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Tea Waste as an effective Bio-adsorbent for the removal of Lead ions from Industrial effluent

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ABSTRACT:
The experiments were conducted in 250 ml conical flasks containing 50 ml of battery industry wastewater with 0.98 mg/L concentration at a constant agitation speed of 250rpm. The optimum dosage of bio sorbent was used as 2.0g, and the optimum time for 150min under room temperature. At the end of bio sorption, the samples were filtered. Analysis is done for obtaining the optimum values and the values are found .The optimum concentration was 400mg/L. The dosage of the adsorbent was optimum at 2g. The optimum contact time is 150min. The agitation speed was 250rpm. The equilibrium sorption data are satisfactorily fitted in the order: Freundlich> Langmuir > Temkin in case of lead ions.

KEY WARDS:Effluent,heavy metal, isotherms, concentration, dosage, speed ,time

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I. INTRODUCTION

The increase in industrial processes has led to the discharge of several heavy metals into the environment which is posing serious threats to humans, plants and animals. Number of heavy metals such as lead, copper, cadmium, chromium, arsenic, zinc, mercury, nickel are released into the environment and water bodies through variety of sources such as metal smelters, effluents from distilleries, battery manufacturing industries, plastics, chemical manufacturing, textile industries, finishing industries, microelectronics and wood preservative producing industries and usage of fertilizer and pesticides. Removal of trace amounts of heavy metal ions from wastewater and drinking water is of great importance due to their high toxicity [Abdel-Ghani and Elchaghaby, 2007; Abdel-Ghani *et al.*, 2009;Resmi *et al.*, 2010].

Heavy metals have a harmful effect on human physiology and other biological systems when they exceed the tolerance levels [Kobya *et al*., 2005]. .Heavy metals are sometimes called “trace elements”. They are the metallic elements of the periodic table. Heavy metals have become of particular interest in recent decades within the framework of environmental investigation. This has without doubt been due to the fact that highly sensitive analytical procedures are available for determining and detecting metal content with high precision. Medical geology is a subfield of geology that studies the effects of chemical in the environment, especially trace elements, on the health of humans and animals. The contribution of the geology is to help isolate aspect environments that may influence the incidence of disease. The ultimate source of the body trace elements is generally rocks. The concentration of trace elements in rocks is varying by rock type. Sometimes, they become concentrated in soil, water, or in air taken up by plants and ingested by humans or animals. Pure water does not exist in nature. The contamination of water is directly related to the degree of contamination of our environment. Rainwater collects impurities while passing through the air. Streams and rivers collect impurities from surface run off and through the discharge of sewage and industrial effluents; these are carried to the rivers, lakes or reservoirs that supply our drinking water (Skeat, 1969). All of the chemicals generated by man will eventually end up in our water supplies. These dangerous products from industry, agriculture and other human activities enter the rivers, lakes, and underground water, and can contaminate our drinking water. Heavy metal analysis on drinking water was done to analyze lead (Pb), zinc (Zn), copper (Cu), cobalt (Co), cadmium (Cd), nickel (Ni), chromium (Cr), molybdenum (Mo), and manganese (Mn) (Hanaa *et al.*,2000).

There are at least 20 metals which cannot be degraded or destroyed. The important toxic metals are Cd, Zn, Pb and Ni. Of these metals, lead is an industrial pollutant enters the ecosystem through soil, air and water. It is hazardous in nature and poses serious threats to humans, plants and animals. Major lead pollution is due to the effluents released from automobiles, battery industries and distilleries. It mainly affects the central nervous system and causes brain disorder. According to the WHO, the maximum permissible limit (MPL) of lead in drinking water is 0.05 mg/L [WHO guidelines, 1984]. Hence proper treatment of industrial wastewaters which are releasing lead into the aquatic and land systems is very important.

Lead is a relatively soft metal with bluish-white lusture but on exposure to air, it becomes covered by a dull, gray layer of basic carbonate that adheres closely and protects it from further oxidation or corrosion. It has a low tensile strength and a relatively poor conductor of electricity. It has a face-centered cubic crystalline structure. Native Lead rarely occurs in nature. It is usually associated with ore with Zn, Ag and Cu, and is extracted together with these metals. The Lead metal is primarily extracted from sulphide ore i.e galena (PbS), which has the 86.6% Lead content. Two other minerals commercially mined for Lead are cerussite (PbCO3) and anglesite (PbSO4). Over 95% of all Lead mined is derived from one of these three minerals. The largest source of Lead, however, is from recycling, & the automobile battery takes the lion’s share**.**

II. MATERIAL AND METHODS

2.1 Preparation of bio adsorbent

The collected tea waste is washed with deionised water. After several washing, the tea waste is soaked in 1N H_2SO_4 for 24 hrs. Then the tea waste is again is washed with deionised water to remove the excess acid. Then it is dried in hot air oven at 100 °C for 24 hrs. It is taken out, crushed and put into a mechanical sieve to separate the particles based on their size. The samples of particular size were separated (mesh no-240). The tea waste is analysed using Fourier Transform Infrared Spectroscopy, X-ray Diffraction and Scanning Electron Microscopy. The separated samples were weighed and sealed with the polythene bags for the analysis of adsorption studies.

