



Removal of Nickel (II) from Gomati river using fly ash as Adsorbent

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Abstract

Heavy metal pollution caused by industrial activities and technological development is posing significant threats to the environment and public health because of its toxicity, non-biodegradability, bioaccumulation and persistent tendency through food chain. Nickel is a non-biodegradable toxic heavy metal ion present in wastewater. In this study, removal of Nickel from aqueous solutions has been described. Fly ash as an adsorbent has been collected from Shree Ram Fertilizers and Chemicals, Kota (SRFC). Batch adsorption experiments were carried out to study the various parameters such as effect of initial metal ion concentration, effect of adsorbent dose, effect of Ph, stirring of reactant mixture, particle size of fly ash. It was found that removal of metal highly 97.8% in 160 min whereas maximum 77.21% in 100 mg/L aqueous solution. When different concentration of solution processes maximum removal of Nickel takes place at pH 2.0 at maximum removal occurs at initial of 400 mg/L.

Key words : Batch Adsorption, Equilibrium Studies, Fly ash, Isotherms

Introduction

Pollution load in the Gomati River is increasing due to global rise in population and our quest to lead comfortable life is resulting in explosive growth of industrial and agricultural activities. Waste water commonly contains metal ions, Cu, Ni, Cd, Cr, Fe, Mn, Zn, Pb, Cs which are not biodegradable and hence are of vital concern¹. Heavy metals are one of

important pollutants in wastewater, and it has become a public health concern because of its non-biodegradable persistent nature². Many toxic heavy metals have been discharged into the environment as industrial wastes causing serious problem of soil and water pollution³. Heavy metals are continuously released into the aquatic environment from natural processes like volcanic activity and weathering of rocks. Industrial processes have greatly enhanced the mobilization of heavy metals⁴.

The permissible limits of Ni(II) in drinking water is 0.07 mg/lit. It causes various types of acute and chronic disorders like hyper sensitivity reactions in the immune system, respiratory illness such as asthma, liver necrosis and carcinoma⁵. Nickel does not occur in natural water. Metal plating wastes when discharged into water courses contribute nickel. Increased use of stainless steel and other nickel containing alloys in water systems also contribute nickel⁶.

Many physicochemical wastewater treatment processes viz. oxidation-reduction, precipitation, ion-exchange, biosorption and liquid membranes are being used to remove nickel(II) present in wastewaters⁷. However, all these processes have their limitations of technical and economical constraints. Adsorption is a viable and attractive method for removal of heavy metals from effluents due to its high efficiency, easy handling and less expensive⁸. The effects of different parameters such as contact time, dosage of adsorbent, pH and temperature have been studied. Calorimetric method is used to measure the amount of nickel (II) present in the solution. Optical density of solution increases with increase in nickel(II)concentration^{9,10}.

Experimental

Method of Estimation of Nickel: UV Vis. Spectrophotometry is the most common technique used for Nickel(II) determination owing to its simplicity and low cost.

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.

Preparation of Nickel Stock Solution: Standard Nickel (II) solution prepared by dissolving 0.673g of pure ammonium Nickel (II) sulphate $(\text{NH}_4)_2\text{SO}_4 \cdot \text{NiSO}_4 \cdot 6\text{H}_2\text{O}$, in water and diluting to 1 dm³.

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 determined¹¹⁻¹² spectrophotometrically according to standard method. The measurements were made at the wavelength $\lambda = 445\text{nm}$, 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,

