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Compare anatase and rutile crystal of TiO_2 for arsenic removal of drinking water

Shahrzad khoramnejadian*

Department of Environment, Damavand Branch, Islamic Azad University, Damavand, Iran

*correspondence should be addressed to Shahrzad khoramnejadian, Department of Environment, Damavand Branch, Islamic Azad University, Damavand, Iran; Tell: +989357970978; Fax: +989357970978; Email: khoramnejadian@yahoo.com.

ABSTRACT

In this research, removal of arsenic from water by two nano-crystals of titanium dioxide has been studied. Anatase and rutile nano-particles in powder form were added to water and the arsenic amount were measured during test. The tests were conducted with and without UV irradiation. Results were showed that UV light accelerated and enhanced the arsenic removal. Anatase had a better arsenic removal than the rutile nanoparticles. In amount of 10 mg/L and 15 mg/L arsenic, the reduction was satisfactory, but for initial amount of 20 mg/L and 25 mg/L arsenic, the reduction were less than lower initial amount. The tests were done at room temperature. The tests showed that an increase in the amount of arsenic in water improves the removal time and impairs the naonparticles' efficiency.

Key words: anatase and rutile crystals; titanium dioxide nanoparticles; arsenic removal; water

1. INTRODUCTION

Life on earth depends on water. Water has important roles in biology, chemistry, and so on. Fresh Water resources in the world are divided into three categories, namely surface water, groundwater, and glaciers. Nowadays, the world is faced with water resource limitations. Population growth, global warming, and pollutants have made water as rare in the future. Safe water is necessary for human health (1). Aside from all the benefits, some diseases, heavy metals, and parasites transfer through water.Many people throughout the world don't have access to clean water. In the 21 century, water would be a global challenge (2). Pressure on water supplies was increased by population growth, global warming, and contaminations (2). In recent years, aqua ecosystems have been polluted by heavy metals, which bring about toxicity and have a trend towards bioaccumulation. Heavy metals are released into water resources by human activities and natural resources. Arsenic (As) is one of the most dangerous heavy metals known as a historical poison and homicide. Arsenic in two forms arsenite (III) and arsenate (V) has contaminated ground waters in many parts of the world (3). Some countries have been affected by high levels of arsenic in their groundwater (4). Geological or anthropogenic source of arsenic has caused arsenic contamination in groundwater. Arsenic is abundant in the earth's crust in organic or inorganic compounds. Mining and using pesticides have caused anthropogenic source of arsenic pollution (4). Arsenic affects human's health in different ways. Arsenic is known as a toxic and carcinogen heavy metal. Liver, kidney, and skin are affected by arsenic. Water purification has been critically demanded for drinking water in many countries and there are many ways to treat water like reverse osmosis, ion exchange, filtration, and adsorption media (5). Nanotechnology is a new method to remove heavy metals from water (5). Nanomaterials are defined as small materials in the size range of 1 to 100 nanometers. Nanoparticles have good sorption, high reactivity, and fast dissolution. These properties relate to their high specific surface area (1, 6). Titanium dioxide TiO_2 is one of the best photocatalysts for water and waste water treatment. TiO_2 has a good physical and chemical property for arsenic removal because of corrosion resistance, low cost, and non-toxicity (7). In this research, arsenic removal by two crystal form of TiO_2 has been studied. In these research two nanoparticle of TiO_2 were compared and the effect of UV light on their removal efficiency was studied.

2. MATERIALS AND METHODS

Nanoparticles of titanium dioxide were obtained in two forms of rutile and anatase from Nano Pars Ltd. (Tehran, Iran). The size of nanoparticle are 20 nm and 30 nm, respectively. Arsenate stoke was prepared by dissolving sodium arsenate in deionized water. Arsenate stoke was mixed with TiO_2 solution and shaken at 260 rpm for 2 hours. Then, it was remained under 8 Watt UV lamp for 24 hours. The amount of arsenic was measured by arsenic test kit after 8, 16, and 24 hours. The samples were prepared and digested in 7 ml nitric acid and 1 ml hydrogen peroxide (30%). The specimens were then placed into microwave instrument ethos plus model (mileston, Italy). The extract were determined by atomic absorption spectroscopy (spectrophotometer AA-200,Varian , Australia).

