

## Biosorption studies on arsenic (III) removal from industrial wastewater by using fixed and fluidized bed operation

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### KEYWORDS

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### ABSTRACT

Previously, activated carbon was used as adsorbent for the removal of heavy metals at batch scale and the reported removal efficiency was up to 25 % (while in our technique the efficiency is up to 75%). The large industries operate with continuous processes and discharge large amount of wastewater containing heavy metals. No research was published for continuous operation using fluidized bed adsorption column till now. The novelty of this study is on the mode of operation (continuous operation at large scale under fixed and fluidized bed conditions), Biosorbent activated carbon (AC), and maximum efficiency of arsenic removal (i.e. 75 %). The Biosorbent activated carbon prepared from waste agriculture material. Industrial wastewater consists of many inorganic and organic pollutants which are discharged into water bodies resulting the serious health problems. Now a days, concentration of arsenic has much increased as compared to the permissive concentration level (25mg/L). Therefore, there is need to reduce this concentration up to threshold value (10µg/L). The use of biosorbents for arsenic removal from wastewater has global significance due to its widespread availability and low cost. Biosorption of Arsenic strongly depends on the initial metal concentration, contact time, speed of stirring, pH and temperature. The maximum arsenic as (III) removed at pH-7.5 is 70%, it was improved to 83% by agitation in batch experiments. While in continuous mode experiments (Fixed bed) the bed height and flow rates were varied. At the Fluidized bed experiments, the maximum As (III) removed was 75%. The effects of several factors such as pH, initial solute concentration, biosorbents dose, has been revaluated in this paper. The low cost, easily available biosorbent AC is recommended for removal of arsenic from contaminated wastewaters to bring them in compliance.

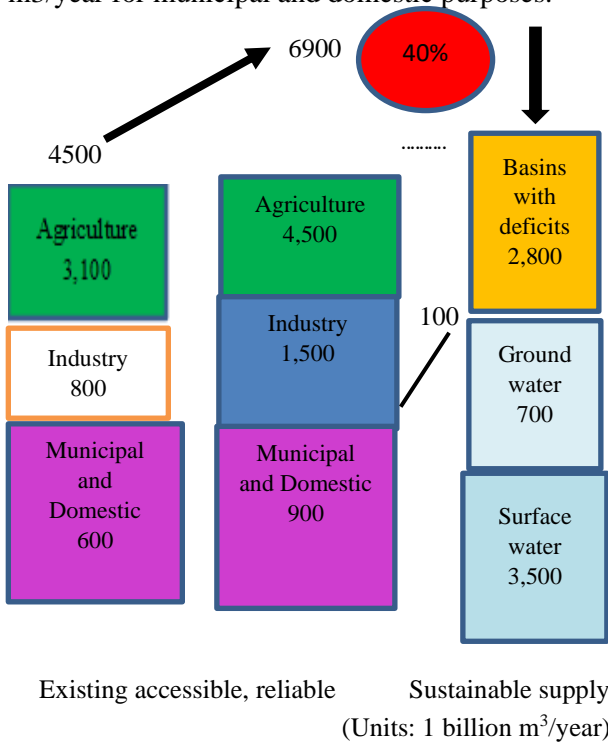
### 1. Introduction

The primary and essential element for all living things in the earth is water. The need for clean water had improved in the previous century as a result of the expanding global population. This pollution is increasing resulting in the decrease of clean water

resources. The Fig. 1 is showing that the problems in relation to the resources of water are expected to become an even higher complicated in the future, as well as the demand of water is predictable to rise along with growth of population, economic development, as well as enhancement in standards of living and so on. In terms of the resources of water, irrigation water for the

production of food accounts for about 70% of water use. Water is too significant for the supply of energy as well as the resulting restrictions on food and energy security are also a concern. There is a strong requirement, for a variety of purposes, to ensure the well-organized allocation of limited resources of water as well as to improve sustainable use of water [1].

The Fig. 1 describes that in 2021, 3,100 m<sup>3</sup>/year water was used for agriculture purpose, 800 m<sup>3</sup>/ year for industrial, and 600 m<sup>3</sup>/year for domestic and municipal purposes. With the compound annual growth rate 2%, in 2030 for agriculture purpose the use of water will be 4,500 m<sup>3</sup>/year, for industry 1500 m<sup>3</sup>/year, and 900 m<sup>3</sup>/year for municipal and domestic purposes.



**Fig. 1.** The Demand of Water will Exceed the Resources of Water by 40% in 2030. [JICA, 2022]

The main pollutants inside the water are the heavy metals (nickel, chromium, lead and arsenic etc. ). Heavy metal cause pollution from excessive environmental discharge brought on by increased industrial and urbanization is a major issue that effects the entire planet. Environmental sustainability is seriously threatened by the hazardous and nonbiodegradable character of metal pollutants as well as their inclination towards living things. Due to their persistent effects on living things, heavy metals such as arsenic, chromium, nickel, mercury, lead, and cadmium are assumed to be major pollutants for clean water resources [2].

In the list of 20 most dangerous heavy metals, the rank of arsenic is first [3]. Arsenic is mostly found in water as a result of a variety of natural processes,

including weathering reactions, biological activities emissions from volcanic, as well as river transport of minerals formations that contain arsenic [4, 5] . In addition to sources of natural, arsenic compounds are also found in agriculture, mining, livestock, as well as process industries which cause ground water and surface water contamination badly[5] . Widespread drinking water contaminants like arsenic are difficult to completely eliminate from drinking water sources using the existing technologies of water treatment [6]. Ground as well as surface water frequently include arsenic as a pollutant . Around the world, arsenic is introduced into ground water as well as surface water that are used as a source of drinking water either naturally (ground water comes into contact with deposits of mineral) or as a result of human activity (surface water is contaminated along fertilizers, pesticides, and discharge of industries) [7-9]

As a metalloid arsenic exist in four states of oxidation: As (0), As<sup>3-</sup>, As(III), As(V). As (III), As(V) are the most dominate states [10, 11]. Since As(III), As(V) are the most prevalent forms of arsenic found in water and pose serious health risks to people they are of great interest from research perspective [12, 13]. However, managing natural sources of arsenic is more difficult and depends upon the mitigation technology, and stringent monitoring of prevention measures. Preventing arsenic water contamination from manmade activities requires a solid water management plan as well as actions from resident authorities [14, 15]. A class 1 carcinogen (cause cancer) is arsenic, and human beings' contamination can occur through consumption of polluted water either food grownup in contaminated soil [16].

