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Study on removal of arsenic from aqueous solutions by low cost adsorbent

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Arsenic occurs naturally in rocks, water, soil, air, animals, and plants. Arsenic contamination in water especially groundwater has been recognized as a poison and cancer causing substance. The present study deals with the biosorption of As (V) from aqueous solution using tea waste (TW) in a batch operation. Fourier transmission infrared spectroscopy (FTIR), were used to analyze the characteristic of tea waste (TW) biomass. The experiment results showed that maximum removal of As (V) by tea waste is 77% respectively at optimum condition.

Keyword: Arsenic, Aqueous Solution, Adsorbent, Agricultural wastes, Adsorption.

1. Introduction

Safe drinking water is one of the important basic needs of every people of the world to live healthy lives. Safe drinking water should meet all the criteria set to be drinkable. Many people in developed countries are enjoying the good quality water through the centralised water supply system [1]. This element is notorious as king of all poisons. Arsenic appears in three allotropic forms: yellow, black and grey, the stable form is a silver-gray, brittle crystalline solid. It tarnishes rapidly in air, and at high temperatures burns forming a white cloud of arsenic trioxide [2]. Arsenic contamination in drinking water is one of the most prominent problems in some countries of the world. Arsenic is generally distributed in the environment (air, water and soil) [3]. Arsenic occurrence in natural water is mostly found in inorganic forms as trivalent arsenite [As (III)] and pentavalent arsenate [As (V)] [4].

The main sources of arsenic pollution in the environment are industrial sectors like galvanization unit, copper smelting, acid drainage, electroplating industry, paint and pigment industry, metallurgical units and metal finishing plants [5]. Arsenic in groundwater was first detected in 1993 following reports of many people suffering from arsenical skin diseases. Further investigations showed the extent of the problem with large areas of the country's water supply being affected and millions of people are at serious risk of arsenic poisoning [6]. The most affected regions include south-east Asian nations notably Nepal (Terai), Pakistan (Punjab), Assam (Brahmaputra plain), Bangladesh and West Bengal (Ganga delta), where the concentration of arsenic surpasses the maximum contaminant level set by WHO in 2003 (i.e., 10 ppb) [7]. Arsenic in natural waters is a worldwide problem. Due to high toxicity and carcinogenic effect of arsenic, the World Health Organization (WHO), the European Commission (EU), and the United States Environmental Protection Agency (USEPA) have recommended a maximum contaminant level (MCL) of 10 μg/L for arsenic in drinking water [8]. The effects of arsenic pollution are serious and dangerous to human life. Especially long-term ingestion of contaminated water can cause various forms of cancer [9]. Human population is

mostly exposed to arsenic through ingestion, inhalation and dermal contact. Ingestion of arsenic contaminated water, foods, drugs, wines, smoke of cigarette and fossil fuels are the various routes of arsenic exposure to the population both acute and chronically [10].

Researchers in many countries are studying the removal of arsenic from contaminated water using several techniques, namely oxidation/precipitation, electrocoagulation/ co-precipitation, lime softening, metal-oxide adsorption, reverse osmosis and nanofiltration, ion-exchange resin, coagulation-microfiltration, etc [5]. Biosorption is a new and promising field of research of biomass wastes for removal of metal ions from aqueous solutions due to cost-effective and environmentally favorable [11]. In this investigation, experiment perform to evaluate the effectiveness of employing a tea waste for the adsorptive removal of As (V) from aqueous solution, using batch experiment and isotherm studies to determine the adsorption capacities.

2. Materials and Methods
2.1 Chemicals
All chemicals used in present work were either of analytical reagent (AR) or laboratory reagent (LR) grade. $Na_2HAsO_4.7H_2O$ (99%), H_2SO_4 (98% w/w, 36N), HCl (98% w/w, 36N) supplied by s.d.fine-chem limited, Mumbai. Distilled water was used in all preparations. Sodium arsenate ($Na_2HAsO_4.7H_2O$) and deionized water was used to prepare synthetic arsenic As (V) ions containing wastewater.

