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RESEARCH ARTICLE

A BATCH STUDIES ON ADSORPTION OF NICKEL (II) USING REDMUD

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Abstract

The objective of this study is to remove the heavy metal Nickel (II) from the industrial effluent and to reuse the waste material Redmud in Nickel removal. Heavy metal Nickel (II) widely used for various manufacturing process, during the process losses occur that mixed in to the effluent. Using Redmud as a adsorbent for the removal of Nickel, the effect of Adsorbent Dosage, contact time, rpm, concentration of Nickel, pH, various size are studied. Equilibrium isotherms for the adsorption of Nickel are measured experimentally and the results are analyzed using Freundlich and Langmuir Isotherm and that concludes Redmud is the good adsorbent for the removal of Heavy metals.

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Introduction

In recent days, world fully depends on industries day to day the number of industries are increasing and the consumption of water is mandatory for all the industries for various reasons. Enhanced industrialization is the reason for various type of pollutant occurs, by this environment gets highly polluted (Bhatnagar *et al.*, 2011). The pollutant present in wastewater is toxic that contaminates the groundwater and not only affects the aquatic life but also the Human beings. A number of processes have been applied for the treatment of wastewater some of these processes are Ion-exchange, Reverse Osmosis and Electrolysis are high cost and requires more energy. Adsorption is considered as the most versatile and low cost adsorbent method for removal of heavy metal (Nhapi *et al.*, 2011). The solid waste materials generated from various industrial activities causes serious problems to the environment. A Beneficial utilization of solid waste can be converted into low cost adsorbent for the treatment of wastewater discharged from various industries. By utilizing the solid waste as a low cost adsorbent the environmental pollution can be controlled, among various industrial by products. Redmud is a solid waste residue formed after the caustic digestion of Bauxite ore during the production of aluminium. The waste material has a reddish colour and is composed of Iron, Aluminium, Silica and Hydroxides, which are responsible for its high surface reactivity, because of these characteristics it is used for removal of toxic heavy metals from waste water (Anna *et al.*, 2006; Yunus *et al.*, 2006). Nickel is a toxic heavy metal and the atomic number is 28. The earth core is composed of 6% Nickel, it is a fairly good conductor of heat and electricity and is highly corrosive resistant due to this it widely used in silver refineries, electroplating and storage battery industries (Housecroft and Sharpe, 2008) Nickel is released into the atmosphere during Nickel mining and by industries as Nickel or Nickel alloys (Davis, 2009; Miessler and Tarr, 2004). During this process, waste and losses of Nickel released into the effluent by which Humans may be exposed to Nickel by breathing air, drinking water. Due to uptake of high concentration of Nickel (II) it causes lung cancer, nose cancer, respiratory failure, allergic reaction. The international Agency for Research on cancer has determined that some Nickel compounds are carcinogenic to humans. According Environmental protection agency the average concentration of Nickel in drinking water is 2µg and breathing of Nickel 0.1-1µg per day. So it is essential to remove Ni (II) from industrial wastewater before being discharged (Barceloux, 1999). For this reason, it is generally used the advanced treatment processes such as Chemical Precipitation, Ion Exchange, Reverse Osmosis, Electro dialysis are used for the removal of heavy metals, the cost of process is very high, the low cost adsorption method is

used for the removal. The aim of this study is to reuse the Redmud and to determine the efficiency of industrial Redmud as adsorbent and to optimize the parameters for the removal of Nickel (II) from aqueous solutions is carried out. The adsorption of Nickel on Redmud was investigated as a function of adsorbent dosage, contact time, rpm and initial concentration, various sizes of adsorbent and pH. The equilibrium data was described by the Langmuir and freundlich adsorption isotherm.

Material and Methods

Redmud (Adsorbent)

Redmud used in this study is obtained from the Madras Aluminium Corporation, Salem, India. Redmud is produced during the Bayer process for Aluminium production. Bauxite ores are usually a mixture of minerals mainly contain iron, Aluminium Oxide, Silica and Titanium. In Bayer process, the Bauxite ores mixed with sodium hydroxide is kept under high temperature (170 °C-190 °C) in a pressure vessel thereby aluminium oxide is dissolved in the solution and the solid residue from the pressure vessel is called as Redmud (Tim *et al.*, 2006). The constituent of Redmud are Fe₂O₃ -45.17%, Al₂O₃ -27.00%, TiO₂ -5.12%, SiO₂ -5.70% and Na₂O -3.64% (Parekh *et al.*, 1976).

