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Disinfection and arsenic removal from water employing heterogeneous photocatalysis.

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Abstract: removal of arsenic and disinfection of water was held employing heterogeneous photocatalysis with UV (solar radiation) and ferric chloride. The effect of many parameters was studied: pH, time of exposure, concentration of ion Fe (III), concentration of As (III).With the optimized parameters a continuous flow system was implemented. Optimal conditions were: concentration of the impregnating solution 5% TiO_2, [Fe (III)]: 15.5 mg / L, [As (III)]: 160 µg / L, exposure time, t: 140 minutes. Achieving removals under Mexican and international (WHO) law, showing a removal of 98% for arsenic and > 99% in disinfection. It was demonstrated that the process of heterogeneous photocatalysis in the presence of iron salts is a good method for oxidizing and removing arsenic from water and disinfection.

Keywords: Arsenic; disinfection; titanium dioxide; heterogeneous Photocatalysis; UV radiation

INTRODUCTION

Water is a scarce resource and indispensable for linving things becoming a determining factor in the quality of life, economic and social development of communities (1). According to the World Health Organization (WHO), in 2005, 1.1 million people were without access to an adequate water source, predicting that by 2015 there will be, in the world, 2.7 billion people without access to basic sanitation (2). The worst part is that more than 3,000 children die every day of diarrheal diseases (3). In addition to the problem that brings a bacteriologically contaminated water source, the presence of other pollutants represents a public health problem like the arsenic. The presence in high concentration of arsenic may cause chronic endemic regional hydroarsenicism, causing dermatological disorders, which can cause some kind of cancers (4). In Latin America the people expose to arsenic are more than 4 million of, usually in low-income areas, including Mexico, were the levels are higher , in some regions like the region of Meoqui-Delicias (Chihuahua), la comarca lagunera (Sonora) among others, the national limits of 25 µg/L and by far the limit of 10 µg / L established by WHO (4)(5). With this we can see the importance of developing and improving low-cost techniques that are practical and economically feasible to be applied in the most exposed areas. One of this techniques are the advanced oxidation processes , for example, the heterogeneous photocatalysis where a catalyst (broad band semiconductor) such as titanium dioxide, under the action of ultraviolet radiation, electron-hole pairs formed, induce redox processes with the adsorbates present in the catalyst surface inactivating bacteria and allowing transform toxic metals such as arsenic (6). This process has the advantage of using sunlight that is an abundant sorce of energy in many regions (6) (7) (8).

Therefore, the aim of this work was to immobilize TiO_2, in PET bottles and plastic pipe, to disinfect and remove arsenic under the action of sunlight and in the presence of iron salts, and passes it to a continuous flow system, resulting high rates of efficiency.

EXPERIMENTAL

Impregnation process

Pet bottles (600 ml) and plastic pipe (29.8 m de large and 8 cm diameter) were used, previously washed and dried at room temperature to constant weight. For the impregnation, a solution of 5% TiO_2 (P25 Aeroxide Acros Organics) acidified with perchloric acid (analytical reagent) at pH 2.5 was used (9). The solution was poured inside the bottle or tube, stirring until a uniform coverage. The remaining suspension was removed and allowed to dry at room temperature for one day. To increase the thickness of the impregnation procedure was repeated

Process level bottle

The bottles filled up with 400 ml of water (tap water) with different concentrations of As (III) (sodium arsenite), Fe (III) (ferric salts), and coliform bacteria (table 1).

Table 1. Values for the process

Fixed values	Variables	Range of value
TiO_2 concentration	[Fe(III)]	0-21 mg/L
	[As (III)]	25-160 μg/L
Impregnation procedure	Irradiation Time	0-180 min
	Coliform	150-1000 NMP/100 ml

Where exposed to sunlight in a horizontal position in a solar concentrator. At the end of each experiment was allowed to precipitate for 24 hours the oxidized arsenic with the iron, without exposure to radiation, for further analysis. An experimental design 2^k was conducted to analyze the effect, on the removal of arsenic, from parameters such as pH of the solution, exposure time, concentration Fe (III) and initial concentration of As (III).

Aplication to continuous flow

This process is conducted by gravity flow of the solution containg As (III), Fe (III) and coliform in concentrically coiled tubing. The retention time was determined based on the optimum exposure time, previously obtained in the bottles experiments, calculating the required flow.