The World Health Organization (WHO) considers arsenic first on the base of priority problem among the noxious substances, because it is one of the most poisonous, and cancer causing chemical compounds [17] . Water contamination has become one of the environmental global issue due to high toxicity of heavy metals specially arsenic (Smedley and Kinniburgh , 2002. In view of adverse effect of arsenic, various techniques such as membrane filtration, ion exchange, biological treatment and adsorption have been exploited for removal of arsenic from wastewater and drinking water. One of the extensively used technique is the adsorption , due to its simple easily operation cost effectiveness and high efficiency. Different adsorbents have been used for removal of arsenic [16]. Currently, bio-based adsorbents (charcoal, rice husk and Biosorbent activated carbon) have been developed and used for removal of heavy

metals from industrial water discharge. The use of biosorbents depends upon the surface morphologies, ease of operation, cost effectiveness and environmental sustainability consideration. Biosorbent activated carbon is one of the best biosorbents for the removal of arsenic due to ease in operation, large surface area, low cost and environmentally friendly nature. Since the biosorbent is made from waste biomass that will reduce the amount of waste biomass in the environment and will be used for Arsenic pollution reduction. Using waste material is a step towards sustainability [18, 19].

## 2. Process Description

Biosorption is a physiochemical process which involves the binding of metal ions to the surface of a biosorbents. In current years, biosorption is regarded as an effective as well as environmentally acceptable alternative method for the removal of heavy metals (nickel , chromium , lead and arsenic etc.) from wastewater effluent produced by various industries [20]. Ion-exchange, biodegradation, solvent extraction, precipitation, oxidation, adsorption coagulation, absorption , flocculation, filtration, membrane technology, irradiation, reverse osmosis, electrodialysis, as well as ozonation, distillation are examples of commercial systems for removing contaminants which are based on thermal, biotic, chemical as well as physical features [21]. The biosorption approach has many advantages over other conventional methods for removing heavy metals, including cost-effectiveness, good metal selectivity, ease of regeneration, metal recovery, as well as most importantly, effectiveness [11].

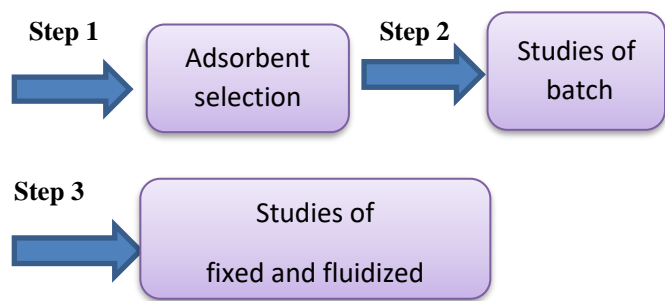
Waste of agriculture as well as derivatives of plants have both been widely exploited as promising biosorbents to remove metals and metalloids [13]. There are some carbon-based biosorbents (zeolites, rice husk, and Biosorbent activated carbon) which are extensively used as an adsorbents. Their cell wall is made up of cellulose, which is primarily poly saccharides, proteins, hemicellulose, and lipids [12]. Potential adsorbents typically have porous gaps where their area of surface as well as polarity typically affect the biosorption process [13]. Because their operational functional groups are fixed inside the lignin as well as hemicellulose, raw biomasses are frequently not prepared to serve as biosorbents. For a few metal ions, rice husk can be thought of as a good adsorbent. Changing the rice husk enhanced rice husk adsorption capacity. But its adsorption capacity is small for arsenic and requires special treatments for regeneration techniques [16]. The use of biosorbent activated carbon to treat water was

first documented in the United States in 1930 [17]. The unprocessed form of graphite known as “biosorbent activated carbon” has highly porous structure that can range in size from tiny molecule pores to noticeable fissures as well as crevices [16]. Coconut shells, wood char, lignin, petroleum coke, bone char, peat, sawdust, carbon black, sugar, peach pits, fish, waste fertilizer, waste rubber tyre, etc. have all been used to manufacture active carbons. The most often used materials are wood (1,30,000 tonnes per year), coal (100,000 tonnes annually), lignite (50,000 tonnes annually), coconut shell (35,000 tonnes annually), as well as peat (35,000 tonnes annually) [18]. The generation as well as characterization of biosorbent activated carbon from various carbon sources were examined by Allen as well as Whitten in 1998. The recent assessment of charcoal productions of science as well as technology.

## 3. Materials and Methodology

In the current study, three biosorbent ( rice husk , zeolite and biosorbent activated carbon) were used to analyze the results of arsenic removal from industrial waste water. The comparison of these were done for various operating parameters (contact time, agitation speed , biosorbent dosage , biosorbent concentration and p H for the removal of arsenic. The biosorbent was prepared in the laboratory. The activated carbon was purchased from sigma Aldrich. biosorbent activated carbon was blended with biomass grinded form rice husk. This biosorbent has enhanced the properties of adsorbent.

The samples were taken from the discharge of glass industry in Hattar industrial zone Wah Cantt. Two samples of five liters were collected. The experiment contains three parts. In step 1, selection of a suitable adsorbent for arsenic removal. In step 2 performing batch experimentations. And in step 3 performing of continuous experimentations. The aim of this research is to remove arsenic by using continuous operation column testing. The testing of batch performed to find out the optimum conditions as well as selection of best biosorbent to engross the arsenic ions from glass industry effluent. Actual batch testing inform us of the adsorption's capacity of the biosorbent activated carbon. The tests on column are additionally used to improve the technology as well as to form a process of continuous for the economical removal of arsenic from glass industry effluent. These experiments of column are of long time, as well as reflect the technology of adsorption to a table scale enhancement of technology. The three process phases scheme is shown below.



**Fig. 2.** Studies scheme

### 3.1. Chemicals And Equipment's

Good purity and analytical reagent chemicals during this research were used. The glassware were systematically washed away with acids such as chromic acid ( $\text{H}_2\text{CrO}_4$ ), sodium hydroxide ( $\text{NaOH}$ ), as well as, tap water, and purified water, in that direction, as well as dehydrated in an furnace preceding to use. Distilled water was used throughout the research. The experimentations of batch process were completed in 250 mL conical flasks at the uppermost of magnetic stirrer. Biosorbent activated carbon was used as an adsorbent in both batch as well as in fixed and fluidized adsorption columns. The solution of hydrochloric acid ( $\text{HCl}$ ) as well as sodium hydroxide ( $\text{NaOH}$ ) of 0.1 M individually were make ready for the adjustment of pH, in deionized liquid, by using a computerized pH meter. The arsenic concentrations in the water was determined with an Atomic Absorption Spectrophotometer (Hybrid generation) technique by using working of standard conditions.

