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Using Fly Ash for Removal of Nickel (II) from Aqueous Solution

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ABSTRACT

Heavy metals have a great tendency to bio-accumulate and end up as permanent additions to the environment. In this study, removal of Nickel from aqueous solutions has been investigated by utilizing a fly ash as an adsorbent. The Fly Ash has been collected from Kota Thermal Power Station (KTPS). Dimethylglyoxime (DMG) is used for the spectrometric determination of Nickel. Batch adsorption experiments were carried out to study the various parameters such as effect of initial metal ion concentration, effect of pH, adsorbent dose, and contact time.

Keywords: Adsorption, Fly ash, batch method, pH, Dimethylglyoxime.

1. INTRODUCTION

The pollution of heavy metals has gained worldwide attention due to their toxicity, difficult degradation, and accumulation in living organism. Therefore, treatment of waste water contaminated by heavy metals is an important environmental concern[1]. Nickel (Ni) is an important heavy metal, and pollution by Nickel has gained importance due to the greater understanding of its persistence and toxicity in the ecosystems[2]. Among various water purification and recycling technologies, adsorption is a fast, inexpensive, and universal method. The development of low -cost adsorbents has led to the rapid growth of research interests in this field[3]. Nickel is one of many trace metals widely distributed in the environment, being released from both natural sources and by anthropogenic activity, with input from both stationary and mobile sources. It is present in the air, water, soil, and biological material[4]. Industrial waste materials, lime, fertilizer, and sewage sludge constitute the major sources of nickel into soils[5]. The acceptance limit of Nickel in drinking water is 0.01mg/L and the industrial discharge limit in wastewater is 2mg/L [6]

Heavy metals like Zn, Cu, and Ni and as are known to have toxic effects at very low concentrations[7] as well as very high concentrations[8]. Nickel has been implicated as an embryotoxin and teratogen[9]. Acute poisoning of Nickel (II) causes headache, nausea, dizziness, chest pain, dry cough, shortness of breath etc. At higher concentration it is a carcinogen, causes cancer of lungs, Nose, and bone. Skin contact with nickel causes a painful disease called 'NICKEL ITCH', which leads to death[10].

Use of fly ash created by coal combustion thermal power plant for the removal of some selected metal ion from aqueous solutions as a low cost adsorbent.[11] However, the most frequently applied method in industries for the waste water treatment is adsorption processes and in this regard, a number of adsorbents like peanut and almond husk[12-13], baggase[14], automobile tires[15], gypsum[16], soya cake[17], blast furnace slag[18] and fly ash[19] have been studied for the removal of different heavy metals. Fly ash has potential use in water treatment because of its major chemical components, which are alumina, silica, ferric oxide, calcium oxide, magnesium oxide and carbon and its physical properties such as porosity, partical size distribution and surface areas[20,21].

2. MATERIAL AND METHODS

2.1 Method of Estimation of Nickel

UVeVis. Spectrophotometry is the most common technique used for Nickel (II) determination owing to its simplicity and low cost.

2.2 Principle of Spectrometric Determination of Nickel Dimethylglyoxime

When we mix Dimethylglyoxime (DMG) with an alkaline solution of Nickel in presence of oxidizing agent such as bromine, forms a red colour complex. The red complex of Ni-DMG contains Nickel in higher oxidation state (probably (III) and also (IV)). The complex absorbs at about 445nm. The intensity of colour varies with time and hence it is necessary to measure the absorbance after a fixed time within 10 minutes of mixing. Cobalt (II), gold (III) and dichromate ions interfere under the experimental conditions.

2.3 Preparation of Nickel Stock Solution

Standard Nickel (II) solution prepared by dissolving 0.673 g of pure ammonium Nickel (II) sulphate $(NH_4)2SO_4.NiSO_4.6H_2O$, in water and diluting to 1 dm^3.

2.4 Procedure for Batch Adsorption Studies

Batch adsorption experiments were carried out at room temperature to be representative of environmentally relevant condition. The effects of various parameters on the rate of adsorption process were observed by varying initial Nickel (II) concentration, amount of fly ash, particle size, pH of solution and temperature of the solution. The solution volume

(V) was kept constant. The change in Nickel (II) concentration due to adsorption was determined spectrophotometrically according to standard method. The measurements were made at the wavelength λ=445nm, which corresponds to maximum absorbance. A pale red colored complex was developed. Using the Equation given, the concentrations of Nickel (II) at different time adsorbed in fly ash was calculated,

qt= (Co-Ct) V/M

Where qt is the amount of Nickel (II) adsorbed onto the fly ash at time t, Co is the initial concentration of nickel (II), Ct is aqueous phase concentration of nickel (II) at time t, V is the volume of the aqueous phase, and M is the weight of fly ash sample.