$$q_t = \frac{(C_o - C_t)V}{M} \quad (i)$$

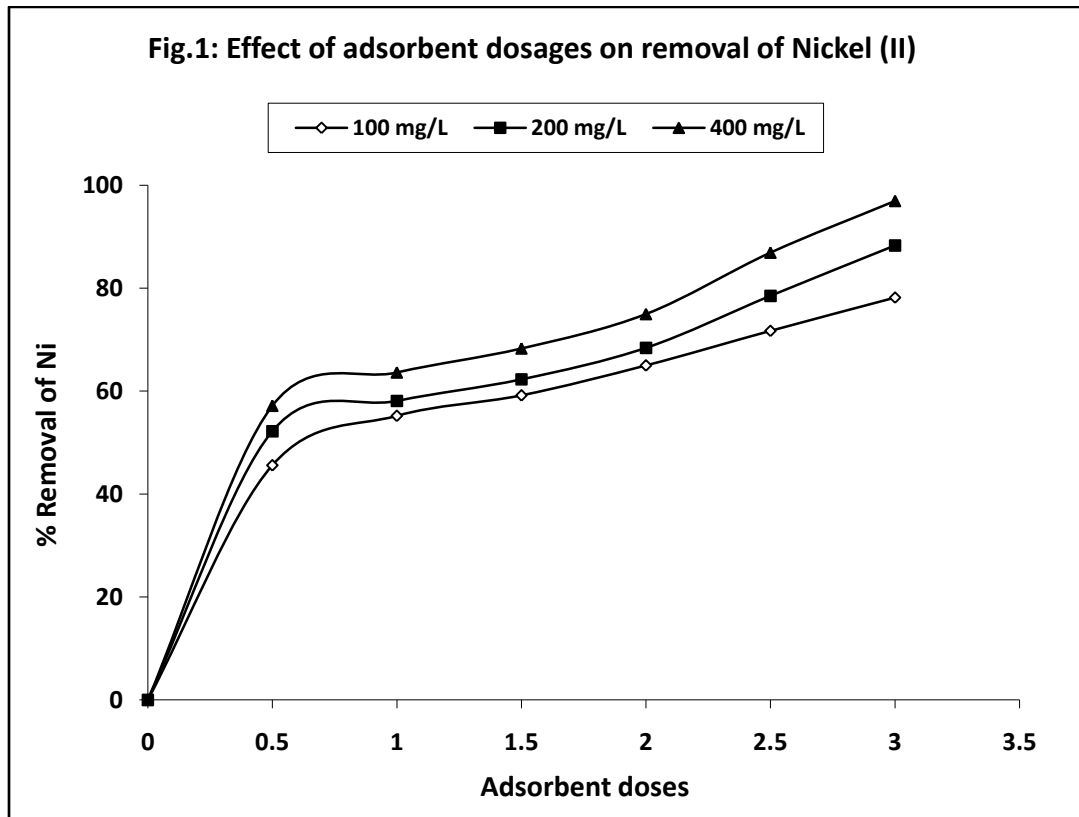
Where q_t is the amount of Nickel (II) adsorbed onto the fly ash at time t , C_o is the initial concentration of Nickel (II), C_t is aqueous phase concentration of nickel (II) at time t , V is the volume of the aqueous phase, and M is the weight of fly ash sample¹³.

Result & Discussion

Effect of adsorbent dosages on removal on Nickel (II)

