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Performance of TiO_2 Nano powder in Removal of Lead from Synthetic Solution

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Abstract - *The purpose of this study is to investigate the capacity of titanium dioxide nanomaterial for lead removal from synthetic solution. The titanium dioxide nano powder was tested by using XRD and SEM instruments for its physicochemical characterization. XRD results shows Rutile titanium dioxide nanoparticles of size 5-15nm. SEM images showed a large bunch of individual TiO_2 nano particle of several sizes which was difficult to distinguish clearly. Various experimental parameters such as effect of pH, contact time of agitation, adsorbent dosage and concentration of lead were carried out to determine percentage variation for removal of lead from aqueous solution. The optimum pH fixed was 9-10 for lead adsorption. Equilibrium isotherms for the adsorption of lead were analyzed by Langmuir isotherm and Freundlich isotherm. Langmuir isotherm model was found to be best of two to represent the data for lead removal using titanium dioxide nano powder. As per study conducted in this project shows, utilization of titanium dioxide in less amount accounted for higher efficiency in the removal of lead from aqueous solution in limited period of time, thus titanium dioxide nano material proved to be beneficial in adopting for the removal of lead from aqueous solution.*

Key Words: *Heavy metal, Lead, TiO_2 nano powder, adsorption.*

1. INTRODUCTION

Many industries, sewage discharges wastewater which contains many pollutants including heavy metal cause hazardous to human health even in low concentration, hence it has to be treated before disposal. Heavy metals are group of 19 elements among them lead, cadmium and mercury do not have biological significance hence they are known to be extremely toxic heavy metals. The heavy metals are high solubility in the aquatic environment. Most of the heavy metals are poisonous to living organisms. Heavy metals are non-degradable and are persevering in the environment through bioaccumulation. Therefore removal of heavy metal from wastewater is necessary in recent days. Many methods are examined by the researchers for the removal of heavy metal from wastewater such as chemical precipitation, flotation, ion exchange, electrochemical deposition, membrane filtration, reverse osmosis and adsorption. These methods tend to be expensive and often impracticable in remote regions. Among these adsorption process has proved to be economical and efficient method [1-3].

1.1 Nanotechnology

Now a day's nanotechnology was used in every field because of its capacity to manipulate structural materials on the level of individual atoms and molecules. Nanometer means one billionth of a meter [10^{-9}]. The nanoparticles have their unique physical and chemical properties this increased interest for researchers and use of nanoparticle in various fields [5, 7].

1.2 Lead

According to Bureau of Indian Standards (BIS) IS10500, the tolerance limit of lead in domestic water is 0.01 and in surface water is 0.1 mg/L. Source of lead pollutants are industries which use lead for sound proofing, flashing, paint. It also used in pulp and paper industries, pipes, ceramics, glass, oil, lead acid batteries and mining activity, petrochemical, refineries, printing, photographic materials, explosive manufacturing, electronics, vehicle emission, agricultural activities by use of pesticides and fertilizers, sewage wastewater [3]. Presence of lead in drinking water cause harmful effect such as anemia, abdominal pain, irritability, it will disturb functioning of brain results in memory loss, headache, hepatitis, it disturb the functioning of kidney, it affects central nervous system, lead breaks blood brain connection causes mental retardation and it will affect brain growth in infants[3].

1.3 Titanium Dioxide Nanomaterial

There are various types of adsorbents are present for the removal of heavy metal from aqueous solution but low adsorption capacities of the most adsorbents, though cheap, their practical applications are limited. So some researches have been carried out to find out reusable and economical adsorbent materials some among them is titanium dioxide nanoparticle has got special consideration for its multivariate properties. Titanium dioxide has special attraction towards it because of its photo oxidative and surface active properties [4]. All these had increased interest to use titanium dioxide for the adsorption of heavy meatal from aqueous solution.

1.4. Objectives of the study

- To study the characteristic of titanium dioxide nanomaterial.
- To study the titanium dioxide nanomaterial performance in lead removal from synthetic lead solution.
- To study the capacity of adsorbent by varying different parameters like contact time of agitation, pH value of lead solution, initial concentration of lead and adsorbent dosage.
- To make an adsorption study through fitting of adsorption isotherm.

2. Materials and methods

2.1. Reagents

Chemicals used in the experiment were: lead powder (99.5%) analytical reagent, Titanium dioxide nano powder purchased from Nano labs from Gujarat (99% purity), nitric acid (HNO_3) (6N), and sodium hydroxide (NaOH) (1N).

2.2. Analytical instruments

The equipments used for the experiments were Digital pH meter, Atomic Absorption spectrophotometer (AAS), XRD, SEM, Magnetic Stirrer, Centrifuge and weighing machine.