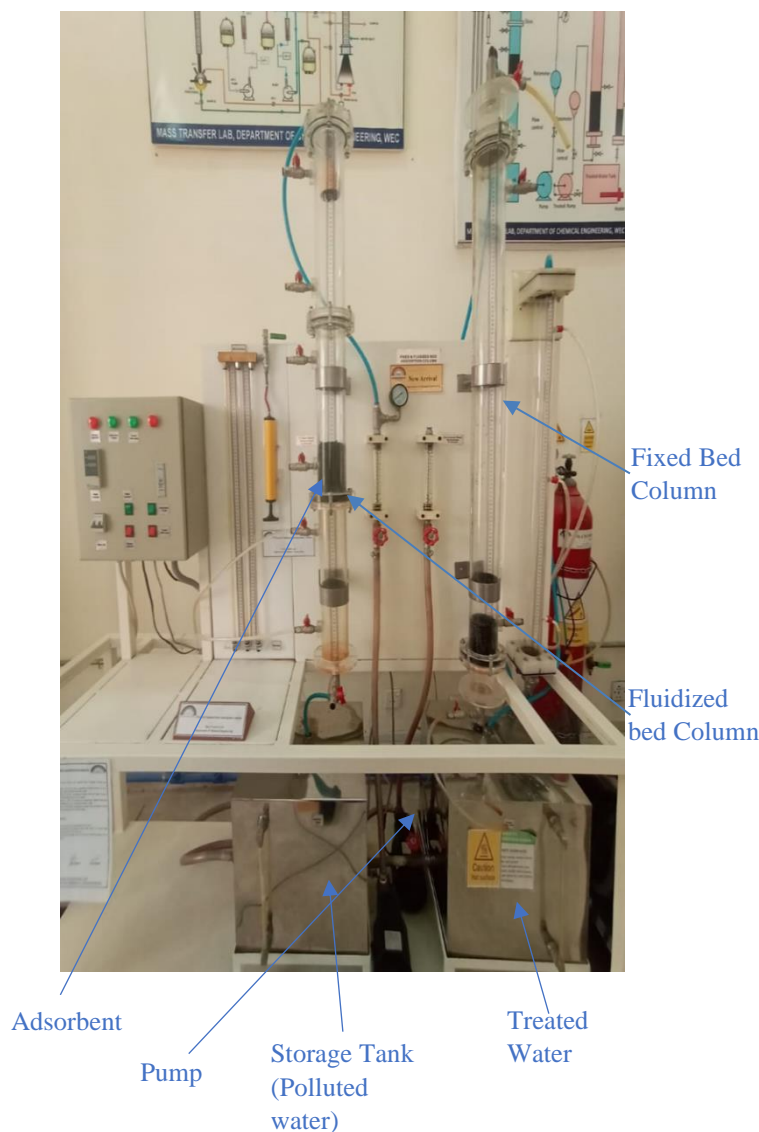
### 3.2. Preparation of As(III) Standard Solution

Sodium (meta) arsenite ( $\text{NaAsO}_2$ , Sigma Aldrich) was used for the source of As(III). For the experiments of adsorption, the stock solution of 100 g/L was made ready, by dissolving 0.1375 mg of sodium arsenite in one liter of distilled water. For As(III) solutions water was taken from RO plant. Working standard solution of 10  $\mu\text{g/L}$ , 15  $\mu\text{g}$  and 20 $\mu\text{g}$  was prepared by appropriate dilution of stock solution. Total six samples were prepared, in which the biosorbent dosage of Biosorbent activated carbon in each sample is added, increasing the quantity of biosorbent from 0.2 to 1.4 g, agitation speed (100-500 rpm), contact time (25-150 min). Then the samples are filtered through a filter paper (0.5 $\mu\text{m}$ ), and forwarded for the analysis of Atomic Absorption Spectrophotometer for the detection of As(III) removal.

### 3.3. Fixed and Fluidized Adsorption Experiments

After the detail batch experiments analysis, A novel literature study As (III) removal has focused the attention (industrialists) by using fixed and Fluidized bed. The most suitable conditions are obtained for removal of As(III) in industrial discharge. Tests on column are applicable to the next trial which give the high scale treatment process. Tests on column are well known like bed columns which are used as well as designed for the purposes of industries.

Fig. 3 depicts the Fixed and Fluidized bed adsorption column, with two pumps, solution tank, treated water tank, and flowmeter (rotameter), the inside of each column measures 150 cm in height as well as 6 cm in diameter. the portion which is lowered the section of adsorbent has sealed through a ring of rubber which keep the adsorbent up. In favor of experimentations on column which was performed by earlier researchers which was found that adsorbent within a column, at each portion of the pillar some pipes having small diameter are being adjusted, one of which is used for the inlet flow, which transferred the discharge to be examined within the pipe through a pump. Initially the fixed bed operation was conducted for the removal of arsenic and after that fluidized bed adsorption studies were evaluated in the current study. In both cases, the industrial discharge was initially stored in the feed tank and treated water was collected in the storage tank. The height of column was the main observing factor for the analyses of results. Counter contact provides the maximum contact for the removal of desired metal (i.e. Arsenic) in the fluidized operation.



**Fig. 3.** Fixed and Fluidized Bed Adsorption

## 4. Results and Discussion

### 4.1. Batch Operation

Various test has been performed to analyze the effect of specific parameters like pH , biosorbent dosage , contact time , agitation speed as well as biosorbent dosage to remove the arsenic from industrial effluents. The results of above test are given below.

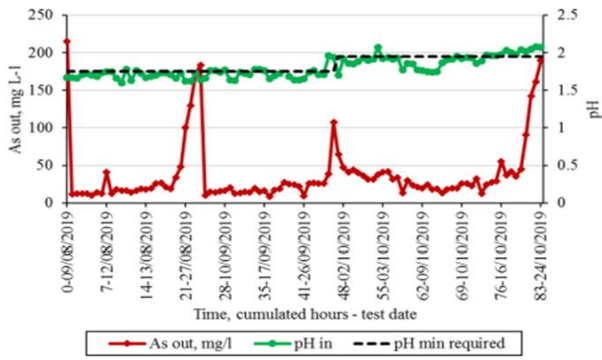
#### 4.1.1. The pH effects for arsenic removal

Fig. 4a shows the effect of pH on the removal of arsenic(III) in the batch operation. It shows the variation of pH from 2.9 - 11.9, It was observed that adsorption of As (III) ions slowly enhances as the early pH of the solution in which biosorbent activated carbon is raised up from 2.9 to 7.5 . But with solution having rice husk , when pH was increased from 2.9 to 11.9 the adsorption of arsenic followed increasing and then decreasing behavior. The maximum removal of arsenic observed

as 55 % for using rice husk. Similar behavior was observed for using zeolite in the solution. It has been observed that when pH was increased from 2.9 to 11.9 the adsorption of arsenic followed increasing and then decreasing behavior. The maximum removal efficiency of arsenic was found as 52 %. The optimum removal of arsenic was found to be 70 %, on pH 7.5 by using biosorbent activated carbon. Later, pH of (As) solution remained in equilibrium position at 7.5. This behaviour of arsenic removal shows the presence of biobased biosorbent peculiar behaviours for water treatment. At pH more than 7.5, the removal of arsenic is almost negligible. This is due to the fact of  $\text{OH}^-$  ion absorption, which decrease the removal process, as well as here after the process of change of adsorbent towards its  $\text{OH}^-$  form, and take part as a vital role leaving at the back of As (III) in the liquefied solution. This is because of the result of arsenic precipitation.

