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Research Article

Studies on the Biosorption of Metal Ions from Water Samples using Sugarcane (*Saccharum officiarum)* Bagasse

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ABSTRACT

The aim of the study is to find the effectiveness of locally available agricultural waste in the adsorption of various metal ions to suggest rural friendly water treatment methodologies. The identified sample for this study is sugarcane (*Saccharum officinarum)* bagasse (the dry residue after extraction of the juice) in the removal of Chromium (VI), Iron (III) and Lead (II) from water samples. Sugarcane (*Saccharum officinarum)* bagasse was obtained from local markets, Chennai, TamilNadu. The biosorption efficiency study design is the batch method by varying the process variables such as exposure time (8, 16 and 24hr), metal ion concentration (1 and 10 mg/l), temperature (25, 35 and45°C), pH (4, 7 and 10) and adsorbent (bagasse) dosage (20, 40, 60, 80, 100 and120 mg/l). The The initial (C_i) and final (C_o) concentrations of the metal ions in the water samples were measured using UV- Vis Double beam Spectrophotometer (Infra IR513D) at 540 nm for Cr (VI), 510 nm for Fe (III) and 530 nm for Pb (II) and adsorption efficiencies were calculated. After optimizing the process variables, the metal ion sample that shows maximum adsorption would be subjected to powder X-ray diffraction (XRD) analysis in X'Pert PRO diffractometer using Cu Ka radiation (40 kV and 40 mA) to probe the amorphous nature of the subjected bagasse sample infused with metal ion. 1mg/l of sugarcane (*Saccharum officinarum)* bagasse shows effective removal of Fe (III) (86.66%), Cr (VI) (84.84%) and Pb (78.83%) at an acidic pH (4) and at a temperature of 45°C during an exposure frequency of 24hr. Sugarcane (*Saccharum officinarum)* bagasse showed maximum adsorption of Fe (III) and the X-Ray Diffraction (XRD) analysis revealed significant high peaks of cellulose with impregnated iron at 2θ. The study concludes the usage of agricultural waste products and its eco-friendliness in the treatment of water in rural areas.

Keywords: Chromium (VI), Iron (III), Lead (II), *Saccharum officinarum* Bagasse

INTRODUCTION

Waste water disposed by various textile, tannery, electroplating and paper industries is a major hazard to the environment and drinking water due to the presence of a large number of contaminants [1, 2, and 3]. Pollution of water with toxic substances is of major concern for human health as well as for the environmental quality [4]. According to recent surveys, the most common contaminants reported in groundwater are heavy metals such as Cr, Cd, Pb, Hg, Zn, Ni and Fe [5].

Predominant and potential contaminant metal ion such as Cr (VI) are known to be toxic and mutagenic and when it enters the gastric system, epigastric pain, nausea, and vomiting, severe diarrhoea, corrosion of skin, respiratory tract and lung carcinoma were noticed [6]. Ingestion of Iron causes health issues like anorexia, oligura, diarrhoea, hypothermia, diphasic shock, metabolic acidosis and mortality [6]. Lead poisoning in human causes severe damage to the kidney, nervous system, reproductive system, liver and brain and causes sickness or death [7]. The permissible level of Cr (VI) in drinking water is 0.05 mg/l, Fe (III) is 0.3 mg/l and Pb (II) is 0.05 mg/l as prescribed by WHO standards [8]. The commonly reported level of chromium in drinking water is 8 mg/l [9], iron is 17 mg/l [10] and Lead is minimum 1 mg/l in Chennai [11].

Since the past few decades, various conventional technologies for the removal of heavy metal ions from aqueous solutions such as chemical precipitation, ion exchange, membrane separation, reverse osmosis and electrochemical treatments have been reported [12]. These methods generally are either expensive or inefficient, especially when the concentrations of heavy metal ions are less than 10mg/l [13]. [14].

Recently, studies have been carried out using various agricultural wastes such as coconut shell [15] [16], orange peel [17], peanut husk [18] as adsorbents to remove heavy metals from water samples. Like coconut fibre (coir), sugarcane bagasse is non-toxic, renewable, biodegradable, modifiable and has great potential in treatment activities [19]. While studying adsorption of any metal ions using agricultural wastes or chemical methods, to confirm the uptake of metal ions and examine the physio-chemical state, X- ray Diffraction technique (XRD) is used. The present study focuses on the different dosages of sugarcane (*Saccharum officinarum)* bagasse (adsorbent) on the removal of metal ions such as Cr (VI), Fe (III) and Pb (II) by varying the important process parameters such as pH, temperature, and contact time.