2.2 Stock solution preparation

1.599g of Lead Nitrate was weighed and transferred to a 1000 ml standard flask. Distilled water was added to the standard flask to dissolve the salt. 10ml of concentrated Nitric Acid is added and water is further added up to the mark to obtain a solution of Lead Nitrate with 1000 mg/L lead ion concentration. The resulting solution was shaken well and stored as stock solution. Adsorbate solutions for further studies were prepared by diluting the stock solution to the desired concentrations. The freshly diluted solutions were used for each biosorption studies. The pH of the test solutions was adjusted using reagent grade sulphuric acid or HCl and sodium hydroxide solution.

2.3 Experimental procedure and conditions

Batch biosorption experiments were conducted in 250 ml conical flasks containing 50 ml of lead ion solution with concentrations 100 mg/L. All the experiments were carried out at room temperature. Initially, 0.5 g of biosorbent of 200-240 mesh size was used in experiments.At the end of the biosorption, samples were collected and filtered with the whatman no.4 filter paper. The solution after filtration process is collected and analyzed to measure the lead ion concentration present in that solution.

Atomic Absorption Spectrophotometer instrument was calibrated within the linear range of analysis and a correlation coefficient of 0.99 or greater was obtained for the calibration curve. 10 ml of clear solution after filtration was analyzed for lead ion concentration at a wavelength of 283.3 nm.The concentrations of the metal ions before and after sorption were determined using atomic absorption spectrophotometer by monitoring the absorbance for the metal ion used. The amount of lead adsorbed by tea waste biosorbent was calculated from the differences between lead quantity added to the adsorbent and lead content of the solution.

2.4 Biosorption studies

$$\% \text{ Biosorption} = \frac{(\text{Initial} - \text{Final metal concentration}) * 100}{(\text{Initial metal concentration})} \quad (1)$$

Adsorption studies were done on tea waste as a function of various parameters:

- Concentration of solution
- Adsorbent Dosage
- Time
- rpm

2.4.1. Effect of lead ion concentration

The experiments were conducted in 250 ml conical flasks containing 0.5 g of tea waste biosorbent at a constant agitation speed 150rpm. The quantity of biosorbent used in experiment was 0.5 g. The initial lead ion concentration present in the solution was varied as 50-500 mg/L. At the end of biosorption, the samples were filtered. During the adsorption process, the flasks were agitated on a shaker for 30min under room temperature.The filtered solution was analyzed in Atomic Absorption Spectrophotometer to measure the lead ion concentration present in that solution.

2.4..2. Effect of bioadsorbant dosage

The experiments were conducted in 250 ml conical flasks containing 50 ml of lead ion solution with 400 mg/L concentration at a constant agitation speed 150rpm.During the bio sorption process, the flasks were agitated on a shaker for 30 min under room temperature. The amount of bio sorbent (dosage) was varied as 0.5g, 0.75g, 1g, 1.25g, 1.5g, 1.75g, 2g, 2.25, 2.5g, 2.75g 3.0g. At the end of bio sorption, the samples were filtered.The filtered solution was analyzed in Atomic Absorption Spectrophotometer to measure the lead ion concentration present in that solution.

2.4.3. Effect of contact time

The experiments were conducted in 250 ml conical flasks containing 50 ml of lead ion solution with 400 mg/L concentration at a constant agitation speed. The quantity of biosorbent used in experiment was 2 g. During the biosorption process, the flasks were agitated on a shaker under room temperature at the period of 60min, 90min, 120min, 150min and 180min. At the end of biosorption, the samples were filtered.The filtered solution was analyzed in Atomic Absorption Spectrophotometer to measure the lead ion concentration present in that solution.

2.4.4. Effect of agitation speed

The experiments were conducted in 250 ml conical flasks containing 50 ml of lead ion solution with 400 mg/L concentration. The quantity of biosorbent used in experiment was 2g. During the biosorption process, the flasks were agitated on a shaker for 150min under room temperature at a constant pH. The agitation speed is varied as 100rpm, 150rpm, 200rpm, 250rpm, 300rpm and 400rpm respectively. At the end of biosorption, the samples were filtered.The filtered solution was analyzed in Atomic Absorption Spectrophotometer to measure the lead ion concentration present in that solution.