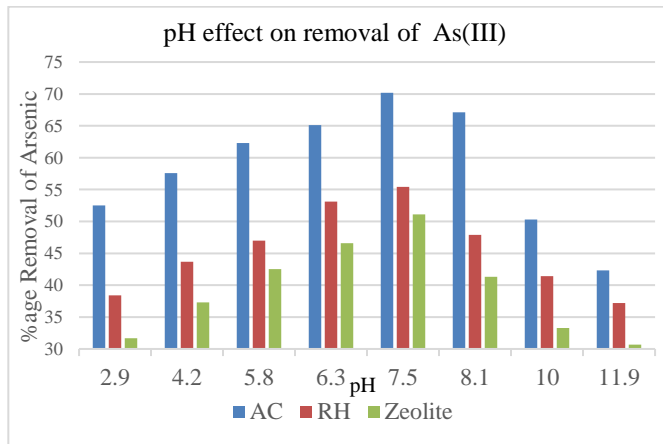
As the pH value increased from 2.9 to 7.5, step wise, the corresponding increase in removal of As (III) was observed. In fact, the driving force of As (III) removal at these acidic pH values is due to the electrostatic attraction between the arsenate anion and the positive charged existing on the surface of the adsorbent [Xiong et al, 2017]. Therefore, the optimized As(III) removal was observed at higher pH value of 7.5. It was maximum at pH 7.5. and a decrease in As (III) removal beyond the 7.5 pH value was also examined. Similar, decrease in adsorption was reported when the pH of the solution increased from 8 to 11 [Meez et al. 2021]. Through the series of experimentation, the authors interpret that the increase in pH cause the increase in the negative charges on the surface, as a result of this the repulsion of arsenate ions from the surface of the adsorbent is promoted and the decreased in adsorption with rising pH [Liu et al, 2010]. It was examined that when the value of pH was <7.5, the arsenic removal percentage drop off was noticed. Although the ranges of pH values beneath 7.5 - 12, the percentage removal of arsenic was also decreased.





**Fig. 4.** Effect of pH for the removal of arsenic [ Stoyanova, Verka, et al].

Above Fig. 4 shows the removal of arsenic by using various values of pH into system and minimum required for the solution. The effect of pH for the removal of arsenic with respect to time. It shows that with increase of pH, the removal of arsenic goes on increase but after reaching 2 p H it achieves equilibrium value and does not increase the adsorption of arsenic solution. The previous work shows below 50% removal of arsenic from waste water.

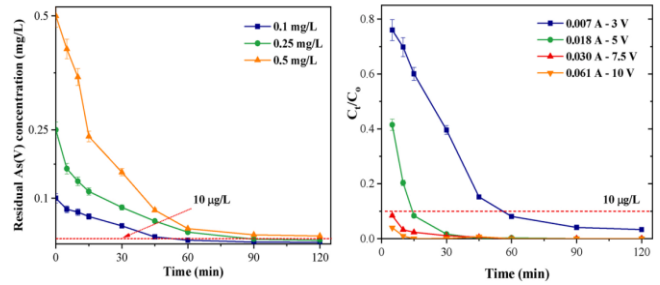


**Fig. 4a.** Effect of pH on removal of arsenic (III)

#### 4.1.2. Effect of Biosorbent dosage

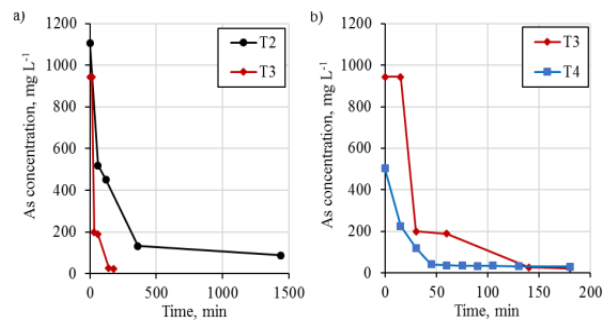
The Fig.4b. depicts the removal of arsenic with the variation of biosorbent dosage at constant speed. The biosorbent dosage was changed from 0.2 gm –1.4 gm. Furthermore, the consequences of dosage were being completed via the value of pH 7.5, which is the maximum value of pH. From the Fig. 4b. it was observed that initially removal of arsenic is strongly based on biosorbent dosage. It was noticed that the removal of arsenic improved with the increase in dosage, reaching an optimum value of on 1.2 gm of biosorbent . It was observed that on 1.2 gm of biosorbent activated carbon , the removal of arsenic was optimum (70%) in comparison to others rice husk (50 %) and zeolite (30%) which indicates the maximum removal efficiency

due to bio based nature and small granular size of the biosorbent activated carbon.

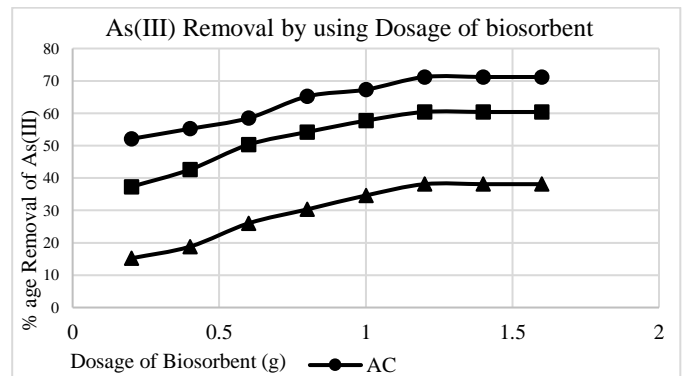


**Fig. 5.** The effect of (a) As(V) initial concentration at 3 V and (b) voltage on As(V) removal [Nguyen, Thi Thuc Quyen, et al.]

Previous literature as shown above represents the effect of voltage on the removal of arsenic with the variation of time. It shows that as the time goes on increase from 30 minutes to 120 minutes the removal of arsenic goes on decrease and ultimately it becomes constant.



