Applications of Advanced Oxidation for Wastewater Treatment

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Abstract

Novel advanced oxidation processes (AOPs) show great promise for application in many wastewater treatment areas. AOPs are an emerging technology that may be employed for specific goals in wastewater treatment. These AOPs utilize the very strong oxidizing power of hydroxyl radicals to oxidize organic compounds to the preferred end products of carbon dioxide and water. Advanced oxidation has been used to treat wastewater from groundwater remediation pump-and-treat systems, manufacturing facilities, domestic wastewater treatment plants, and others. But advanced oxidation has not been widely applied yet because the chemical processes behind advanced oxidation is not completely understood. Specific operating conditions and reactant doses are necessary for complete mineralization of the organics, and for effective wastewater treatment.

Introduction

Many physical, biological, and chemical processes are used in wastewater treatment. But some contaminants found in wastewater are recalcitrant to some degree to commonly applied processes. Chemical oxidation processes are transformation processes that may augment current treatment schemes. Oxidation processes may destroy certain compounds and constituents through oxidation and reduction reactions.

Advanced oxidation is chemical oxidation with hydroxyl radicals, which are very reactive, and short-lived oxidants. The radicals need to be produced on site, in a reactor where the radicals can contact the organics in the wastewater. Hydroxyl radicals may be produced in systems using: ultraviolet radiation/hydrogen peroxide, ozone/hydrogen peroxide, ultraviolet radiation/ozone, Fenton's reagent (ferrous iron and hydrogen peroxide), titanium dioxide/ultraviolet radiation, and through other means.

Application to WW Treatment

As shown in Figure 1, AOPs may be used in wastewater treatment for (1) overall organic content reduction (COD), (2) specific pollutant destruction, (3) sludge treatment, (4) increasing bioavailability of recalcitrant organics, and (5) color and odor reduction.

Advanced oxidation was investigated for reducing the overall organic content, measured with chemical oxygen demand (COD), of a wastewater from an industrial facility that produced cleaners and floor care products. The wastewater contained up to 5% surfactants, solvents, and chelating agents. The COD of the wastewater from the facility needed to be reduced in concentration before discharge to the local public treatment facility.

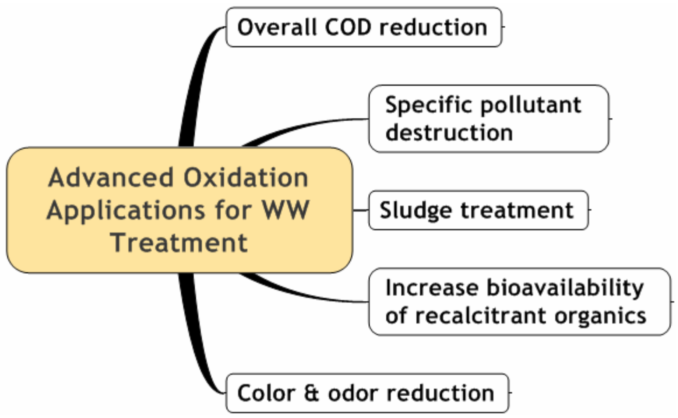

Figure 1. Application of AOPs for WW treatment [1].

Bench-scale experiments were conducted to evaluate the potential for reducing the COD of this wastewater with Fenton's reagent. The results of the experiments showed that Fenton's reagent was very successful, reducing the COD more than 96% as shown in Figure 2. It was also found in these experiments that the reactions were exothermic (3.748 ± 0.332 J of heat were released per mg/L COD removed). This heat could be captured for useful purposes in the facility.

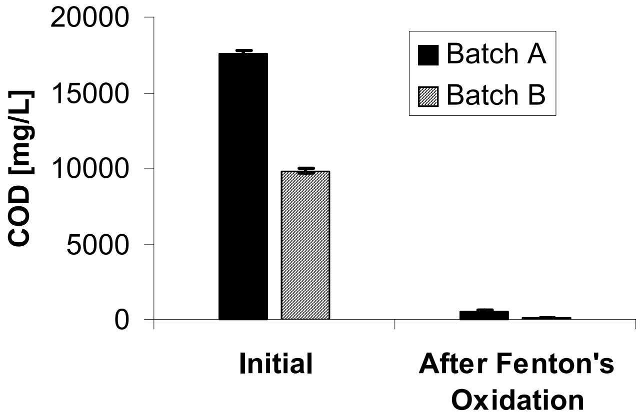

Figure 2. Reduction in COD of an industrial WW with Fenton's oxidation.