2.2 Adsorbent
Tea waste collected from tea stalls and restaurants were washed and boiled with hot distilled water (75 °C) up to colour removal. After colour removal it is dried in hot oven at 105 °C for 12 hours. The dried material converted into powder form by mixer grinder and screened to size 120 µm. Again this powder dried at 105 °C for 6 hours and then stored in plastic bags at room temperature. Now it was ready to use as an adsorbent [12].

2.3 Adsorbate
$Na_2HAsO_4.7H_2O$ were obtained in analytical reagent (Sd fine chem. Co.) and used without further purification synthetic 1000 ppm stock solution prepared for arsenic metal.

> Arsenic solution: 4.1646 grams of $Na_2HAsO_4.7H_2O$ was added in 100 ml of distilled water in 1000 ml volumetric flask. It was dissolved by shaking and the volume was made up to the mark. Arsenic solution concentration of this solution was 1000 mg/l.

2.4 Batch mode adsorption studies
The adsorption of arsenic on tea waste was studied by batch technique. The general method used for this study is described as below:
A known weight of tea waste adsorbent (e.g. 0.5 g adsorbent) was equilibrated with 100 ml of the arsenic solution of known concentration (10, 20, 50 and 100 ppm) in 8 stoppered borosil glass flask at a fixed temperature (30 ^{0}C) in an orbital shaker for a known period (30–150 Min.) of time. After equilibration, collect sample (10 ml) from each flask in time interval of 30, 60, 90,120 and 150 minutes, the suspension of the adsorbent was separated from solution by filtration using Whatman No. 1 filter paper. The concentration of arsenic ions remaining in solution was measured by atomic absorption spectrophotometer (GBC AVANTA PM, HG3000). The effect of several parameters, such as pH, concentrations, contact time and adsorbent dose on the adsorption was studied. The pH of the adsorptive solutions was adjusted using sulfuric acid, sodium hydroxide and buffer solutions when required adsorption of metal ions on the walls of glass flasks determined by running the blank experiments was found negligible.

The results of these studies were used to obtain the optimum conditions for maximum heavy metals removal from aqueous solution. The percent heavy metal removal was calculated using Eq.

Metal ion removal (%) = [(C_o − C_e) /C_o] × 100 …………………………………………………..…(1)

Where C_o: initial metal ion concentration of test solution, mg/l; C_e: final equilibrium concentration of test solution, mg/l [13].

3. Result and Discussion
3.1 FT-IR (Fourier Transform Infrared) Spectral Analysis
FTIR spectroscopy method was used to show the functional groups present on the surface of the adsorbent. As shown in figure 5.1 major difference in