2.5Adsorption isotherms

In order to successfully represent the equilibrium adsorptive behavior, it is important to have a satisfactory description of the equation state between the two phases composing the adsorption system. Several isotherm models are available to describe this equilibrium sorption distribution. The Langmuir equation is used to estimate the maximum adsorption capacity corresponding to complete monolayer coverage on the adsorbent surface and is expressed by

Langmuir equation: $\frac{1}{qe} = \frac{1}{qmax.b} . \frac{1}{ce}$ --- 2.1

Where qe is the amount adsorbed at equilibrium (mg/g) and Ce is the equilibrium concentration of metal ions in solution (mg/L).The Freundlich model is an empirical equation used to estimate the adsorption intensity of the sorbent towards the adsorbate and is given by

Freundlich Equation: $\ln qe = \ln kf + \frac{1}{n} \ln ce$-----------------------------------2.2

The adsorbing species–adsorbate interactions can be explained using the Temkin isotherm equation. It is based on the assumption that the heat of adsorption of all the molecules in the layer decreases linearly with coverage due to adsorbate– adsorbate repulsions, and the adsorption is a uniform distribution of maximum binding energy

Temkin Equation: $qe = BT \ln A + BT \ln Ceq$--------------------------2.3

The other parameters are different isotherm constants, which can be determined by regression of the experimental data. In the Langmuir equation, θ (mg/g) is the measure of adsorption capacity under the experimental conditions and *b* is a constant related to the energy of adsorption. Freundlich treatment gives the parameters, *n*, indicative of bond energies between metal ion and the adsorbent and *K*, related to bond strength.

III. RESULTS AND DISCUSSIONS

Characteristics of adsorbing material

3.1 Scanning Electron Microscopy

A scanning electron microscope (SEM) was used to examine the surface of the adsorbent and the SEM photographs shows changes in the surface of the particle.

A scanning electron microscope (SEM) is a type of electron microscope that images a sample by scanning it with a high-energy beam of electrons in a raster scan pattern. The electrons interact with the atoms that make up the sample producing signals that contain information about the sample's surface topography, composition, and other properties such as electrical conductivity.

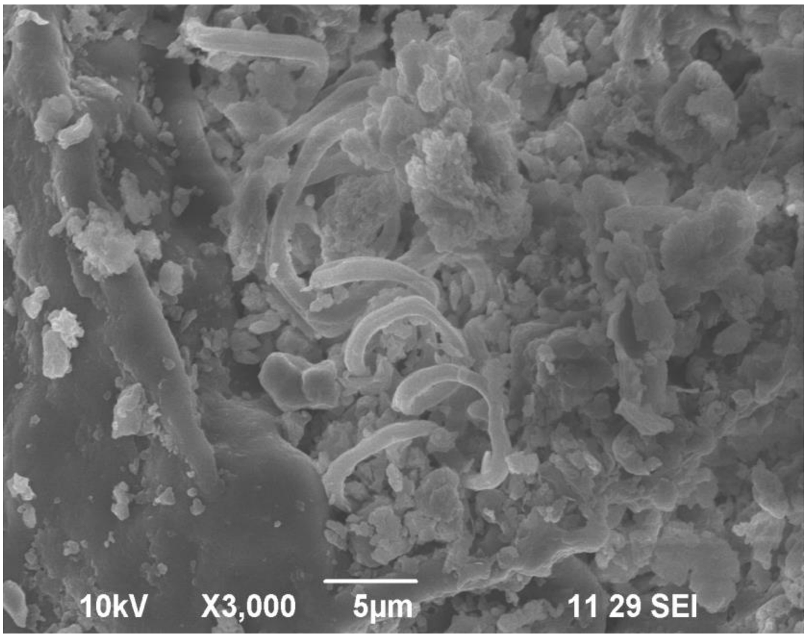

Figure 1.a.

3.2 X-Ray Diffraction

X-ray scattering techniques are a family of non-destructive analytical techniques which reveal information about the crystallographic structure, chemical composition, and physical properties of materials and thin films. These techniques are based on observing the scattered intensity of an X-ray beam hitting a sample as a function of incident and scattered angle, polarization, and wavelength or energy.