Advanced oxidation can also be used to destroy specific pollutants that remain in wastewater after other treatment steps (For examples see Bergendahl & O'Shaughnessy [1]). Fenton's oxidation was used by Bergendahl *et al.* [2] to decrease the concentration of organic contaminants in water. Experiments with a pilot-scale system (shown in Figure 3) were undertaken and illustrated successful degradation of many of the contaminants present with Fenton's oxidation. Many of the contaminants present in this wastewater were significantly decreased in concentration (*i.e.* m- and p-xylenes), although some were not (*i.e.* 1,1,1-trichloroethane). Overall, there was an 81.8% reduction in organic contaminant mass in the water following Fenton's oxidation. Fenton's oxidation has also been found to be very effective for mineralizing methyl *tert*-butyl ether (MTBE) in water [3].

The destruction of endocrine disruptors, a class of contaminants that have recently been found in wastewater, with ozone was investigated by Nakagawa *et al*. [4] using pilot-scale reactors. As shown in Figure 4, they were able to obtain significant reduction in estradiol, bisphenol A, and nonylphenol concentrations with a 1 mg/L ozone dose, but no destruction in estrone. An ozone dose of 5 mg/L resulted in almost complete destruction of estradiol, bisphenol A, and nonylphenol, and only 20% reduction in estrone concentration. These experiments show that the effectiveness of advanced oxidation is dependent on the specific compound to be destroyed.

Figure 3. Pilot-scale Fenton's oxidation system used for destruction of organic contaminants in water [5].

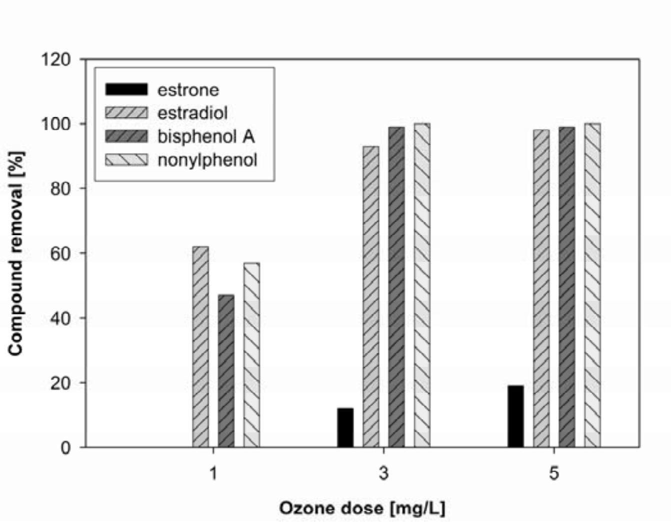

Figure 4. Destruction of endocrine disruptors with ozonation (taken from Bergendahl & O'Shaughnessy [1]).

The hydroxyl radicals produced by AOPs are also effective for treating and conditioning sludge produced from wastewater processes as they destroy cell walls of microorganisms. The cell material becomes solubilized with advanced oxidation, and amenable for further oxidation or other treatment. AOPS can be implemented into wastewater systems using two configurations as shown in Figure 5.