Preparation of Redmud

The collected Redmud for this study is crushed using crusher and it is sieved by various sieve shaker finally 250micron size particle is used for further studies. The specific gravity of Redmud is 3.1 is calculated through Pycnometer test and the pH of Redmud is 11.2.

Preparation of Ni (II) Solutions

The stock Ni (II) solution is prepared by dissolving 4.48g of Nickel sulphate anhydrous in one litre of distilled water, the final concentration of Nickel solution is 1000ppm, from the stock solution is further diluted with distilled water to desired concentration for obtaining the test solution (80 ppm) and used for further experiments.

Analysis of Nickel

UV double beam absorption spectrophotometer (LABINDIA-UV3092) is more accurate method for the analysis of Heavy metal by which the initial and residual concentration of Nickel is analysed.

Batch Experiments

Batch adsorption experiments are conducted by adding known quantity of Redmud in 100ml of Ni (II) solution and the flask was agitated at the speed of 120rpm in a rotary shaker. Batch experiments are conducted for various parameters such as Optimum Dosage, Contact Time, Agitation, Initial Concentration, pH and Various Size of adsorbent using Isotherm study and the kinetics of Nickel (II) adsorption on the Redmud is evaluated. The adsorbent is separated from the solution by filtration and the removal efficiency of Nickel (II) using UV spectrophotometer the percentage removal efficiency is determined based on the wavelength at 394 nm.

The amount of Ni (II) adsorbed by the adsorbent and the percentage removal of Ni (II) are calculated using the following Equations:

$$Q = (C_0 - C_e)$$

$$\text{Removal Percentage of Nickel (II)} = \frac{C_0 - C_e}{C_0} \times 100$$

Where,

Q - Adsorption capacity of Redmud

C₀-Initial concentration of Nickel

C_e-Residual concentration of Nickel

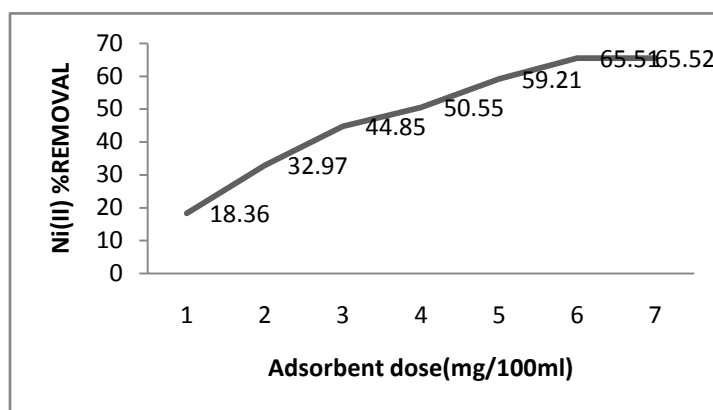
Equilibrium Studies

The Langmuir and freundlich isotherm models are used to determine the adsorption of components from a liquid phase onto a solid phase. Through this isotherm model we find out the amount of adsorbate on the adsorbent is analyzed.

Result and Discussion

Effect of Adsorbent Dosage

The effect of dosage on the adsorption is studied by varying the amount of adsorbent from 1 to 7g. Optimum dosage is an important factor in adsorption studies, which control the capital cost and operation cost. 100ml of 80ppm of Ni (II) solution is taken in 250ml conical flask of varying weights such as 1 to 7 g of Redmud is added and then it is kept in shaker for 90min. Through the UV adsorption spectrophotometer measured at 394 nm, the presents of Nickel concentration in that filtered solution. The graph is drawn between Percentage removals of Ni (II) VS Dosage of adsorbent as shown in Fig 1. The maximum percentage removal of Ni (II) is analysed as 65.52% for 7g of Redmud and is observed that the percentage removal of Ni (II) increases with the increase in the adsorbent dosage, due to its availability of more surface on the adsorbent to absorb the metal ions and the increase the rate of adsorption of Heavy metals (Rio and Parwate, 2002).