**Fig. 6.** Effect of seeding on As removal kinetics; b) Kinetics of As removal with different initial concentrations [ Stoyanova, Verka, et al. ]

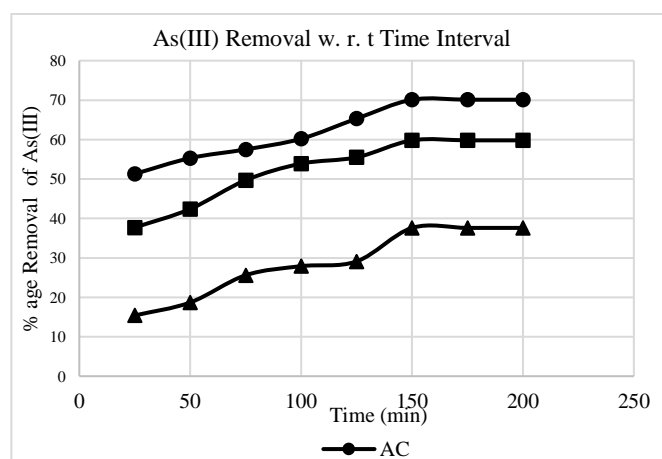


**Fig. 4b.** Effect of biosorbent dosage on arsenic removal [19, 20].

#### 4.1.3. Contact time effect for the removal of arsenic

The results of contact time as well as agitation speed on the arsenic adsorption by biosorbent AC is shown in the Fig. 4c. individually. The Fig. 4c designates the effect of biosorbent activated carbon for arsenic removal from

process industry effluent with various time of contact. The time which has been selected in this experiment was 25, 50, 75, 100, 125, 150, as well as 175 minutes . It was observed that biosorbent AC works best at optimum operating parameters including time of contact (150 minutes) , agitation speed ( 100 rpm), biosorbent dosage ( 1.2 gm), p H (7.5) industrial discharge water by using fixed and fluidized bed operation . The quantity of As (III) adsorption precipitously increased with increasing time of contact in the early points (25 ,50 ,100, 125, 150 minutes ), and it reaches to equilibrium value after 150 minutes till 200 minutes based on the current set of conditions . Effect of contact time on the biosorption of As (III). The results shows that arsenic removal was maximum at 150 minutes (70 %) for biosorbent AC as compared to other rice husk (60%) and zeolite (38%). similar to this research has been given by a number of researches [Ahmad et al., 2022; Kim et al., 2010].

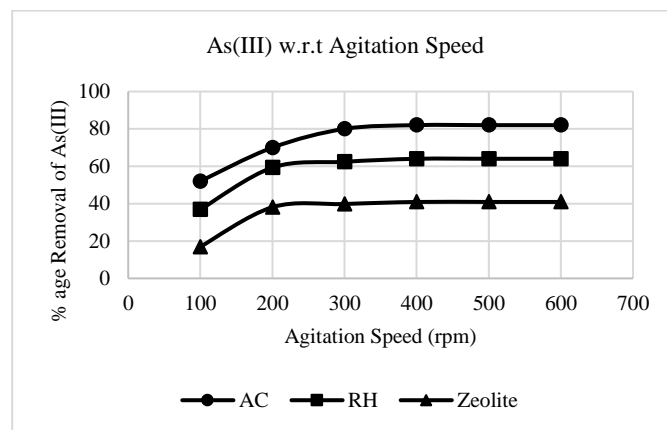


**Fig. 4c.** Effect of contact time of biosorbent on the removal of arsenic {Ahmad, 2022, Activated biochar is an effective technique for arsenic removal from contaminated drinking water in Pakistan}

#### 4.1.4. Agitation speed effect for the removal of arsenic

Fig. 4d represents the effect of agitation speed on the removal of arsenic. It shows that agitation speed too disturbs the process of adsorption, which has been cleared by Fig.4d. By increasing the speed of shaking, the As (III) adsorption increased as well as reached to optimum value at 400 rpm. In spite of the fact that the former experimentations had been performed at 400 rpm, the step verified that it has an optimal agitation speed to promise the obtainability for arsenic (As) take up on the sites of all surface. By slowing the speed of agitation AC rather than of scattering in solution concentrate which suppressed numerous active sites of adsorbent beneath the upper layers. Initially removal of arsenic increases but after reaching it attained the

equilibrium and this behaviour remained constant till 600 rpm for the current operating conditions.

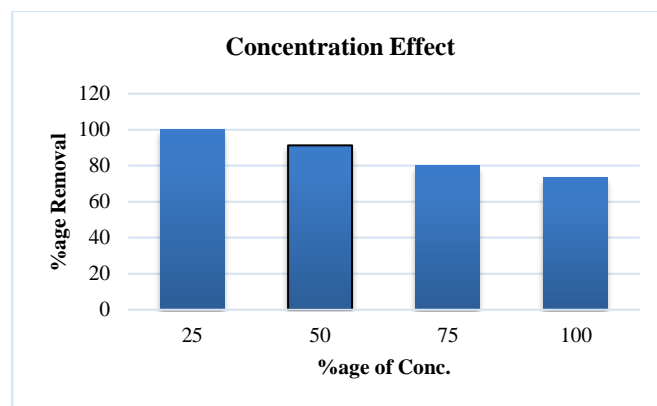


**Fig. 4d.** Effect of Speed of Agitation on the removal of arsenic

#### 4.1.4. The Biosorbent concentration effects for the removal of arsenic

The Fig.4e. shows the results of biosorbent activated carbon for the removal of arsenic from chemical industry effluents by means of concentration dilution. Nominated dilution of concentration for this research work were (0, 25, 50, 75 as well as 100 %). Furthermore, the results of concentration of dilution was accomplished by means of optimum (pH-7.5) dosage of bio-sorbent 1.2 g, speed of agitation 400 rpm, as well as time of contact 150 min.

From Fig. 4e it can be noted that on higher concentration, the removal of arsenic by using biosorbent activated carbon was low also if it was slowly decreased by enhancing the ratio of dilution. Thus, on greater dilution the ions of arsenic were expanding easily, also by using biosorbent activated carbon. It was adsorbed in the results higher removal of adsorption percent. The removal of arsenic was enhanced by enhancing the concentration dilution.



**Fig.4e.** Effect of biosorbent concentration for arsenic removal

## 4.2. Fixed and Fluidized Operation

The efficiency of arsenic removal was enhanced in continuous operation was 75% by treating huge amount of industrial waste water with large throughput. The various results has been shown to analyze the continuous behaviour of adsorption column.