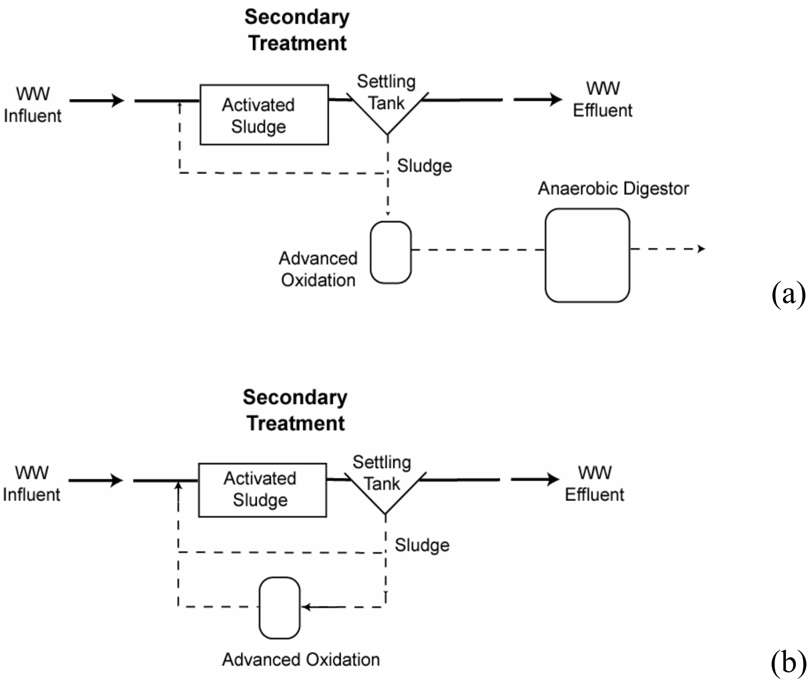

Figure 5. Two schemes for implementing AOPs in sludge treatment. (a) Advanced oxidation of sludge before anaerobic digestion. (b) Advanced oxidation of recycled sludge (taken from Bergendahl & O'Shaughnessy[1]).

Treatment scheme (b) in Figure 5 was investigated by Yasui and co-workers [6-8] in a full-scale activated sludge system treating 120,000 gal/d municipal wastewater. Part of the recycled sludge in the system was subjected to ozonation. The WW treatment system was run for up to 10 months, with no excess sludge disposed – It was a sludgeless system.

New efforts have focused on integrating advanced oxidation with other technologies. Molecular sieve zeolites have great capacity to adsorb organic contaminants from water [9]. Yet these contaminants are merely transferred to the solid phase. However, advanced oxidation can destroy these adsorbed contaminants and regenerate the sorbent. Figure 6 shows preliminary experiments where silicalite, after repeated adsorption cycles with chloroform in water, becomes saturated and unable to sorb any more contaminant (after cycle 8). But after advanced oxidation, the silicalite regains its original sorption capacity (after cycle 9).

Conclusions

AOPs can be utilized in wastewater treatment for: overall organic content (COD) reduction, specific pollutant destruction, sludge treatment, increase of bioavailability of recalcitrant organics, and color and odor reduction.

Acknowledgements

The following were contributors: Stephanie Hubbard, Derek Sykes, Prof. Robert Thompson, Professor Ayse Erdem-Senatalar, Dr. Natalia Koryabkina, and Dr. Arjan Giaya. Triton Systems funded the work shown in Figure 6 (through an NIH grant).

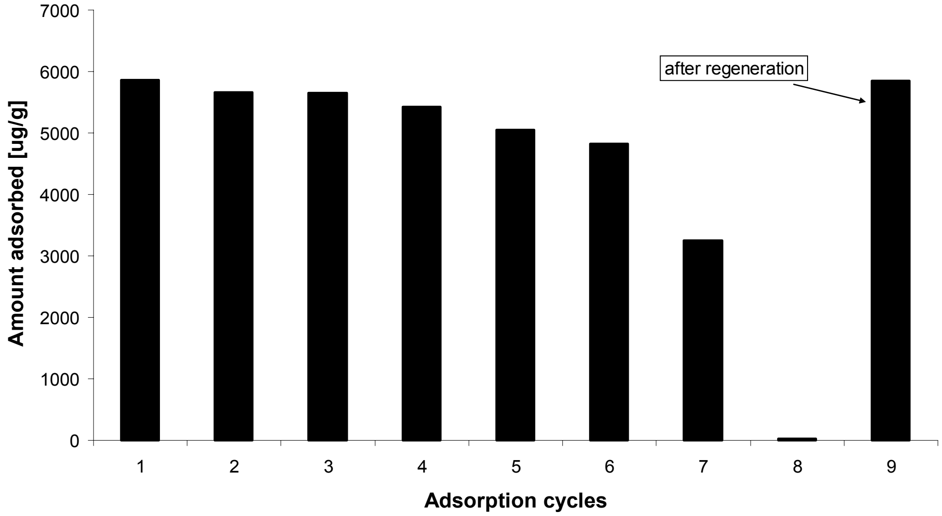

Figure 6. Regeneration of silicalite saturated with chloroform using Fe^o/H_2O_2 advanced oxidation. Regeneration only after 8th adsorption cycle.

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