Effect of parameters on the removal of As(III) in column mode

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Abstract- **In a continuous up-flow fixed bed column system, dried powder prepared from the leaves of Achyranthes aspera has been used to biosorb As (III). The effect of bed height, flow rate, and initial metal ion concentration on As (III) removal was studied. A 25 cm column bed height, flow rate of 1.66 mL/min, and initial metal ion concentration of 1000 g/L were used to determine the uptake capacity. As an eluant, 10% NaOH was used in the desorption experiments. The column was regenerated and reused three times. The good uptake capacity and ability to regenerate showed the applicability of this biosorbent in industrial processes, as well as data generated would help further in upscaling the adsorption process.**

Keywords: Arsenic, biosorption, Achyranthes aspera, column mode, desorption

I. INTRODUCTION

From ancient times, toxicity of arsenic has been established. The fact that it was present in the aqueous system as pollutants has attracted attention from scientists and researchers all over the world. The geothermal dissolution of mineral and ores is one of the main sources of its entry into water. Mining, smelting non-ferrous metals and burning fossil fuels are also contributing to the anthropogenic arsenic contamination of water resources [1,2]. Its toxicity results in various health hazards and is found to be related to skin, lung and liver cancer. Its toxicity results in various health hazards and is found to be related to skin, lung and liver cancer. It leads to black foot disease, disseminated and sighted melanosis, diffuse and spotted keratosis, nonpitting oedema, and Bowen's disease and gangrene [3]. The maximum permissible limit of As (III) in drinking water is 10 μg/L [4]. Solvent extraction, chemical precipitation, ferricite precipitation, ion exchange and reverse osmosis are some of the conventional methods that have been used in reducing Arsenic concentrations in water. There are pros and cons of each method. The methods indicate that the removal of metal is incomplete. And it costs high amounts and causes an adverse effect on the environment [5]. Absorption processes, especially using biological materials, have their own benefits and are gaining significant reputation in the last few years. It's environmentally friendly to use this method. It is an economic domestic technique for removing metal ions from water even at high concentrations, and it has excellent performance [6]. In the present work dried powder of Achyranthes aspera leaves (DPAL) has been used to study the effect of various process parameters on the biosorption of As (III) in column mode.

II. MATERIALS AND METHODS

A. Column design and experimental procedure

Different bed heights were achieved, fixed column experiments were performed in laboratory with borosilicate glass columns diameter 2 cm and length 30 cm stacked with various levels of DPAL. Sorbent was packed between two reinforcing layers of 1 cm thick glass wool for ensuring that the it does not float A peristaltic pump (Miclins PP-10) in an up-flow mode was used to adjust the metal ion solution of desired concentrations and pH 7, followed by infusion into column at preferred flow rate. The samples were taken from the exit of the column at various times to be analysed for Arsenic by an Atomic Absorption Spectrometer, aShimadzu 06300. The column was closed when the concentration of metals in effluent exceeded the original metal ion level by more than 99 %. The column was rinsed with 100 ml deionized double distilled water in upward direction at the same speed as used for biosorption of arsenic from a solution containing arsenic. At a flow speed of 1.66 mL per minute desorption was achieved by dropping 10% NaOH through the column surface in an upwards direction. A sample of the effluent metals solution has been collected and analysed for Arsenic content. Once the desorption cycle was completed, the column was rinsed with deionized double distilled water in the same way as biosorption, until the eluting distilled water reached pH 7.0. For subsequent cycles, the desorbed and recovered column beds have been used. In the same way as indicated, a new cycle ofsorption and degradation has been repeated. All the experiments were performed in triplicates at room temperature (±30 °C) and the mean values were taken.

III. RESULTS AND DISCUSSION

B. Effect of bed height

Figure 1 shows the breakthrough curve obtained for adsorption of arsenic to DPAL at various heights, 5, 15 and 25 cm (obtained by The packing of 12.4 g, 21.5 g and 35.2 g biosorbent respectively into a column) in a constant flow rate of 1.66 mL per minute with 1000 g L initial arsenic concentration. Table 1 shows the results obtained, showing a difference in volume of breakthrough between low and high beds. In this case, it can be explained that the axial dispersion phenomena have been predominant during mass transfer as a result of reduced bed height and thus metal ions diffusion has decreased. Thus, there is insufficient time for the solute to diffuse into the whole of the adsorbent mass. Therefore, when the bed height decreased from 25 cm to 5 cm, a decrease in volume of solution used was observed for 2012.3 to 503.1 mL. Furthermore, the sorption capacity has been demonstrated to have increased with

increasing bed height. The increase was due to increased doses of biosorbate in bigger beds, resulting in more As (III) adsorption sites. As a result, when bed height increased, the stay times and exhaustion periods were lengthened on these two factors. Since the breakthrough time is the determining factor of the process, the larger it is, the greater the intraparticulate phenomenon and the adsorption capacity of the bed.