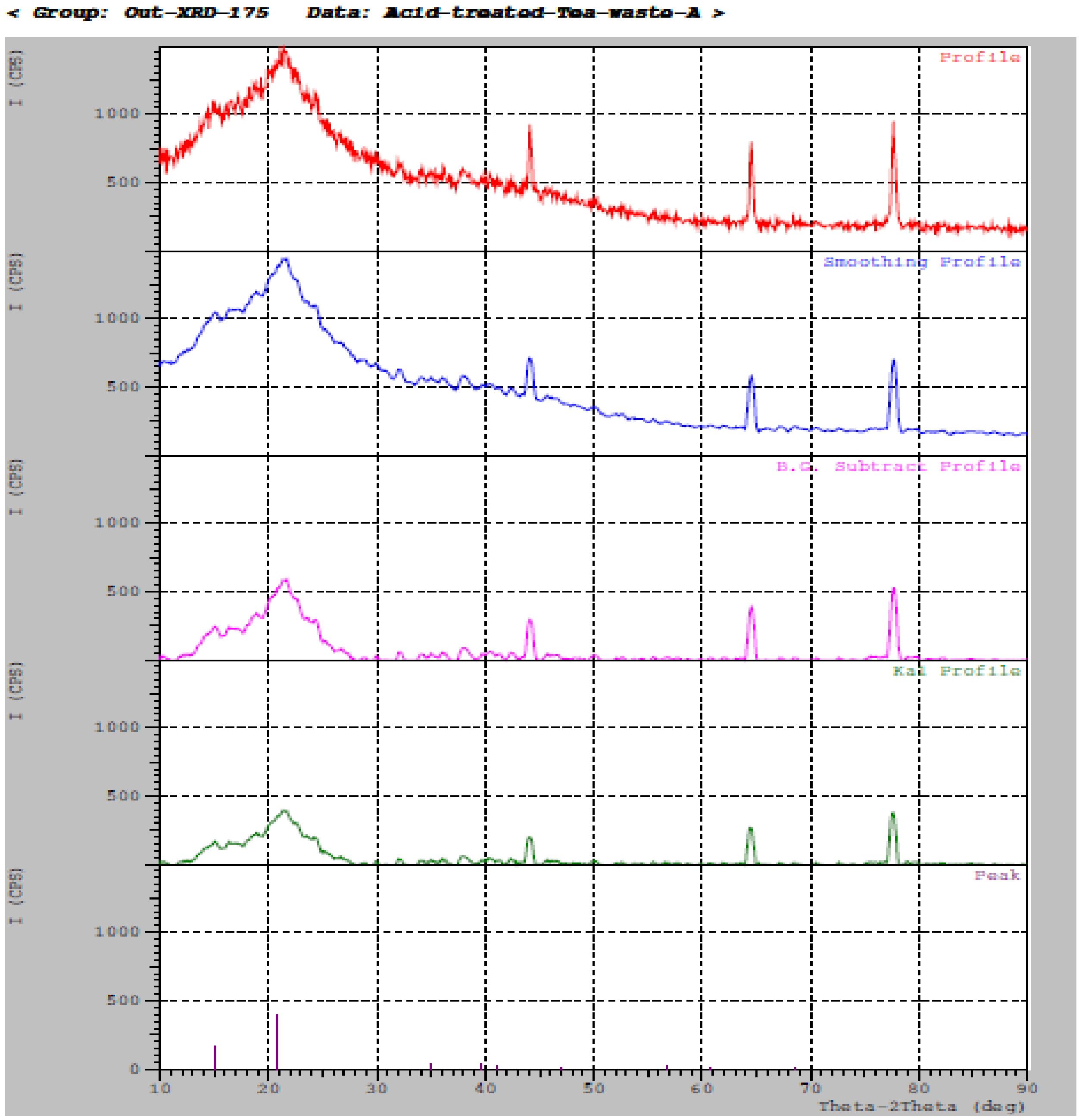

Figure 1.b.

3.3 Fourier Transform Infrared Spectroscopy

FT-IR stands for Fourier Transform InfraRed, the preferred method of infrared spectroscopy. In infrared spectroscopy, IR radiation is passed through a sample. Some of the infrared radiation is absorbed by the sample and some of it is passed through (transmitted). The resulting spectrum represents the molecular absorption and transmission, creating a molecular fingerprint of the sample. Like a fingerprint no two unique molecular structures produce the same infrared spectrum. The size of the peaks in the spectrum is a direct indication of the amount of materials present. It can determine the quality or consistency of a tea waste sample. It can determine the amount of components present in a mixture.

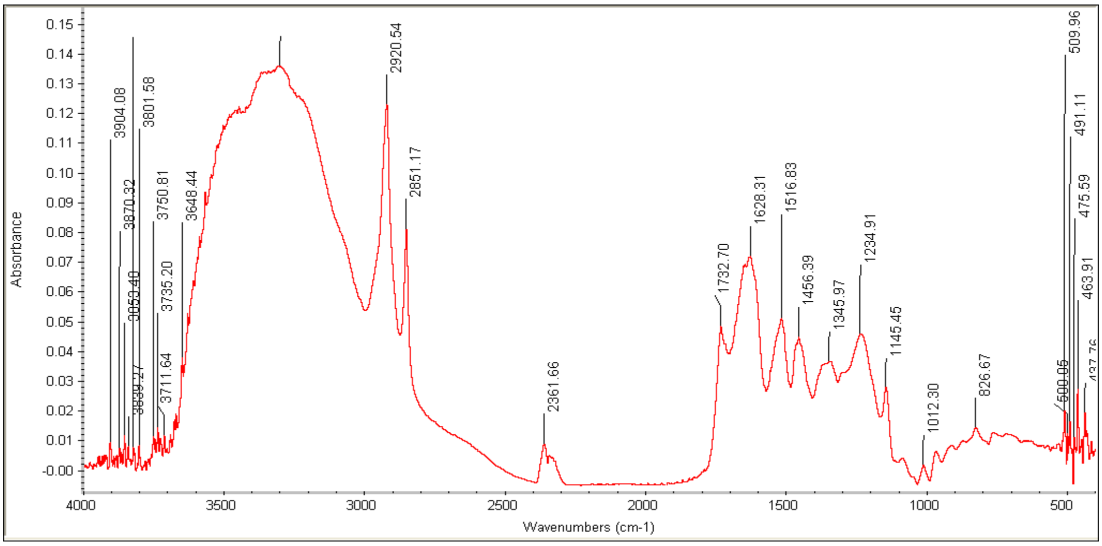

Figure 1.c.