3. RESULTS AND DISCUSSION

At the beginning of the experiment, the amount of arsenic was measured. Then after every 8 hours, the arsenic amount was measured. Two samples were prepared: one sample with anatase and the other with rutile. The rate of arsenic removal under UV light was higher than that of no treatment. According to Figure 1 the arsenic amount decreased during the experiment time. The result shows that anatase TiO_2 is more active than rutile TiO_2. Arsenic removal from water by rutile TiO_2 nonoparticles were shown in Figure 2.

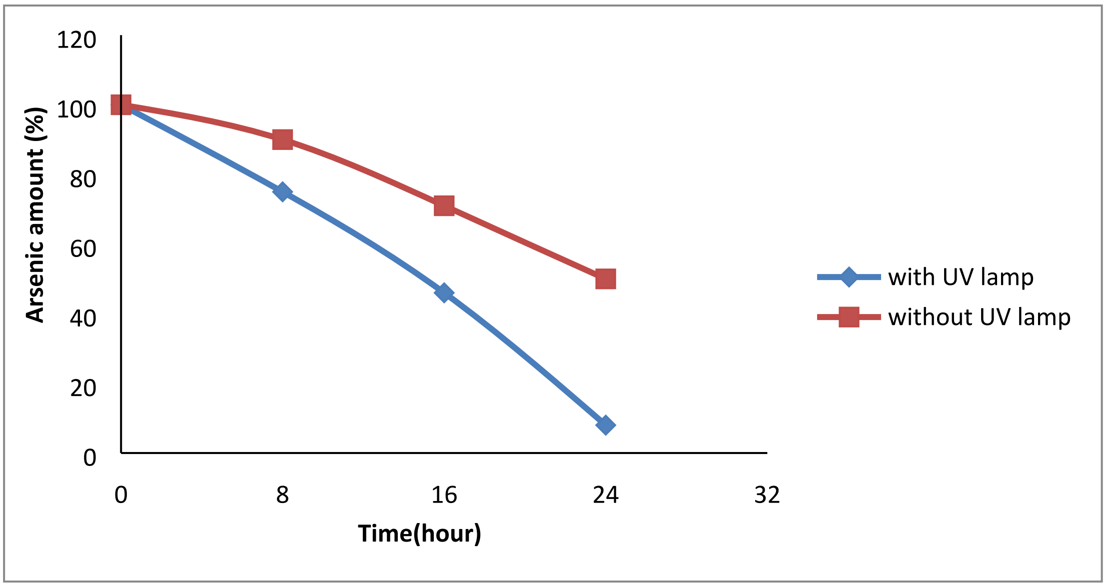

Figure 1. Trend of arsenic amount during experiment time by anatase TiO_2

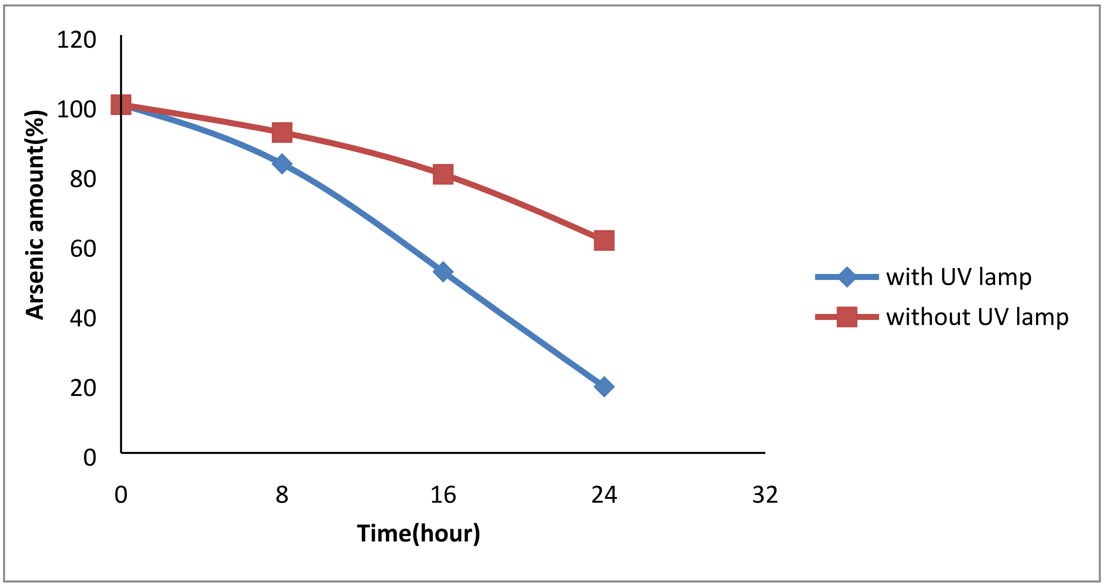

Figure 2. Trend of arsenic amount during experiment time by rutile TiO_2

Anatase particles have more surfaces, which leads to more contact with the environment's arsenic and its higher removal rate. This issue was observed in other researches as well. Figure 3 illustrates the relationship between the initial amounts of arsenic and its removal by nanoparticles.

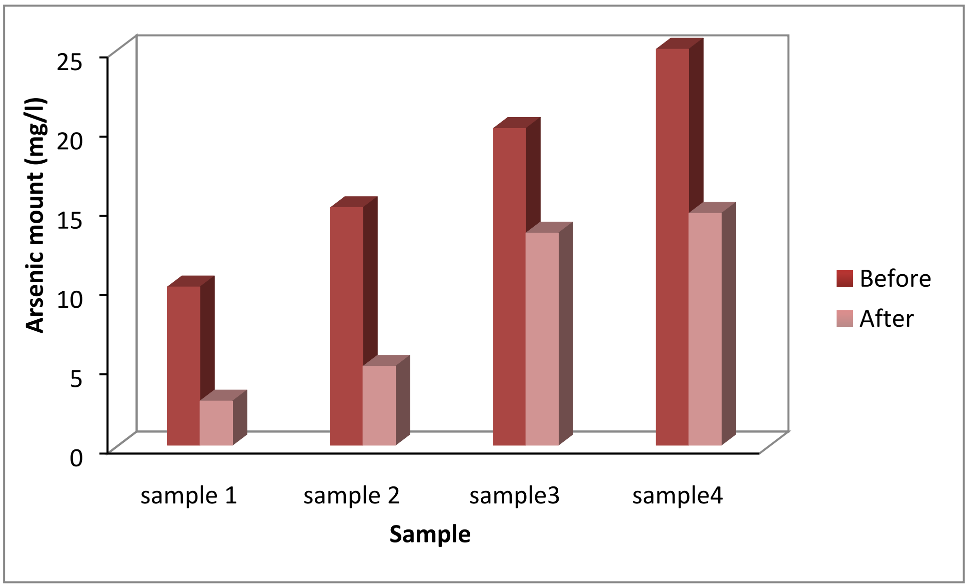

Figure 3. Different amount of arsenic before and after using nanoparticles

In amounts of 10 and 15 mg/l arsenic, there is a dramatic reduction by the end of the test. However, in amounts of 20 and 25 mg/l, the results were not satisfactory. Based on other researchers' opinion if the amount of arsenic in the solution goes up, it settles and covers the particles of titanium dioxide. As a result, the connection surface of nanoparticles and the environment's arsenic amount decreases in the aquatic media. This test is conducted by mixing similar amounts of anatase and rutile (50-50). It seems that by increasing the amount of arsenic, photocatalytic reactions undergo disorder. Experiments were done at room temperature; however, some studies on the effect of temperature on arsenic removal (8). According to these researches, increasing temperature had a negative effect on TiO2 absorbance. Also with increasing pH, arsenate removal decreased. This reduction observed in other research (9); but, an increase on pH (10) leads to an increase in aresic (V) removal.

4. CONCLUSION

In this research, the arsenic in water is removed by nanoparticles of anatase and rutile titanium dioxide. The tests were conducted with and without UV irradiation. The results reveal that UV causes an increase in the removal efficiency of arsenic in water. The nanoparticles of anatase were more able to remove the arsenics compared with the rutile nanoparticles. In addition, the tests presented that an increase in the amount of arsenic in water leads to a concomitant increase in the removal time and a decrease in the naonparticles' efficiency.

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AUTHORS CONTRIBUTION

This work was carried out in collaboration among all authors.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interests with respect to the authorship and/or publication of this article.

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