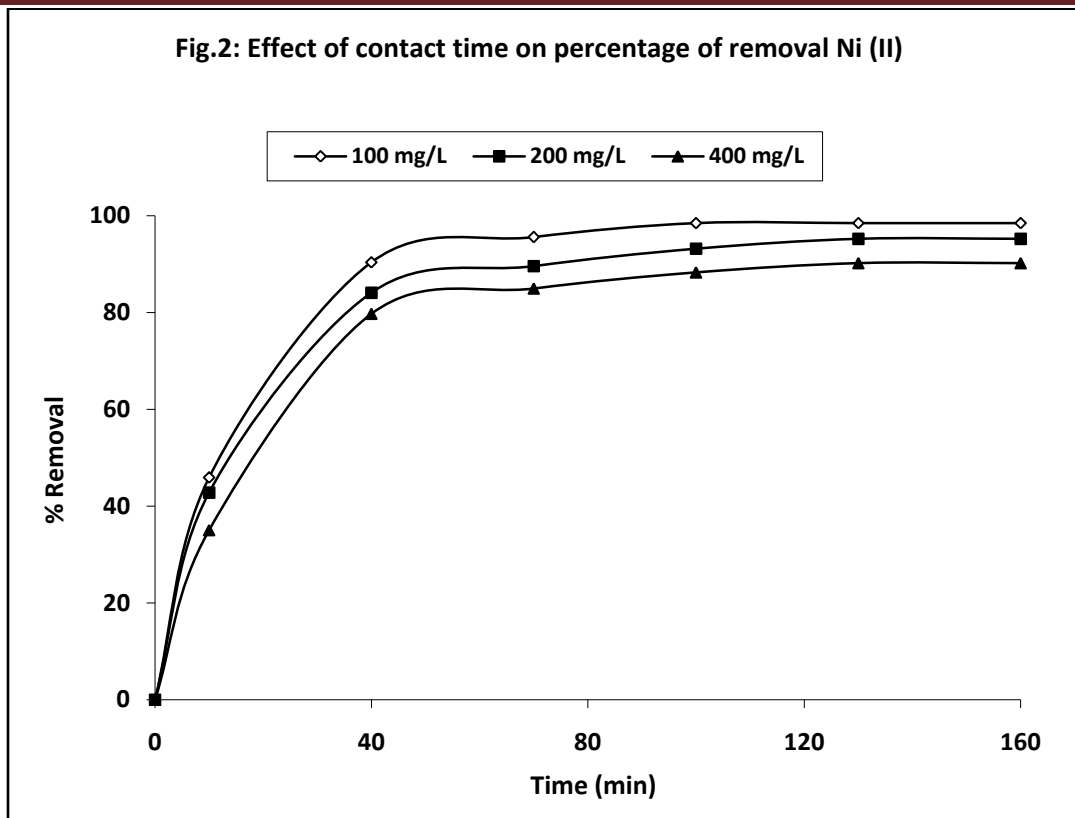
It is important parameter in adsorption studies because it suggests the capacity of adsorbent for a given starting concentration of effluents. The initial concentrations of a Nickel in effluent vary from sample to sample collected from different sites 100 mg/L to 400 mg/L. It can be observed that increasing dose of adsorbent increased minimum and maximum removal percentage of Nickel removal from effluent 100 mg/L Ni (II) concentration 57.6% to 96.0% at concentration 200 mg/L 51.2% to 87.04% and 400 mg/L 44.8% to 76.8% having variable doses

of fly ash 0.5gm, 3.0gm per batch. It conclude that for a fixed initial concentration the decrease in adsorption capacity with increase adsorbent dose might be due to the available more free adsorption sites in the adsorption reaction¹⁴.



