Original research

Efficacy of Silica nanoparticles in decreasing nitrite content of water

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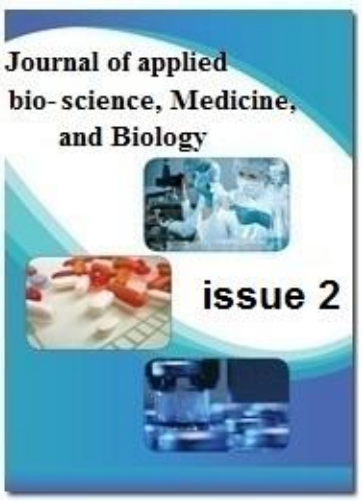

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Abstract

Drinking water may be contaminated with nitrates and nitrites, which is mostly because of sewage spillage into the drinking water sources. Nitrite is toxic and carcinogenic, and forms methemoglobin. Infants are more vulnerable than adults because of their specific physical and nutritional conditions. Different approaches have been taken for reduction of the amount of nitrite in the water. The aim of this research was to show the usage of nanoparticles of silica for decreasing nitrites in water by mixing 0.1 g/mL of SiO2 with different concentrations of nitrite and photometric measurement of supernatant optical density. For the first time it showed that nitrite will be absorbed by silica nanoparticles optimally when in contact for 24 hours, and the maximum reduction is around 72%.

Keywords: silica nanoparticles, nitrite, water, reduction

Introduction

Quality of water is one of the most important determinants of health & hygiene [1]. Qualitative as well as quantitative characteristics of drinking water, especially its mineral and organic contents are routinely checked by relevant sectors in each country [2]. Naturally, water contains some mineral materials, divided as macro elements and micro elements. Salts of calcium, magnesium, natrium, potassium, chlorides, etc., are among the first group, and iodine, fluoride, chromium, selenium, vanadium, etc. are include in the second group [3]. All of these elements are useful for health if of standard amount, above which they will cause health problems [4].

Water may be contaminated by some agents, depending on its source. One of the most important contaminations is microbial, which may induce human as well as animal disease [5]. Contamination of water by heavy metals is among the problems in industrial areas [6]. Drinking water can be contaminated with nitrates and nitrites, which is mostly because of sewage spillage into the drinking water sources, and in rural areas due to use of chemical and organic compounds applied on earth [7, 8]. Reports indicate that daily oral intake of nitrite in USA is 0.3 to 2.6 mg on average, mostly through food but 1-3% of which is through drinking water [9]. In infants, the proportion of nitrite intake through water (via consumption of milk and other fluids) is higher and therefore is more important ,After intake of nitrite, it is directly absorbed by the digestive tract, and induces hemoglobin oxidation to form methemoglobin, which loses oxygen-carrying capability, resulting in cyanosis [10, 11].

Infants are more vulnerable than adults to adverse effects of nitrites due to their specific physical and nutritional conditions, including a) higher intake and absorption of fluids; b) higher pH in the gastrointestinal tract, and more active bacteria; c) hemoglobin F is more sensitive to oxidation by nitrites; and d) lower reductase activity of infant erythrocytes [12]. Nitrites may also be transformed into N-nitroso compounds in the body, which are carcinogenic. If nitrites are taken along with

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nitrosable amines by animals, will also show carcinogenic activity [13]. Organic as well as non-organic nitrites may induce hypotension in the human body, and a dose of 30-60 mg of sodium nitrite is used in management of angina pectoris [14].

Different approaches have been taken for reduction of the amount of nitrite in the water, including the following: demineralization by reverse osmosis or distillation [15], ion exchange [16], blending [17], electrodialysis [18], use of natural or synthetic zeolites such as DDAC, SDBAC or clinoptilolite [19], use of metal catalysts such as palladium [20], use of anaerobic bioprocess [21], use of sulfamic acid [22], heterotropic and nitrite-oxidizing bacteria [23] and finally use of synthetic biofilters [24, 25].

Nanoparticles have unique physical and chemical properties due to their small size and high surface-to-volume ratio, hence having enormous applications in industry and health sciences [26]. In this study, nanoparticles of silica have been used for decreasing nitrites in water, and their efficacy in different incubation (reaction) times has been evaluated.

