Research article

Removal of arsenic from semiarid area groundwater using a biosorbent from watermelon peel waste

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A B S T R A C T

Groundwater is one of the most important reservoirs in semi-arid and arid zones of the world, particularly in Mexico. The aims of this work were to produce a biosorbent from watermelon peel waste and a biosorbent with citric acid treatment and to evaluate both biosorbents with different concentrations of arsenic in groundwater. The biosorbents were produced with watermelon peel residues, which were observed by SEM microscopy to evaluate their physical morphology. Its removal potential was tested at concentrations of 0, 1, 13, 22, and 65 µg/L of arsenic, and both adsorption capacity and removal percentage were analyzed by final measurement obtained by atomic absorption spectrometry. The pH was measured throughout the experimentation maintaining ranges between 5.5 and 7.5. The biosorbent without treatment presented clearer and more compact flakes. At the microscopic level, the biosorbent without treatment presented pores with a more circular shape, and the biosorbent with treatment was more polygonal, similar to a honeycomb. The highest removal percentage was 99.99%, for both treatments at 4 h. The biosorbent without treatment at 4 h with arsenic concentrations of 65 µg/L presented the highest adsorption capacity (2.42 µg/g). It is concluded that watermelon peel biosorbent is a material that has the potential to remove arsenic from groundwater. This type of biosorbent is effective to remove arsenic and could be used in the field, however, it still needs to be optimized to convert it into a material completely suitable for large-scale use.

1. Introduction

Groundwater is the largest source of supply in arid regions, for different uses (irrigation, industrial, urban public, and livestock). The extraction of large volumes has led to an increase in demand for fresh water. An excess in the extraction produces negative effects

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on the environment. Such as the detachment of rocks and their dissolution in aquifers, releasing compounds into the environment that are not regularly present [1].

The arsenic presence in the environment either through geogenic or anthropogenic pathways, has become a relevant problem throughout the world. The World Health Organization (WHO) recommended a safe limit of 10 μg/L of this element [2]. However, every country has its specific regulations with different limit values.

This geogenic drinking water problem threatens millions of people around the world [3–6]. The main continent affected is Asia with more than 120 million people exposed. Followed by America and Africa, where respectively more than 48 and 24 million inhabitants are at risk [7–9]. Drinking contaminated water is responsible for 80% of all illnesses and deaths in developing countries [10].

For this reason, the challenge of understanding the mobility of arsenic in groundwater, delimiting the dangerous areas of drinking water extraction, geochemical analysis, and, above all, the creation of technologies for the removal of this element is huge. Over time, effective methods have been created for the removal of As, some of the most common are precipitation, coagulation (use of salts, such as iron and aluminum), osmosis, adsorption, and absorption [11–19]. Unfortunately, although these methods are successful in removing As from aqueous media, their high energy, chemical, and operational costs, along with the creation of toxic sludge, are a major obstacle to drinking water treatment [16,20–24].

One of the most used techniques is adsorption, known for more than a century, which has been maintained until today. It is efficient, simple, and produces minimal toxic sludge [13,25–29]. For this reason, science has the challenge to improve the adsorbent materials and the quality of the water supplied [15,22,24,29–34].

Biosorption is a technique derived from adsorption. Biosorption has been considered a promising As removal method from groundwater and for other elements [17,27,35–43]. In contrast to other conventional procedures, like oxidation, filtration, reverse osmosis, electrokinetics, ion exchange, coagulation, flocculation, or phytoremediation [16,18,19,22,25,36,44–48]. This method is preferred because it, has the advantages of low cost, high efficiency, negligible sludge production, the chance of recovery of As, and regeneration [49].

Multiple organic waste materials have been investigated as potential removers of several pollutants [12,17,20,25,35,36,39,42,43, 50–54], one of the most promising is the watermelon peel. This material is natural, cheaper, abundant, and a huge source of non-essential amino acid, citrulline along with carotenoids, cellulose, pectin, and proteins. These compounds have several organic functional groups like –COOH, –OH, –NH$_2$, which can easily bind and replace As [49–51,55]. Watermelon peel can be an ideal material to apply as a biosorbent in different real scenarios [49,56]. A few investigations have proved that watermelon peel is an effective material for the remediation of arsenic in groundwater. Shakoor et al. [49] obtained a xanthated watermelon peel with a dose of adsorption of 1 g/L, on another hand a remotion with percentages of 98–99%, and the research of Lochan Aryal et al., 2022 [57], with La (III) loaded carboxyl functionalized watermelon rind who obtained a maximum biosorption capacity of 62.50 mg/however, more research is still needed to fully characterize the watermelon rind, as it is required to test it under several conditions, to implement it in a final removal system that can be used in small communities and home.