2.3. Analysis of Pb (II)

The lead concentration was determined by using Atomic Absorption Spectroscopy. The setup of AAS is shown in fig. 2.1.

Fig.2.1 Atomic Absorption Spectrometer

- Firstly the specific hallow cathode lamp of lead was inserted.
- The wavelength was set to 217 nm for 0-20µg/mL concentration.
- The air compressor was started and appropriate air pressure was maintained during the flame burning and then acetylene gas and air was supplied to AAS.
- The flame color appeared was bluish and changed to dark orange yellow after inserting the sample capillary into the Pb solution.
- Calibration was done by using lead solution of concentration 2, 8, 14 and 20 mg/L.
- The calibration curve was plotted by computer through GBC avanta of version 1.33 software.
- The mean value of the concentration of the samples to be analyzed were shown and noted.

2.4. Adsorption experiments

0.1 g of TiO_2 nano powder (adsorbent) was placed in the 250ml of lead solution with initial concentration of 20mg/L at varying pH. Then solution was mixed with magnetic stirrer for the constant time of 90 minutes at room temperature, the mixture was then centrifuged then it is analyzed for remaining lead concentration to find out optimum pH.
The equilibrium experiments were carried out by procedure described above with optimum pH of 9-10 by varying concentration of lead varying in 20-60mg/L.

3. RESULTS AND DISCUSSION

3.1. Analysis of characteristic of adsorbent

The powder XRD pattern of the material taken at the begin and end diffraction angle (2θ) values between 5˚ and 90˚ showed seven peaks at 3.6105, 27.3055, 36.2394, 41,1733, 54.168, 62.8582, 69.0104 is as shown in fig.3.1. The mineralogical study recommended that the material refrence line patterens compares to JCPDS: No 870710 and 770443. The 2θ value at peak 62.825˚ confirms the TiO_2 rutile phase structure. The strong diffraction at 62.825˚ and 69.158 ˚ indicating TiO_2 rutile phasethe size of the sample caluclated by Debye-Scherer equation was 5-15nm. The SEM (Scaning Electron Microscope) images shows the cluster shape of adsorbent is as shown in fig.3.2.

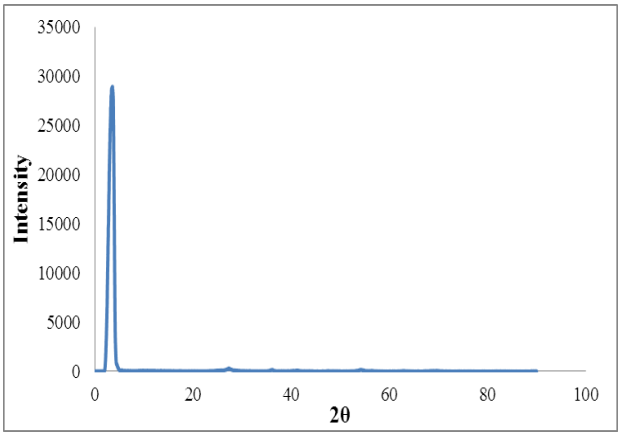

Fig.3.1. XRD pattern of TiO_2 Nano particle

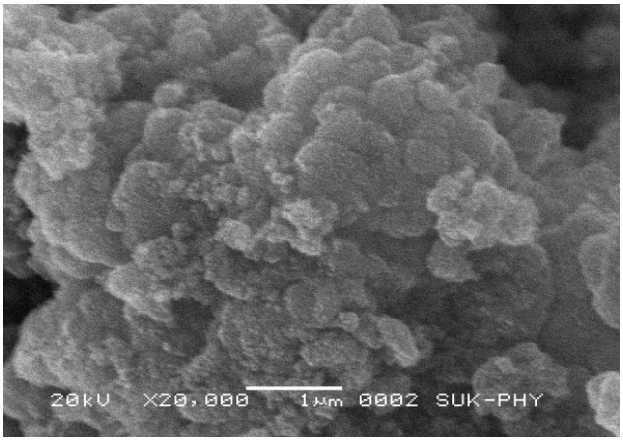

Fig3.2. Scanning electron micrographs (SEM) of TiO_2

3.2. Isotherm modeling

The effect of lead concentration on percentage adsorption of TiO_2 nano powder was studied for adsorption isotherm study. The study was carried out by varying lead concentration (20, 30, 40, 50 and 60 mg/L) and 0.1 gm of titanium dioxide nano powder was added at constant pH of 9-10, at 90 minutes of constant time. From fig.3.3 it can be seen that adsorption efficiency decrease with increase in initial concentration of lead. The maximum percentage removal of lead was 97.727% at 90minutes with 20mg/L initial concentration and is minimum 68.26% at 90 minutes with 60 mg/L initial concentration.