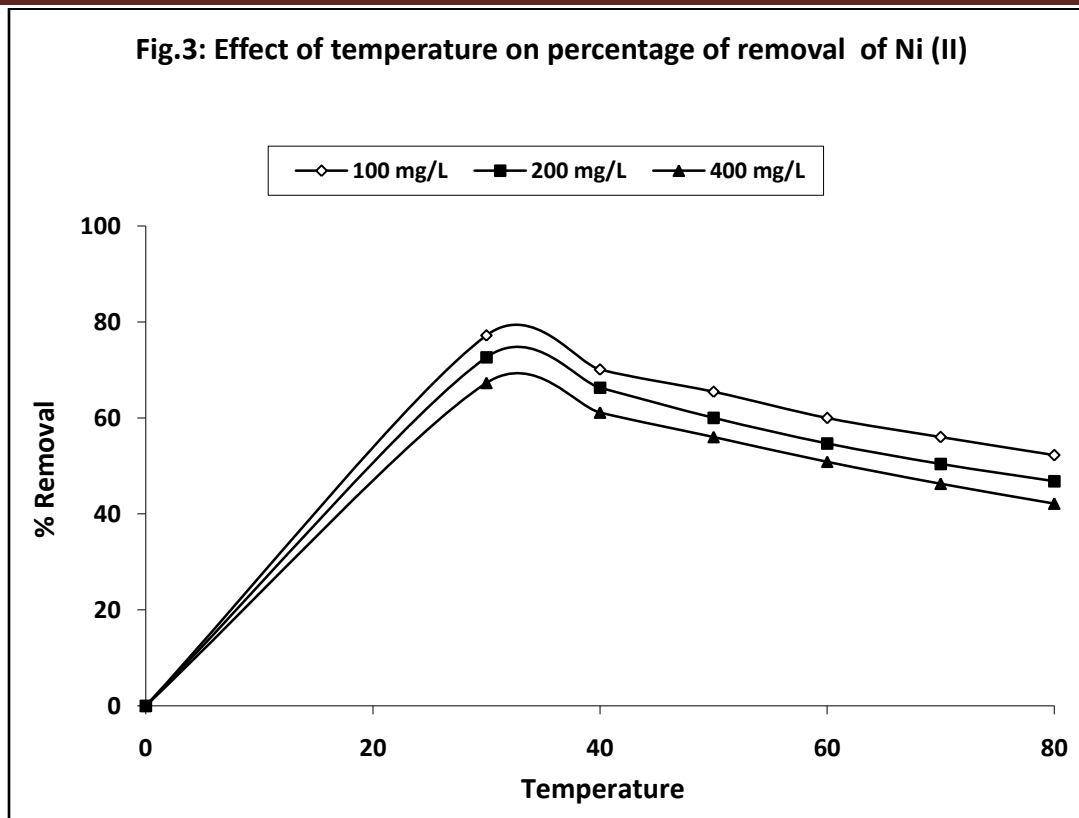
Effect of contact time on percentage of removal of Ni (II)

The contact time experiments were carried out at 30°C. The initial concentration of Ni was 100-400 mg per litre. The contact times were designed 30 minutes intervals. The removal of nickel from aqueous solution on fly ash increase until the equilibrium is attained. The equilibrium time is independent on previous concentration of Ni(II) in effluents. It is observed that increasing in adsorption contact time was attained in 100 min by 100 mg/L initial concentration, 130 min by 200 mg/L, 400 mg/L concentration of Ni(II). It was observed that removal of Ni from aqueous solution is highly depending on initial concentration of solution pH. It affects the surface of adsorbent, degree of ionization and speciation of adsorbate¹⁵.



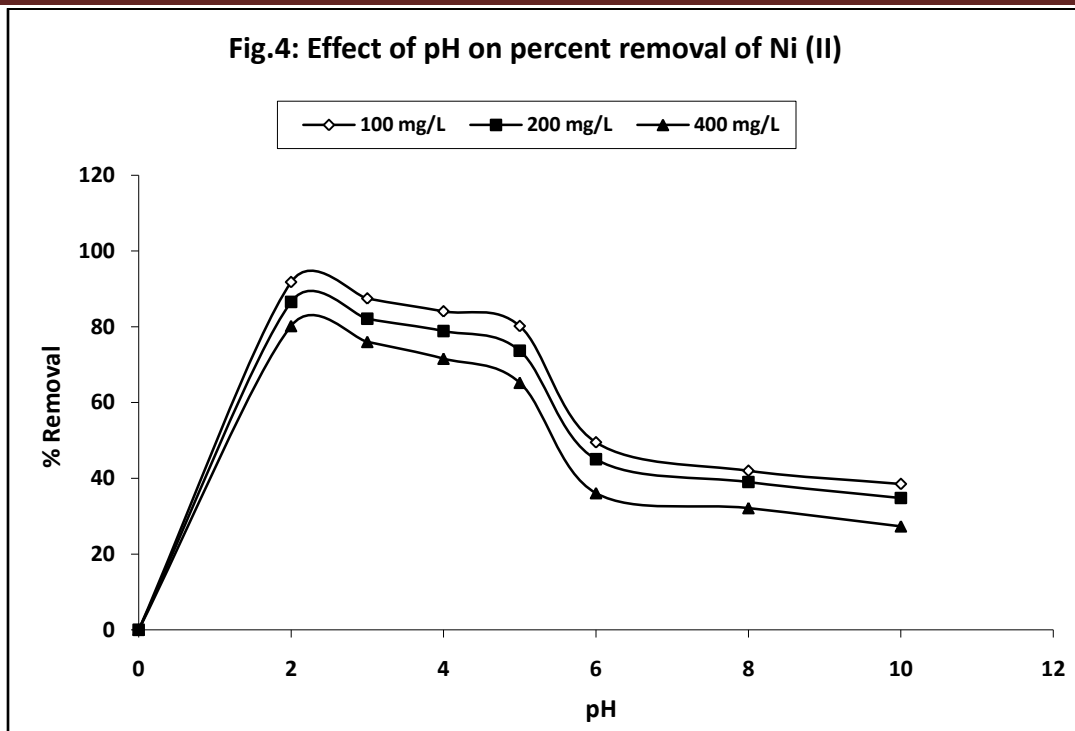
Effect of temperature on percentage of removal of Ni (II)