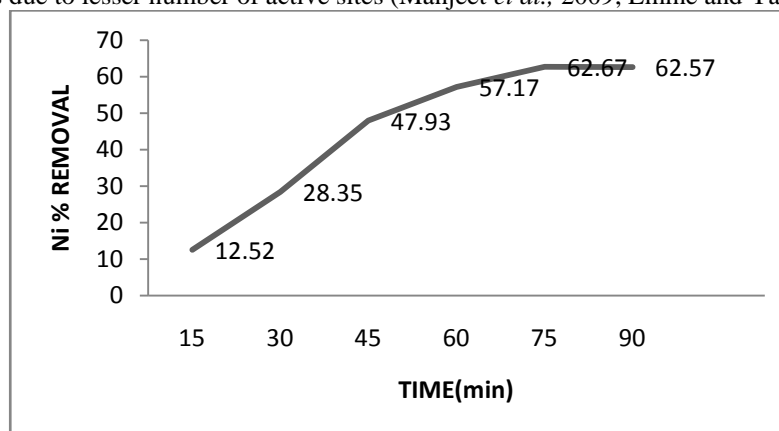


$C_0=80\text{mg/l}$, $V=100\text{ml}$, $t=90\text{min}$

Fig 1. Effect of adsorbent dose on Percentage removal of Ni (II)

Effect of Contact Time

A graph is drawn between the Effect of Time on Adsorbent and Percentage removal of Ni (II) using Redmud as shown in Fig 2. 7g of Redmud was used for this experiment at different contact time such as 15, 30, 45, 60, 75, and 90 minutes. 100ml of 80ppm synthetic solution was taken in six conical flasks and treated with the Redmud for different time for the fixed dosage of Redmud. The Percentage removal of Ni (II) concentration is measured as 62.57% at contact time of 75 minutes using UV absorption spectrophotometer and the graph is drawn between the Percentage removal of Nickel VS contact time from as shown in Fig 2. At the initial stage the rate of removal of Ni (II) was higher due to availability of more number of active sites on the surface of the adsorbent and became slower after 75 minutes due to lesser number of active sites (Manjeet *et al.*, 2009; Emine and Yasar, 2005).

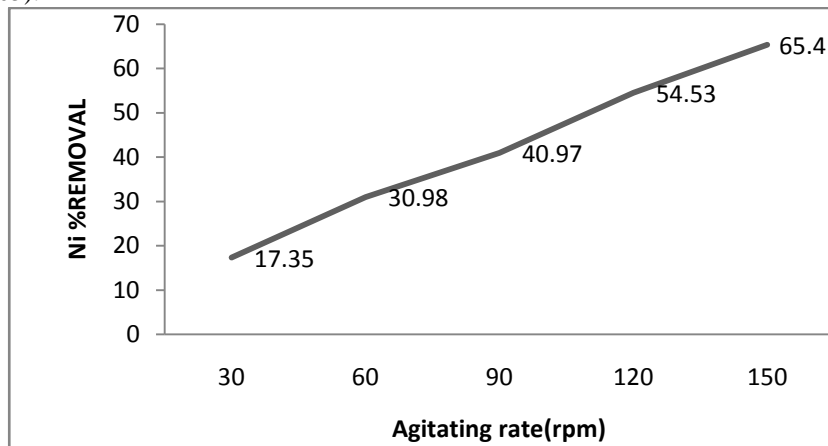


$C_0=80\text{mg/l}$, $v=100\text{ml}$

Fig 2. Effect of contact time on Percentage removal of Ni (II)

Effect of Agitating Rate

The Orbital Shaker (REMI) is used to agitate the samples and the agitation speed varied from 30, 60, 90, 120 and 150rpm. The Percentage removal efficiency is calculated as 65.40% at 150 rpm. The graph is drawn between Percentage removal of Ni (II) VS rpm as shown in Fig 3. The reduction of Ni (II) increased with an increase in agitating rate. The maximum agitating rate was 200rpm because of the limited capacity of the agitator (Emine and Yasar, 2005).