Materials and methods

Preparation of different concentrations of nitrite and silica nanoparticles:

We made an initial aqueous solution of 1 g/L nitrite (Merck, Germany), and prepared concentrations of 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, and 0.8 mg/L. Two mL of each concentration was added in a tube to 2 mL of nanoparticles of 0.1 g/mL (10 nm, 600 m2/g) silica (Lolitech, USA).

Nitrite measurement assay:

At times of 0.5, 1, 1.5, 2, 5, 10, and 24 hours, we added 100 microliter of the reagent No. 23 from the nitrite test kit (Vaheb, Iran) to each of the above-mentioned tubes, left them for 3 minutes at

room temperature, added 50 microliter of the reagent No. 24, and made a shake for 12 minutes at room temperature. The resulting purple color is proportional to concentration of nitrite in solution. To prevent light scattering by nanoparticles of silica, we centrifuged tubes for 10 minutes at 3000 rpm, and then transferred a sample of supernatant into the cuvettes of the photometer model Clima (Tajhizat Sanjesh, Iran), and read the absorbance (optical density, OD) at 550 nm. Each test was triplicated, and the mean optical density was obtained.

Results and Discussion

Results show optical densities of different concentrations of nitrite in time intervals of 0.5 to 24 hours after addition of silica nanoparticles. As is seen, optical densities decrease as the incubation time increases, and the lowest OD is related to 24 hours incubation. At the 10 hours incubation, there is a small increase in OD, and the difference between 5 and 24 hours incubation time is little.(Figures 1 and 2)

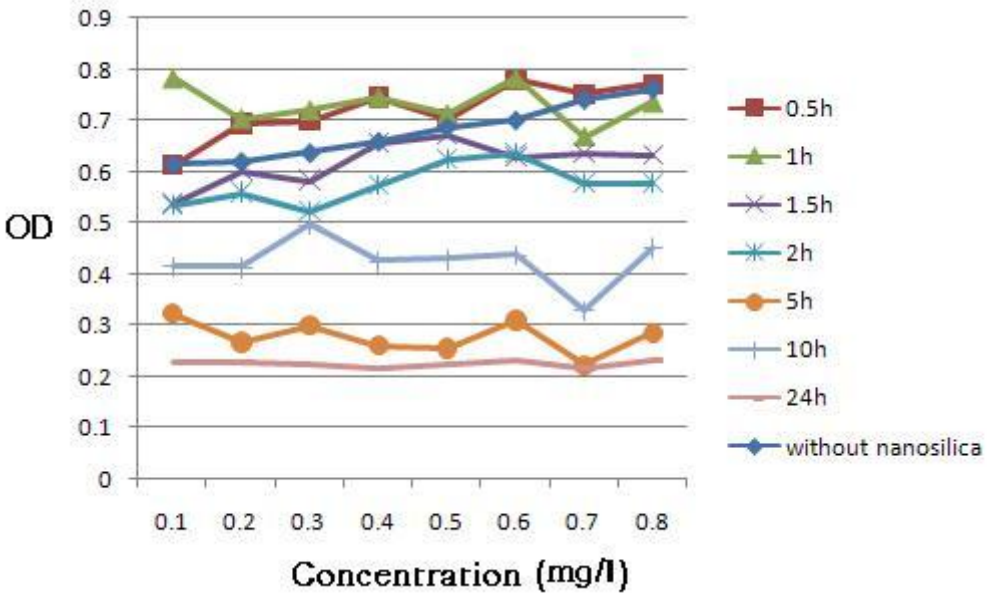

Figure1 Optical density versus concentration of nitrite in different incubation times