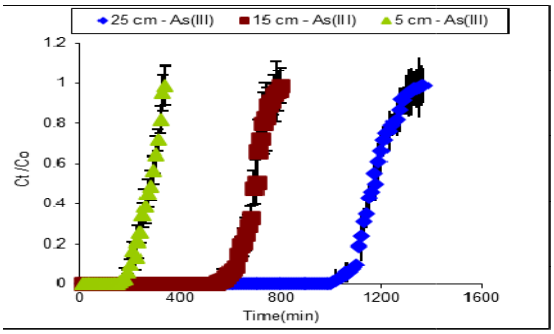

Fig. 1 Breakthrough curve at various bed heights (Flow rate = 1.66 mL/min, initial [As (III)] = 1000 µg/L)

C. Effect of flow rate

Effect of flow rate on As (III) adsorption on DPAL was studied at various flow rates while initial As (III) concentration (1000 µg/L) and bed height (25 cm) were kept constant. The graph in Figure 2 shows the normal concentration of arsenic against time at different flow rates. Table 1 present evaluation of treated volume, breakthrough and exhaustion times, adsorption capacity and arsenic removal percentages was done with respect to flow rate and from the sorption data. As the flow rate increased, it has been observed that there was a decrease in breakout time, exhaustion time uptake capacity and % removal. This is due to a decrease in the solute's staying time within the column when flow increases, which leads to less diffusivity for sorbent particles.

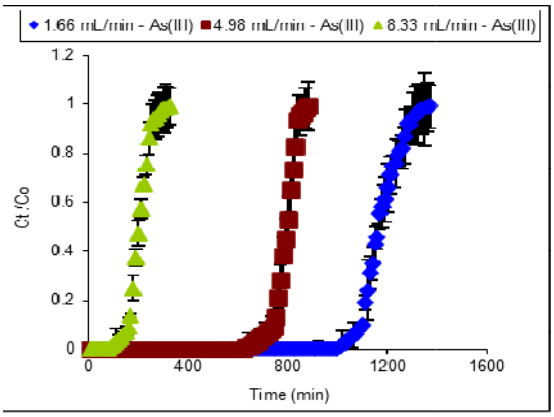

Figure: 2 Breakthrough curve at various flow rates (Bed height = 25 cm, initial [As (III)] = 1000 µg/L)

D. Effect of initial metal ion concentration

Figure 3 and Table 1 shows the effect of initial As(III) concentrations 500 to 1000 g/100 ml at a constant bed height of 25 cm and flow rate 1.66 mL per minute. The results show that the volume treated prior to breakthrough reduced as a result of an increase in As(III) concentration. This can be explained by higher concentration of metal ions in the bed, which is absorbed more quickly, thus shortening the time of breakthrough. Moreover, an increase in initial concentrations of metal ions was found to increase uptake capacity. The concentration difference of the solute in the solution compared to the sorbent can therefore be explained as a key driving force for adsorption.

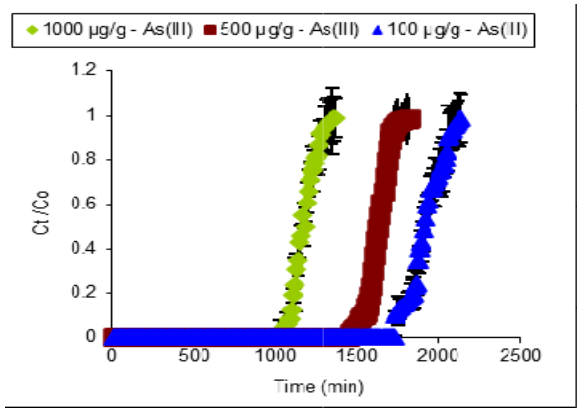

Fig. 3 Breakthrough curve at various initial As (III) concentration (Bed height = 25 cm, Flow rate = 1.66 mL/min)

Table I: As (Iii) Adsorption Data for Fixed Bed Dpal Column at Different Parameters

Process Parameters	Veff (mL)	tb (min)	Te (min)	q (µg/g)	% removal
Bed height, Z (cm)a					
5 (12.4 g)	503.1	155	365	35.18	69.35
15 (21.5 g)	1397	565	812	51.35	76.56
25 (35.2 g)	2012.3	1121	1325	68.56	86.17
Flow Rate, Q (mL/min)b					
1.66	2012.3	1121	1325	68.56	86.17
4.98	3425.2	430	680	57.08	58.19
8.33	4282.8	280	520	41.35	45.85
Initial metal ion concentration, Co (µg/L)c					
100	3641.8	1814	2214	17.73	61.8
500	3132.3	1522	1945	39.73	80.11
1000	2012.3	1121	1325	68.56	86.17

