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Magnetite Iron Oxide/Activated Charcoal (Fe_3O_4-AC) Composite for Arsenic Removal

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Abstract:
The article focuses on the development of magnetic Fe_3O_4 over the activated charcoal for the removal of arsenic (III) from synthetic aqueous solution. Chemical activation of activated charcoal was done using HNO_3 at 200^{o}C to enhance the adsorption capacity of activated charcoal. Again, to enhance its adsorption capacity it was loaded with magnetic Fe_3O_4 which was synthesized by hydrothermal process. Batch study was conducted in which effect of pH, effect of contact time, effect of adsorbent dose on the arsenic adsorption were studied. The results shows that the activated charcoal loaded with magnetic Fe_3O_4 could remove arsenic very effectively at pH 8 at maximum adsorbent dose 1.2 g/L with the contact time 45 min at room temperature. Furthermore, the adsorption data were studied with Langmuir and Freundlich adsorption isotherm to analyze the equilibrium of the experiment. Langmuir model best fitted with the experimental results with the maximum adsorption capacity 7.28 mg/g. this finding indicated that the activated charcoal loaded with magnetic Fe_3O_4 could be used for the removal of trivalent arsenic from aqueous solution.
Keywords: *Arsenic (III), Fe_3O_4, Activated charcoal, Langmuir model, Freundlich model*

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I. Introduction:

The whole countries in the world facing a problem of waste water contamination and its purification [1]. The government agencies around the world searching out the solution of wastewater contamination and its treatment by making various policies and in that Indian government specially focus on the swachchabharatabhiyan through that the treatment water of ganga river is the mainline task now a days. For the treatment of wastewater and also for the removal of toxic metal ions, organic and inorganic pollutants there are many methods available like reverse osmosis, physico-chemical treatment, advance oxidation treatment, coagulation-flocculation process, ion exchange, membrane filtration etc [2]. But treatment of wastewater is not an easy task because many facts have to be considered if we are looking for the treatment of wastewater. In to that first one is the process should be feasible, it should be carryout at any suitable workplace, it should be cost effective and as the green parameter consist it should not generate waste [3]. Looking in to that view the current work was carries out in which the removal of toxic metal i.e., arsenic from the synthetic aqueous solution onto the Magnetite Iron Oxide/Activated Charcoal (Fe_3O_4-AC). The activated charcoal is well known for the purification of wastewater because of its high porosity, easy availability, cost effective and Regenerability [4-6]. Furthermore, is surface is available for the modification by using surface active agents, nanomaterial, polymers etc. which will enhance its BET surface area and ultimately the adsorption capacity increases. Arsenic contamination is the major concern the various parts of the India [7]. As per the WHO guideline the maximum permissible limit for the arsenic in groundwater is 10 µg/L but in India highest concentration of arsenic was found to be in the range 0.003 - 3700µg/L. Usually inorganic arsenic is more toxic than the organic arsenic. In natural water arsenic persist in two oxidation state: arsenite (+3) and arsenate (+5). Long-term exposure to arsenic from drinking-water can cause diverse types of cancers, including skin, lungs, urinary bladder, kidney liver, and prostate cancers [8-9]. In developing countries two methods are widely used for the arsenic removal from wastewater one is precipitation and another is adsorption. A large amount of chemicals is required in precipitation method which finally creates sludge in the form of arsenic sulfide, calcium arsenate or ferric arsenate. On the other hand, adsorption method is easy to handle, cost effective and efficient and can be applied for the treatment of wastewater containing trace amount of pollutants [10]. Hence, the objective of this study was to find out the adsorption capacity of Magnetite Iron Oxide/Activated Charcoal (Fe_3O_4-AC) composite for the removal of As (III) from aqueous solutions

II. Material and Method

Synthesis of Adsorbent (Fe_3O_4-AC Composite)

Magnetic Fe_3O_4 was prepared by dissolving 0.8 g of $FeCl_3.6H_2O$ in 40 ml deionised water to it 2 ml ammonia solution were added under constant magnetic stirring at room temperature stir this mixture for about 30 min. Chemical activation of activated charcoal was done using HNO_3 at 200°C to enhance the adsorption capacity of activated charcoal. In beaker 0.1 g of activated charcoal were dissolve in 20 ml distilled water and 8 ml ethanol. Both this mixture was then transferred to Teflon crucible. For the hydrothermal treatment at 120°C, Teflon crucible was inserted in to stainless steel autoclave for 3 h. After the hydrothermal reaction, the autoclave was cooled down to room temperature. After that, the product was filtered, washed with deionised water and ethanol several times. The sample was dried in an oven at 60°C for 10 h Then, the obtained product designated as Fe_3O_4-AC composite and kept in cold condition for further studies.

