Eucalyptus wood charcoal as Biosorbent for removal of lead(II) ions from aqueous solution

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ABSTRACT *The adsorption of lead(II) ions in aqueous solution was performed in this study on carbonized Eucalyptus wood. The wood charcoal was characterized using XRD and SEM-EDX. The batch experiments were performed to optimize the parameters for the maximum adsorption of the lead ions and the parameters included were - amount of adsorbent, initial dye concentration, contact time, pH of the lead solution and temperature. The maximum adsorption of 95.80% was obtained at 10 ppm initial dye concentration, 6.0 g/L adsorbent, pH 9 and at 40°C. Thus, this study indicates carbonized Eucalyptus wood as effective low cost adsorbent for the removal of lead ions from aqueous solutions.*

Keywords: *ICT, Student Teachers, Attitude.*

I. INTRODUCTION

Water pollution is a severe environmental concern of the present world and is escalating at an alarming rate despite all mitigating measures due to ever-increasing industrialization. The wastewater contaminated with heavy metal ions has become a serious environmental issue in recent years [1,2]. Release of poorly treated industrial wastes contaminated with organic and inorganic pollutants including heavy metals enhance the problem to a greater extent. Heavy metal contamination due to human industrial activities such as agriculture, mining and manufacturing is increasing rapidly. Industrial wastewater contaminated with the heavy metals [3,4] is discharged into fresh water streams. These toxic heavy metals do not degrade into harmless end products, they bioaccumulate in aquatic plants and animals [5,6].

Among the heavy metals, lead (Pb) is often present in industrial wastewaters. Lead being an important element is widely used in various industrial processes though the treatment strategy of lead contaminated effluents depends on the type of industries concerned. International authorities like United States Environmental Protection Agency (USEPA) and United States Agency for Toxic Substances and Disease Registry (USATSDR) have already acknowledged it as one of the hazardous and non biodegradable heavy metals posing danger to human and other life forms [7]. It has been reported that vital organs and systems are damaged and cause disruption in normal metabolic functioning of the body upon lead poisoning [8]. Lead is known to cause neural toxicity, depression, encephalopathy, mood changes, dizziness, forgetfulness besides attacking kidney, liver and brain in In human beings [9]. The industrial processes that contribute to anthropogenic lead pollution are battery manufacturing units, metal plating, lead mining, smelting operations, printing along with ceramics and glass goods productions [10]. In order to mitigate lead poisoning World Health Organization (WHO) has restricted its maximum concentration in drinking water to 0.01 mg/L [11] and Environmental Regulatory Authority of India has directed to lower the concentration of lead to 1.0 mg /L in effluents before disposal [12]. Consequently, to comply with the limits recommended by different bodies, the removal and recovery of heavy metals from wastewater is significant in the protection for the environment and human health.

Some chemical treatment procedures like reverse osmosis, coagulation, chemical precipitation, electro dialysis, ultra filtration are employed with a view to clean waste waters [13]. These methods can remove Pb(II) from wastewater, but have several disadvantages such as high energy input, high cost, incomplete removal, high reagent requirements, and generation of toxic sludge & secondary pollution [14,15, 16].

Biosorption has been emerged as an competitive, effective and inexpensive technology because of its high efficiency and easy handling nature for heavy metal ion removal [17]. Biosorption is a process that involves a solid phase (sorbent or biosorbent; biological material) and a liquid phase (solvent, normally water) containing a dissolved species to be sorbed (sorbate, metals ions) [18,19]. Biosorption of heavy metals on the surface of bio-materials occur through different functional groups such as carboxylic, amino, hydroxyl, phenolic, sulfhydryl, ester, and phosphate [16]. Recently, many industrial, agricultural and forestry sources such as Mentha arvensis [20], Coriolus versicolor [21], low cost agricultural waste [22], iron oxide nanomaterials [23], maize tassel [24], etc. have been used as biosorbents successfully, but high volumes of wastewater still demands exploration of newer adsorbents. The heavy metal ions removal from wastewater such as Pb(II) is imperative due to their bioaccumulation tendency, toxicity, persistence, and non–biodegradability in nature [25,26].

