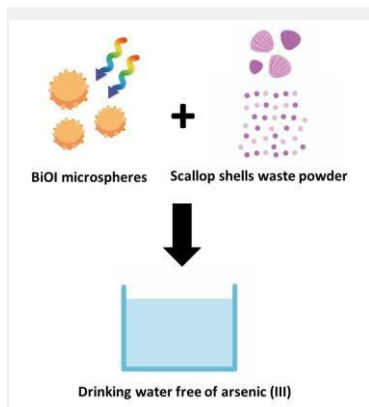


Removal of arsenic (III) in drinking water using Bismuth oxyiodide (BiOI) and scallop shell waste.

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Arsenic is an element which can be found naturally in some soils. In addition, it can be a by-product of industrial mining processes. In this way, arsenic (III) can be easily found in drinking water. Considering the toxicity of this element, various technologies have been developed to remove it from water. Among the most used technologies is heterogeneous photocatalysis, which uses semiconductors such as TiO_2 P-25. An alternative to TiO_2 P-25 is BiOI because it has the advantage that activation occurs with visible radiation, implying a more efficient use of radiation from the sun. The present work will focus on the photooxidation of As (III) to As (V), followed by the subsequent adsorption of As (III) onto scallop shell waste powders from northern Chile to remove As (III) from drinking waters.

Introduction

Currently, a wide variety of chemical compounds and elements have characteristics that are harmful to health and the environment. Arsenic (III) is a polluting element. This can be a by-product of industrial processes such as mining. In Chile, arsenic (III) is naturally found in some soils. Thus, arsenic can be easily found in water for human consumption. Various technologies have been developed to remove the toxicological aspects of arsenic (As^{+3}) from water [1].

One of the most promising is heterogeneous photocatalysis using semiconductors such as titanium dioxide (TiO_2 P-25), bismuth (III) oxide (Bi_2O_3), iron (III) oxide (Fe_2O_3), and tungsten oxide (WO_3), among others. However, the most studied semiconductor is TiO_2 as it has various useful characteristics, such as high photocatalytic efficiency throughout the working pH ranges and thermal and chemical stability. Despite having all these advantages, this material presents a band gap of approximately 3.20 eV, which implies that its activation is carried out using ultraviolet radiation ($\lambda < 390\text{nm}$), which limits its efficiency under solar radiation [2].

Therefore, it is necessary to evaluate the removal of arsenic (As^{+3}) with materials that are activated by visible radiation and that allow the most efficient use of sunlight. Tests developed using the semiconductor BiOI for the degradation of organic molecules will enable us to consider using BiOI to remove arsenic (As^{+3}) in water.

In this study, the removal of Arsenic (As^{+3}) was evaluated using microspheres of BiOI and the adsorption of As on scallop shell waste from northern Chile in waters for human consumption treated with photooxidation and filtration.

Material and Methods

BiOI microspheres were obtained using Mera's

125 mL frosted erlenmeyer alongside 70 mL of

2017 methodology [3]. The scallop shells from northern Chile were obtained in the IV region from a local company dedicated to the farming, processing, harvesting, and marketing of this mollusk. These wastes were in a first stage washed to remove residues present, such as sand and organic materials. The washing process was carried out in a large enough container to ensure a good distribution of the scallop shells; these were submerged in a 4% sodium hydroxide (NaOH) solution for 24 hours. The scallop shells were then removed from this solution and rinsed three times with abundant distilled water.

Once the cleaning was done, the scallop shells were dried at 100°C for 1 hour using a drying stove QUIMIS Q314M230. The scallop shells were located with their concavity upwards and uniformly inside the furnace. Subsequently, the samples were ground and sieved to obtain the ranges in sizes of particles reported in Table 1. Characterization of physical and chemical properties of the obtained materials were determined using different techniques. 300 mL of a 1.6 ppm arsenic (III) solution were added to a borosilicate glass batch reactor. The solution was realized using deionized water. 600 ppm BiOI microspheres were then added. The reactor was left in the dark for 30 minutes, stirred, and cooled with water. At the end of the adsorption-desorption time, an aliquot of 35 mL was taken, corresponding to a reaction time of 0 minutes. The Xenon lamp was then turned on. Aliquots were taken at 10, 20, 30, 40, and 60 minutes. All samples were centrifuged for 15 minutes at 4500 rpm to remove the BiOI semiconductor.