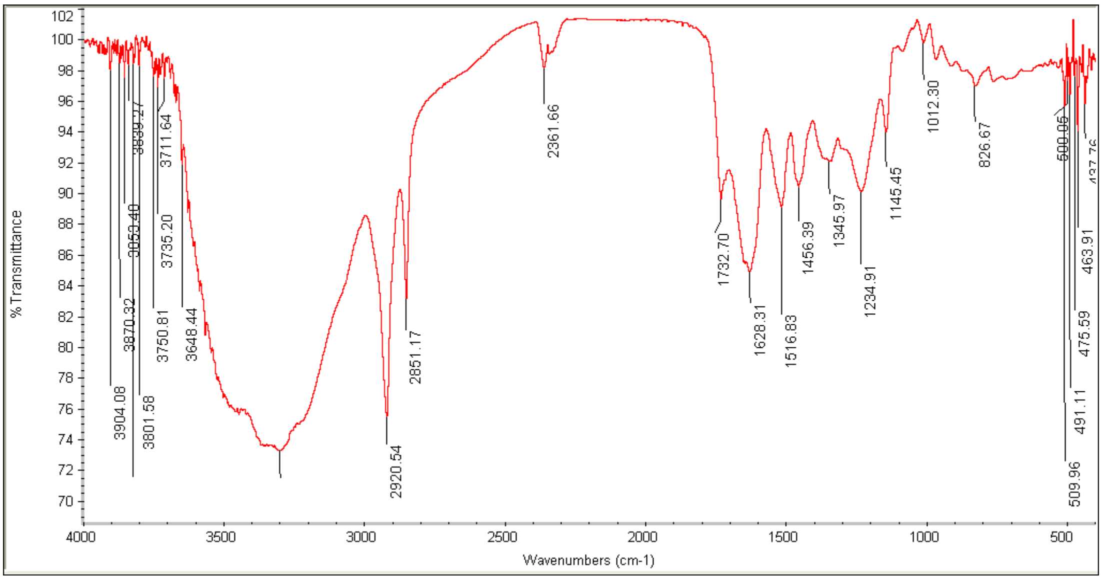

Figure 1.d.