The objective of the present study was to evaluate charcoal prepared of eucalyptus, completely chemical free and environmental friendly as a low cost biosorbent for the removal of Pb(II) from aqueous solution. The removal efficiency was investigated by a series of experiments under different experimental conditions such as solution pH, contact time, initial concentration, temperature and biosorbent dosage.

II. MATERIALS AND METHODS

2.1 Chemicals and reagents

Lead nitrate and other chemicals in analytical grade were purchased from S D Fine Chemicals (India). The stock solution (1000 mg/L) of lead ions was prepared by dissolving 1.60 g of lead nitrate in 1 L of deionized water. The working solutions were prepared by diluting the stock solution to the desired concentrations.

2.2 Preparation of the biosorbents

The raw Eucalyptus wood was first cleaned with fresh water to remove the soil, sand and any other undesirable material and then, kept in sunlight for seven days. It was cut into small pieces, dried at 50°C in an air oven for 24 h. and further reduced to small size particles through grinding. These particles were paralyzed in a furnace at 350°C temperatures for 4 hours. The produced char was grinded, sieved and stored in an air tight container and labeled as EWC.

2.3 Characterization of biosorbents

The X-ray diffraction studies were done by XRD analyzer (Pan analytical X'pert Pro diffractometer, D/max rA) at 45 kV and 40 mA (Cu Kα = 1.50406 Å). Morphological structures of the adsorbent was drawn using scanning electron microscope (SEM) JSM-6510 LV, JEOL and elemental composition was performed by energy-dispersive X-ray spectroscopy (EDS) INCax-act, Oxford Instruments.

2.4 Batch experiments for lead ions removal

The batch experiments were conducted in 250 mL Erlenmeyer flasks with the working volume of 100 mL of aqueous solution. The initial pH of the solution was adjusted to the desired value by adding 0.1 M NaOH or HNO_3. The required amount of adsorbent dose was added in the flasks. The flasks were shaken for the specified time period in a temperature controlled incubation shaker at 120 rpm. The flasks were withdrawn from the shaker after the desired time of operation. The supernatant and the spent adsorbent were separated by using the centrifugation at 5000 rpm for 15 minutes and operation (R24 REMI Centrifuge, Mumbai, India). The concentration of Pb(II) on supernatant was analyzed by Atomic Absorption Spectrophotometer (Model – ElementAS AAS4141, Electronics corporation of India Limited).. All experiments were carried out in triplicate and the average values are presented.

The amount of equilibrium absorption Q_e (mg/g) of the dye was calculated by:

$$Q_e = \frac{C_0 - C_e}{w} V \tag{1}$$

The percentage removal of lead ions was calculated as:

$$\%\ removal = \frac{C_0 - C_e}{C_0} x\ 100 \tag{2}$$

where, C_o and C_e (mg/L) are initial concentration and equilibrium concentration respectively.

III. RESULTS AND DISCUSSION

3.1 Characteristics of the biosorbent

The XRD pattern of carbonized eucalyptus adsorbent is illustrated in Fig. 1. The 4 main peaks are at 2θ values of 14.92, 24.38, 30.08 & 38.17 and few smaller peaks at 15.28, 30.78, 31.45, 35.95, 39.85, 43.49, 46.46, 46.99 and 50.02.