### 4.2.1. Kinetics of Arsenic adsorption

It was noted that as the time passes, the As(III) uptake enhances. Though the As(III) adsorption was quick in the initial 150 min, after that the rate become slow down when the equilibrium approached. At the initial concentration of arsenite 25 ppm, 70 % of As(III) elimination was achieved, correspondingly, in the first 150 min at pH,7.5.

### 4.2.2. Langmuir isotherm model

Langmuir isotherm model shows the adsorption of solute on the solid surface which shows the mono layer adsorption. The plot of equilibrium concentration ( $C_e$ ) to maximum given concentration ( $C_e/q_t$ ) is given in Fig. 4f. This shows the linear which is in accordance to the Langmuir isotherm model. Biosorption dynamics portrays the As(III) uptake rate, which governs the residence time of Arsenic uptake at the solid-solution interface. The kinetic of arsenic biosorption is established, by investigating adsorption with the help of pseudo first-order and pseudo second-order, kinetic models. The agreement between experimental data and the model predicted values was expressed by the correlation coefficients ( $R^2$ ) and the high ( $R^2$ ) value indicates that the model successfully explains the kinetics of arsenic adsorption.

The pseudo first-order equation is :

$$\frac{dq}{dt} = k_1 (q_e - q_t) \quad (1)$$

After integration and applying boundary conditions  $t = 0$  to  $t = t$  and  $q_t = 0$  to  $q_t = q_t$ , the integrated form of pseudo first order equation becomes

$$\log_e(q_e - q_t) = \log_e(q_e) - \frac{k_i}{2.303} t \quad (2)$$

A linear relationship is established by plotting  $\log_e(q_e - q_t)$  vs.  $t$  should give a linear

M relationship from which  $k_i$  and  $q_e$  can be determined from the slope and intercept of the respectively. Fig. 4f gives the pseudo-first order model

After integration and applying boundary conditions  $t = 0$  to  $t = t$  and  $q_t = 0$  to  $q_t = q_t$ , the integrated form of pseudo first order equation becomes

The pseudo second-order adsorption kinetic rate equation is expressed as shown

$$\frac{dq}{dt} = k_2 (q_e - q_t)^2 \quad (3)$$

integrating (iii) and rearrangement gives (iii) and let  $h$  ( $\text{mg/g}\cdot\text{h}$ ) is  $h = k_2(q_e)^2$

$$\left(\frac{t}{q_t}\right) = \frac{1}{h} + \frac{1}{q_e} t \quad (4)$$

The plot of  $(t/q_t)$  and  $t$  of Eq. 3 established a linear relationship from which 'q<sub>e</sub>' and 'k<sub>2</sub>' were determined from the slope and intercept of the plot respectively.

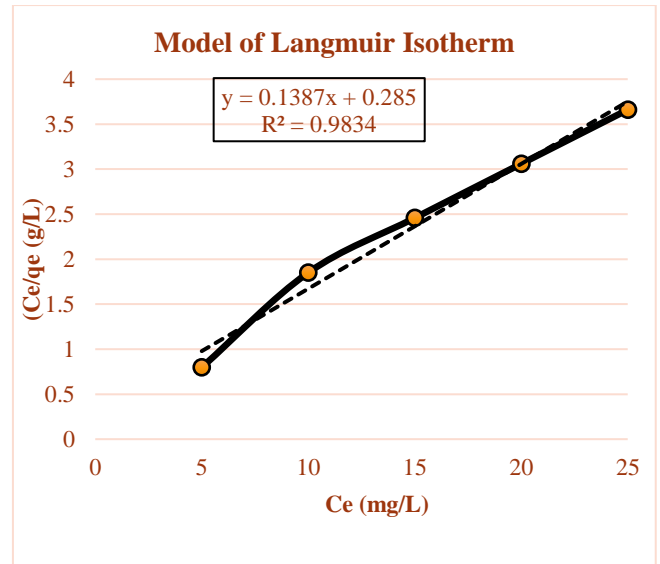


Fig. 4f. Langmuir isotherm model

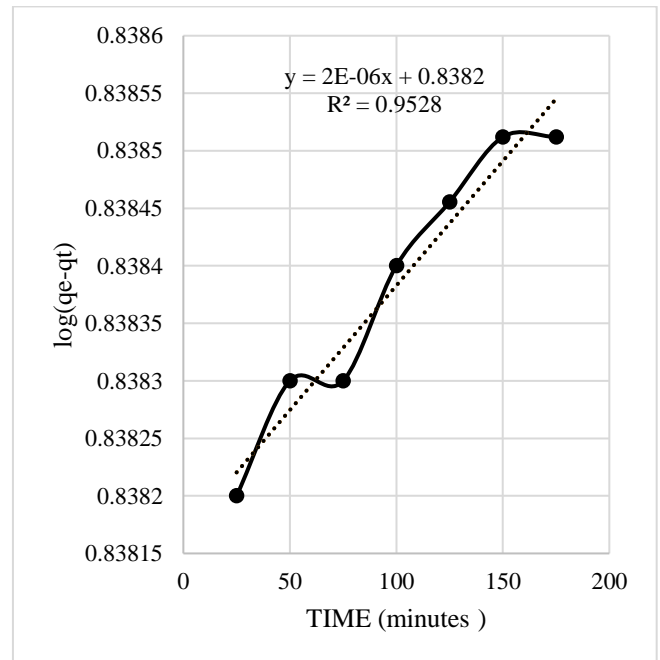
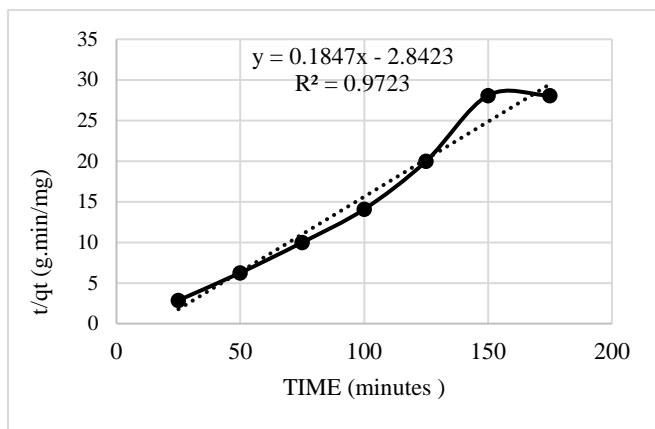
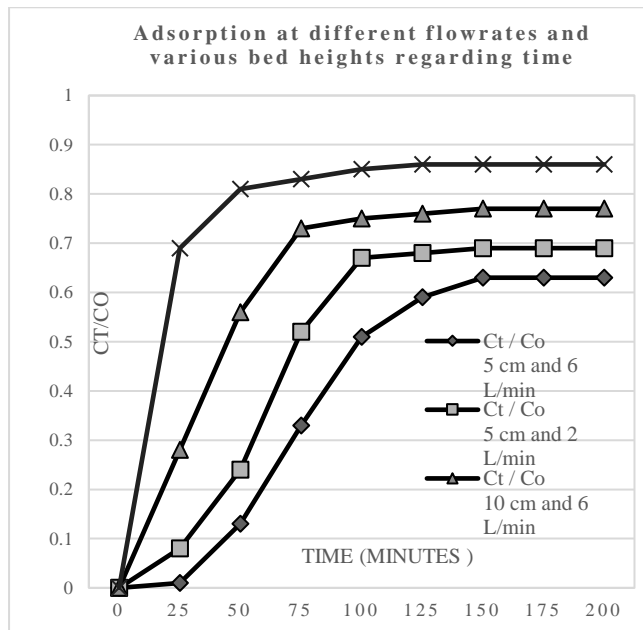