3.4 Biosorption Studies

3.4.1 Effect of Concentration

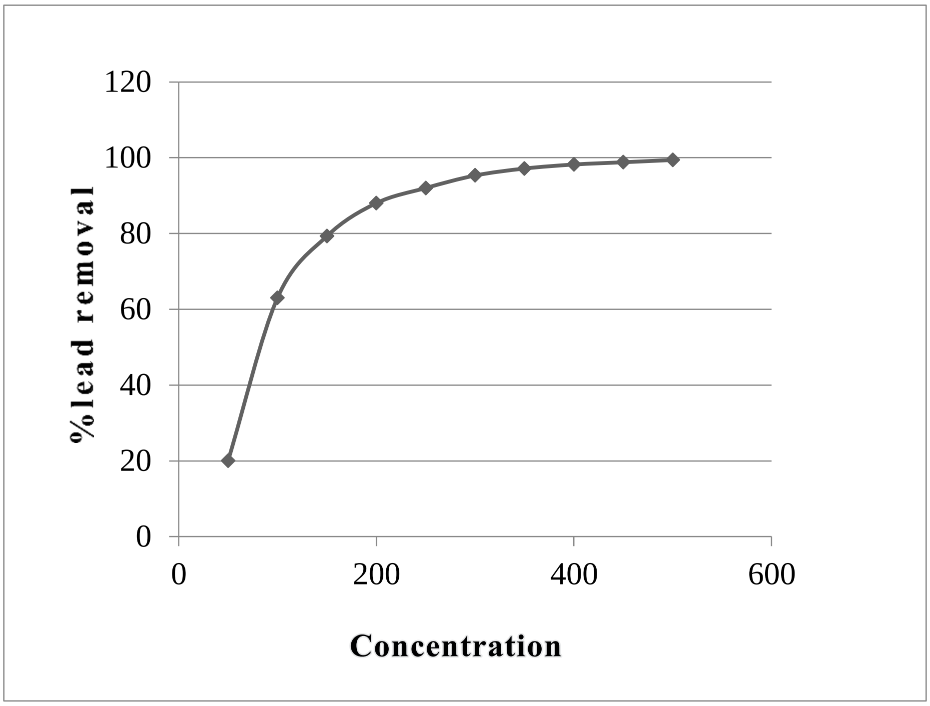

Figure 2

3.4.2. Effect of Dosage

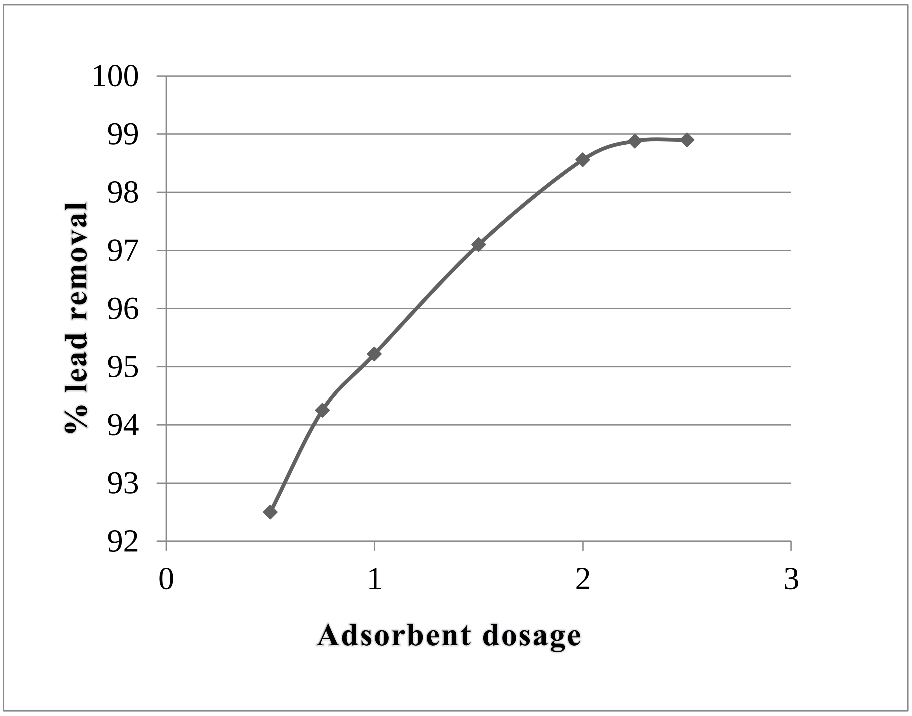

Figure 3

3.4.3. Effect of Time

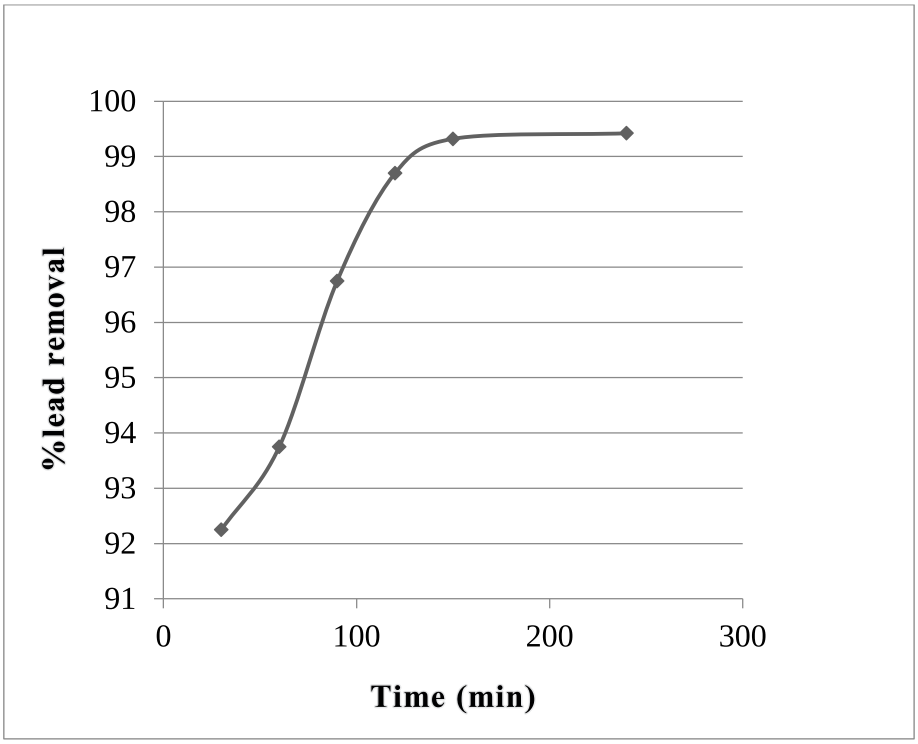

Figure 4

3.4.4. Effect of Agitation Speed

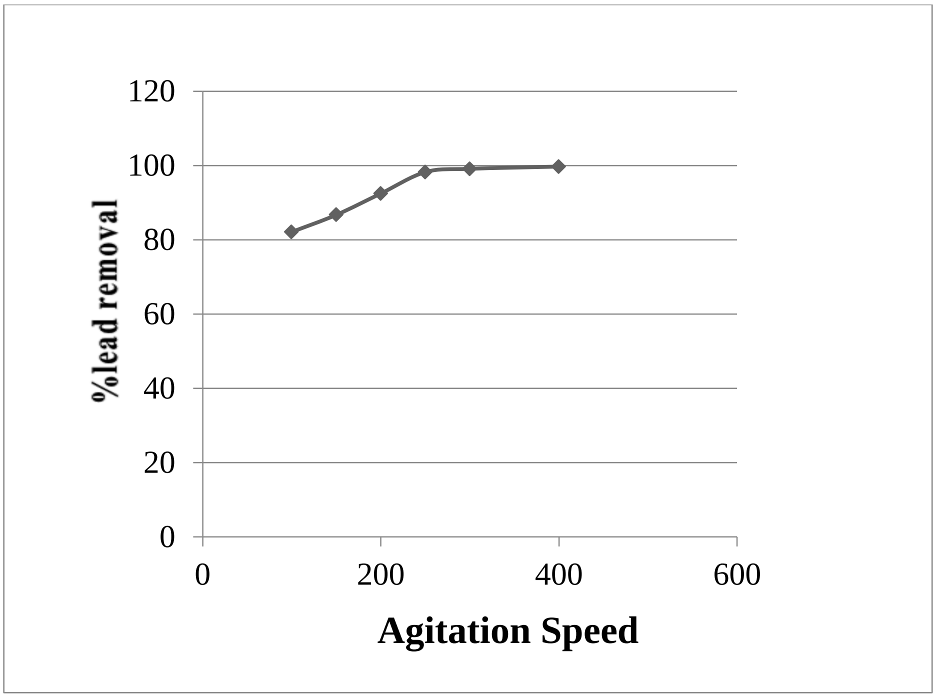

Figure 5

3.5. Adsorption Isotherm Studies

3.5.1. Langmuir Isotherm

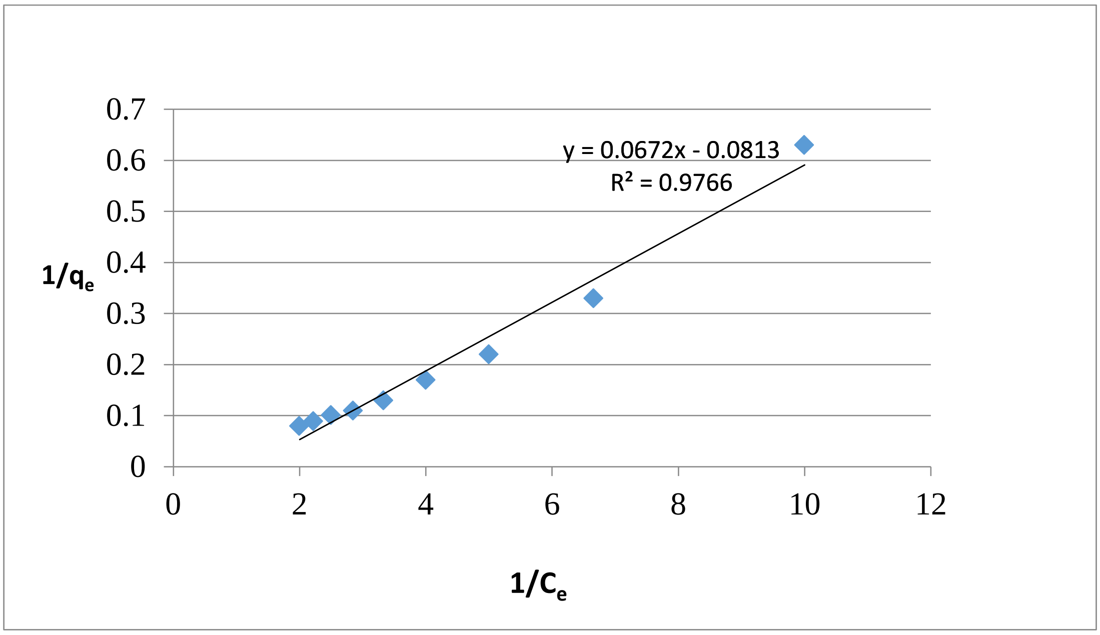

Figure 6

3.5.2.Freundlich Isotherm

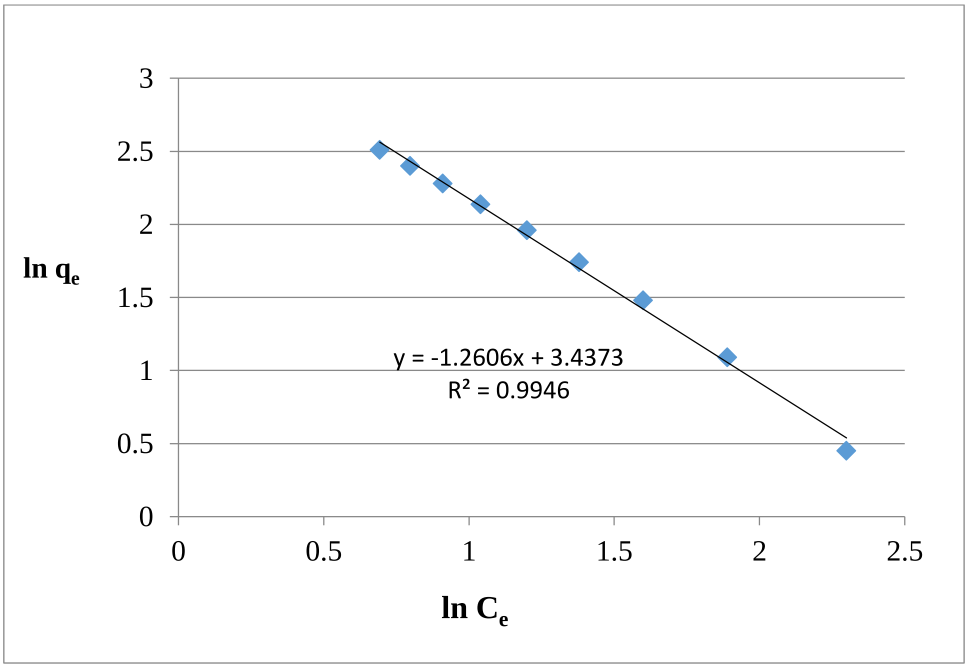

Figure 7

3.5.3. Temkin Isotherm

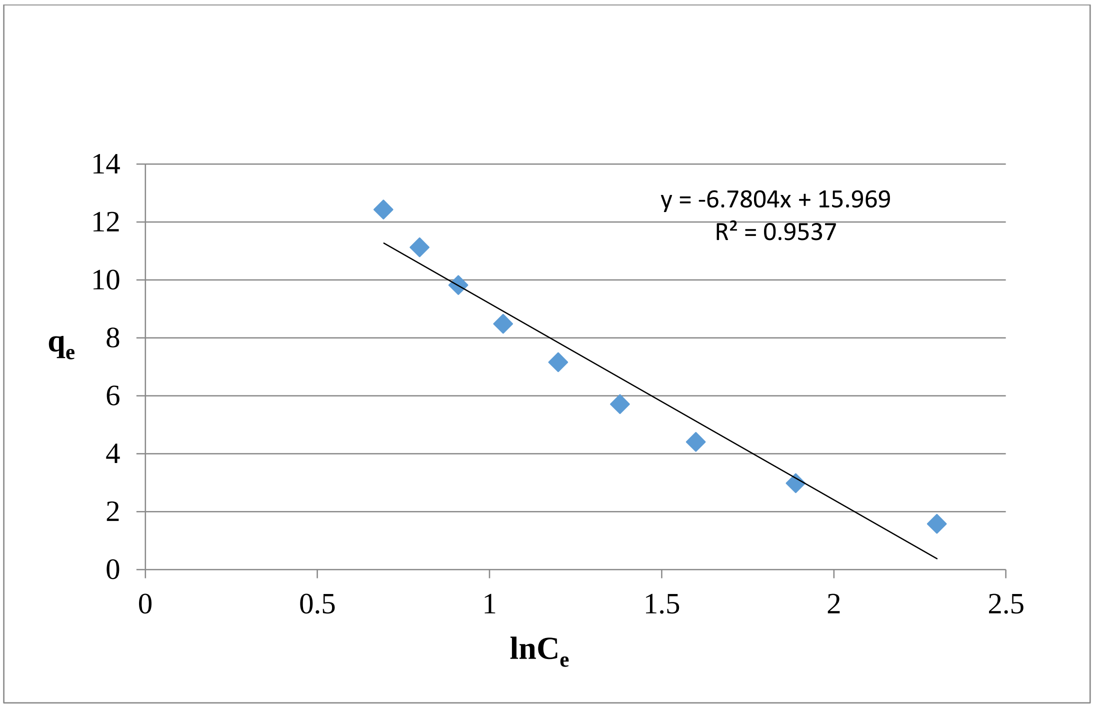

Figure 8

3.6.Industrial Effluent Analysis

Industrial effluent was collected, to find the presence of metals in the effluent. The concentrations of the metal ions before and after sorption were determined using atomic absorption spectrophotometer. The metals present in distillery industry effluent were lead, arsenic and traces of other metals. The initial lead ion concentration present in the solution