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Removal of Lead from Groundwater of Veppanthattai block, Perambalur district, Tamil Nadu, India, using Sugarcane Bagasse as Adsorbent

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ABSTRACT

The present work measures the adsorption capacity of sugarcane bagasse to remove excess lead from groundwater. Batch adsorption experiments were carried out to evaluate the adsorption equilibrium, and the effects of four parameters (pH, adsorbent dosage, equilibrium time, and particle size) on the adsorption of lead were investigated. Characterization of the adsorbent was carried out through SEM and FTIR instruments. Results confirm that the adsorption of lead takes place successfully on the surface of the adsorbent. The maximum efficiency of adsorption is up to 50% achieved in 5 g adsorbent dosage, at an optimum pH 5, with a contact time of 120 minutes, and 53 μm adsorbent size at 38.

Keywords: Lead, Groundwater, Sugarcane bagasse, Adsorbent

1. INTRODUCTION

Heavy metals are non-ecological pollutants and they are very much complicated to remove naturally from the ecosystem. Almost all heavy metal elements are extremely toxic when their concentration exceeds their permissible limit in the environment. The high concentration of heavy metals may accumulate in the human body, disrupt the human food chain and possibly its effect causes severe health problems if the metals exceed the permitted concentration¹. The improper dumping of toxic pollutants in water bodies is one of the greatest

environmental problems of recent decades and many efforts have been made to minimize this problem².

Lead is a relatively abundant metal in nature, occurring in lead minerals. In the atmosphere, it is relatively more abundant than other heavy metals. It is a serious cumulative body poison. Natural waters generally contain up to 200 ppb of Pb, although in some cases 400 ppb of Pb have been reported. Pb enters waterbodies from industries, mine and smelter discharges or from dissolution of old lead plumbing. Lead-bearing limestone and galena (PbS) contribute lead to natural waters in some locations. Acute lead poisoning in humans causes severe dysfunction of the kidneys, reproductive system, liver, and the brain, and central nervous system, and results in sickness or death. Lead poisoning from environmental exposure is thought to have caused mental retardation in many children. Mild lead poisoning causes anemia. The victim may have headache and sore muscles, and may feel generally fatigued and irritable.

The Agricultural Biomasses (sugarcane bagasse) was taken for the adsorption process in our study. It chiefly consists of lignin, cellulose, hemicellulose and few proteins which create them effective adsorbent for heavy metal cations. Sugarcane bagasse contains lignin (18%) cellulose (45%) and hemicellulose (28%). Cellulose is a crystalline homo-polymer of glucose with $\beta 1 \rightarrow 4$ glycosidic linkage and posses intra-molecular and intermolecular hydrogen bonds. Hemicellulose is a heteropolymer of mainly xylose with $\beta 1 \rightarrow 4$ linkage with further substances of acetyl feruloyl and glycouronyl groups. Sugarcane bagasse contains carboxylic and hydroxyl groups and hence can be a cheap, attractive and effective adsorbent for the removal of heavy metals from water³. In the current study, an attempt has been made for the removal of the lead ion of groundwater, using the sugarcane bagasse as a natural, feasible, suitable and low-cost adsorbent. Because of lead ion concentration in some stations, they are nearly exceeding the permissible limit.

2. MATERIALS AND METHODS

2. 1. Preparation of adsorbent

The sugarcane bagasse was collected from V. Kalathur village of perambalur district, Tamilnadu, India, and the bagasse was thoroughly rinsed with distilled water to remove dust and other impurities and it was dried at room temperature. The resulting material was grained and sieved in the size of 53, 106, and 300 μm particle size. This material was used as an adsorbent for adsorption studies.

2. 2. Batch adsorption experiments

The adsorption experiments were carried out in a batch process at 38 °C temperature. 5 g of adsorbent material was added to 50 mL of the sample. The substance was shaken thoroughly using a mechanical shaker rotating with a speed of 100 rpm. The concentration of lead in the filtrate was analyzed using the AAS. The experiments were repeated three times, and average values were reported. The data obtained in this batch studies were used to calculate the percentage removal of the metal ion, by using the following mass balance expression:

$$\text{percentage removal} = \left(\frac{C_0 - C_E}{C_E} \right) \times 100$$

where: C_O and C_E are the initial and equilibrium concentrations (ppm) of the metal ion solution, respectively.