MATERIALS AND METHODS

2.1. Collection and preparation of *Saccharum officinarum* bagasse

Saccharum officinarum bagasse was obtained from local market located at Anna nagar, Chennai. It was washed thoroughly with tap water to remove the dust particles, then soaked overnight in 0.1 N NaOH solutions for removes the mineral elements and enhances the acidic property and hydrophilicity of the surface. Then washed well with Double-distilled water (DDW) and they were soaked in 0.1 N CH_3COOH for a period of 2–3 hr to remove the traces of NaOH. It was thoroughly washed again with DDW till the wash water became colourless and then filtered, well dried, powdered and sieved before use.

2.2 Preparation of adsorbate solutions

Stock solution of Cr (VI) (1000µg/ml) was prepared by dissolving 2.83g of Potassium dichromate in 1000 ml of water. Stock solution of Fe (III) (1000µg/ml) was prepared by dissolving 7.02g of ferrous ammonium sulphate in 1000 ml of water. Stock solution of Pb (II) (1000µg/ml) was prepared by dissolving 1.57g of Lead acetate in 1000 ml of RO water. Experimental Cr (VI), Fe (III) and Pb (II) solutions of different concentrations were prepared by diluting the stock solution with suitable volume of water [20].

2.3 Adsorption efficiency of Sugarcane (*Saccharum officinarum)* bagasse by varying the process parameters

Batch adsorption studies for Cr (VI), Fe (III) and Pb (II) were carried out to investigate the effect of different parameters such as pH, temperature (ºC) contact time (hr) and adsorbate concentration (g). The adsorbate solutions were prepared by measuring various concentrations (1 and 10 mg/l) and was subjected to various pH levels (4, 7 & 10). pH was adjusted using 0.1N HCl and 2N NaOH (Mathew *et al.,* 2013). The weight of *Saccharum officinarum* bagasse was tried from 20, 40, 60, 80, 100 and 120 mg at three different temperatures (25°C, 35°C and 45°C) and sampling was carried out at different exposure times namely 8, 16 and 24 hr.

Each batch were set-up in triplicates and the initial (C_i) and final (C_o) concentrations of the metal ions in the water samples were measured using UV-Vis Double beam Spectrophotometer (Infra IR513D) at 540 nm for Cr (VI), 510 nm for Fe

(III) and 530 nm for Pb (II) [20]. The adsorption percentage of efficiency were calculated using the formula, % removal = C_i-C_0 / C_i x100 where Ci and Co are initial and final equilibrium metal ion concentration (mg/l) respectively.

2.4 **X-Ray Diffraction (XRD) Analysis**

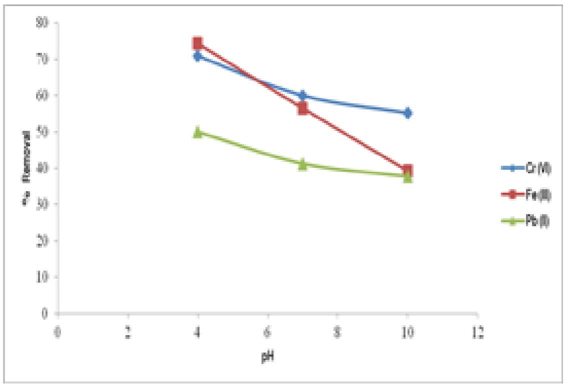
Powder X-ray diffraction spectroscopy (XRD) analyses were carried out to study the amorphous nature of the bagasse sample that showed maximum metal ion removal in X'Pert PRO diffractometer using Cu Ka radiation (40 kV and 40 mA).The relative intensity (a.u) is measured to discriminate the various D spacing and the results are compared with x-pert pro database (International Center for Diffraction Data (ICDD), to confirm peaks that substantiate adsorption [21].