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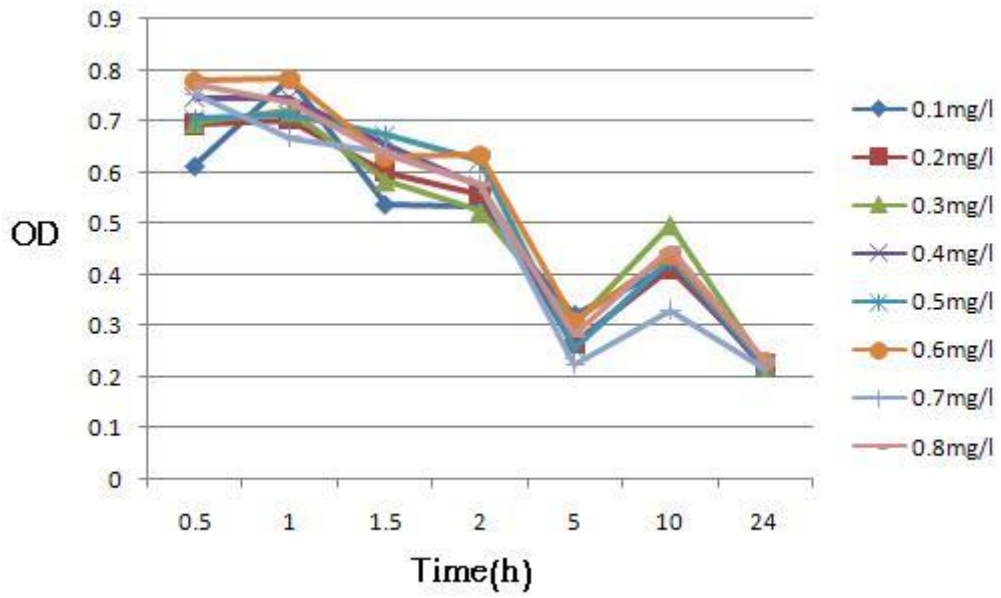

Figure2 Optical density versus incubation times in different concentration of nitrite

Results reveal different concentrations of nitrite and their percent decrease in various incubation times. The highest decrement is at 24 hours incubation time. The maximum decrease in incubation times of 1.5, 2, 5, 10, and 24 hours are 17%, 24.4%, 69%, 55.6%, and 72%, respectively.(Figures 3 and 4)

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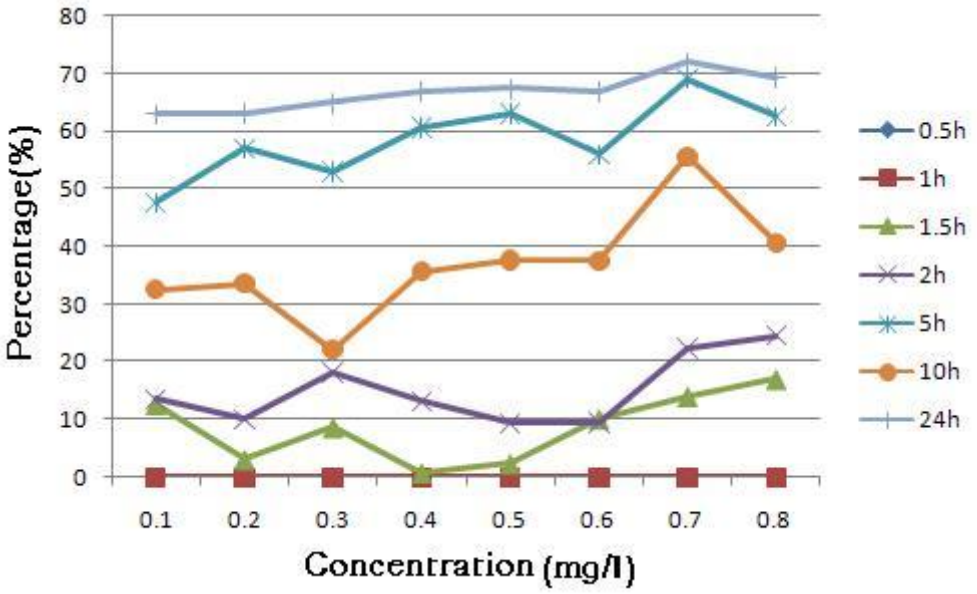

Figure3 different concentration of nitrite versus percent reduction at different incubation times

