder is found to be a lucrative and efficient adsorbent. In this study upto 90 % absorption of metals has been observed on silica.
- Maximum absorption was recorded at 4 gm of silica adsorption
- In general silica power showed higher absorption efficiency for lead and lower for Zinc.

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