Samples obtained at 60 minutes were gravity-filtered on scallop shell waste with different diameter ranges BS, MS, and SS. The removal percentage of arsenic (III) was determined using a colorimetric method using a UV-visible Evolution 220 Thermo Scientific spectrophotometer. The colorimetric method consists of transferring a 30 mL sample aliquot into a deionized water. Subsequently, 20 mL of concentrated sulfuric acid were added to the same flask and cooled

in a water bath down to room temperature. At the same time, 0.0100 g of silver diethyldithiocarbamate (DDCT Ag) was weighed in a beaker and dissolved with 5 mL of pyridine; this solution was placed in an arsenic absorption tube.

16 g of granular zinc was added to the frosted Erlenmeyer and connected to the absorption tube, ensuring the sealing of the ground unions. The system was left under moderate agitation for two hours. Finally, the absorbance of the solution contained in the tube was determined between 450 and 650 nm, setting 523 nm as the wavelength to calculate the Arsenic (III) removal percentage by this technique.

Results and Discussion

The diffraction spectrum shows the tetragonal structure for BiOI (JCPDS No. 10-0445). Such diffraction peaks confirm the high purity of the synthesized BiOI. Diffractograms of scallop shell waste from northern Chile, specifically from Tongoy Bay, are mainly composed of calcium carbonate, a single phase, and correspond to a rhombohedral calcite crystal structure, as the diffraction peaks coincide satisfactorily with the JCPDS 05-586 card. The XRF technique confirms this composition. SEM shows that the BiOI sample exhibits a hierarchical microsphere morphology formed by nanosheets with a smooth and irregular surface, with an average size of 4 μm . The morphology of scallop shell waste powders is similar to that of "whiskers." All the powders obtained for the different ranges of particles studied (BS, MS, and SS) showed a similar morphology.

Table 1 presents the values of the textural properties of the materials used. The BiOI sample shows a Type IV isotherm with an H3 hysteresis loop, characteristic of mesoporous materials.

The three analyzed scallop shell materials (BS, MS, and SS) present type IVa isotherms. The loop is H3 type; these loops are given by non-rigid aggregates of plate-like particles [4]. In this study, heterogeneous photocatalysis using BiOI microspheres allows the removal of 56.4% of arsenic (III) in drinking water. This is due to the photooxidation suffered by arsenic (III) to arsenic (V) in this process. By filtering the solution after photocatalysis through a bed of scallop shell waste of different size ranges, an excellent removal of arsenic (III) was obtained. This removal percentage was similar for the three wastes used (see Figure 1).

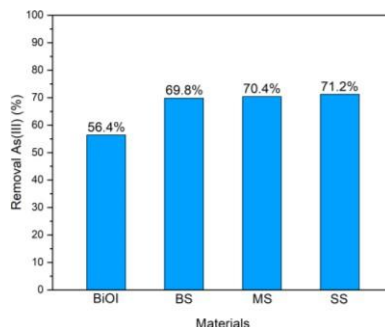


Figure 1. Arsenic (III) removal percentage using BiOI in different particle size ranges of scallop shell residues (BS, MS, and SS).

Table 1. Codification and properties of scallop shells waste and BiOI.

Sample	Codification	Particle size range (μm)	Surface area (m^2/g)	Average pore diameter (nm)	Arsenic removal percentage (%)
Scallop shells waste Big size	BS	595-1000	3	7.6	69.8
Scallop shells waste Medium size	MS	250-595	4	10.4	70.4
Scallop shells waste Small size	SS	<250	1	18.0	71.2
Semiconductor BiOI	BiOI	----	7	16,3	56.4

Conclusions

This study shows that it is possible to use BiOI microspheres combined with scallop shell waste generated in Northern Chile to remove arsenic pollutants in drinking water. In addition, BiOI microspheres permit 56.4% of arsenic (V) removal using different particle size ranges of scallop shell waste; this removal percentage is similar with all sizes (approximately 70%).

Acknowledgments

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