Fig.4g. Pseudo-first-order kinetic model





**Fig.4h.** Pseudo-second-order kinetic model

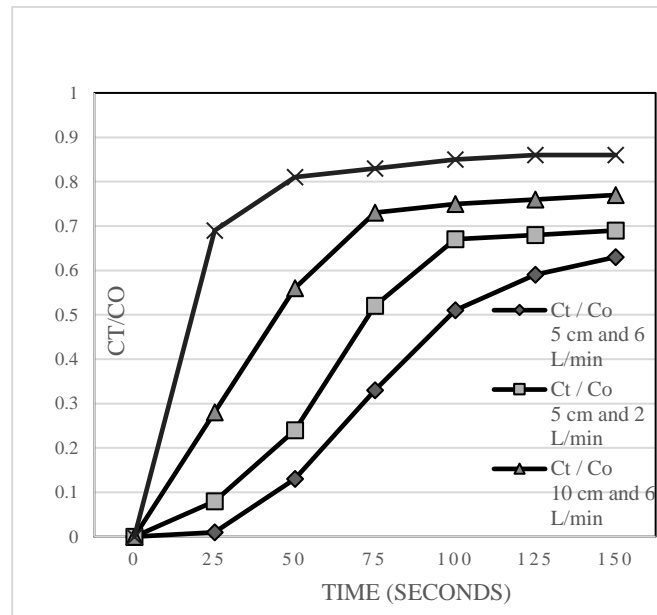


**Fig. 4i.** Effect of adsorption at different flow rates on fluidized behaviour

The adsorption mechanism of fluids assimilates adsorbent near by the inlet of the solution is first of all saturated, as well as the maximum limit of adsorption is first accomplished. For the reason that, the time goes the movement of saturation region down to the outlet mattress. At this point despite the fact that the component of saturation reaches to the pore of the awareness of inlet is nearly undistinguishable to the awareness at the pore. The curve required among the preliminary understanding, as well as pass by time, either the quantity of treated liquid is well-known as the curve of breakthrough.

The Fig. 4i. in fluidized adsorption bed, the biosorbent activated carbon's performance parameters are defined by means of breakthrough curves, in which results are plotted between  $C_e/C_0$  ratio, as well as time [16]. The effect of rate of flow on the adsorption of As (III) at biosorbent activated carbon is that the initial As (III) concentration (25 mg / L), the As (III) of the pH- 2

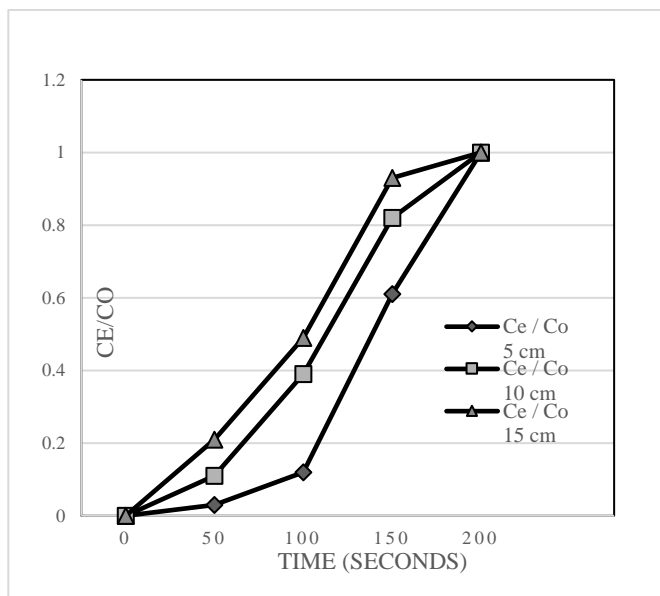
column, as well as the height of the bed, (15 cm) are kept constant. It is held. It shows a plot of wastewater having, As (III) concentration over time at various rates of flow.



**Fig. 4j.** Effect of time on the concentration ratio (CT/CO) at various flow rates

Fig. 4j shows the graph between total concentration to maximum concentration  $CT/CO$  and time. This shows that the removal of arsenic at various height of fluidized bed column. There are two main behaviours of the results. The  $C_t/C_0$  ratio was obtained for constant height and different flow rate and constant flow rate to different height. When the bed height was 5cm, with increase in the flow rate from 2 L to 6 L the ratio was decreased from 0.7 to 0.61 but with increase in height from 5cm to 10 cm at constant flow rate 2L/min, then the ratio of  $C_t/C_0$  will be increase from 0.69 to 0.80. similarly, for constant height 10cm and various flow rate 2L/mint to 6L /mint the ratio goes on decrease from 0.7 to 0.8.

With a boom in flow wages from 1 – 3 L / min, the time necessary to obtain a step forward (t) descent from 75 – 20 minutes. Furthermore, for the reason that the rate of float extended, the clearance of As (III) reduced from 86 – 20 %. Which is most in the whole likelihood, for the reason that of reduced time consumed in contact with biosorbent activated carbon, via the industrial wastewater. At the end, a decrease rate of waft exists for sufficient touch time between As (III), as well as the adsorbent to obtain equilibrium, as well as the ultimate smooth continuous movement charge for the column become one liter per minute, that is the bottom goes with the rate of flow feasible in the column.