3. DISCUSSION

3. 1. Effect of pH

The effect of pH in the aqueous solutions on the percentage removal of lead ion was studied using sugarcane bagasse as adsorbent, at different pH (**Figure 1**) ranging from 2 to 7 by maintaining all other factors constant (adsorbent dose 5 g, temperature 38 °C, shaking speed 100 rpm and contact time 2 h 30 min). The pH of the medium was achieved using necessary quantities of 0.1 M hydrochloric acid and 0.1 M sodium hydroxide solution..

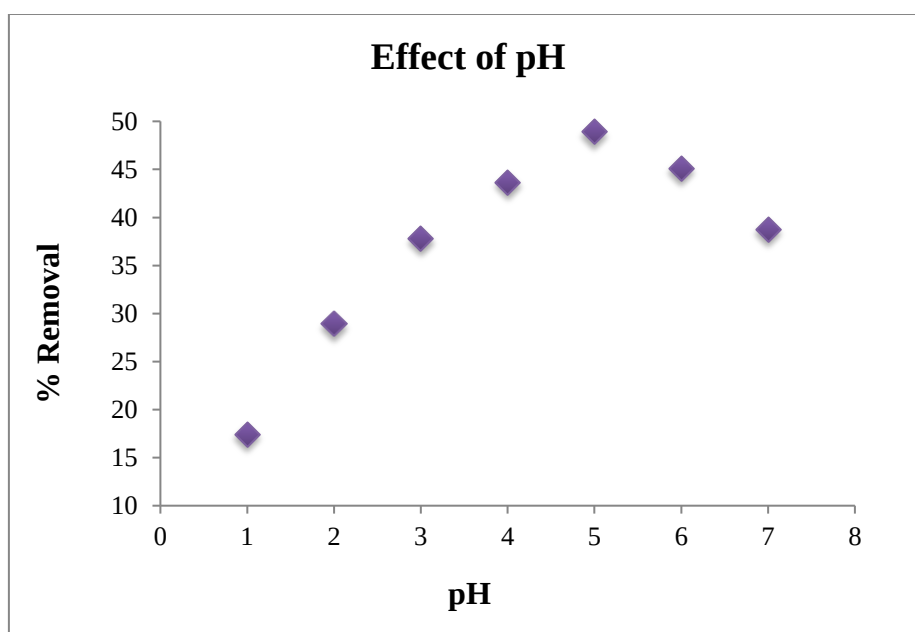


Figure 1. Effect of the pH on lead ion removal by sugarcane bagasse

From pH 1 to 5, the adsorption of the lead ion on the adsorbent is gradually increased, after that, it decreased, *i.e.*, 17.43% was removed at pH 1 and this is increased up to 48.92% at pH 5. And then it was noted 45.1% at pH 6 and 38.75% at pH 7.

The maximum adsorption occurs at the optimum pH of 5.0 and hence pH was maintained constant at 5.0 for all other studies. At low pH values, H^+ ions occupy most of the adsorption sites on the adsorbent surface, and fewer amounts of lead ions could be sorbed because of electrostatic repulsion with H^+ ions on the adsorbent surface. When the pH value increases, the adsorbent surface is more negatively charged, and the adsorption of metal ions increases and reaches equilibrium at pH 5.0. At a higher pH (above 5.0) the decrease in the adsorption efficiency was due to the formation of metal hydroxides⁴.

3. 2. Effect of adsorbent dose

Effect of an adsorbent dose was carried out with sugarcane bagasse in different adsorbent doses, from 1 g to 10 g in a 50 mL solution at pH 5.0, for a contact time of 2 h 30 min at 38 °C (**Figure 2**). The sugarcane bagasse dose is a significant parameter, as it helps in the determination of the amount of the adsorbent for a given initial metal ion concentration. The number of available sites for adsorption depends upon the amount of the adsorbent during the adsorption process.