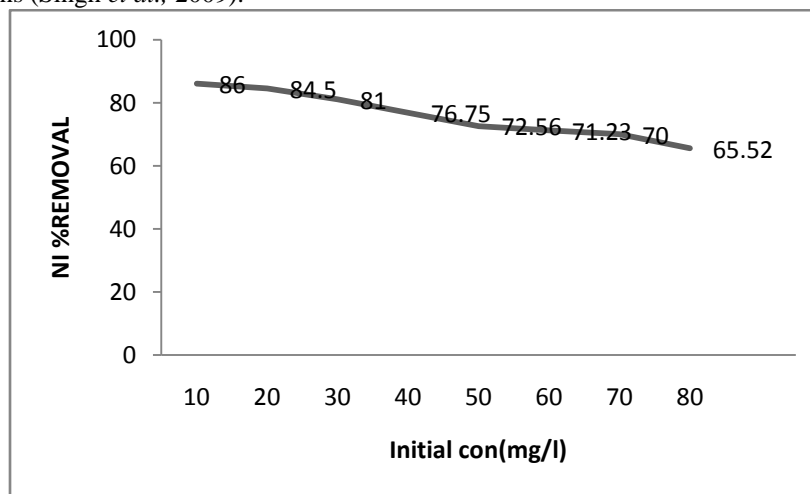


Co=80mg/l, v=100ml

Fig 3. Effect of Agitating Rate on Percentage removal of Ni (II)

Effect of Initial Concentration

The experiment is carried out at varying concentrations of Ni (II) solution from 10ppm to 80ppm per 100ml solution and at a contact time 75minutes. The minimum and maximum removal efficiency of Nickel is analyzed as 65.52% and 86.0% as shown in Fig 4. The percentage removal is greater with lower initial concentration than with higher initial concentrations. At low initial concentration, Ni (II) ions have more binding sites are available when the concentration increases, the number of ions competing for available binding sites in the adsorbent that controls Ni (II) ions at various concentrations (Singh *et al.*, 2009).



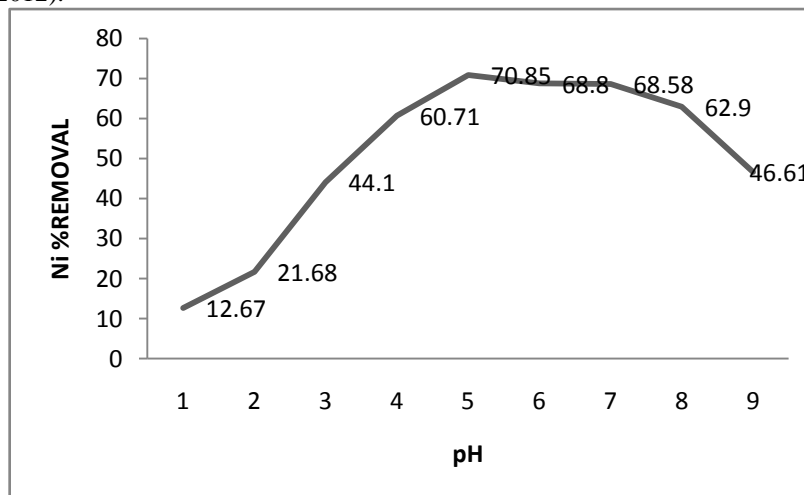
V=100ml, t=75min, rpm= 150

Fig 4. Effect of initial concentration on Percentage removal of Ni (II)

Effect of pH

The batch adsorption studies at different pH values are carried out in the range from 1 to 9. The maximum adsorption of Ni (II) ions are analysed at pH 5 and the percentage removal of Ni (II) at pH 5 is 70.85%. Fig 5 shows the Percentage removal of Ni (II) ions increases as the pH rises and after pH 7 the removal percentage decreased, this is due to at low pH Hydrogen ion concentration is high and there is a competition between H⁺ ions and the Ni

(II)ions in the adsorbent sites so repulsive force take place. For higher pH, OH⁻ ions highly present and the precipitation started to decrease percentage removal of Ni (II) due to high pH (Manjeet *et al.*, 2009; Emine and Yasar, 2005; Rudre *et al.*, 2012).