the region 3878.49 to 3606.53 cm^{-1} were ascribed as the vibration on N-H and O-H functional groups. The weak band at 2366.46 cm^{-1} were assigned to the C-H stretching mode, which represents the aliphatic nature of the adsorbents. The absorption bands at around 1741.32 to 1424.05 cm^{-1} were characteristics of uC=C in aromatic rings. Furthermore, peaks at 1039.38 (TW) were attributed to Si-O stretching and Si-O is bending indicating of the silica presence [14].
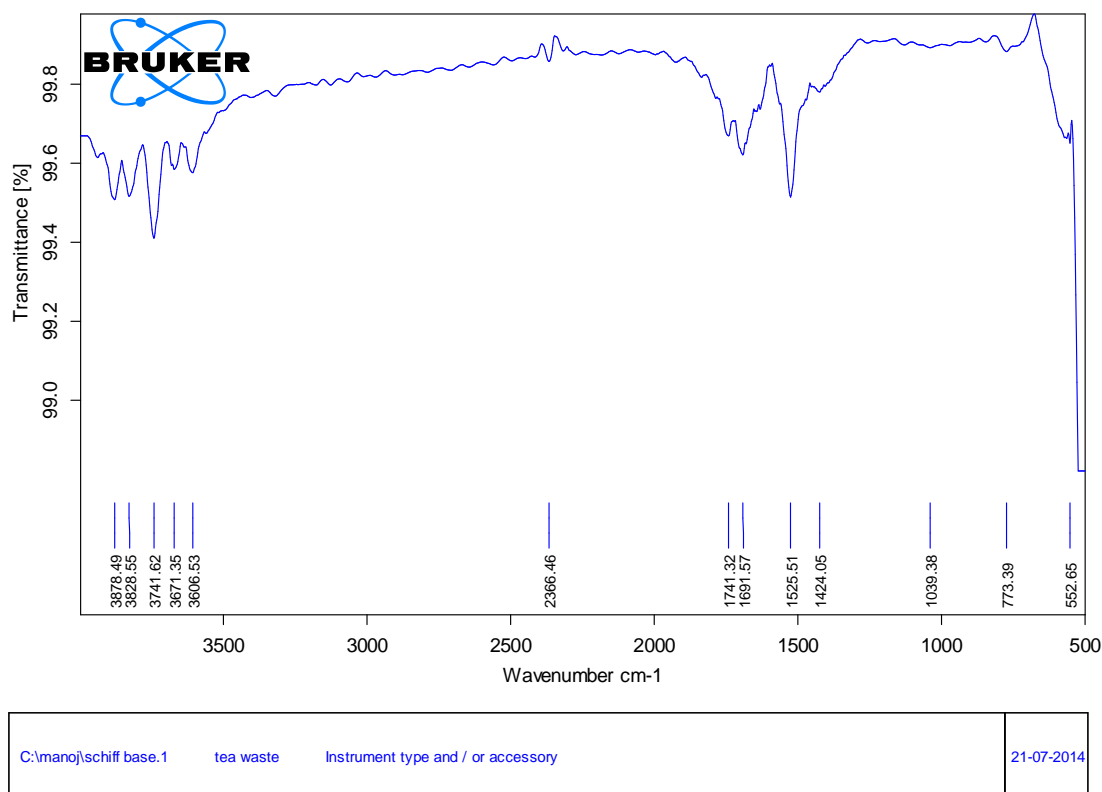
Fig 1: Fourier transform infrared (FTIR) spectrum of tea waste biomass.

3.2 Effect of contact time

Fig. 2 shows the variation in the percentage removal of As (V) with a contact time using 0.5 g/100 ml of tea waste adsorbent at 6 pH for varying initial arsenic ions concentration ranging from 10 ppm to 100 ppm. It is observed that maximum removal for As (V) ions are nearly 77% respectively even throughout the 90 min. contact times. It is observed that in all cases the percentage removal is comparatively lower for 30 min. contact time, with increasing removal efficiencies at higher contact time up to 90 min and then gradually decrease at 120 & 150 minutes.

3.3 Effect of pH

pH variation is one of the most important parameters controlling uptake of heavy metals from wastewater and aqueous solutions. Fig. 3 shows the effect of pH on As (V) removal efficiencies of tea waste adsorbent. These studies were conducted at an initial metal ions concentration of 10, 20, and 50 ppm in 100 ml solution, and constant adsorbent dose 0.5 g /100 ml solution and agitation period are 90 min. for arsenic ions at varying the pH in each solution.