2.5 Kota Fly Ash Characteristics

The fly ash is predominantly composed of SiO_2 and Al_2O_3 with small amount of Fe_2O_3 which together account for 90.79% by mass of total ash content. CaO content of fly ash has a relatively low value 1.2.According of the ASTM C618; this fly ash can be classified class F for having a less than 10%CaO content and greater than 70%content of SiO_2, Al_2O_3, and Fe_2O_3 altogether.[22]. The loss of ignitition(LOI), a measure of unburnt carbon in the fly ash was reported to be having a low value 0.8.The LOI values can be used as an indicator for the efficiency of the combustion chamber at the thermal power station[23].

3. RESULTS AND DISCUSSION

3.1 Effect of Variation of Initial Nickel (II) Concentration and Contact time

The effect of variation of initial Nickel concentration was studied on figure 1.1. It was apparent that with an increase in initial Nickel concentration from 6mg to 12mg, the amount of adsorption of Nickel increase, while the percentage adsorption decreases. Initially percentage adsorption increases rapidly till 14 min and becomes constant thereafter.

The initial concentration of metal ion provides an important driving force to overcome all mass transfer resistance of metal ions between the aqueous and solid phases.[24]. it is clearly shows that by increasing the concentration gradually, there is decrease in the percentage removal. As the ratio of sportive surface to ion concentration decreases with increasing metal ion concentration and so metal ion removal was reduced. At low initial concentration of metal ions, more binding sites are available, but as the concentration increase, the no. of ions competing from for available binding sites in the biomass increased[25].

Results revealed that uptake of adsorbate species is fast at the initial stages of the contact period and thereafter, it becomes slower near the equilibrium. In between these two stages of the uptake, the rate of adsorption is found to be constant. This is obvious from the fact that a large number of vacant surface sites are available for adsorption during the initial stage. After elapse of time, the remaining vacant surface sites are difficult to be occupied due to repulsive forces between the solute molecules on the solid and bulk phases.

The adsorption capacities of Nickel increased rapidly in the beginning of the adsorption and reaching to equilibrium, it become constant a short contact time necessary to reach equilibrium indicates that the predominant mechanism is that of chemisorption[26].

Contact time has negligible effect on adsorption of Nickel on fly ash. As we increase contact time till 92 hrs., adsorption amount remain almost constant.

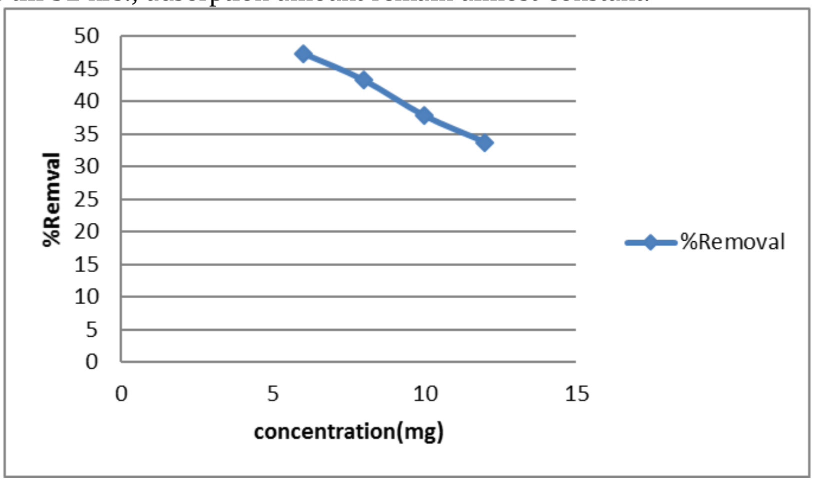

Figure: 1.1 Change in percentage adsorption of Nickel (II) with time at different initial Nickel (II) concentration

3.2 Effect of Adsorbent Dosage

It is observed from the figure 1.2, that percentage adsorption increase with increasing amount of fly ash from 1 g to 3 g as an adsorbent.

There is an increase in adsorption of Nickel (II) with increase of amount of fly ash. It is inferred that the Nickel (II) adsorption increases with increase in amount of fly ash due to greater availability of the exchangeable active sites or the surface area for adsorption onto fly ash samples. Moreover the percentage of metal ion adsorption on adsorbent is determined by adsorption capacity of the adsorbent. The maximum adsorption is observed at the dosage of 3g among all five amounts of fly ash.