E. Regeneration

Multiple reuse of the sorbent, which significantly reduces the cost of the process and reduces the dependency of the process on continuous supply of the sorbent, and opens up the possibility of recovering metal from the liquid phase, is required for the successful biosorption process operation. For 3 cycles of sorption and desorption at 1.66 mL per minute, the DPAL was reused in this study. The column

was packed with 35.2 g of DPAL to yield 25 cm bed height and a flow rate of 1.66 ml per min has been adjusted. For three sorption degradation cycles Table 2 summarises breakthrough times, exhaustion time, the uptake capacity, elution periods and percentage of elution efficiency. In Fig. 4, it has been noted that as the regeneration cycle progresses, a decrease in breakthrough time is achieved and an increase in exhaustion period leads to more extensive mass transfer area. But in each of the three cycles, a good metal sorption capacity was obtained. While selecting a desorbent that does not affect the physical state and metal uptake capacity of the sorbent shall be regarded as an appropriate choice. For this system, for all three cycles of sorption and desorption, 10% NaOH has a good elution efficiency of more than 98%, Fig. 5. It is an appealing treatment option for solutions containing As(III) owing to the economic and ecological advantages of using DPAL together with its good sorption capacity.

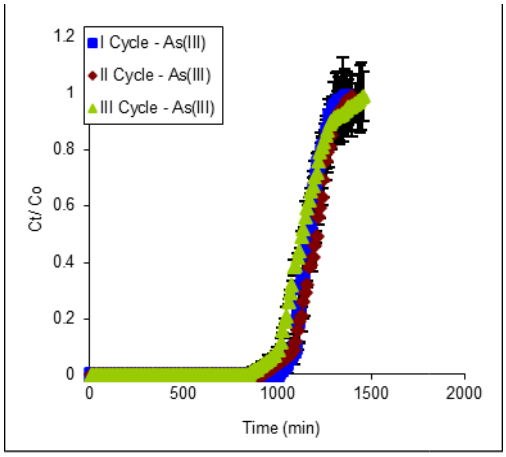

Fig. 4 Breakthrough curves for As (III) sorption during three sorption-desorption cycles (Bed height = 25 cm, flow rate = 1.66 mL/min, initial arsenic concentration = 1000 µg/L)

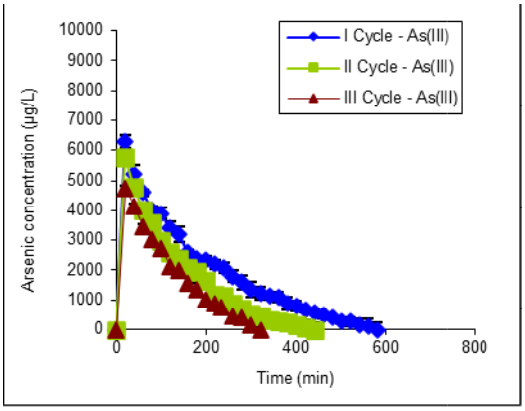

Fig. 6 Elution curves for desorption of As (III) during three sorption-desorption cycles (Eluant = 10% NaOH, Flow rate = 1.66 mL/min)

Table II: Sorption Process Parameters for Three Sorption-Desorption Cycles of Arsenic onto Dpal

Cycle	Veff (mL)	tb (min)	te (min)	q (µg/g)	% removal	Time for elution (min)	Elution efficiency (%)
I	2012.3	1121	1325	68.56	86.17	560	99.1
II	1958.1	952	1398	65.47	84.62	440	99.56
III	2001.4	860	1481	64.39	82.24	320	98.86

IV. CONCLUSIONS

In this study, a suitable biosorbent for the continued removal of As (III) in aqueous solution has been identified as DPAL The height of the bed, flow rate and initial metal ion concentration have a very important role to play in As (III) sorption.

The sorption performance has improved as a result of increasing the height of the bed. However, it has been observed that the capacity to absorb reduces with a rise in flow rates. Higher uptake has been seen as a result of increasing As (III) concentration. At 25 cm bed height, 1.66 mL per minute flow rate and 1000 g of initial metal ion concentration, the maximum uptake of 68.56 g was observed. For three cycles of sorption and desorption the adsorption performance of DPAL in removal of As (III) has been successfully tested. In all three cycles, the sorption capacity of DPAL was found to be satisfactory. Therefore, by using DPAL as an adsorbent, it is possible to extract the adsorbed arsenic from the biosorbent and reuse the adsorbed arsenic. Regenerating sorbent acts as potential source of As (III) apart from being economical and easy removal methods. The regenerated biosorbent may be used for removal purposes, and then disposed of without any adverse effect on the environment..

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