For the consideration of adsorption process, it might be endothermic or exothermic in nature. We had taken 100 mg/L to 400 mg/L Nickel initial concentration of effluents taken for this study. With an increase in experimental temperature from 30°C to 80°C, the adsorption of Ni(II) decrease on surface of fly ash. It shows the endothermic nature of reaction. On analysis of Fig.-3 we found that the equilibrium state might be due to the adhering of Ni ion on surface of fly ash¹⁶. It can be seen from Fig.-3 initially removal percentage of Ni(II) increase very sharply with increasing temperature 30°C. The rising temperature of experiment favors the sorbate transport with the pores of sorbent. The increasing sorption with rising temperature might be due to increase in the number of sites generated because of breaking of some internal linkage of active surface of the sorbent. The maximum and minimum removal percentage of Ni (II) 77.21% to 52.25% in 100 mg/L and 72.65% to 46.81% in 200 mg/L and 67.28% to 42.15% in 400 mg/L in initial concentration of solution.



Effect of pH on percentage of removal of Ni (II)

The removal of heavy metal from effluents by fly ash depends on the pH of initial effluents. For batch equilibrium studies experiment carried out in different pH values. The pH range was selected between 2-10 to avoid metal hydroxides, which has been observed at pH more than 6.5 for hydroxide formation 6 to 10 pH considered. Low sorption at lower pH (2.0) might be due to hydrogen ions competing with metal ions on the sorption site which show maximum removal percentage of Ni. It concludes that higher hydrogen ions concentration, the adsorbent surface becomes more positively charged. It reduces attraction between metal ions and adsorbent. As soon as pH increases, more negatively charges surface of fly ash become available, thus facilitating greater metal sorption and reduced percentage of Ni (II) removal¹⁷.