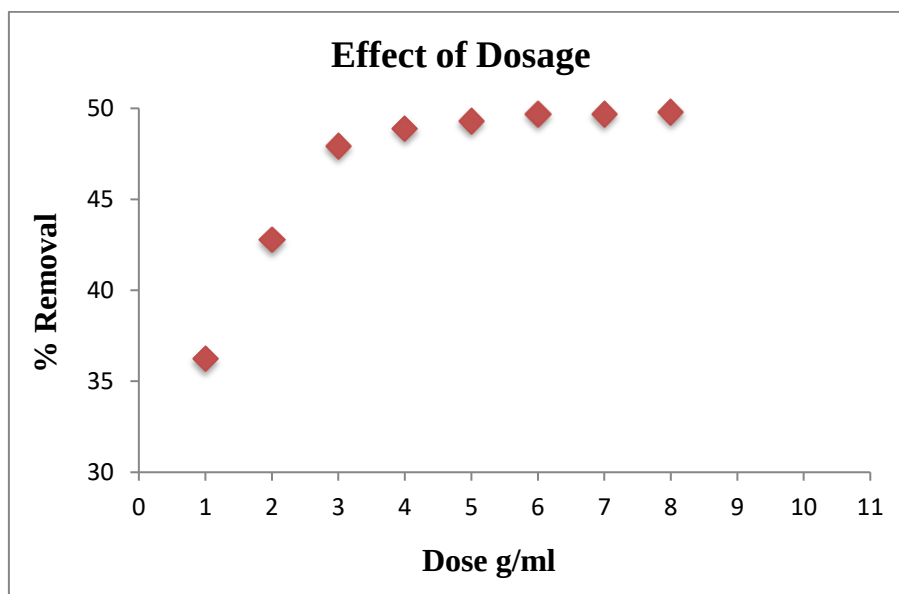


Figure 2. Effect of the adsorbent dose on lead ion removal by sugarcane bagasse

It was noted that the amount of lead ion removal increased from 24.8% to 47.93% with an increase in bagasse adsorbent dose from 1.0 to 5.0 g. The increase in the removal of metal ion from aqueous solutions can be attributed to the increased number of sites available for adsorption. The percentage removal of metal ions increases with an increase in the adsorbent dose due to the greater availability of the surface area, and thus, active sites. However, there is almost constant level in the removal of lead ion, when the dosage of the adsorbent is above 5 g. This means that adsorption reaction is feasible to attain to a dynamic equilibrium. With the purpose of achieving the minimum dosage for maximum lead ion removal, 5 g is selected as the optimum dosage.

3. 3. Effect of equilibration time

Batch adsorption experiment was carried out with bagasse by changeable the contact time from 30 to 240 min at 38 °C, though keeping the other parameters constant. From the study, it is noted that the removal of lead ion increased with the increase in the contact time and that the equilibrium is reached in 120 min of contact time. This is mainly due to the rapid adsorption of metal ions that takes place during the initial stages on the external surface of the adsorbent (sugarcane bagasse). The sorption percentage changed from 17.3% at 30 min to 43.6% at 120

min. However, there is almost constant level in the removal of lead ion, when the contact time is above 120 min (**Figure 3**). The curve in figure was found to be single and continuous leading to equilibrium, suggesting the possibility of the formation of monolayer coverage of lead ions on the adsorbent surface. Hence, 120 min contact time was chosen as the optimum time for the sorbents for further inspection. The data obtained from this test was further used successfully to assess the kinetics of the adsorption process.