**Fig. 4k.** Effect of bed height and time on equilibrium concentration ratio (CE/CT)

**Table 1**

Comparison of efficiency , selectivity and effectiveness

Serial No.	Previous study			Current study			
	Efficiency	effectiveness	selectivity	efficiency	effectiveness	selectivity	
1	25%	[Meez, Elie, et al.]	Low	High	75 %	High	High
2	35%	[Mondal, Monoj Kumar, and Ravi Garg]	high	Low	80 %	High	High

## 5. Conclusion and Recommendation

By comparing the process of batch adsorption as well as some researchers have highlighted the prospectus of modifying biosorbent activated carbon with metal to enhance the removal of arsenic. Some gaps were found while going through the literature, therefore, further work could be achieved by using different blend of modified biosorbent for the removal of arsenic (III) from industrial discharge. The effect of pressure drop could also be obtained with the change in flowrate of untreated waste water. The feasibility analysis could also be carried out to achieve the techno-economic analysis on the industrial discharge. The other forms of arsenic like As (V) removal efficiency could also be done by using the fixed and fluidized adsorption bed column . The other industrial discharge having maximum arsenic concentration could also be studies in the future that would be benefit to the community. This research work

The forward step factor important to depend upon the mattress's peak. When the height of the bed turns into low such as (5 cm), an early curve of leap forward was revealed. For the reason that the height of the mattress prolonged from 5-15 cm, the "t" cost raised up from fifty to hundred minutes. Enhanced beds behind schedule of breakthroughs as well as the performance of progressed column.

The Fig. 4k shows that as a result, the impact of As (III) initial concentration, at the overall performance of forward step is enhanced, as well as the consequences are given b continuous mode adsorption processes, the highest efficiency obtained on the batch process of adsorption is (>82%) which is very greater from that of continuous mode adsorption processes. But to processes large amount of waste water continuous mode adsorption was necessary. Fixed and Fluidized adsorption beds have removed 70%.

indicated that arsenic could be removed by an low cost bio- waste product biosorbent activated carbon with the equilibrium time of 1.15 hours. A pseudo second-order kinetic model was statistically significant at the 95% confidence level.

## 6. References

- [1] E. Meez, A. K. Tolkou, D. A. Giannakoudakis, I. A. Katsoyiannis, and G. Z. Kyzas, "Activated carbons for arsenic removal from natural waters and wastewaters: A Review," *Water*, vol. 13, no. 21, p. 2982, 2021.
- [2] Y. Xiong et al., "Arsenic transformation and adsorption by iron hydroxide/manganese dioxide doped straw activated carbon," *Applied Surface Science*, vol. 416, pp. 618-627, 2017.

- [3] Z. Liu, F.-S. Zhang, and R. Sasai, "Arsenate removal from water using Fe<sub>3</sub>O<sub>4</sub>-loaded activated carbon prepared from waste biomass," *Chemical Engineering Journal*, vol. 160, no. 1, pp. 57-62, 2010.
- [4] Villaescusa and J.-C. Bollinger, "Arsenic in drinking water: sources, occurrence and health effects (a review)," *Reviews in Environmental Science and Bio/Technology*, vol. 7, pp. 307-323, 2008.
- [5] P. L. Smedley and D. G. Kinniburgh, "A review of the source, behaviour and distribution of arsenic in natural waters," *Applied geochemistry*, vol. 17, no. 5, pp. 517-568, 2002.
- [6] G. Ungureanu, S. Santos, R. Boaventura, and C. Botelho, "Arsenic and antimony in water and wastewater: Overview of removal techniques with special reference to latest advances in adsorption," *Journal of environmental management*, vol. 151, pp. 326-342, 2015.
- [7] P. Van Straaten, "Mercury contamination associated with small-scale gold mining in Tanzania and Zimbabwe," *Science of the Total Environment*, vol. 259, no. 1-3, pp. 105-113, 2000.
- [8] D. Chakraborti et al., "Groundwater arsenic contamination and its health effects in the Ganga-Meghna-Brahmaputra plain," *Journal of environmental monitoring: JEM*, vol. 6, no. 6, pp. 74N-83N, 2004.
- [9] V. Campos, "Arsenic in groundwater affected by phosphate fertilizers at Sao Paulo, Brazil," *Environmental Geology*, vol. 42, pp. 83-87, 2002.
- [10] D. Bohrer, E. Becker, P. C. Nascimento, V. Mörschbacher, L. M. De Carvalho, and M. da Silva Marques, "Arsenic release from glass containers by action of intravenous nutrition formulation constituents," *International journal of pharmaceuticals*, vol. 315, no. 1-2, pp. 24-29, 2006.
- [11] N. Yogarajah and S. S. Tsai, "Detection of trace arsenic in drinking water: challenges and opportunities for microfluidics," *Environmental Science: Water Research and Technology*, vol. 1, no. 4, pp. 426-447, 2015.
- [12] J. S. Wang and C. M. Wai, "Arsenic in drinking water—a global environmental problem," *Journal of Chemical Education*, vol. 81, no. 2, p. 207, 2004.
- [13] Z. Li, Q. Yang, Y. Yang, C. Xie, and H. Ma, "Hydrogeochemical controls on arsenic contamination potential and health threat in an intensive agricultural area, northern China," *Environmental Pollution*, vol. 256, p. 113455, 2020.
- [14] A. M. Pintor, B. R. Vieira, S. C. Santos, R. A. Boaventura, and C. M. Botelho, "Arsenate and arsenite adsorption onto iron-coated cork granulates," *Science of the total environment*, vol. 642, pp. 1075-1089, 2018.
- [15] S.-L. Lo, H.-T. Jeng, and C.-H. Lai, "Characteristics and adsorption properties of iron-coated sand," *Water science and technology*, vol. 35, no. 7, pp. 63-70, 1997.
- [16] L. Hao, M. Liu, N. Wang, and G. Li, "A critical review on arsenic removal from water using iron-based adsorbents," *RSC advances*, vol. 8, no. 69, pp. 39545-39560, 2018.
- [17] T. S. Singh and K. Pant, "Equilibrium, kinetics and thermodynamic studies for adsorption of As (III) on activated alumina," *Separation and purification technology*, vol. 36, no. 2, pp. 139-147, 2004.
- [18] M. Jang, W. Chen, and F. S. Cannon, "Preloading hydrous ferric oxide into granular activated carbon for arsenic removal," *Environmental science and technology*, vol. 42, no. 9, pp. 3369-3374, 2008.
- [19] E. Bazrafshan, H. Faridi, F. K. Mostafapour, and A. H. Mahvi, "Removal of arsenic from aqueous environments using *Moringa peregrina* seed extract as a natural coagulant," *Asian Journal of Chemistry*, vol. 25, no. 7, pp. 3557-3561, 2013.
- [20] F. Kord Mostafapour, E. Bazrafshan, M. Farzadkia, and S. Amini, "Arsenic removal from aqueous solutions by *Salvadora persica* stem ash," *Journal of Chemistry*, vol. 2013, 2013.
- [21] Ahmad et al., "Activated biochar is an effective technique for arsenic removal from contaminated drinking water in Pakistan," *Sustainability*, vol. 14, no. 21, p. 14523, 2022.