This work contributes to the SDGs (The Sustainable Development Goals) with goals: three (health and well-being), six (clean water and sanitation), eleven (sustainable cities and communities), and fourteen (life below water) [58].

The aims of this work were: a) to produce a biosorbent from watermelon peel waste; b) to produce a biosorbent with a citric acid treatment; c) and evaluate both biosorbents with different concentrations of arsenic in groundwater.

2. Materials and methods

2.1. Biosorbent production

The biosorbent was obtained from watermelon peel waste. The organic residues were provided by a local fruit stall. These were collected for eight consecutive months. The shells were daily washed and rinsed with distilled water to proceed with the biosorbent production process.

According to several studies, the watermelon shells received different treatments before being used as adsorbents. A treated method was used according to different investigations [49–51,56,59]. The treatment consists of letting the watermelon shells dry in the sun for 72 h, then they are deposited in the oven at 65 °C for 72 h. Once they were completely dry, they were ground and sieved to different particle sizes. We used the one obtained with mesh #24 corresponding to 0.710 mm, getting the powder that constitutes the Natural Biosorbent (NB), this receives a subsequent treatment that is explained below and its product was called Biosorbent with treatment (TB).

The morphological structure of both biosorbents was analyzed by SEM (Scanning Electron Microscopy) at the Terahertz National Science and Technology Laboratory (LANCYTT) of the Autonomous University of San Luis Potosí (UASLP). A base covered entirely with carbon tape was prepared, this allows the biosorbent to be fixed on the surface. The biosorbent sample was placed in this area and proceeded to metalize in Sputtering. A layer of 30 nm gold was deposited for final analysis under the microscope. The sections were analyzed in their central portion with a 448x zoom.

2.2. Treated biosorbent (TB)

The NB was treated with citric acid (C$_6$H$_8$O$_7$, purity 99.5%, Meyer ®), which is a chelating substance because its low pH reacts with metal ions producing a metal chelate that reacts to form a ring, adjusting the structure of the compounds and incorporating functional organic groups. The process was elaborated taking as reference some previous studies with biosorbents [17,30,49,51,56,59]. A portion

of 50 g was mixed with 600 ml of 0.5 M citric acid for 1 h at room temperature. Subsequently, the solution was placed in the oven at 50 °C for 24 h, after which time the temperature was increased to 120 °C and 90 min waited. The biosorbent was allowed to cool, and then four washes with deionized water were performed. Finally, this solution was left to dry in the oven at 50 °C for 72 h, obtaining the treated biosorbent (TB).

2.3. Experimental design

A series of adsorption experiments were carried out to determine the efficiency of the biosorbent for the NB and the TB in triplicate.

Five tubes were placed, which contained 0.5 g of biosorbent and 20 ml of groundwater from the Calera aquifer, from different wells and with different concentrations (0, 1, 13, 22, and 65 μg/L). These samples were obtained from groundwater and analyzed. The type of this groundwater is calcium, sodium, and/or magnesium bicarbonated. This kind of water is a result of the reaction between sodium chloride and silica that arise from the earth's core in the presence of water, initially forming sodium silicate and then sodium bicarbonate from water. Arsenic concentrations in groundwater were chosen since they are the most frequently found in real samples obtained from the study site.

The tubes with the different solutions and the biosorbent were stirred for two and 4 h, afterward, they were separated by centrifugation at 4000 rpm for 10 min, filtered, and the remaining liquid was recovered to proceed to the final determination of arsenic by spectrophotometry atomic absorption (section 2.4).

With these experiments, 5 tubes were obtained for each concentration in triplicate: NB-2 (natural biosorbent with 2 h of reaction), NB-4 (natural biosorbent with 4 h of reaction), TB-2 (biosorbent treated with 2 h of reaction, and TB-4 (biosorbent treated with 4 h of reaction).

The completely randomized experimental model was used (Equation (1)).

$$Y_{ij} = \mu + \mathbf{T}_i + e_{ij} \tag{1}$$

where Y_{ij} represents the response variable (adsorbent), μ mean value, $\mathbf{T}_i$ treatment, e the error, i th treatment, and j repetitions [60].

Analysis of variance was performed to determine the effect of the biosorbent on arsenic removal, using the Fisher distribution.

2.4. Arsenic determination

The analytical determinations were performed at the Hydrogeochemistry Laboratory of the Autonomous University of Zacatecas with atomic absorption spectrophotometry (Thermo Scientific ICE AA 3300, Waltham, MA, USA) by hydride generation. Calibration for atomic absorption spectrophotometry was performed using an appropriate dilution standard. All determinations were made under the guidelines described in APHA-SMWW 2006 [61].