Adsorption assays using different masses of adsorbent to adsorbate solution were carried out in order to assess the effect of adsorbent amount on Nickel (II) removal. It is obvious that in an increase in the removal percentage of Nickel with increase amount of adsorbent because at a fixed initial concentration of sorbate the increase in the adsorbent amount provides a larger surface area or adsorptive sites[27]. The decrease in adsorbed amount per unit mass of adsorbent is a generally observed behavior which is also reported such as adsorption of nickel on papaya seeds, on pomegranated peel activated charcol, calcined brick powder and doum seed coat and soon.[28–30].

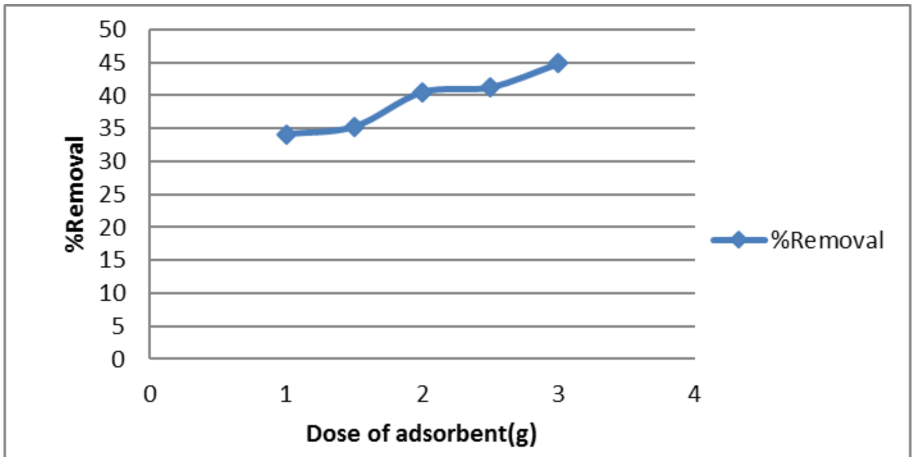

Figure: 1.2 Change in percentage adsorption of Nickel (II) with time at different adsorbent dosages

3.3Effect of Variation of pH of Solution

It's apparent from Figure 1.3 that with increase in pH from 2 to 10 adsorption of Nickel (II) initially increase in pH 2 to 6 then decreases from pH 6 to 10.Maximum removal of Nickel were observed at pH 6.

The pH dependency is both related to the surface properties of the adsorbent and Nickel species in solution[31]. At low pH values, metal cations and protons compete for binding sites on adsorbent surface which results in lower uptake of metal. It has been suggested that at highly acidic condition, adsorbent surface ligands would be closely associated with H3O+ that restricts access to ligands by metal ions as a result of repulsive forces[32]. It is to be expected that with the increase in pH values, more and more ligands having negative charge would be exposed which result in increase in attraction of positively charged metal ions[33]. In addition, at higher pH, more than 7, the lower binding is attributed to reduced solubility of the metal and its precipitation[32].

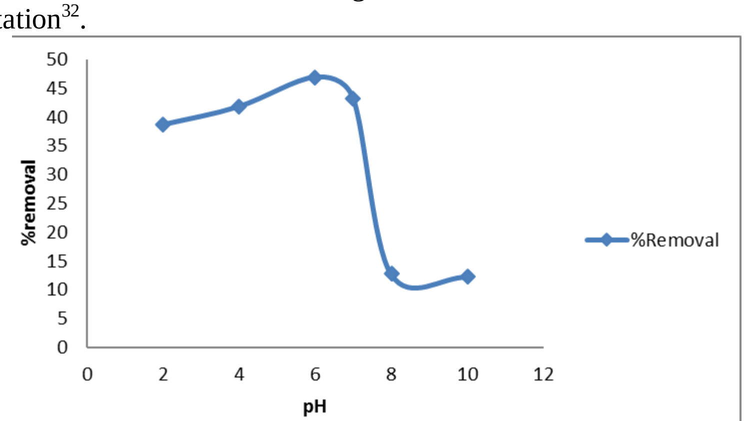

Figure: 1.3 Change in percentage adsorption of Nickel (II) with time at different pH

4. CONCLUSION

In this study of heavy metal, namely, nickel (II) was selected for removal from aqueous solution using fly ash as an adsorbent. Batch experiments were conducted to study the impacts of variation of initial metal ion concentration, contact time, adsorbent dose, and pH. With the increase in the initial metal ion concentration, percentage adsorption was decreased. Whereas the adsorption increased with the increase in the adsorbent dosages. Variable of pH showed a remarkable impact due to chemical nature of surface and the ligands and the interaction between charged species. This study provide a cost effective and useful design of waste water treatment plants for the removal of Nickel that uses waste as a resource and helps to get rid of waste disposal expenses .Fly ash have excellent adsorption capacity in controlling air and water pollutant .Fly ash is a promising low cost adsorbent for the removal of nickel from contaminated waste water.

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