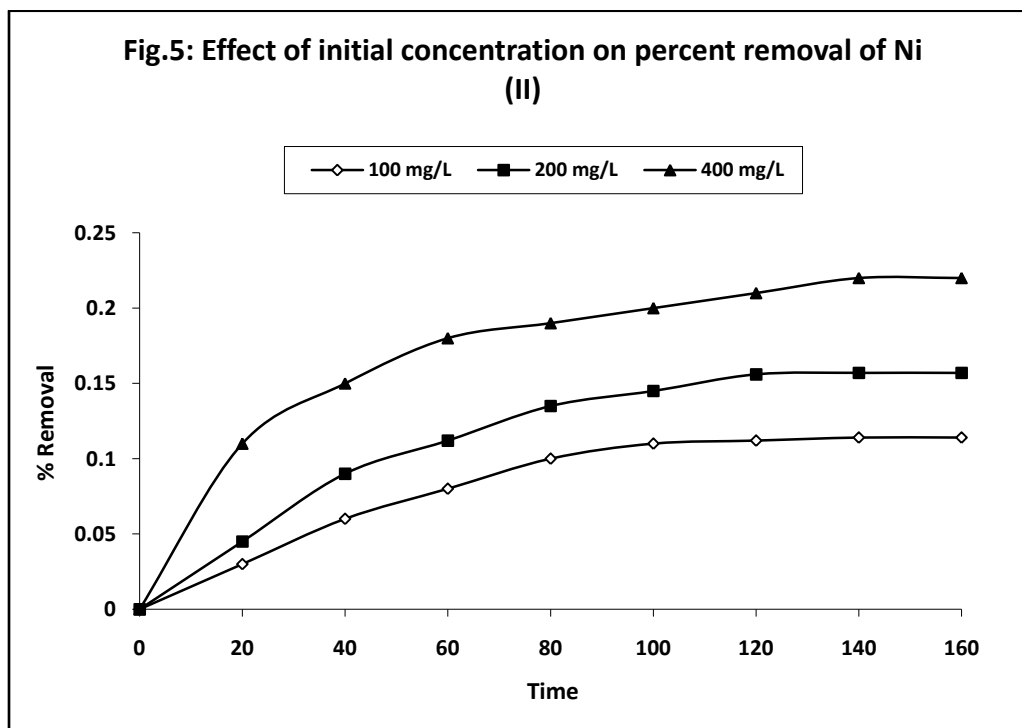


On observation of figure-4 it observed that maximum removal of Nickel takes place at pH 2.0 having effluent concentration 100 mg/L. As soon as concentration of Nickel increased the removal of Ni(II) decreased as presented in figure-2 for 400 mg/L concentration. This is because of pH, the surface of fly ash are positive and therefore formation of complex with Nickel ion. The complex formed in this process will be adsorbed on the adsorbent surface. The maximum and minimum removal percentage, of Ni (II) was found 91.82% to 38.50% in 100 mg/L, 86.56 to 34.79% in 200 mg/L and 80.22% 27.32% on 400 mg/L initial concentration of Ni (II). The hydroxyl metal complexes have greater affinity for adsorption than hydrated metal ion¹⁸.

Effect of initial concentration on percentage of removal of Ni (II)

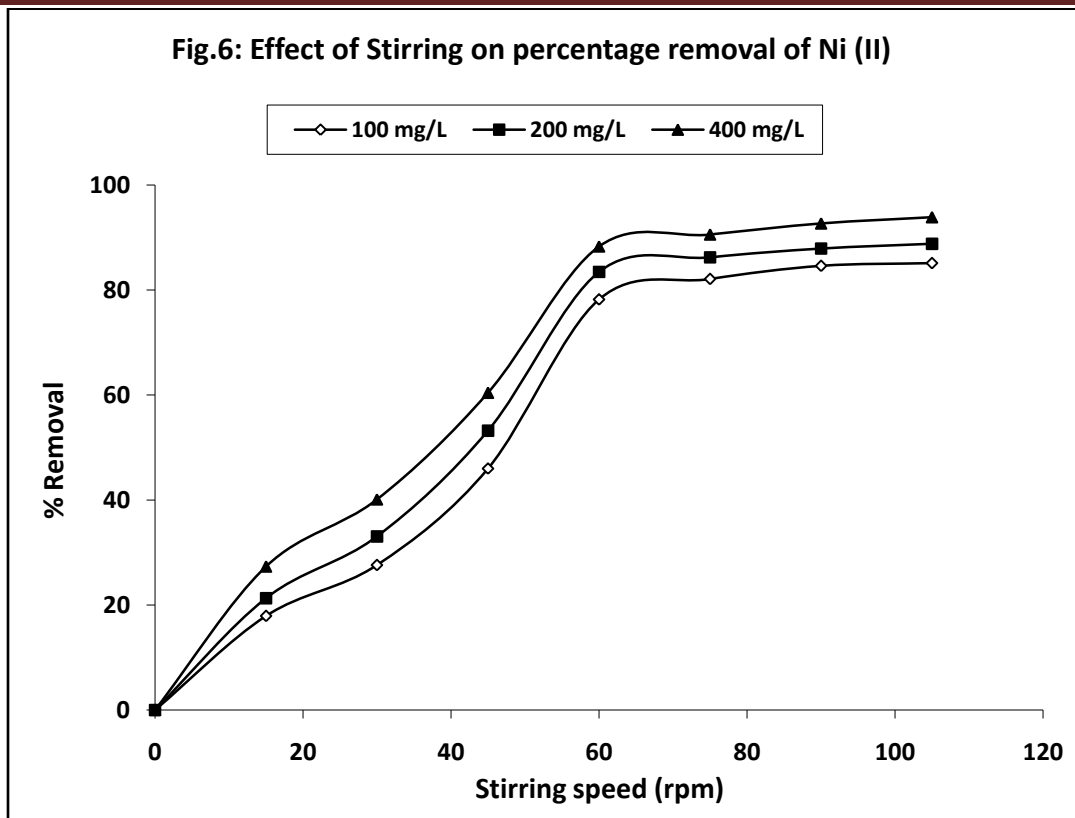
The removal of Ni(II) by adsorption of flyash increase at an extent with time until the equilibrium is attained. It is fact that equilibrium time of adsorption is independent with the initial concentration of Ni(II) in solutions. The extent of Ni(II) removal on fly ash by adsorption process decreases from 100 mg to 400 mg per litre (Fig.-5). The removal percentage of Nickel