The percentage adsorption increases with pH to attain a maximum a 7 pH for As (V) and there after it decreases with further increase in pH. The maximum removals of As (V) at 7 pH were found to be nearly 78%, respectively.
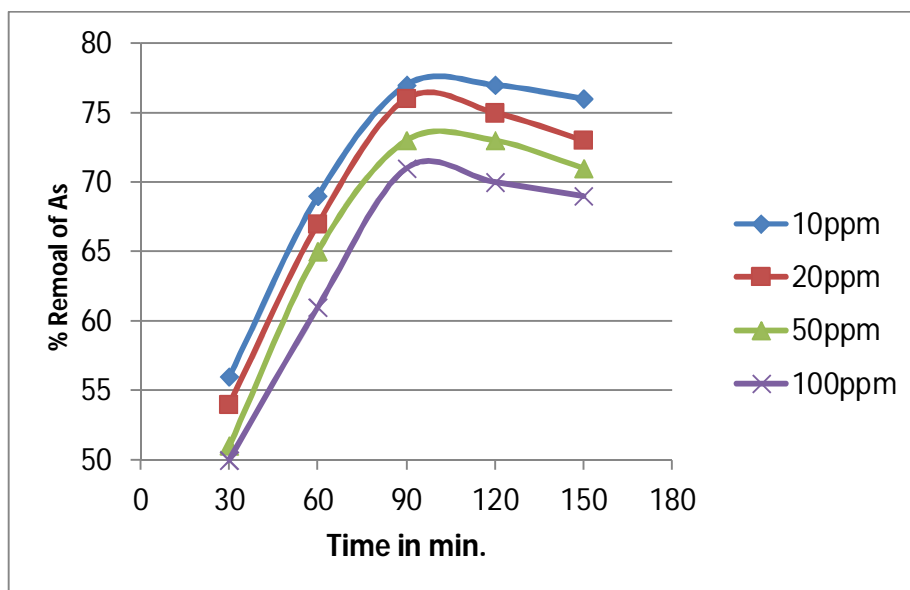
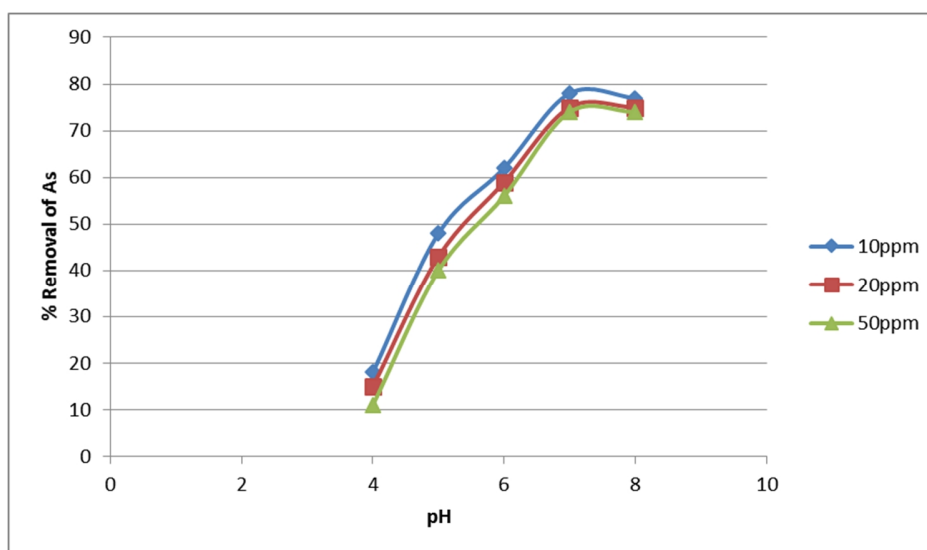**Fig 2:** Effect of contact time on percentage removal of arsenic ion by tea waste adsorbent.

Fig 3: Effect of pH on percentage removal of arsenic ion by tea waste adsorbent.

3.4 Effect of adsorbent dose

The results for adsorptive removal of As (V) with respect to adsorbent dose are shown in Fig.4 over the range 0.2 to 1 gram/100 ml, at pH 7 and 90 minutes contact time. The percentage removal of As (V) is seen to increase with adsorbent dose. It is observed that there is a sharp increase in percentage removal with adsorbent dose for As (V) ions. The maximum

removal of As (V) 78% respectively at 0.6 gram dose amount of tea waste adsorbent.