Batch Adsorption Experiment

In the batch study various parameter like effect of pH, adsorbent dose, contact time were studied for the removal of Arsenic on Fe_3O_4-AC composite. A known concentration of Arsenic (III) solution was taken in a stoppered bottle to which definite amount of Fe_3O_4-AC composite were added and shaken at 500 rpm on rotary shaker for 1 h. After equilibrium the reacting solution was then filter and concentration of As(III) before and after was determine by molybdenum blue method at 840 nm using spectrophotometer.

III. RESULT AND DISCUSSION

Effect of pH: To study the effect of pH on As(III) removal in pH range 1-12 on Fe_3O_4-AC composite using 1.2 g of adsorbent, 5 mg/L initial As concentration and contact time 60 min are kept constant. 0.1 N HCl and 0.1 N NaOH was used to adjust the desired pH.

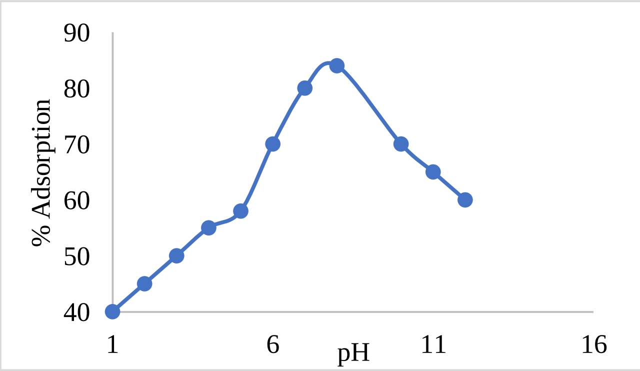

Fig. 1: Effect of pH

Effect of dose: To study the effect of adsorbent dose on As(III) removal on Fe_3O_4-AC composite by varying the dose of adsorbent from 0.1 g to 1.2 gm. pH 8, 5 mg/L initial As concentration and contact time 60 min are kept constant

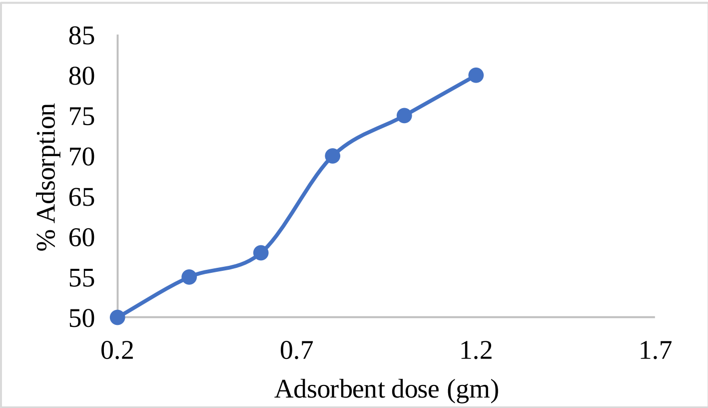

Fig. 2. Effect of adsorbent dose

Effect of contact time: The effect of contact time on the percentage of As(III) removal by Fe_3O_4-AC composite adsorbent was studied at different contact time from 5 to 120 min. Other parameters were kept constant,such as the adsorbent dose 0.5 g/L, initial As(III) concentration 5 mg/L, and pH 8. All the experimentswere carried out at room temperature. The percentage removal of As (III) adsorbed was calculated byusing the following equation.

$$\% \text{ As(III)Removal} = \frac{(\text{Co} - \text{Ce}) \times 100}{\text{Co}}$$

Where Co = Initial concentration of Arsenic (mg/L) and Ce= final concentration of Arsenic (mg/L).