increases from 45 to 80% by increasing starting concentration of Ni(II) in aqueous phase from 100 mg/L to 400 mg/L at 30°C having pH 6.0.



Effect of stirring on percentage of removal of Ni (II)

Contact time and mixing influence adsorption process of an adsorbent. This process can be also evaluated by performing various batch is charging stirring with constant rpm. The mixing time vary from 15 min. to 105 min. They effluent and adsorbent mixture was mixed together placing on shaker at rpm 350 for a particular design minute. During this experimental parameter temperature and pH kept constant. The analysis of reaction mixture at different duration presented in figure-6. The equilibrium time is independent of initial concentration of Ni (II) in solution¹⁹.

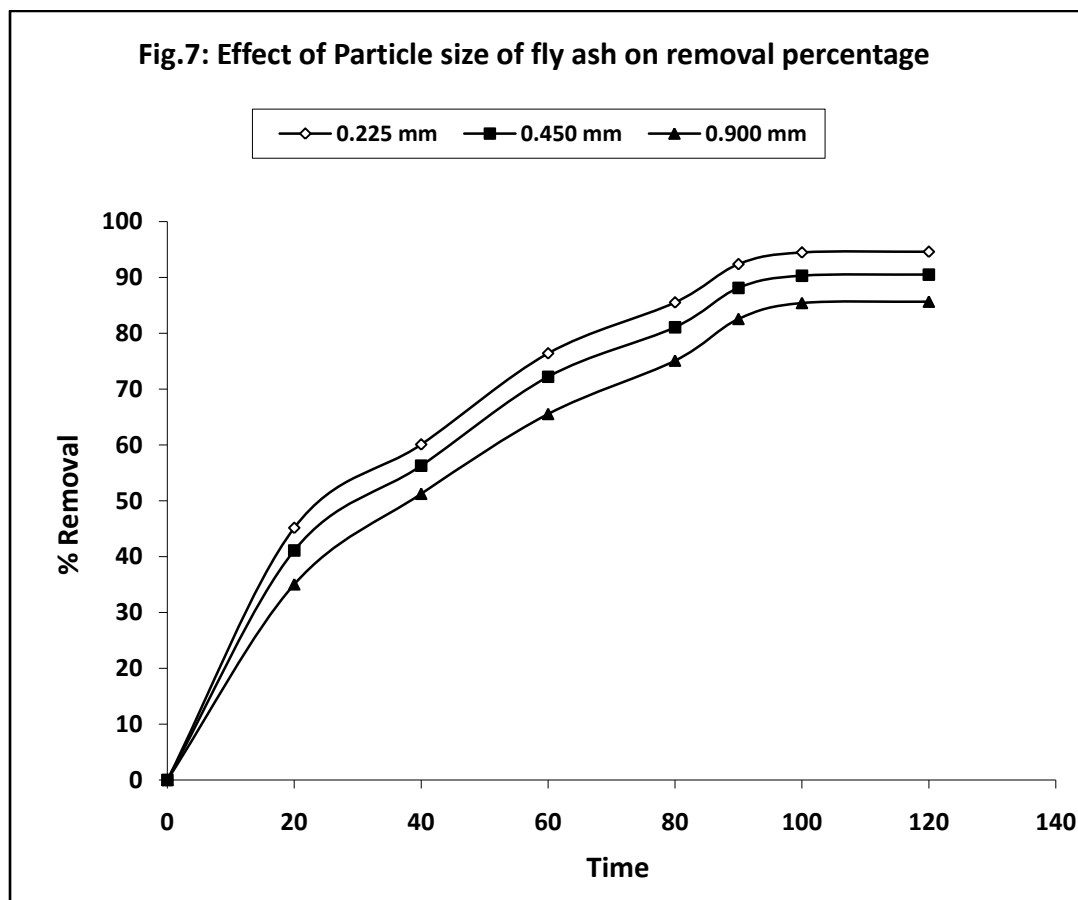


At 100 mg/L initial concentration maximum removal of Ni (II) was found 85.12 at 105 rpm, at 200 mg/L, 88.82% and 400 mg/L initial concentration 93.87%. It shows that removal of Ni (II) depend on initial concentration of Ni (II). The removal percentage of Ni (II) was faster in low concentration and achieved equilibrium at 105 rpm mixing which shows maximum saturation of active sites²⁰.

Effect of particle size of fly ash on removal percentage

Commercial fly ashes received from thermal power plant have varying particle size. Experiment performs with adsorbent size showed that smaller fly ash particle sizes have better Nickel (II) removal. The smaller particle sizes have larger surface area for adsorption of nickel per unit mass of fly ash as compared to larger particle size. Smaller particle of 0.225 mm when mixed the initial concentration of Ni⁺⁺ 50 mg/L in effluent solution decrease to 23.75 mg/L in 90 minute of operation. The larger particle size i.e., 0.900 mm at fixed initial concentration of Nickel adsorbed 40.00 Ni⁺⁺ in the same solution. The flyash showed better removal efficiency of