was 0.98 mg/L.The experiments were conducted in 250 ml conical flasks containing 50 ml of battery industry wastewater with 0.98 mg/L concentration at a constant agitation speed of 250rpm. The optimum dosage of bio sorbent was used as 2.0g, and the optimum time for 150min under room temperature. At the end of bio sorption, the samples were filtered. The filtered solution was analyzed in Atomic Absorption Spectrophotometer (ELICO-SL 194) to measure the final lead ion concentration present in that solution. The result shows that final concentration present in battery industrial wastewater was 0.042 mg/L. The percentage removal for lead ions was found to be 95.71%.

IV. CONCLUSIONS AND RECOMMENDATIONS

The present study shows that chemically treated tea waste is an effective adsorbent for the removal of lead ions from aqueous solutions. The adsorption process is a function of the adsorbent and various parameters like concentrations, dosage, time and rpm. The maximum percentage removal found to be 95.71%. Equilibrium was achieved practically in 150min. The equilibrium sorption data are satisfactorily fitted in the order: Freundlich > Langmuir > Temkin, in case of lead ions.

The adsorbent proved to be very effective on industrial waste water. Waste water from battery industry in Coimbatore, Tamil Nadu was collected and was tested for the presence of lead. It was found to contain 0.98mg/L of lead. And after treating the effluent with the bio adsorbent, it was found to remove 95.71% of lead from the waste water.

The economic feasibility of low cost adsorbents is estimated in the present study. It is found that tea waste which is cheap and available in abundance locally is the most economical among all the developed low cost adsorbents, and much cheaper than any other adsorbents. The result is not only important for the industries but also to the planet Earth in general due to the resultant social and environmental benefits.

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