Arsenic determination was carried out following the standard (NMX-AA-051-SECFI) [62], which indicates the atomic absorption spectrophotometric method with hydride generation. The standard solutions were prepared with a standard of arsenic for atomic absorption spectroscopy (AA), a highly characterized and high-purity sample. All the experiments were performed at room temperature of 23 ± 2 °C. The pH of the water was measured before and after treatment.

2.5. Estimation of the efficiency of the biosorbent

The effectiveness of the biosorbent was evaluated employing the removal percentage that can be observed in Equation (2).

$$\%As = \frac{C_0 - C_e}{C_0} X\ 100 \tag{2}$$

where C_0 represents the initial concentration and C_e the final concentration of the arsenic solutions used in μg/L [49].

The adsorption capacity of the biosorbent was evaluated for each of the samples with Equation (3).

$$q_e = \frac{(C_0 - C_e)\ V}{m} \tag{3}$$

where q_e represents the adsorption capacity, C_0 is the initial concentration, and C_e is the final concentration of the arsenic solutions used in μg/L, m is the mass of the biosorbent (g), and V is the volume of the solution (L) [49].

3. Results and discussions

3.1. Biosorbent production

The quantity produced and collected of watermelon peel biosorbent was 8418.70 g, which was separated by particle size, through sieving in different meshes.

It was chosen to work with the biosorbent collected from mesh #24 (0.710 mm) because it was where the greatest amount of this material was obtained, in addition, no previous study has worked with this size of biosorbent, all preceding studies were carried out with smaller sizes below 0.150 mm.

Fig. 1. Biosorbent produced. A) NB and B) TB.

3.2. Characterization of the biosorbent

The texture and color of the obtained biosorbent are similar to that reported by other works with this same residue or with different ones [17,49–51,56,59]. This can be seen in Fig. 1.

The NB and TB, show different morphological characteristics to the naked eye for the same particle size. As can be seen in Fig. 1. The color of the material darkens after the modification with citric acid and the treatment procedure.

The morphological characteristics of both biosorbents were evaluated with more detail in SEM microphotographs, which can be seen in Fig. 2. It can be seen in the 2 mm microphotographs (Fig. 2. (A and B)), a significant difference in the materials presents more compact flakes for the NB. At 200 μm (Fig. 2. (C and D))the pores of both materials can be distinguished, observing the NB pores with a more circular shape and with more polygonal treatment, similar to a honeycomb. This is corroborated with the images at higher magnification on a 50 μm scale (Fig. 2. (E and F)), where these pores can be better appreciated.

The treatment of watermelon biosorbent significantly increased the surface area, and the abundance of acidic groups on the surface facilitating the cation sorption, these groups may interfere with binding anionic species like oxyanions [27].

The pore sizes were also analyzed for both biosorbents, these are shown with their respective measurements in the SEM microphotographs in Fig. 3.

This analysis is relevant because porosity is a volumetric fraction both on the surface and in the internal structure. Composed of pores that are decisive for evaluating the resistance of materials, but above all the ability to store materials. Biosorbents have adsorption sites as their main mechanism of action, this is a process of adhesion of atoms, ions, molecules, or particles of a material on its surface. Creating an adsorbate film around the adsorbent material. For all this, it is relevant to observe the surface and the morphological structure of the biosorbent produced, to determine its adsorption capacity in both presentations. Similar images were obtained by other researchers with the same type of biosorbent and the same technique [49,51].

3.3. Evaluation of the biosorbent

In all the adsorption experiments carried out, the pH was measured throughout the experimentation maintaining ranges between 5.5 and 7.5. The NB presented a higher percentage of removal than the TB, which improved its removal at 4 h of experimentation. For the TB at 2 and 4 h, a similar behavior was observed, with better results at low concentrations of arsenic in groundwater (Fig. 4). The pH range was from 5 to 7.5.

When seeking to design a water treatment or treatment plant, the retention times must be short, over time, and with various investigations, this has been improved to reduce it from days to hours, through various treatment methods [63]. For this reason, and because several previous studies [17,36,38,42,56,59,64], report similar times of contact with the biosorbent, two and 4 h were chosen to observe the behavior of this material in the removal of arsenic.

In Fig. 4 section A, the percentage of removal for the NB is presented in two and 4 h of contact. It is observed that as time increases, the removal percentage is higher. This reaches a maximum peak and stabilizes. On the other hand, in section B, the percentage of removal for the biosorbent with treatment for both time periods is shown. Its behavior is similar to that of the natural biosorbent, reaching a maximum peak, only that it falls and then stabilizes again.