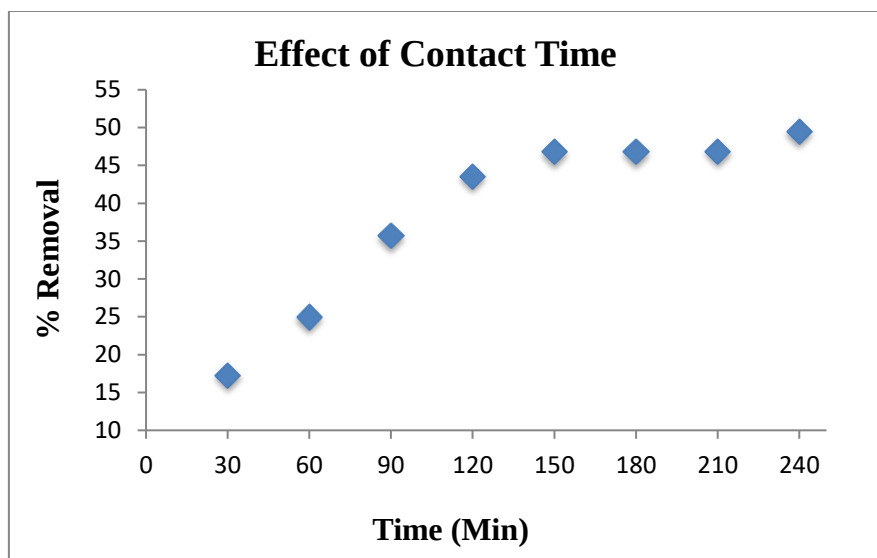


Figure 3. Effect of the contact time on lead ion removal by bagasse

3. 4. Effect of particle size

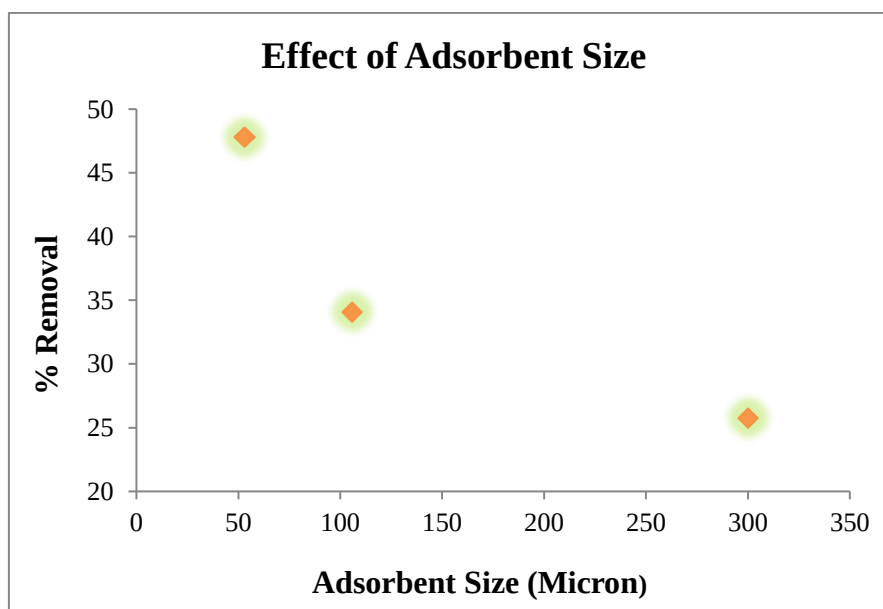


Figure 4. Effect of the particle size on lead ion removal by bagasse

Effect of the particle size was carried out with sugarcane bagasse by changing the adsorbent sizes, *i.e.*, 53, 106, and 300 μm at 38 $^{\circ}\text{C}$, and maintaining the other parameters such as pH 5 and adsorbent dose 5 g as constant (**Figure 4**). The adsorption level from 47.8 reduced to 25.8 percent is noted on an increase in particle size from 53 to 300 μm which proves that the effective adsorption takes place at a smaller particle size.

This is a known fact that the smaller particle size has more surface area and access to the particle pores and facilitated adsorption. It is also understood that the breaking up of larger particles, to form smaller ones, opens some minute sealed channels, which might then become available for adsorption and so the sorption by smaller particles is higher than that of larger particles. These observations specify that lead ion sorption occurs by a surface mechanism.