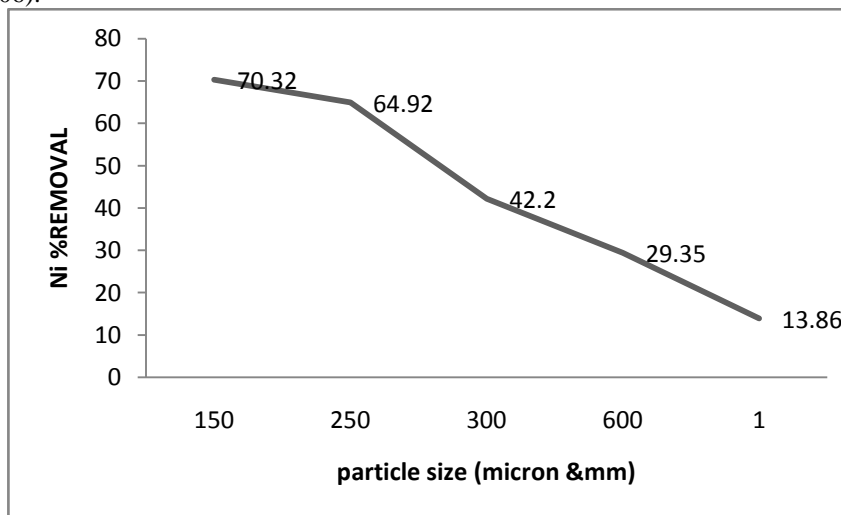


V=100ml, t=75min, rpm= 150

Fig 5.Effect of pH on Percentage removal of Ni (II)

Effect of Particle Size

The batch adsorbent studies on various size of adsorbent (150micron-1mm) sieved Redmud were used. In each study 7g of adsorbent in 100ml of Ni (II) solution is agitated for 75min, the adsorbent gets separated and the supernatant solution is analyzed for Ni (II) concentration. The percentage removal of Ni (II) is calculated as 70.32% at 150micron. A graph is drawn between Particle size and Percentage removal of Ni (II) as shown in Fig 6. The increase in particle size decreased due to the percentage removal of adsorbate the decrease in particle size increases the metal uptake. This is due to smaller particles have greater surface area for bulk adsorption (Singh *et al.*, 2009; Suwannee and Suttawadee, 2006).



V=100ml, t=75min, rpm= 150

Fig 6.Effect of Particle size on Percentage removal of Ni (II)

ADSORPTION ISOTHERMS

The Langmuir and freundlich model are tested in this study in which Adsorption is described through isotherms that are function which connect the amount of adsorbate on the adsorbent. The Langmuir isotherm model is the most common model used to quantify the amount of adsorbate adsorbed on an adsorbent. Irving Langmuir was awarded the Nobel Prize in 1932 for his investigation concerning surface chemistry. Langmuir isotherm describing

the Adsorption of Adsorbate (A) onto the surface of the Adsorbent (S). The Langmuir isotherm equation is derived from rational consideration and is given by,

$$1/(X/m) = 1/q_m + 1/K_A \cdot q_m (1/C_e)$$

Where, X/m is the amount adsorbed per unit weight of adsorbent Redmud (mg/g), K_A , q_m are constants, K_A is the Rate of adsorption, q_m is the adsorptive capacity of Redmud, C_e is the equilibrium concentration of adsorbate in solution after adsorption (mg/l).

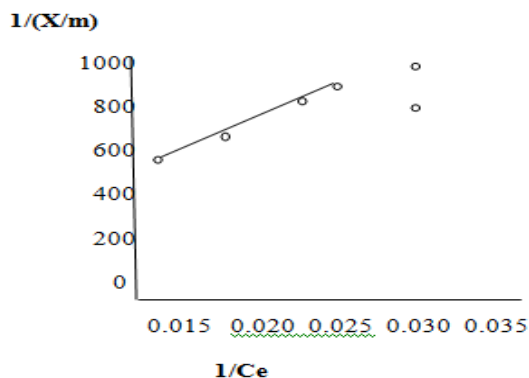


Fig 7. Langmuir Isotherm

A graph $1/C_e$ VS $1/(X/m)$ is plotted and the value of $K_A=0.0202$ and $q_m=0.0018$ were calculated from the slope and intercept of the plotted graph as shown in Fig 7. The Langmuir isotherm can be expressed in terms of a dimensionless value R_L , is defined as