The adsorption capacities are shown in Fig. 4. In section C, the behavior of NB is observed, where the time of 4 h presents capacities greater than that of 2 h. On the other hand, in section D, the adsorption capacities for TB are presented, which are very similar without significant differences.

The highest percentage of removal (99.99%) was presented for NB and TB at 4 h. The first one (NB) had the highest capacity of adsorption (2.42 μg/g) at this time of contact with concentrations of 65 μg/L of arsenic (Table 1).

NB-4 showed higher removal percentages than NB-2, the maximum percentages were 99.99% and 81.53% respectively. TB-4 also showed the highest percentage than TB-2, with 99.99% and 82.30% as the maximum respectively, this can be seen in Table 1.

It can be observed how the adsorption capacity and the removal percentage increase together with the arsenic concentration for NB-2. For NB-4 the same thing happens only with the adsorption capacity and in terms of the removal percentage, it remains above 93% (Table 1).

For TB-2 and TB-4, the adsorption capacity decreases a little for the concentration of 13 μg/L of arsenic and then has its maximum
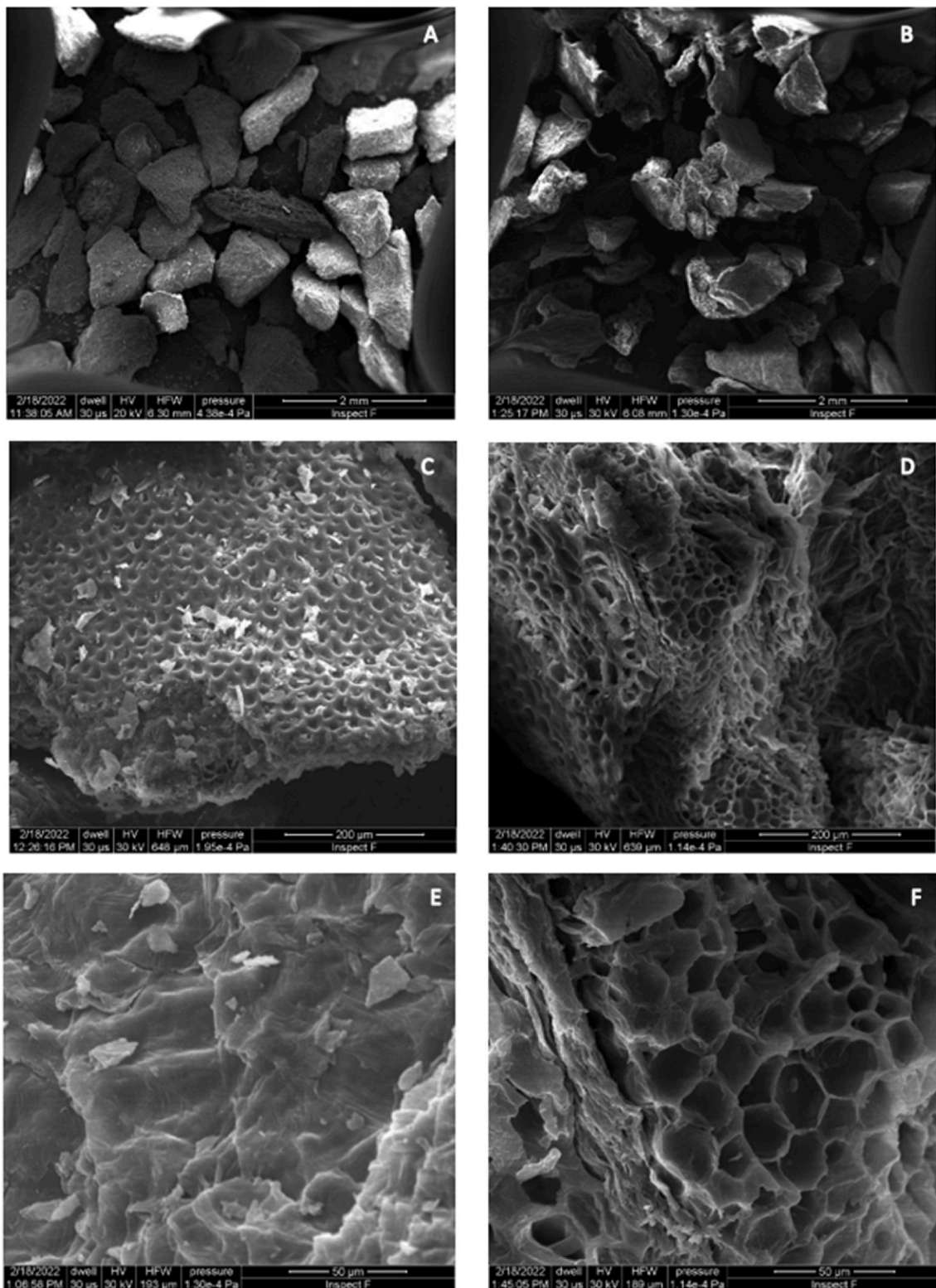
Fig. 2. SEM (Scanning Electron Microscope) microphotographs. A) Natural biosorbent (48X), B)Biosorbent with treatment (48X), C) Natural biosorbent (480X), D) Biosorbent with treatment (480X), E) Natural biosorbent (1920X). F) Biosorbent with treatment (1920X).
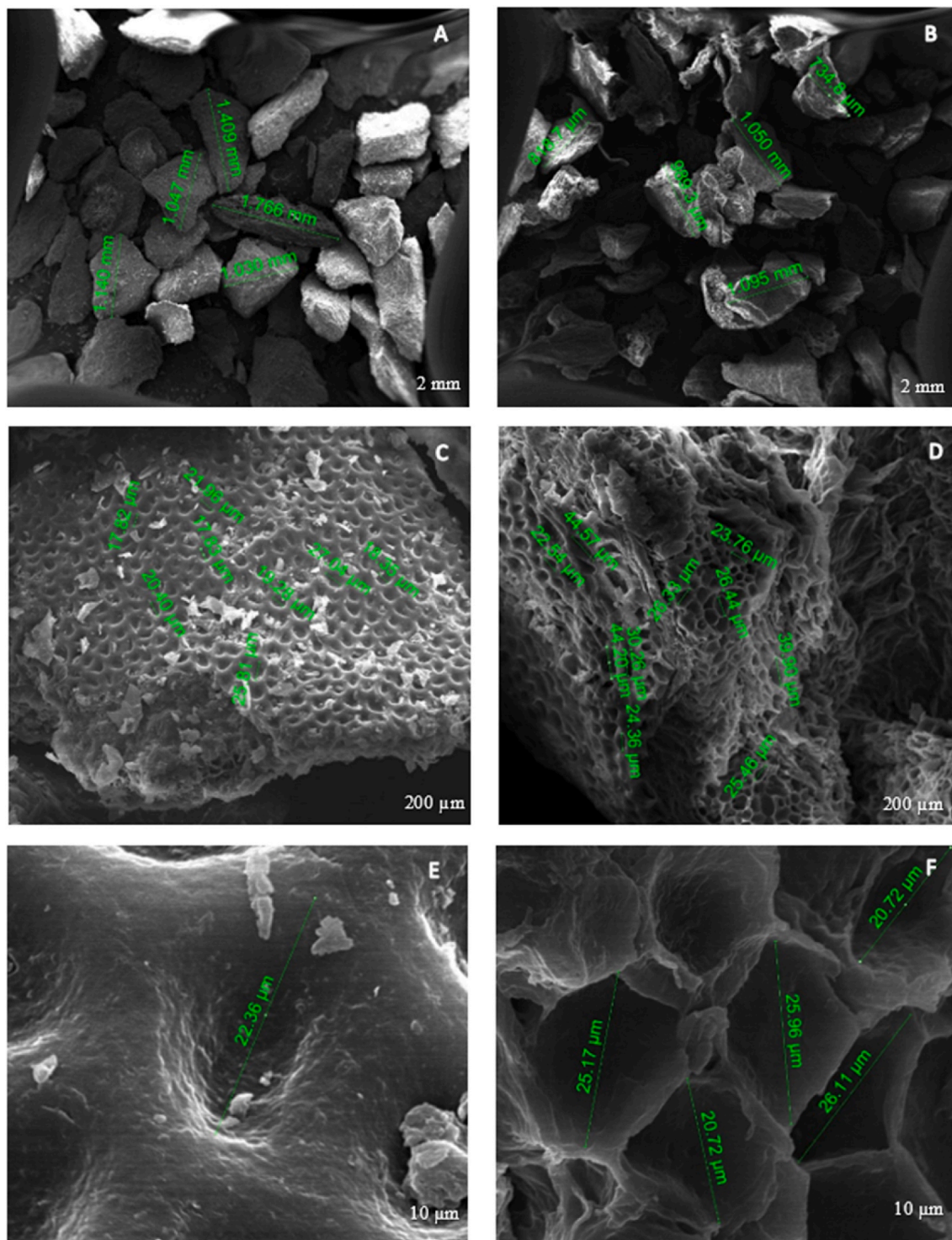
Fig. 3. SEM (Scanning Electron Microscope) microphotographs. A, C, E: NB pore sizes. B, D, F: TB pore sizes.

peak at 65 µg/L. Similarly, for removal percentages at 13 µg/L these decrease and present the highest percentage at concentrations of 1 µg/L of arsenic (Table 1).