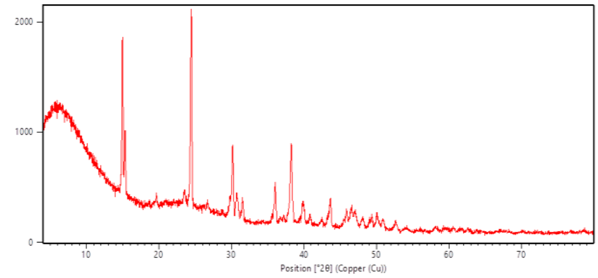

Fig.1 XRD analysis of Eucalyptus Wood Charcoal

The adsorbent samples were analyzed by scanning electron microscopy (SEM) coupled by energy dispersive X-ray spectroscopy (EDX). The application of these techniques made it possible to visualize the surface morphology of adsorbents. The image (2 a & b) of microscopy SEM shows a porous aspect which facilitates materials adsorption.

In addition, spectrum EDX shows the presence of various elements which were analyzed using EDX (Fig 3) as Calcium, Magnesium, Sodium and Potassium.

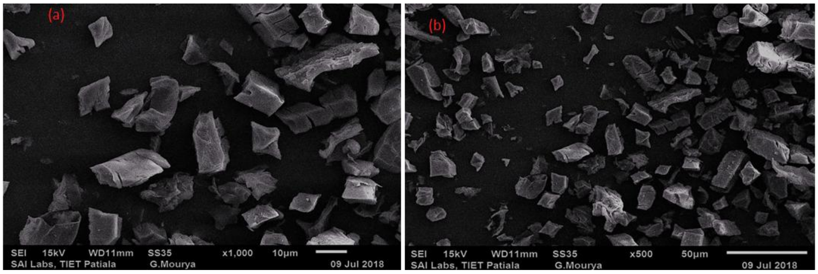

Fig 2 SEM image of Eucalyptus Wood Charcoal carbonized at 350°C

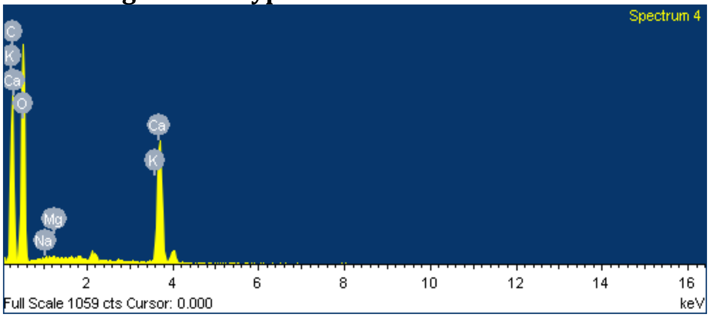

Fig 3 The EDX image of Eucalyptus Wood Charcoal carbonized at 350°C

The process parameters such as solution pH, adsorbent dose, initial dye concentration, time and temperature were chosen as the independent input variables and the efficiency of dye removal as the dependent output variable.

3.2 Effect of pH

The effect of solution pH on the Pb(II) removal was conducted over the pH ranged from 5.0 to 11.0, thereby avoiding hydrolysis and precipitation of Pb(II) ions at higher pH value. The pH values of solutions were adjusted with 0.1 M HNO_3 and/or NaOH. Because the pH of the solution could affect the valence and amount of heavy metal ions in aqueous solutions, the quantity of the functional groups on the biosorbent surface sites, and the interaction between biosorbent and heavy metal ions [27,28,15], it is one of the controlling factors influencing the heavy metal ions removal[7, 29].

It is observed that a gradual rise in the removal efficiency and adsorption capacity of Pb(II) took place with an increase in pH from 5.0 to 9.0 and decreased slightly at the pH > 9.0 (Fig. 4). The maximum removal efficiencies occurred at pH 9.0 and reached 93.2%. It was well known that a lower pH resulted in high concentration of H+ in the solution, thus the functional groups of the biosorbent surface were protonated [7,30]. Hence, Pb(II) ion adsorption was hindered owing to the competition between H+ and Pb2+ for the active sites on the surface of the biosorbent. In contrast, at higher pH, the H+ concentrations decreased and the functional groups of biosorbent surface were deprotonated [31].