$$R_L = 1 / (1 + K_A \cdot C_o)$$

Where, C_o is the Initial concentration (mg/l) R_L is the Indicates the isotherm. There are four probabilities for the value of R_L (i) for favourable adsorption, $0 < R_L < 1$, (ii) for unfavourable adsorption, $R_L > 1$, (iii) for linear adsorption, $R_L = 1$, (iv) for irreversible adsorption, $R_L = 0$. The values of R_L is 0.012 for the studied system at different dosage were found to be in between 0 to 1 which indicate favourable adsorption of Nickel onto the adsorbent (Manjeet *et al.*, 2009; Pandey *et al.*, 2007; Senthil *et al.*, 2007). Freundlich isotherm model can be applied for heterogeneous surfaces. The first mathematical fit to an isotherm was published by Freundlich in 1894. The linearized Freundlich model isotherm was applied for the adsorption of Nickel and is expressed as

$$\text{Log}(X/m) = \text{Log } K_F + 1/n (\text{Log } C_e)$$

Where, (x/m) is the amount of Nickel adsorbed at equilibrium (mg/g). C_e is the equilibrium concentration of Nickel in solution (mg/l). K_F and n are the constants values are calculated from the intercept and slope of the plot (Fig 8). To evaluate the constants, a logarithmic plot of C_e VS X/m was made and a linear relationship is found to exist as shown in Fig 8. The value of intercept from the figure is $\text{Log } K_F = 1.23$. The slope of the line will give the value of $n = 1.25$. The value of K_F indicates the adsorption capacity and n denotes the adsorption intensity. The result indicated that the adsorbent has several different type of adsorbent sites and the calculated n value 1.25 indicate moderately adsorption of Ni (II) on Redmud (Nwabanne and IGabokwe, 2012; Park *et al.*, 2006; Abdel- Razek, 2011).

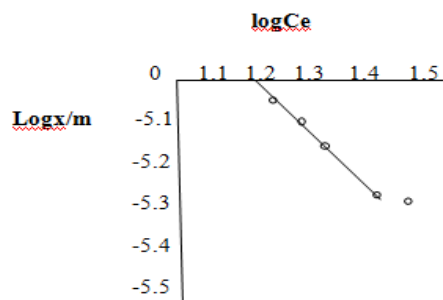


Fig 8. Logarithmic plot of Ce VS X/m

Conclusion

Redmud the waste created on the extraction of aluminium from its Bauxite ore. Redmud is one of the good adsorbent by using it as adsorbent the removal of Ni (II) can be performed and the disposal problem can be minimized. The maximum percentage removal of Ni (II) is 65.52% at 7g of Redmud and the percentage removal of Ni (II) is observed which increases with the increase in the adsorbent dosage by the availability of more surface of the adsorbent to absorb the metal ions and this increase the rate of adsorption. The percentage removal of Nickel is 62.67% at an optimum time of 75 minutes. The equilibrium Agitation rate for the percentage removal of Nickel is 65.40% at 150 rpm for 75 minutes, the reduction of Ni (II) increased with an increase in agitating rate. The maximum and minimum initial concentration for the percentage removal of Ni (II) is 86% and 65.52%. The percentage removal is greater with lower initial concentration than with higher initial concentration. At low concentration of Ni (II) ions, more binding sites are available when the concentration increases the number of ions competing available at binding sites in the adsorbent gets decreased. The batch adsorption studies at different pH values are carried out in the range of 1 to 9. The maximum percentage removal of Ni (II) at pH 5 is 70.85%. The Varying adsorbent size for the percentage removal of Ni (II) is 70.32 % at 150micron shows that the increase in particle size decreased the percentage removal of adsorbate that decrease in particle size increases the metal uptake, this is due to smaller particles have greater surface area for bulk adsorption. The Langmuir and freundlich adsorption models are well suited for the experimental data and as conclusion the adsorbent selected for this study proved to be good adsorbent for the Removal of Heavy metals.

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