These removal percentage results are similar compared to other arsenic removal methods, for example, Kang et al. (2014) [65], found an average removal of 93.8% with an iron adsorbent; by electrocoagulation Omwene, Çelen et al. (2019) [66], removed 93% and Thakur & Mondal, (2017) [67], 98.51% of arsenic; Karki et al. (2022) [68], with a laterite adsorbent, presented a maximum
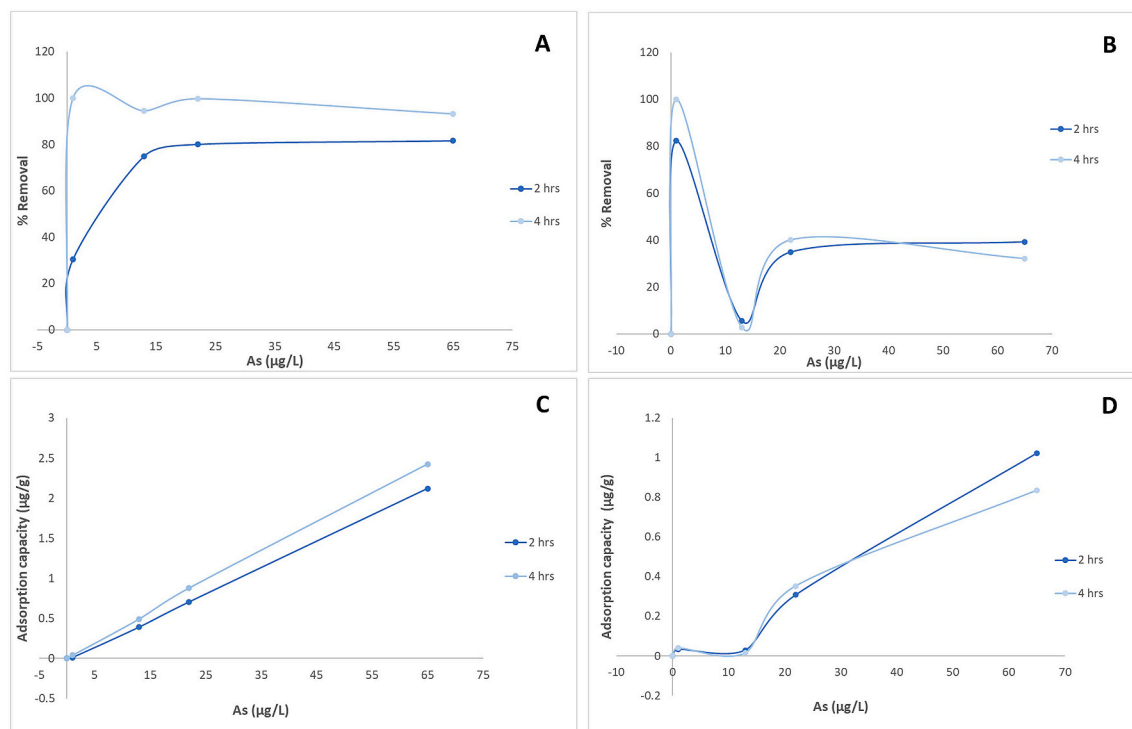
Fig. 4. A) %Removal of arsenic for the NB; B) %Removal of arsenic for the TB; C) Adsorption capacity of the NB; D) Adsorption capacity of the TB.

Table 1
Adsorption capacity and pH for the different treatments.

C_0 As (µg/L)	C_e As (µg/L)	q_e (µg/g)	% Removal
NB-2			
0	0.000	0	0
1	0.697	0.012	30.333
13	3.257	0.39	74.949
22	4.400	0.704	80
65	12.000	2.12	81.538
NB-4			
0	0.000	0	0
1	0.000	0.04	99.999
13	0.714	0.491	94.508
22	0.058	0.878	99.735
65	4.420	2.423	93.2
TB-2			
0	0.000	0	0
1	0.177	0.033	82.3
13	12.273	0.029	5.59
22	14.300	0.308	34.998
65	39.423	1.023	39.349
TB-4			
0	0.000	0	0
1	0.000	0.04	99.999
13	12.623	0.015	2.903
22	13.168	0.353	40.144
65	44.090	0.836	32.17

*C_0= Initial concentration, C_e= Final concentration, q_e = adsorption capacity.

removal of 98.84% and 99.66% for As (III) and As (V) respectively; and Yin et al. (2022) [45], with zero-valent iron nanoparticles, removed 99.9% and 70.9% of As (V) and As (III).