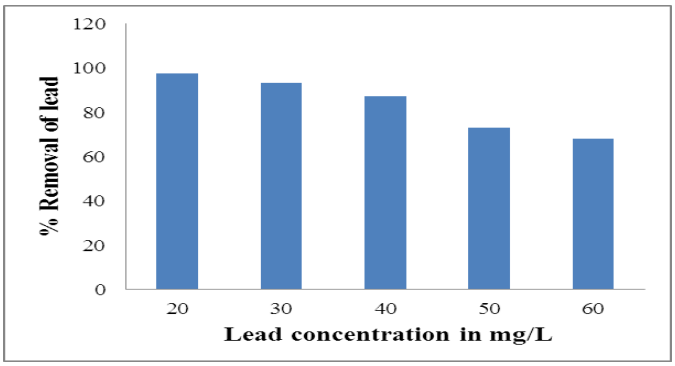

Fig.3.3. Effect of concentration on adsorption capacity of titanium dioxide nano powder.

The amount of lead adsorbed per unit mass of the adsorbent (q) was calculated by using the fallowing equation.

$$q = \frac{C_0 - C_e}{m} \quad \text{..... (3.1)}$$

Where: C_0-Initial concentration of lead, C_e - Final concentration of lead, m- Mass of the adsorbent added for the experiments.

Fig3.3. demonstrates equilibrium data as obtained on adsorption of Pb (II) by TiO_2 nano powder. The adsorption isotherm was studied by using Langmuir isotherm and Freundlich isotherm.

Langmuir model: $q_e = \frac{Q_0 K_L C_e}{1 + K_L C_e}$ ..... (3.2)

Freundlich model: $Q_e = K_f C_e^{1/n}$ ..... (3.3)

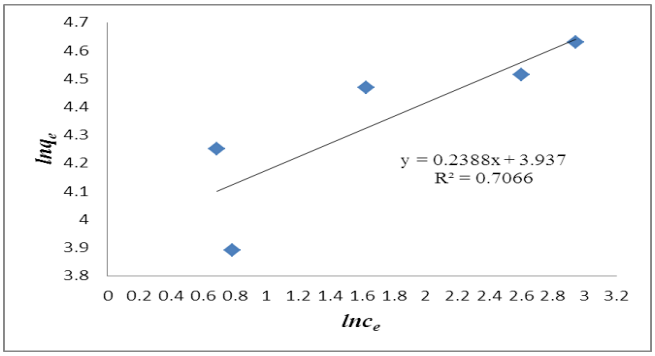

Fig.3.4. Graph showing Freundlich isotherm fit for TiO_2

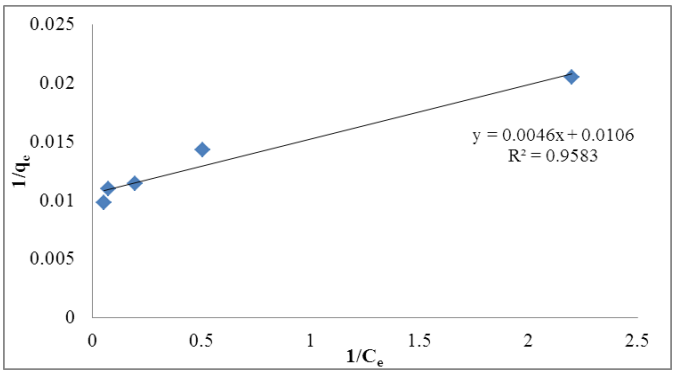

Fig.3.5.Graph showing Langmuir isotherm fit for TiO_2

Freundlich and Langmuir isotherm plot of lead adsorption by titanium dioxide nano powder demonstrated in Fig.3.4. and Fig.3.5. The coefficient of regression R^2 is observed to be 0.7006 and 0.9583 for Freundlich and Langmuir isotherms, respectively. From the regression coefficients, it can be said that the Langmuir isotherm is the best fit out of two.

4. CONCLUSIONS

The following conclusions were drawn based on the experimental results carried out.

- From XRD analysis it is found that synthesized particles are tetragonal rutile phase TiO2 of size 5-15nm
- Highest percentage removal of titanium dioxide nano powder was 97.727 at pH 9-10
- Regression coefficient for freundlich isotherm was found to be 0.7006 and for Langmuir isotherm 0.9583 respectively so it can be said that Langmuir isotherm is best suited to describe the equilibrium adsorption data.

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