3. 5. Characterization Studies

Scanning Electron Microscope (SEM) analysis

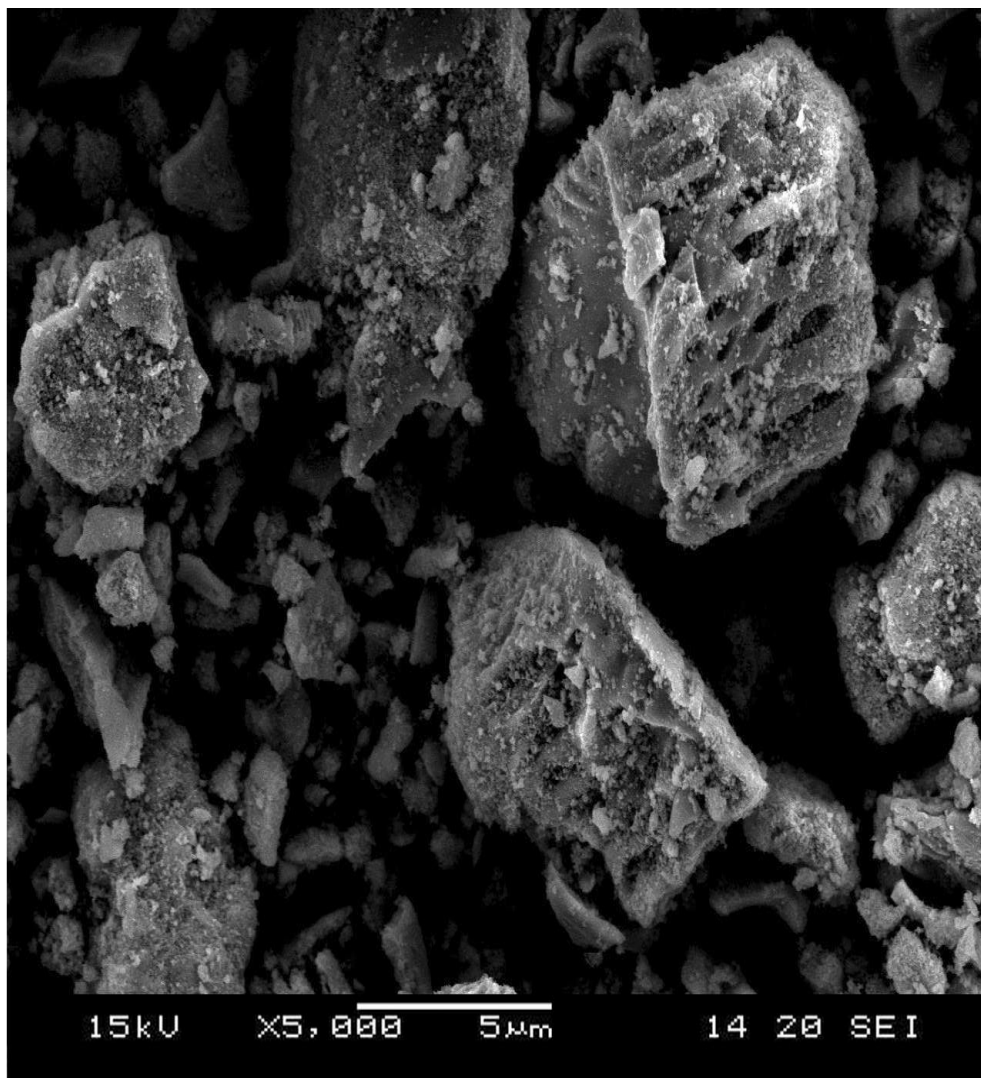


Figure 5. SEM image of sugarcane bagasse before adsorption

The surface morphology of the sugarcane bagasse was observed using scanning electron microscopy (SEM), and the corresponding SEM micrographs obtained, before and after adsorption of lead ion, at an accelerating voltage of 15 kV at 5000 $\times$ magnification are given in **Figures 5** and **6**. The surface of adsorbent becomes visible to be rough, black and more porous (Figure 5). In this case, the sponge-like structure with some bright spots confirms the adsorption of the lead on sugarcane bagasse (Figure 6). Close inspection of these micrographs along with the density difference found before and after adsorption showed that the adsorption of lead ion takes place on the surface of the sugarcane bagasse.