On the other hand, there are also investigations that with other alternatives present lower percentages of removal of this element, for example, Tabaraki & Heidarizadi, (2018) [42], using a brown alga *S. glaucescens* presented a bioabsorption efficiency of 62.06% for As (III) and 71.82% for As (V); Verma et al. (2019) [69], produced two *citrus limmeta* biosorbents, PAC-500 and PPAC-500, with which

Table 2
Comparison of various adsorbents with the biosorbent used in this study.

Adsorbents	Arsenic species	q_e (µg/g)	Maximum % Removal	References
NB-4*	As (V), As (III)	2.42	99.99	
TB-2*	As (V), As (III)	1.023	82.3	
Iron oxide-coated sand	Organic arsenic	8	73.6	[72]
Untreated Laterite	As(V)	565	47.6	[73]
Eggshell	As (V), As (III)	2650	87	[51]
Java plum seed	As (V), As (III)	3240	78	[51]
Chemically modified watermelon rind	As (V), As (III)	3560	99	[49]
Natural laterite	As (V), As (III)	4380	98	[74]
Charred orange peel	As(V)	34070	98	[75]
Rare-earth metals (REMs) lanthanum, cerium, and yttrium)				[76]
3D flower-like ceria composite	As(V)	14400	–	[77]
Clay + Ce (OH)n	As (V), As (III)	5100	98	[78]
Electrospun chitosan-polyvinyl (Ce (III)) alcohol nanofiber	As (III)	18000	95	[79]

they eliminated 72.5% As (III), 76.4% As (V) for the first, and the second 61.7% As (III), 76.35% As (V); and Flores, (2009) [70], removed 89.45% arsenic with 1 g of *Soyatal* rock.

Regarding the adsorption capacity (q_e), the NB-4 was higher than NB-2, with 2.42 and 2.12 µg/g respectively corresponding to the highest arsenic concentration.

For TB the opposite happened, being TB-2 the one that showed the highest adsorption capacity with 1.02 µg/g in contrast to 0.83 µg/g of TB-4, in the same way in the highest arsenic concentrations (Table 1).

The same occurs with other investigations regarding the adsorption capacity, for example: Aryal et al. (2022) [40] who analyzed a new biosorbent for the removal of phosphate from water by loading Zr (IV) with shell of saponified watermelon, finding an adsorption capacity of 27.63 mg/g at a pH of 4.0; Daware & Gogate, (2021), comparing ultrasound-assisted adsorption and conventional batch adsorption using tea residue-based biosorbent for effective pyridine removal, showing the maximum for ultrasound-assisted adsorption with 37.38 mg/g adsorption capacity under optimized conditions of pH 6; that of El-Nemr et al. (2022) [71], who investigated biochar-NH2 as a possible biosorbent and found that the estimated determined sorption capacity was 140.85 mg/g for Cu (II) ions of water-soluble solutions and Yılmaz & Tugrul, (2022) [38] who studied six fruit peels, chemically activated with $ZnCl_2$ and carbonized by microwaves, as biosorbents to remove zinc from aqueous solutions, where the maximum biosorption capacity was determined to be 39.18 mg/g for lemon, 35.78 mg/g for orange, 14.76 mg/g for watermelon, 13.06 mg/g for melon, 12.2 mg/g for pineapple and 9 mg/g for banana peel.

It is observed that the TB (Table 1) presented lower effectiveness than the NB, this may be because when treating the biosorbent with acid, not only its surface is changed, increasing the porosity, but also acid functional groups (such as carboxylic ones) are added. This leads to negative charging, which is not good for adsorption, as it interferes with the binding of anionic species such as arsenic oxyanions. This agrees with other investigations [11,27,32,39], concluding that the treatment of this biosorbent with acid is essential, but it is still necessary to carry out another one to reduce or eliminate negatively charged surfaces. In Fig. 4, the adsorption capacity for both biosorbents is shown. It can be seen that the NB has a higher adsorption capacity, increasing this as the arsenic concentrations are higher. On the other hand, TB has similar behavior, only that in this case the adsorption capacity at small concentrations of arsenic is low.