It is apparent that the percent removal of heavy metals increases rapidly with increase in the dose of the adsorbents due to the greater availability of the exchangeable sites or surface area. Moreover, the percentage of metal ion adsorption on adsorbent is determined by the adsorption capacity of the adsorbent for various metal ions.
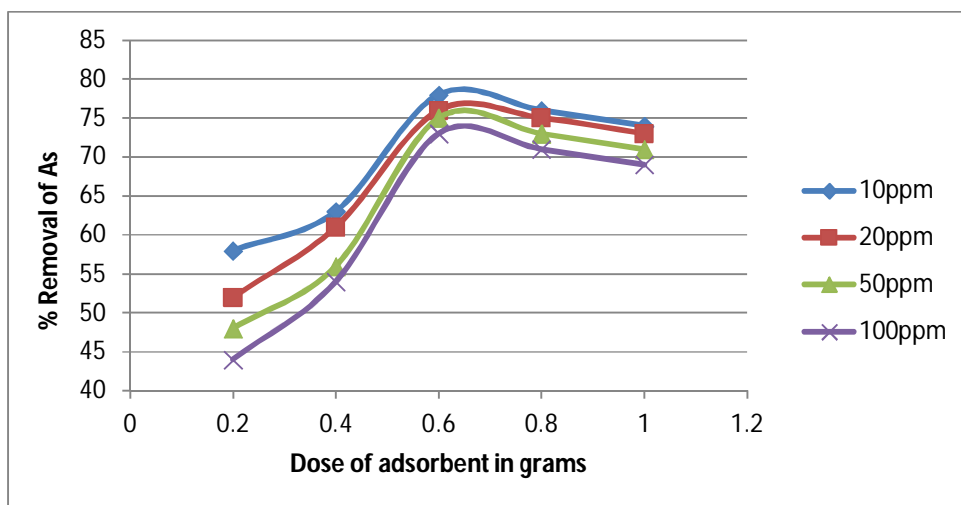
Fig 4: Effect of adsorbent (amount) dose on percentage removal of arsenic ion by tea waste adsorbent.

3.5 Effect of initial concentration

The effect of concentration on percentage removal of arsenic ion by tea waste at 0.5 g/100 ml adsorbent dose, 6 pH and 90 contact time are shown in Fig. 5. It can be seen from the figure that the percentage removal decreases with the increase in initial arsenic concentration for As (V) the percentage removal is highly effective on the 10 ppm for initial concentration after which percentage removal decreases gradually to below 56%. At lower initial metal ion concentrations, sufficient adsorption sites are available for adsorption of the heavy metal ions. Therefore, the fractional adsorption is independent of initial metal ion concentration. However, at higher concentrations the numbers of heavy metal ions are relatively higher compared to availability of adsorption sites. The maximum removal of As (V) ion are 77%, respectively at 10 ppm concentration. Hence, the percent removal of heavy metals depends on the initial metal ions concentration and decreases with increase in initial metal ions concentration.
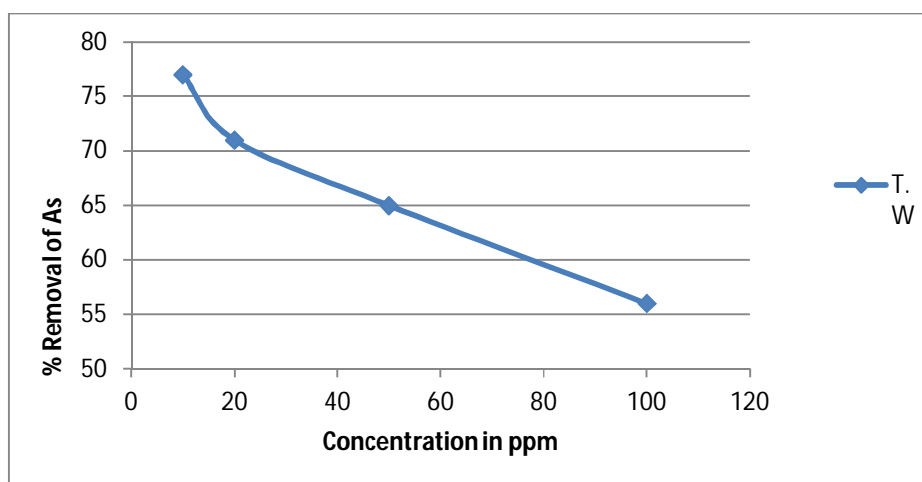

Fig 5: Effect of concentration on percentage removal of arsenic ions by tea waste.

4. Conclusion

Tea waste is a cheap and effective adsorbent for the removal of as ions from aqueous solution. Experimental results showed that maximum removal of As (V) by tea waste at optimum condition (7 pH, 90 min. contact time, 0.5 g/100 ml adsorbent dose and

10 ppm concentration) is 77%. These experimental studies on adsorbents would be quite useful in developing an appropriate technology for the removal of arsenic ions from contaminated industrial effluents.

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