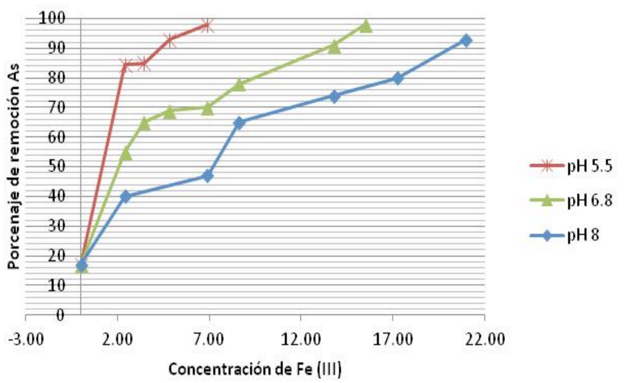
Analytical determination

The determination of As and Fe, in different samples of the experiment, was carried out by atomic absorption spectrophotometry (GBC model AVANTA P) after acid digestion in a microwave equipment MarsX. Coliform analysis was done immediately after the treatment using the equipment Colilert 24 hours.

RESULTS AND DISCUSSION

Removal of arsenic. Influence of pH and Fe (III)

The ability of TiO_2 imprenated to remove arsenic was between 17-20% of the initial concentration of arsenic considered in the experiment (25-160 µg / L). Graph 1 shows the influence of pH at various concentrations of ion iron (III) with a retention time of three hours.



Graph1. Efficiencies of arsenic removal at different pH and concentrations of Fe (III). Exposure time: 180 minutes. [TiO_2] 5%. Co [As] = 160 µg /L

At lower pH (5.5) the removal efficiency of As is higher with lower concentrations of Fe. The arsenic removal increases from 93% to 95% with 4.82 mg / L Fe (III) obtaining concentrations of As in water treated between 11.2 to 8 µg / L. For a pH of 6.8 and 13 mg / L of Fe (III) concentrations the concentrations obtained were under 25 µg / L (nom-127SSA) and for concentrations less than 10 µg / L (WHO) it was required a concentration of 15.5 mg / L of Fe (III). The natural pH of water from wells in Chihuahua ranges from 6.5 to 8.5. According to this study, at a pH of 6.8, with 13 mg/ L Fe (III) and an initial concentration of 160 µg / L of As, removal efficiencies were obtained over 90%, (> 16 µg / L). While for pH 8 removal was only 80% (32 µg / L). This indicates that it is necessary to acidify the water before the treatment for higher removal efficiencies of As.

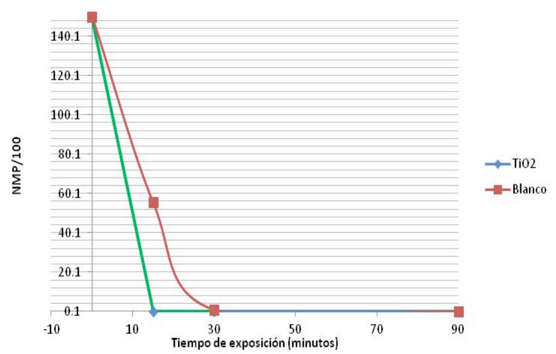
Influence of the exposition time and arsenic concentration

The experimental design allowed to determinate de exposition time and the concentration of Fe(III) required for a given initial concentration of As. The exposition time was varied from 2 to 3 hours and the initial concentration of arsenic in 25 µg/L and 160 µg/L.

By increasing the retention time of 120 minutes to 180 minutes, for high concentrations of arsenic (160 µg/L) the removal increased in 4%. For the initial concentration of 25 µg/L As, the increase was of 2% indicating that up to 120 minutes, removal is minimal. In general, the proportion of As removal efficiency increases slightly with increasing concentration of Fe (III).

Disinfection

According to the results obtained with the TiO_2 and the average concentrations of UV radiation of 8.205 mW/cm^2 UV-A only 15 minutes are required to reduced the concentration of total coliform in water well of 150 NMP/100ml total coliform and 10 NMP/100ml of E.coli, to <1 MPN/100 (Graph 2). On the other side without the presence of the dioxide titanium film it is require at least 30 minutes. Considering a very bacteriologically polluted water with high initial coliform concentrations (up to 1000 NMP/100ml) the time required for disinfection are within the range of the time required for removal of As this confirms that the process is effective for water disinfection and removal of As



Graph 2. Water disinfection. Coliforms [Co] = 150 MPN/100 ml ; 90 minutes exposure time.

Continuos flow application

Efficiency was analyzed in continuous flow process. Using the optimum pH 6.8, C_o [As (III)] = 160 µg / L, Co[Fe (III)] = 15.5 mg / L. The results of the treated water showed no detectable levels of arsenic in the analyzed samples (removal efficiency greater than 99%). Likewise disinfection efficiency was greater than 99% with an initial concentration of 724.7 NMP/100ml.

CONCLUSIONS

The results show that the process of heterogeneous photocatalysis is an efficient process for arsenic oxidation and disinfection of water, in the presence of iron salts allows removal of arsenic, obtaining potable water for human consumption according to national and international regulations. The process can be scale to continuous flow which will treat larger volumes of water with an inexpensive and simple procedure avoiding mismanagement of the bottles or external contamination.

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