94.61% to 85.65% with contact time 2.0 hour heavy particle size 0.225 mm, 0.450mm, 0.900 mm and pH 5. It concluded that small mace of flyash particle size have better removal efficiency of heavy metal from Gomati river water²¹.



Discussion

In present study, fly ash is chosen for the removal of heavy metal Ni(II) from polluted sites sample of Gomati river using adsorption studies. Different parameters such as adsorbent dosage, pH, initial concentration of solution, agitation time, particle size of fly ash are conducted as batch experiments⁹. The maximum removal of Ni(II) was 400 mg/L fly ash 97.8%. It might be due to availability of maximum free adsorption site in high dosages of fly ash. In respect to contact time depends on equilibrium which depends on previous concentration of Ni(II) in effluent. Interaction between nickel ion and free adsorption site of fly ash increase

removal of nickel. Removal process of nickel removal is endothermic¹³. Above 30°C adsorption site activate more which facilitate removal of Ni(II). For pH study it was found that higher H⁺ concentration adsorption site become more active due to positively charged, which reduces adsorption of Ni(II)¹⁶. As solution become alkaline, more negatively charge surface of fly ash available and increase sorption of Ni⁺⁺. In case of initial concentration of Ni its solution the adsorption process decrease from 100 mg/L to 400 mg/L. It assumes that availability of maximum Ni⁺⁺ in solution complete adsorption process⁸.

Stirring of time and speed of azitation also influenced the adsorption of nickel. The removal percentage of nickel was faster at low concentration 100 mg/L at 90-105 rpm mixing. In this case maximum saturation of active site takes place and show fruitful result. Small particle of fly ash 0.125 mm show maximum active sites. It was found that 94.61% to 85.65% removal of nickel observed of particle size 0.225 mm in 2 hrs contact time in comparison to 0.450 mm and 0.900 mm particle size of fly ash.

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