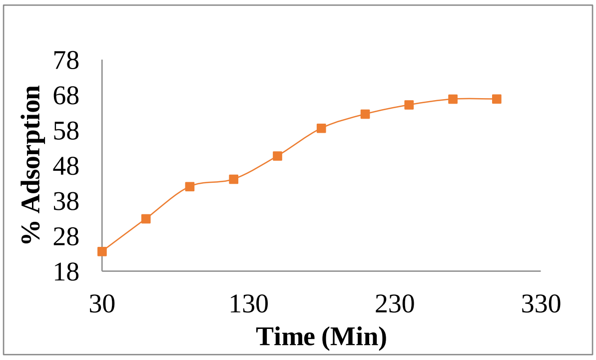

Fig.3. Effect of contact time

Adsorption Isotherm

To study the interaction between As(III) and magnetite Fe_3O_4-AC composite the equilibrium data was scrutinized and studied by using Langmuir and Freundlich adsorption model.TheresultsinAs(III) removal experimental data tobothFreundlichandLangmuirequation

Isotherm Modelling

***Langmuir Adsorption Isotherm*: -** The Langmuir isotherm model can be given as:

$$\frac{1}{q_e} = \frac{1}{Q^0 b} \times \frac{1}{Ce} + \frac{1}{Q^0}$$

The Langmuir constant Q^o is a measure of adsorption capacity and b is the measure of energy of adsorption. In order to observe whether the adsorption is favourable or not, a dimensionless parameter 'R_L' obtained from Langmuir Isotherm. The values of Q^o and b were evaluated from the intercept and slope of linear plots of $1/q_e$ vs. $1/C_e$ respectively.

***Freundlich Adsorption isotherm*: -** It is most commonly used adsorption isotherm model which describes adsorption on heterogeneous surfaces with interactions among adsorbed molecules. It helps to investigate the nature of adsorption and the adsorption capacity of an adsorbent. The linear form of Freundlich isotherm model is

$$\log q_e = B. \log C_e + \log K_f$$

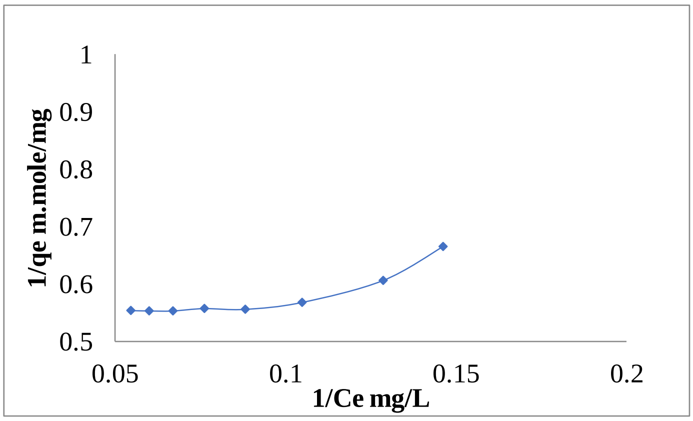

Fig.4: Langmuir Adsorption Isotherm

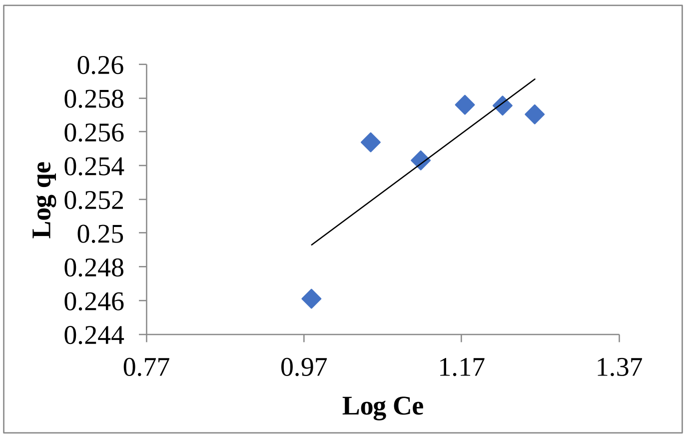

Fig. 5: Freundlich Adsorption Isotherm

IV. CONCLUSION

Fe_3O_4-AC composite shows good adsorption efficiency for the removal of As (III). The removal efficiency was found to be rapid at initial stage and then slow down because it is depending upon the concentration of metal ions and active sites on the adsorbent for the binding of metal ions. The adsorption isotherm data was best revealed by the Langmuir adsorption isotherm. The maximum removal efficiency was found to be at pH 8. Batch study indicates that as the adsorption dose, contact time increases adsorption capacity increases.

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Conflict of interest: Nil

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