RESULTS

3.1. Adsorption efficiency with Effect of pH

Process variable, pH was subjected at 4, 7 and 10 values while keeping the values temperature (45°C), exposure time (24hr) and adsorbent (bagasse) dosage (120mg/l) as constant for the metal ions such as Cr (VI), Fe (III) and Pb (II) (1mg/l) and the Fig. 1a shows the effect of pH on the removal and the adsorption has proved very effective at a pH of 4 for Fe (III) (74.35%), Cr (VI) (70.83%) and Pb (II) (49.99%) respectively.

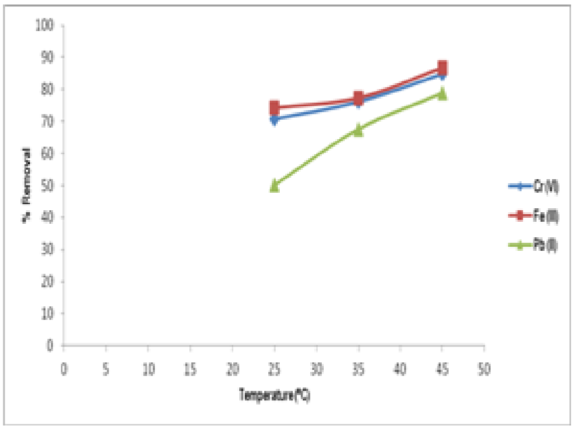
Figure 1a: Effect of pH



3.2. Effect of Temperature (°C)

Process variable, temperature was tried at 25°C, 35°C and 45°C while keeping the values such as pH (4), exposure time (24hr) and adsorbent (bagasse) dosage (120mg/l) as constant for the metal ions such as Cr (VI), Fe (III) and Pb (II) (1mg/l) and the Fig. 1b shows the effectiveness of adsorption of metal ions such as Cr (VI), Fe (III) and Pb (II). The removal of Fe (III) (86.66%), Cr (VI) (84.84%) and Pb (II) (78.83%) at the temperature of 45°C is observed.

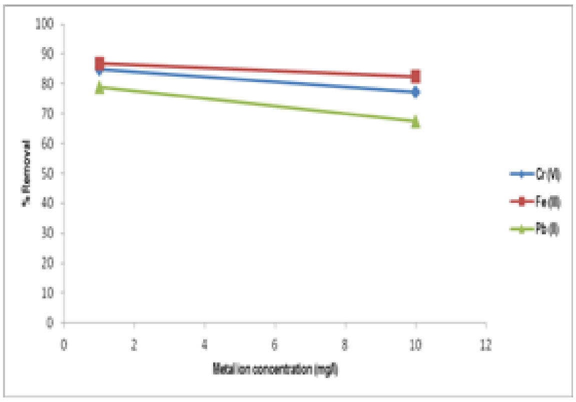
Fig. 1b: Effect of Temperature (ºC)



3.3 Effect of metal ion concentration on adsorption (mg/l)

Process variable, metal ion concentration, namely, Cr (VI), Fe (III) and Pb (II) was tried at 1 and 10 mg/l while keeping the values such as pH (4), exposure time (24hr) and adsorbent (bagasse) dosage (120mg/l) as constant and the Fig.1c shows that the low dosage (1mg /l) had higher impact on adsorption of metal ions in the order, Fe (III) (86.66%), Cr (VI) (84.84%) and Pb(II) (78.83%).

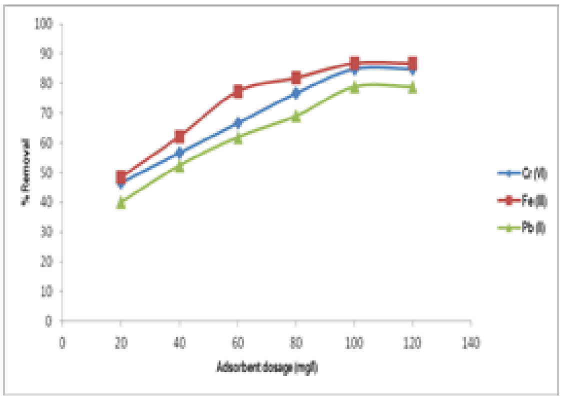
Fig. 1c: Effect of metal ion concentration (mg/l)



3.4 Effect of adsorbent dose (mg/l)

The adsorbent, sugarcane (*Saccharum officinarum)* bagasse was tried for its effective removal of metal ions at six different weights namely 20, 40, 60, 80, 100 and 120 mg/l while keeping values such as pH (4), exposure time (24hr), temperature (45^{o}C) and metal ion concentration (1mg/l) as constant. Fig. 1d shows significant adsorption at the dosage level of 120 mg/l for Fe (III) (86.66%), Cr (VI) (84.84%) and Pb(II) (78.83%) respectively. The study infers that at low adsorbent dosage, the amount of metal ions adsorbed per unit is high.