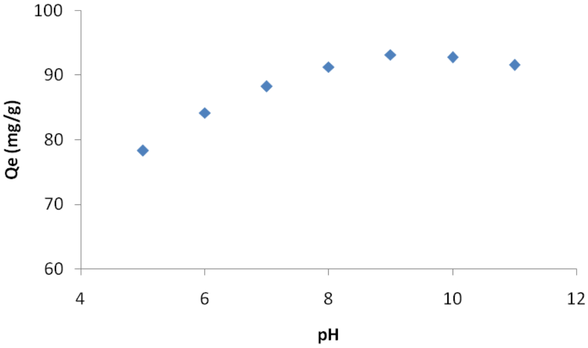

Fig 4 Effect of pH on adsorbed quantity of lead ions onto EWC. Initial Conc.10 ppm, adsorbent dosage 6 g/L

3.3 Effect of lead ion concentration and contact time

The lead ion concentration in the range of 10 to 50 g/L was studied for the evaluation of the effect of initial lead ion concentration on adsorption using EWC at 30°C and responses are shown in Fig. 5. It was observed that as the concentration of lead ions is increased from 10 ppm to 50 ppm, Q_e increased from 1.67 mg g^{-1} to 8.33 mg g^{-1} in 60 minutes when solution pH was 7 and adsorbent dose was 6 g/L. The adsorbed quantity for EWC adsorbent increases by increase in initial concentration of lead ions. This can be explained by the presence of a large number of molecules which will diffuse toward sites of the adsorbent surface and consequently partial adsorption depends on the initial concentration [32]. At higher concentrations, a high concentration gradient is established providing a thermodynamic driving force which overcomes the mass transfer resistance of lead ions from aqueous solution on the solid phase. This gives the increase in the probability of collision of lead ions with the binding sites of the adsorbent increases, resulting in higher adsorption capacity [33].

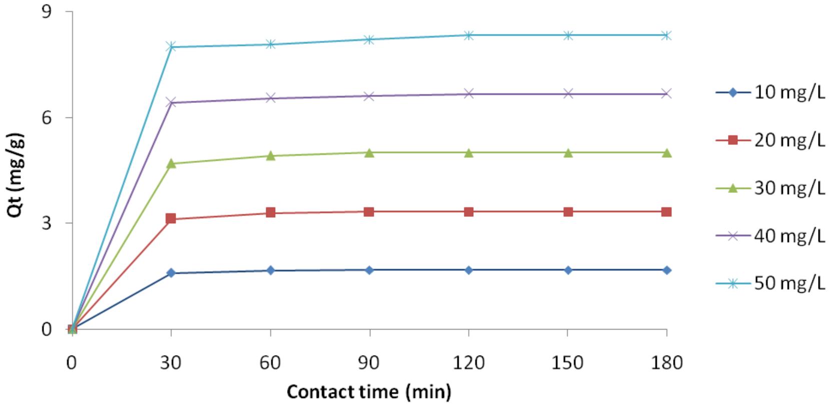

Fig 5 Effect of contact time and lead ion concentration. Interval of initial concentration (10–50 mg/L), adsorbent amount: W= 6.0 g/L, pH= 7.0, T= 30°C

3.4 Effect of adsorbent dosage

Since surface area available for lead ions has direct effect on adsorption, So for the effect of adsorbent dose in the range of 1.5 to 6.0 g/L was studied with 50 mg/L initial lead ion concentration, pH 9 at 30 °C. At low adsorbent dose, considerably higher lead ion adsorption was observed, which decreased linearly as the adsorbent dose increased (Fig.6). The influence of adsorbent dosage on the adsorbed quantity of lead ion with time is represented in Fig. 6. The adsorption percentage increased with adsorbent's dosage rise, but the amount of adsorbed dye per adsorbent unit mass decreased with a rise in adsorbent amount from 1.5 to 6 g/L. As the adsorbent amount increases, the number of active sites available for adsorption increases as well; thus, the percentage of removal also increases. Since all active sites may not be available during adsorption due to overlapping between active sites themselves and the adsorbed amount (mg/g) of adsorbent decreases. The increased adsorbent dose at constant lead solution and volume lead to saturation of available active sites because most of the binding sites are blocked due to aggregates formation and low surface area [34,35].