Compared with other investigations carried out to eliminate arsenic, other treatments have higher adsorption capacities, but there are also methods in the range of those found in this investigation. For example, Tabaraki & Heidarizadi, (2018) [42], a brown alga *S. glaucescens* presented capacities of 116.6 mg/g for As (III) and 207.3 mg/g for As (V); Verma et al. (2019) [69], presented its maximum adsorption capacity at 2000 µg/g with biosorbents produced with *citrus limmeta* residues; Xie et al. (2022) [80], using iron oxides doped with manganese found a maximum adsorption capacity of 59.44 mg/g for As (III) and 31.68 mg/g for As (V); Fang et al. (2022) [81], with bimetallic magnetic MOFs, presented a maximum capacity of 358.96 µg/g for As (III) and 497.85 µg/g for As (V); and Thirunavukkarasu et al. (2002) [72], with a Fe^{3+} resin, found a maximum adsorption capacity of 8 µg/g.

Other studies have tested different biosorbents with different polluting elements, obtaining good percentages of removal, for example, Seidi et al. (2021) [64], which present various chemical modification strategies for the thiolation of chitosan and cellulose in the form of mercaptans, xanthates, and dithiocarbamates, for the removal of ions toxic metals from water; in addition to Daware & Gogate, (2021) [82], which compares ultrasound-assisted adsorption and conventional batch adsorption using tea residue-based biosorbent for effective pyridine removal, presenting the maximum for ultrasound-assisted adsorption with 98.2% removal under optimized conditions of pH 6.

Even so, although the NB (without treatment) presents better mean results in terms of arsenic removal efficiency, treating it allows for minimizing problems that arose such as water pigmentation and fungal growth in solutions. For this reason, in the field of application, it is more advisable to use a biosorbent with treatment that helps improve the quality of this material for cleaning water.

Table 2 shows a comparison of some important natural adsorbents already studied in relation to this study. It is observed that in terms of the percentage of removal, the biosorbent studied in this investigation has an excellent behavior, surpassing others that already exist. On the other hand, this material also has limitations. The most relevant is the low adsorption capacity, which in relation to other studies is very low. Causing the amount of material required to remove arsenic from water to be greater compared to others.

According to the analysis of variance performed on the treatments with their respective repetitions, with a retention time of 2 h, a

Table 3

Analysis of variance.

Factor	Sum of Squares	Degrees of Freedom	Mean Square	Fisher Distribution (Fc)	Significance Level (α)
Treatments	274,37	4	68,591	3702	0.042
Error	185,26	10	18,526		
Total	459,63	14			

significant difference was found with a significance level (α) of 0.04 (Table 3). This indicates that there is a difference between groups or treatments. When groundwater containing arsenic is not applied to the biosorbent, the result is zero, that is, the control and it can be indicated that the biosorbent does not contain arsenic.

Regarding the treatments (1, 13, 22, 65 μg/L), it was found that the water with 65 μg/L of arsenic exceeds the amount of 1 μg/L with a significance level of 0.05. However, at 13 and 22 with the level of significance was 0.16 and 0.23, they have a similar retention capacity between these treatments.

4. Conclusions

Groundwater is one of the most important reservoirs for water supply with different uses in semi-arid and arid zones of the world, particularly in Mexico. In this research, analysis and evaluation of the behavior of a watermelon peel biosorbent were carried out, concerning the removal of arsenic dissolved in water.

Watermelon peel biosorbent is a material that has the potential to remove arsenic from groundwater. The biosorbent without treatment presented clearer and more compact flakes. At the microscopic level, the biosorbent without treatment presented pores with a more circular shape, and the biosorbent with treatment was more polygonal, similar to a honeycomb.

The highest removal percentage was 99.99% for both biosorbents at 4 h of contact and the highest adsorption capacity obtained was 2.42 μg/g for NB-4. TB shows advantages that make the biosorbent a more suitable material for its application in the field. The analysis of variance presented a level of significance (α) of zero, which indicates that there was a difference between groups or treatments. More analyzes are still necessary to create an alternative with this type of materials to apply them in the field in real time. Future research should focus on the application and creation of safe, reliable, effective, sustainable, economical, and simple remediation methods.

Author contribution statement

Jennifer Ortiz Letechipia: Performed the experiments; Wrote the paper.

Julián González-Trinidad; Cruz Octavio Robles Rovelo: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Hugo Enrique Júnez–Ferreira; Ada Rebeca Contreras Rodríguez: Contributed reagents, materials, analysis tools or data.

Carlos Bautista–Capetillo: Analyzed and interpreted the data.

Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of interest's statement

The authors declare no conflict of interest.

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