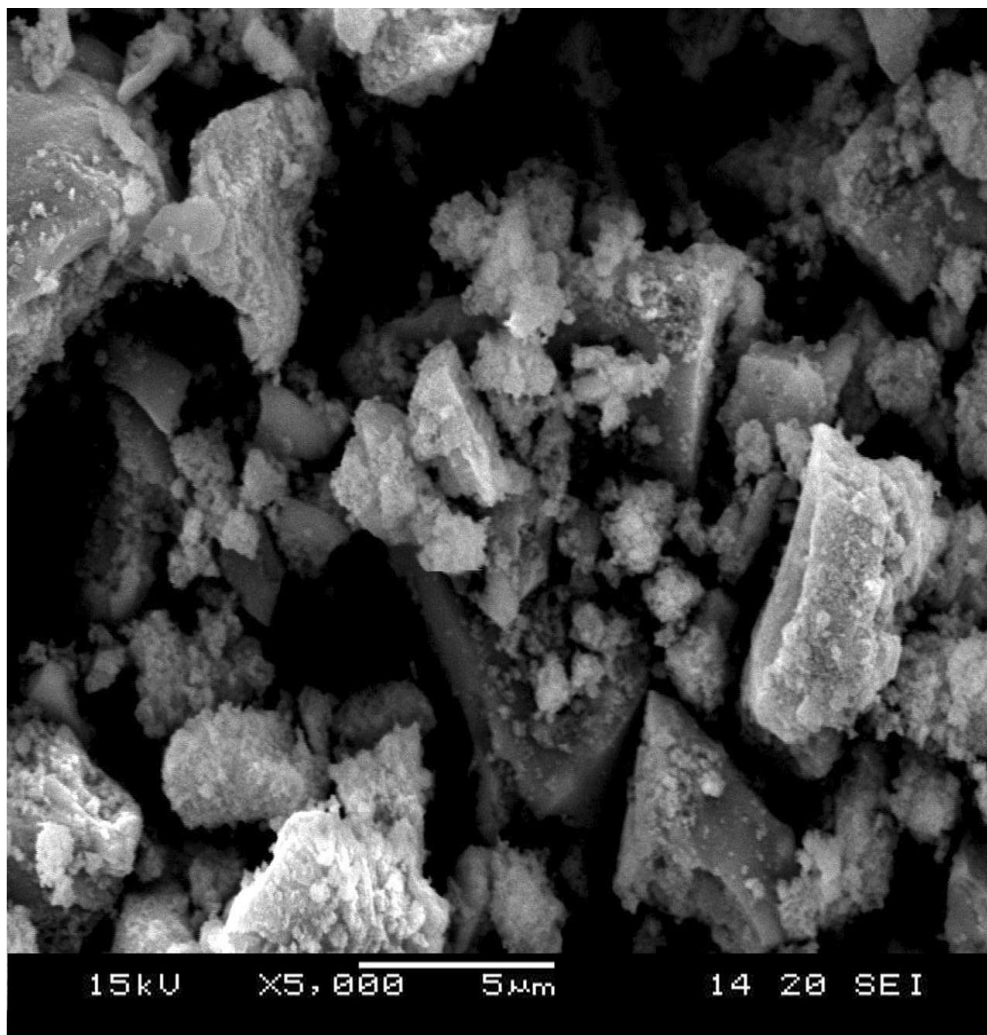


Figure 6. SEM image of sugarcane bagasse after adsorption

Fourier Transform infrared (FTIR) analysis

FTIR spectroscopy is a useful tool to identify the different functional groups present in the adsorbent (**Figure 7**). The intense broadband 3,394.11 cm^{-1} is assigned to the O–H

stretching vibration of water and the alcoholic groups. The presence of water is confirmed by its bending vibration at $1,641.20\text{ cm}^{-1}$.