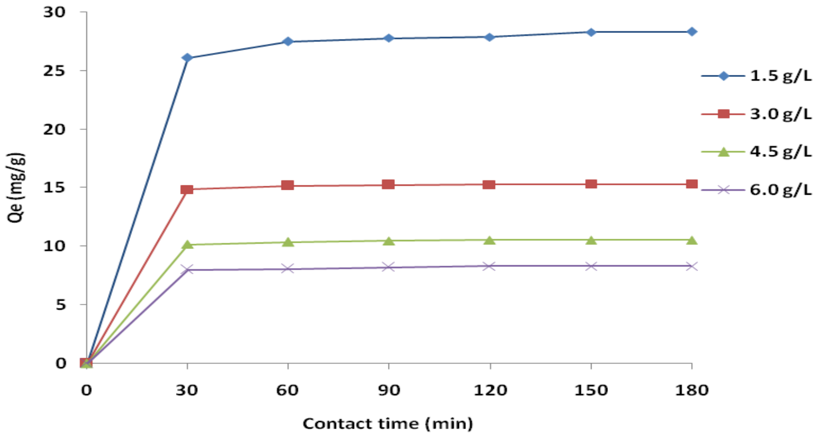

Fig.6 Effect of adsorbent amount on adsorption quantity, Initial lead 50 ppm, pH =9, Temp =30 °C

3.5 Effect of Temperature

It is important to include the effect of temperature during the lead ion adsorption. In this work, we have studied the effect of temperature on the lead ion adsorption in the range of 30–60°C (Fig. 7). The number of binding sites for dye molecules on the adsorbent surface may be increased by the increased temperature [36]. This may be illustrated by the fact that the increased temperature adds power to the adsorbate molecule spread rate across the external limit layer and the internal pores of the adsorbent particles as a result of reduced solution's viscosity. On increasing the temperature the lead ions, mobility increases and hence it leads to the increase in absorption on the biosorption surface. As shown in Fig. 7 the absorption (%) increases up to 40°C and thereafter remains constant till 50°C. The adsorption decreased when the temperature was further increased to 60°C from 50°C

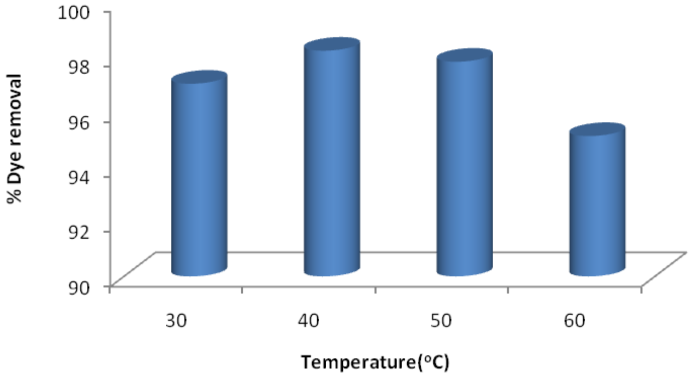

Fig. 7 Effect of Temperature on adsorption of lead ion on EWC

IV. CONCLUSION

The present study shows that lead ions could be adsorbed from the aqueous solutions in eco-friendly conditions using carbonized eucalyptus adsorbent. The maximum adsorption of 98.20% was obtained at 10 ppm initial dye concentration, 6 g/L adsorbent and at 40°C. Therefore, Carbonized Eucalyptus Wood can be used as effective low cost adsorbent for the removal of lead ions from aqueous solutions.

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