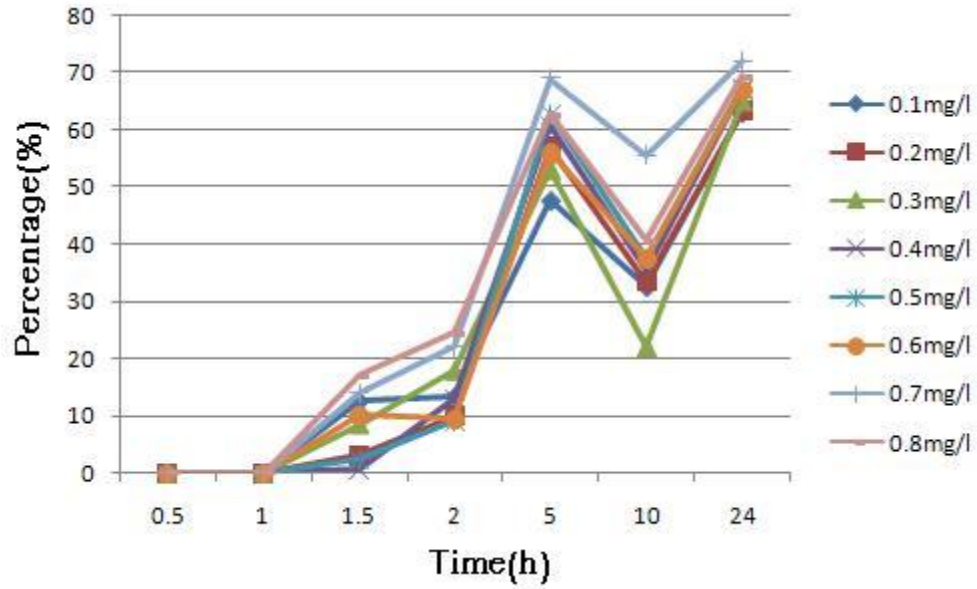

Figure4 different incubation times versus percent reduction at different concentration of nitrite

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The paired t-test on the results showed that there is a meaningful difference between the control group and the 24, 10, 5, 2, and 1.5 hours groups at various concentrations of nitrite (p value= 0.001). Figure 5 shows the nanoparticles.