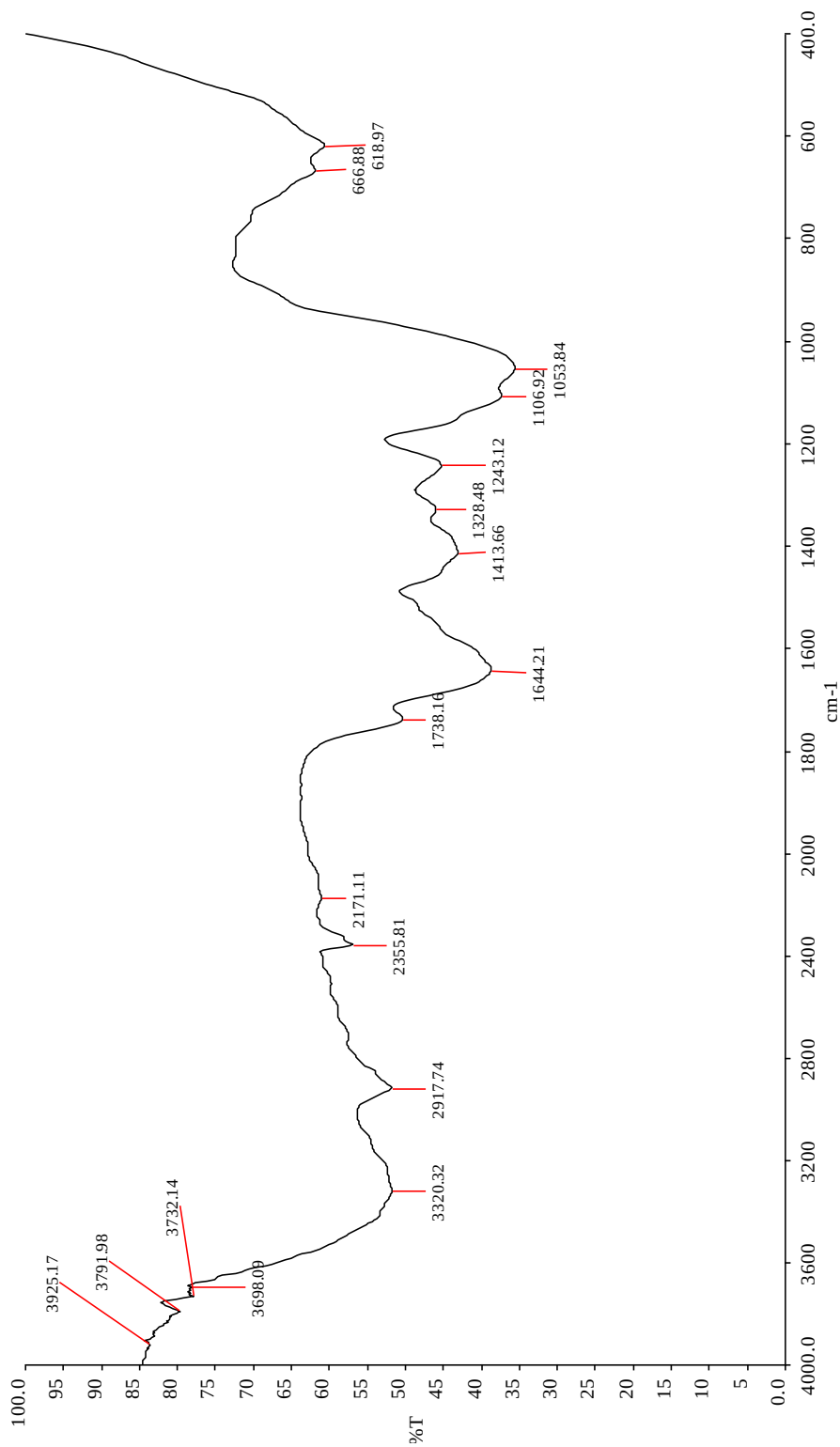


Figure 7. FTIR image of sugarcane bagasse before adsorption

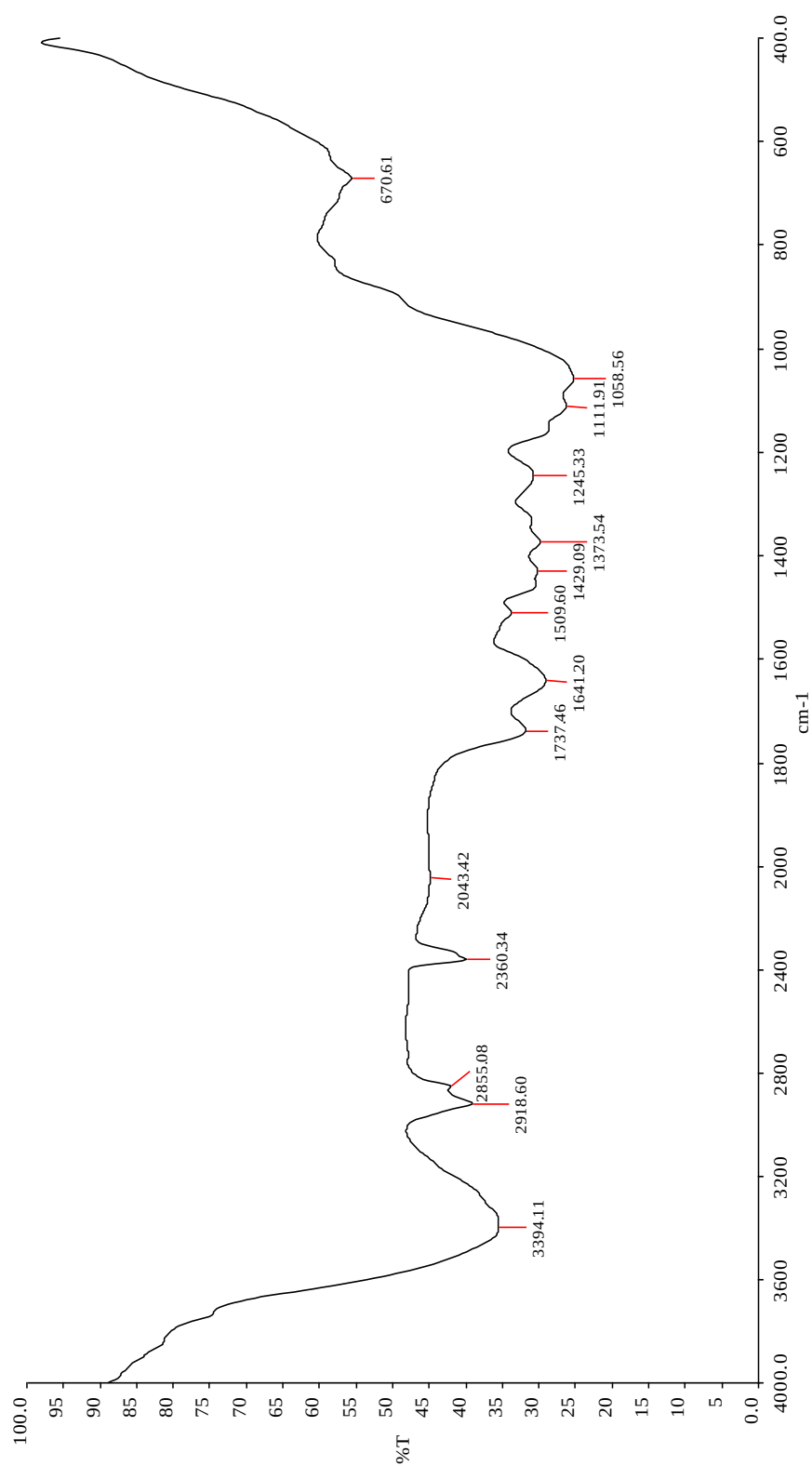


Figure 8. FTIR image of sugarcane bagasse after adsorption

The presence of the alkyl groups is evident by the intense peaks at $2,918.60\text{ cm}^{-1}$ due to the CH_2 vibrations. Their presence is also evident by their $-\text{CH}_2-$ bending vibrations at $1,373.54$ and $1,429.09\text{ cm}^{-1}$. The presence of C=O group is identified by the intense peaks at $1,737.46\text{ cm}^{-1}$. The intense broad peak at $1,058.56\text{ cm}^{-1}$ is assigned to the C–O stretching vibration of the alcoholic groups (**Figure 8**). These results also agree with the surface chemistries of other agricultural by-products, such as rubber wood sawdust⁵ and the heartwood of Areca catechu powder⁶.

4. CONCLUSION

The results presented above confirm that the adsorption of lead takes place successfully on the surface of the adsorbent. The maximum efficiency of adsorption is up to 50% achieved in 5 g adsorbent dosage, with an optimum obtained at pH 5, and a contact time of 120 minutes, under $53\text{ }\mu\text{m}$ adsorbent size.

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