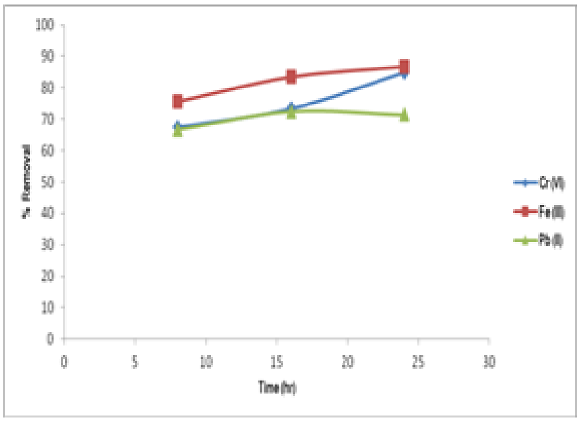
Fig. 1d: Effect of adsorbent dosage (mg/l)



3.5 Effect of exposure time (hr)

Process variable, exposure time (hr) at a frequency of 8,16 and 24 was studied for the adsorption of Cr (VI), Fe (III) and Pb (II) while keeping the values such as pH (4), temperature (45^{o}C), metal ion concentration (1mg/l) and adsorbent (bagasse) dosage (120mg/l) as constant. Fig.1e explains the rate of adsorption is very fast initially during the 4 hr and reached equilibrium at the 24th hr in the order of metal ions such as Fe (III) (86.66%), Cr (VI) (84.84%) and Pb (II) (78.83%).

Fig. 1e: Effect of Exposure time (hr)



3.6 X-ray diffraction (XRD)

Sugarcane (*Saccharum officinarum)* bagasse showed maximum removal of Fe (III) among other metal ions. Therefore, the adsorbent impregnated with Fe (III) was characterized by powder X-ray diffraction (XRD) with a X'Pert PRO diffractometer using Cu Ka radiation (40 kV and 40 mA). Crystallographic identification of the prepared sorbent was accomplished by comparing the experimental XRD pattern to that of the International Center for Diffraction Data (ICDD), standard hematite (α-Fe_2O_3) (00-033-0664). The XRD result (Fig.1f and 1g) showed significant peak (22.212) for the sugarcane bagasse and the Fe (III) impregnated (22.242) at 2θ degrees. The major peaks in the diffractometer pattern confined to the standard, hematite (α-Fe_2O_3).

Fig. 1f: Powder (XRD) patterns obtained using X'Pert PRO (Cu Ka radiation 40 kV and 40 mA) (Control : α-Fe_2O_3) at 2θ

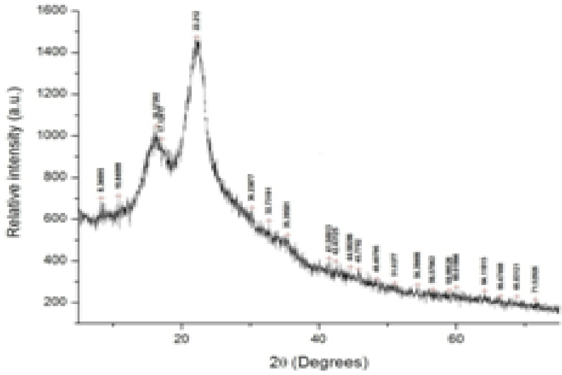
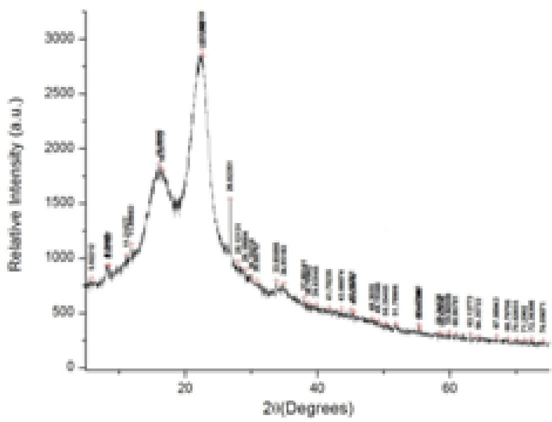