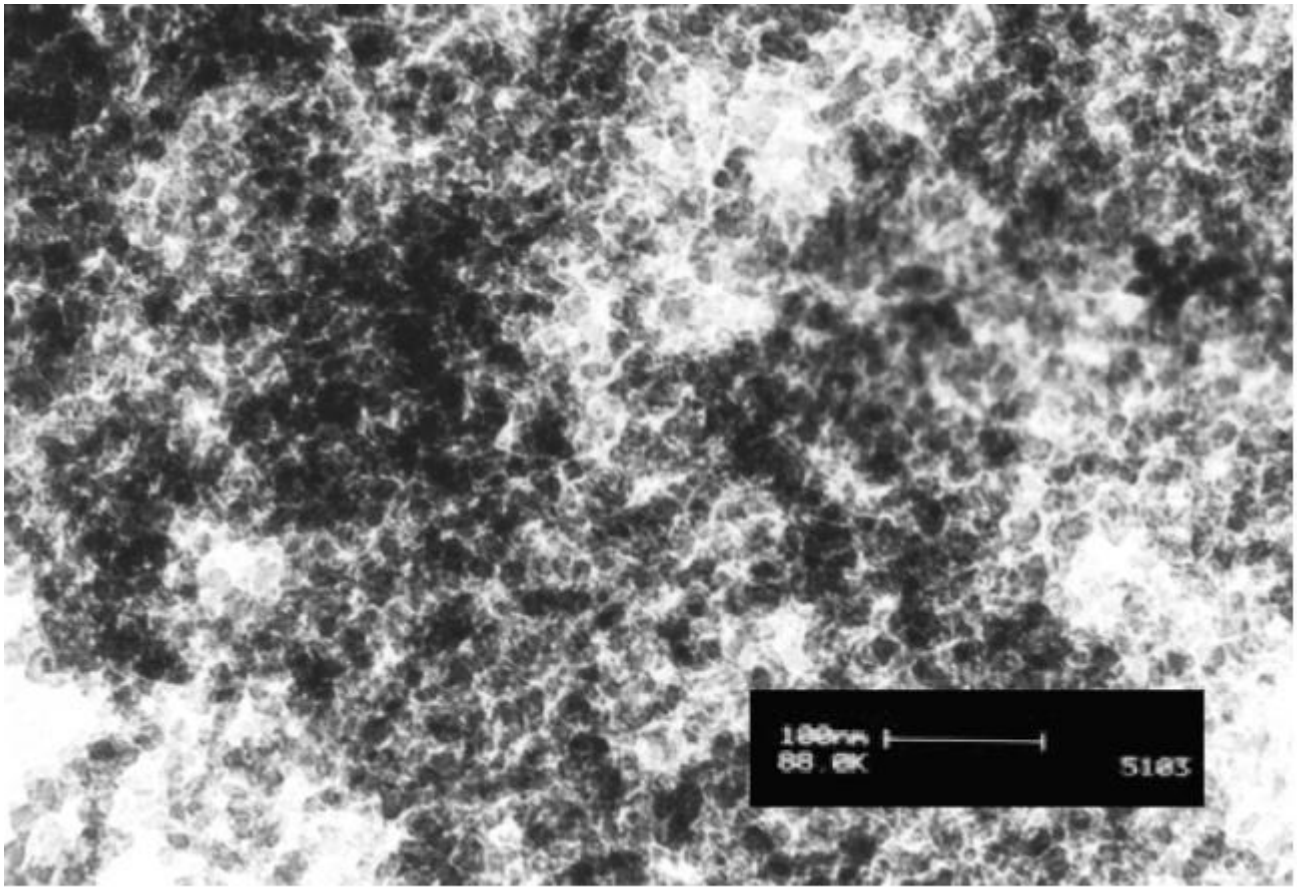

Figure5 silica nanoparticles taken by TEM

It is important to reduce the amount of nitrite in water, especially when it is contaminated with sewage or chemical agents. Various approaches have been studied for this purpose, as mentioned before [15-25]. Nanoparticles have been found useful in numerous industrial and health-related

fields [26]. No previous data regarding the application of silica nanoparticles for nitrite reduction are on record. Our research focused on ability of silica nanoparticles in decreasing or omitting nitrite in water, and for the first time showed that nitrite will be absorbed by silica nanoparticles optimally when in contact for 24 hours, and the maximum reduction is around 72%. Statistical paired t-test on these values showed that there is a significant difference between the control group and 1.5, 2, 5, 10, and 24-hours groups (p-value=0.001). Also there was a direct correlation between the incubation time and percent reduction in nitrite.

As is seen in the figures, increasing incubation time results in higher adsorption of nitrite to silica nanoparticles, but there is a sudden separation of ions from nanoparticles at 10 hours, resulting in a high optical density. At 24 hours, the reverse occurs, which is probably due to early saturation of nanoparticles, but it might also has been a technical laboratory mistake.

Porous silica and silica nanoparticles have unequivocal utilities for elimination of heavy metals [27], toxins [28], dyes [29], and ions [30], but the main concerns about their use in water treatment is omission of them from treated water, because little is known about their potential effects on human and animals after their absorption in digestive tract. Rabolli in 2010 evaluated the effect of different sizes of nanoparticles on various human cells, and showed that their cytotoxicity will decrease by increasing their size (i.e., by decreasing their surface-to-volume)[31].

It can be concluded based on this study that the minimum needed incubation time for attachment of nitrite ions to silica nanoparticles is 1.5 hours. The concentration of silica nanoparticles in this study was 0.1 g/mL, the uppermost incubation time was 24 hours, and the tests were carried out at room temperature. Future research may evaluate the effect of longer incubation times, higher concentrations of nanoparticles, and other temperatures on its efficacy. Elimination of other unwanted constituents of water may be studied in the future. Also, the cytotoxicity of nanoparticles

of silica in the body should be investigated when it is anticipated that some amount of it might be taken by human and animals.

3. Conclusion

In this research, nanoparticles of silica have been studied for decreasing nitrites in water and for the first time showed that nitrite will be absorbed by silica nanoparticles optimally when in contact for 24 hours, and the maximum reduction is around 72%.

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