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Photodegradation performance of 1,1,1-trichloroethane in aqueous solution: In the presence and absence of persulfate

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HIGHLIGHTS

- 1,1,1-Trichloroethane is frequently detected in contaminated groundwater with recalcitrant characteristics.
- VUV/$S_2O_8^{2-}$, a novel photochemical technology, is developed and compared with VUV process for 1,1,1-TCA degradation.
- VUV/$S_2O_8^{2-}$ process is more effective in TCA decomposition, but more sensitive to the solution matrix than VUV process.
- Several intermediates are detected in VUV/$S_2O_8^{2-}$ process, while none in VUV process.

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ABSTRACT

Photodegradation of 1,1,1-trichloroethane (TCA), a chlorinated solvent, with VUV and VUV/$S_2O_8^{2-}$ processes was investigated. The effects of various parameters including solution pH, Cl^- and HCO_3^- anions, and humic acid (HA) were evaluated. The results indicated that TCA can be effectively removed under VUV irradiation, and the addition of $S_2O_8^{2-}$, significantly enhanced TCA removal. TCA decomposition in both processes follows the pseudo-first-order kinetic model. In the pH adjusted solutions (from pH 3 to 11), maximum TCA degradation rate occurred at pH 3 and remarkable inhibition at pH 11 in the two processes. Both Cl^- and HCO_3^- anions, as well as HA, adversely affected TCA degradation performance. Moreover, TCA degradation in the VUV/$S_2O_8^{2-}$ process was more sensitive to all the influence factors than in the VUV process. The organic chlorine in TCA was released completely to chloride ion as a final product in both processes. Several reaction intermediates, including 1,1-dichloroethylene, 1,1,1,2-tetrachloroethane, perchloroethylene, carbon tetrachloride, chloroform, and dichloromethane were identified during TCA degradation in the presence of $S_2O_8^{2-}$. In summary, it can be concluded that the presence of persulfate was much more effective than the VUV alone, but the latter was more environmentally friendly due to the formation of nontoxic intermediates.

1. Introduction

The chlorinated solvent, 1,1,1-trichloroethane (TCA), has been used widely for several decades as one of the major chemical solvents in adhesives, aerosols, textile processing, extraction solvents, industrial solvent blends, and metal degreasing. As a result of its extensive usage and improper disposal, TCA has been reported as a contaminant in at least 823 of the 1662 National Priorities List sites identified by the U.S. Environmental Protection Agency (USEPA) [1]. The appearance of TCA in soils and groundwater has been of great concern because of its recalcitrant characteristic and potential to cause liver, nervous system and circulatory system problems from the long-term exposure. Hence, currently the maximum contaminant level of TCA in drinking water has been set at 0.2 mg L^{-1} [2]. In contaminated sites TCA in groundwater is susceptible to abiotic and biotic transformations. The biotransformation of TCA is a relatively slow process and can produce even more toxic intermediates, such as 1,1-dichloroethane, 1,1-dichloroethylene (1,1-DCE), and vinyl chloride, as well as the terminal product of TCA dechlorination, chloroethane, through the metabolic reactions of microorganisms [3,4]. Therefore, it is

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