Fig.1g: Powder (XRD) patterns obtained using X'Pert PRO (Cu Ka radiation 40 kV and 40 mA) (Sugarcane (*Saccharum officinarum)* bagasse and the Fe (III) impregnated) at 2θ



DISCUSSION

4.1. Adsorption efficiency of sugarcane (*Saccharum officinarum*) bagasse with Effect of pH)

The pH of the aqueous solution is an important operational parameter in the adsorption process because it affects the solubility of the metal ions, concentration of the counter ions on the functional groups of the adsorbent and the degree of ionization of the adsorbate during reaction [11], [18] and [22]. pH 4 might be the optimum in adsorption studies as sugarcane (*Saccharum officinarum)* bagasse become positively charged due to protonation of the amino groups. The dichromate ions, exist mostly as anions ($Cr_2O_7^{2-}$, $HCr_2O_7^-$, $HCrO_4^-$ and CrO_4^{2-}) leading to electrostatic attraction between sorbent and sorbate. In case of ferric ions, it remains as cations, the concentration of proton existing in the solution will be decreased (when compared to very low pH) and hence will not give a chance to compete with Iron ions on the adsorption sites of seeds thus facilitating greater Fe (III) ions uptake [20] and [21].

4.2 Effect of Temperature ($^{\circ}$C)

As the temperature increases, the adsorption efficiency increases due to the attractive forces between the adsorbents surface [20]. The increase in adsorption efficiency with temperature indicated that the reaction follows the endothermic pathway [11].

4.3 Effect of metal ion concentration on adsorption (mg/l)

The removal efficiency of the metal ions by the biosorbent increases with increase in the initial metal ion concentration. At lower ions concentration in the solution, the ions would interact with the binding sites and thus facilitated almost 100% adsorption whereas at higher concentrations, more ions are left unadsorbed in the solution due to the saturation of the binding sites [11], [22] and[23].

4.4 Effect of adsorbent dose (mg/l)

The study infers that at low adsorbent dosage, the amount of metal ions adsorbed per unit is high. Increasing the adsorbent dose provides greater surface area and availability of more active sites leading to the enhancement of metal ion uptake [24]. However, at higher dosage, the ions adsorbed are higher due to the availability of more empty binding sites as compared to lower dosage which has less binding sites to adsorb the same amount of metal ions in the adsorbate solution [25].

4.5 Effect of exposure time (hr)

The metal uptake by the sorbent surface will be rapid initially; slowing down as the competition for decreasing availability of active sites intensifies by the metal ions remaining in solution [21]. The number of active sites in the system is fixed and each active site can absorb only one ion in a monolayer therefore metal uptake by the sorbent surface is rapid initially and then decreases as the availability of active sites decreases thus slowing down the transfer of metal ion from solution to adsorbent surface [20]

4.6 X-ray diffraction (XRD)

The experiment reveals that like coconut fibre (coir), sugarcane (*Saccharum officinarum)* bagasse is rich in lignocelluloses that constitute cellulose, hemicelluloses and lignin [28] The predominant component of lignocelluloses is cellulose, a linear β (1, 4) – linked chain of glucose molecules [29]. It is non-toxic, renewable, biodegradable, modifiable and has great potential in treatment activities [19]. Sugarcane (*Saccharum officinarum)* bagasse, the fibrous matter can be further probed for water treatment processes and can also be incorporated as adsorbent in filters and would serve as an economically viable technology

CONCLUSION

The experiment reveals that like coconut fibre (coir), sugarcane (*Saccharum officinarum)* bagasse is rich in lignocelluloses that constitute cellulose, hemicelluloses and lignin [27]. The predominant component of lignocelluloses is cellulose, a linear β (1, 4) – linked chain of glucose molecules [25]. It is non-toxic, renewable, biodegradable, modifiable and has great potential in treatment activities [25]. Sugarcane (*Saccharum officinarum)* bagasse, the fibrous matter can be incorporated as adsorbent [28]. The study concludes the usage of agricultural waste products and its eco-friendliness in the treatment of water in rural areas.

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