Solar-UV Photo-oxidation from Arsenite to Arsenate by using TiO_2 Photocatalyst

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Yuko Maruo[1], Daisuke Ino[1], Tomoyasu Takaoka[1], Hisaaki Gyoten[1]

1 Advanced Technology Research Laboratories (ATRL), Panasonic Corporation, 3-4 Hikaridai, Seika-cho, Soraku-gun, Kyoto 619-0237 Japan

Abstract

Natural contamination of groundwater by arsenic has become a threatening problem in many parts of the world. As(III) is predominant species in groundwater. However, As(III) can not be removed efficiently by conventional method such as coagulation and adsorption. Thus, these methods usually require a preliminary oxidation to convert As(III) into As(V), since As(V) is easily removed in contrast to removal of As(III). We have investigated the oxidation of As(III) into As(V) by employing TiO_2 suspension with UV irradiation. The concentration of As(III) decreased with increase in UV irradiation time. On the other hand, concentration of As(V) increased with decrease in the concentration of As(III). This results shows that photocatalytic reaction on TiO_2 was responsible for oxidation of As(III).

Keywords: Oxidation of arsenite, TiO_2 suspension,

1. Introduction

Pollution of groundwater by arsenic has been significant environmental problem. Arsenic is well known to be a toxic element. Elevated As in groundwater is predominantly caused by the minerals containing arsenic. Natural contamination of groundwater by arsenic has become a threatening problem in many parts of the world, especially in areas where groundwater is the only or major drinking water resource. Actually, exposure of human body to arsenic through drinking groundwater has been reported from many countries such as Bangladesh[1], China and India.[2] Arsenic mainly exists in inorganic form and has main two oxidation state such as As(V) and As(III) in natural water. In groundwater, As(III) is predominant species in groundwater, because groundwater has anoxic and reduced conditions.[3]

The conventional methods for removal of arsenic from polluted water are coagulation and adsorption on iron oxide or activated alumina.[4] These methods usually require a preliminary oxidation to convert As(III) into As(V), since As(V) is easily removed in contrast to removal of As(III). Oxidation of As(III) has been achieved by using H_2O_2, NaOCl or Cl_2.

In this study, TiO_2 photocatalyst was employed for oxidation of As(III). Water treatment by employing TiO_2 photocatalyst is attracting widespread interest due to excellent performance in pollutant destruction. We investigated the oxidation of As(III) into As(V) by using TiO_2 photocatalyst.

2. Experimental method

Chemical materials used in this study were TiO_2 powder (P25, Degussa). $NaAsO_2$ was used as the source of As(III).

TiO_2 suspensions were by thoroughly mixing 0.01 g of P25 TiO_2 powder in 100 mL of ultrapure water solution. This mixed solution was ultrasonicated for at least 1 hour, followed stirred at 300rpm for 1 hour.

Monochromatic UV source used in the oxidizing

Contact: Yuko Maruo, Advanced Technology Research Laboratories, Panasonic Corporation
Address:3-4 Hikaridai, Seika-cho,,Soraku-gun, Kyoto 619-0237
E-mail Address:maruo.yuko@jp.panasonic.com, phone number:+81-774-98-2517

experiments was obtained from the combination of a xenon lamp (MAX301, Asahi Spectra Co.,Ltd, Japan) and a band-pass filter. The wavelength of the monochromatic UV was λ = 350 nm with a full width at half maximum of 10 nm. This monochromatic UV source was irradiated onto a batch reactor vessel filled with a 5 ml sample solution which involves As(III) at the concentration of 1000 μg/L. Power density of the UV was 1 mW/cm^2 at the bottom of a reactor vessel. To fairly evaluate an effect of inherent adsorption of As(III) onto the surface of TiO_2, the UV irradiation was started two hours later from the time when photocatalyst and As(III) were mixed. Quantitative analysis of As(III) were performed by using a high performance liquid chromatography and inductively coupled plasma coupled with mass spectrometer system.

3. Results and discussion

The highest photocatalytic activity of P25 TiO_2 is obtained in the form of TiO_2 suspension with treated water. Due to a high affinity of P25 TiO_2 to aqueous solution, TiO_2 nanoparticles are thoroughly dispersed in the suspension.

Figure 1 shows a result of TiO_2 photooxidation of As(III). Horizontal axis represents the irradiation time of UV, and vertical axis means the concentration of As(III) measured by the HPLC/ICP/MS. There was a small decrease of concentration at the UV irradiation time of 0 mins. This is due to the inherent adsorption of As(III) onto the surface of photocatalyst.

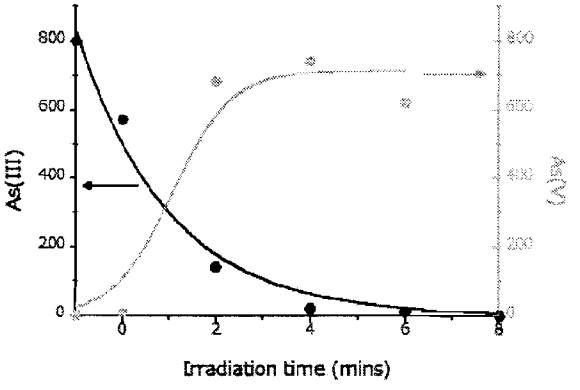

Figure 1 The change in concentration of As(III) and As(V) with irradiation time.

With increase of the UV irradiation time from 0 to 8 mins, an exponential decrease of the As(III) concentration was observed. It is obvious that the decrease of As(III) concentration is attributed to the photooxidation of As(III) occurred by TiO_2 photochemistry. On the other hand, concentration of As(V) increased with decrease in the concentration of As(III). The change in concentration of As(III) and As(V) indicated that photoreaction of TiO_2 was responsible for oxidation of As(III) to As(V).

As(III) was oxidized through three potential reactions in the TiO_2 and UV system. Hydroxy radicals, trapped holes and superoxide radicals, which are generated by the photoreaction on TiO_2, participate in oxidizing reaction of As(III). Oxygen also plays important role, since oxygen is a photogenerated electron scavenger to give superoxide radicals which can oxidize As(III) to As(V).[5] The other oxidant is OH radicals which produced by the reaction of water molecules with trapped hole. As previously discussed, oxidation by OH radicals is dominant for oxidation of As(III).[6]

4. Conclusion

We investigated the oxidation of As(III) by using TiO_2 suspension for efficient removal of arsenic in groundwater. In the TiO_2 and UV system, the concentration of As(III) decreased with increase in irradiation time. On the other hand, concentration of As(V) increased with decrease in that of As(III). OH radicals generated by TiO_2 photoreaction was mainly oxidizing agent for oxidation of As(III). This results shows that treatment by TiO_2 is effective method for preliminary oxidation of arsenic involved in groundwater.

5. References

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