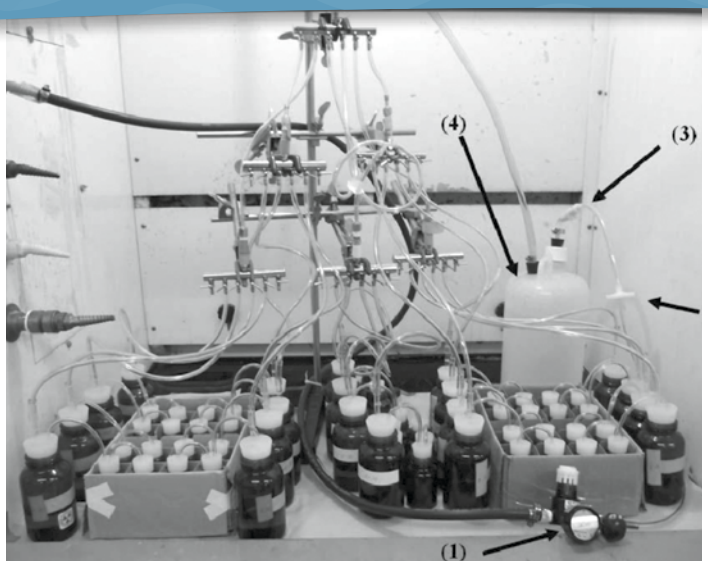
Executive Summary

WERF

Advanced oxidation coupled with biodegradation – shown to remove an otherwise difficult-to-remove pharmaceutical from wastewater



Experimental setup for assessing the biological stability of effluents treated with advanced oxidation process versus those not treated with advanced oxidation process.

Demonstrating Advanced Oxidation Coupled with Biodegradation for Removal of Carbamazepine (INFR6SG09)

The Central Issue

Some pharmaceuticals are resistant to removal in conventional wastewater treatment. Residual amounts of the parent compound and of transformation byproducts (i.e., partial breakdown products) in wastewater effluents raise questions about possible impacts on aquatic life. Carbamazepine (CBZ), an anti-seizure medicine, is one such pharmaceutical. It is resistant to conventional and most advanced wastewater treatment technologies and is widely detected in monitoring programs. Previous work has shown that advanced oxidation processes (AOPs) are effective at degrading CBZ, but little is known about its transformation products. This research seeks to answer whether CBZ and its breakdown products can be removed in the wastewater treatment process.

Context and Background

This research builds on recent studies by the same research team on the relative role of nitrogen removing biological technologies on the biotransformation potential of several difficult-to-remove pharmaceuticals. Those studies show that stable, more polar biotransformation intermediates are formed during biological degradation and may remain in effluents, even when the parent compound is largely biotransformed or sorbed. The researchers selected wastewater plants that use ultraviolet (UV) disinfection of effluents as the place to study the fate of these transformation byproducts. The research had two study objectives: 1) to determine whether AOP can degrade CBZ in wastewater matrices, and 2) to evaluate whether the transformation byproducts of advanced oxidation of CBZ are more biodegradable than the parent compound. The researchers examined whether UV light combined with hydrogen peroxide (H_2O_2) AOP can oxidize CBZ to primary products using conditions bounded by those currently accepted by the drinking water and reuse water industry for this technology. After the AOP evaluation, the potential for biodegradation of the oxidation and photolysis products by activated sludge microbial community was examined.

Findings and Conclusions

The results of this study indicate that the AOP-derived oxidation products of CBZ are mineralized (i.e., completely removed) by activated sludge bacteria retrieved from a conventional treatment plant. 90% degradation of the parent compound was achieved using a UV/AOP treatment level of 1800 mJ/cm^2 UV fluence and 10 mg/L dose of H_2O_2.

The research indicates that AOP treatment followed by a biological degradation process at wastewater treatment plants (either via engineered processes such as biofiltration or through constructed wetlands downstream of the effluent) may be able to achieve a significant level of CBZ mineralization.

This result cannot be achieved by either AOP or biodegradation alone. However, some level of CBZ oxidation by UV treatment of nitrified effluents (without H_2O_2 addition) was also shown to occur and deserves further study. The role of nitrate absorption of UV light and its relative impact on both production of hydroxyl radicals and screening of UV from H_2O_2 should be further investigated. The outcome of this study is a significant achievement in the ongoing effort to develop methods that remove pharmaceuticals from effluents.

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Management and Policy Implications

Coupled AOP-biodegradation can be a promising technology. The results of this research have possible implications for other difficult-to-remove trace organic compounds. The strategy of performing UV-H_2O_2 based AOP together with downstream biodegradation could be beneficial, especially for other aromatic ring-bearing pharmaceuticals and personal care product chemicals. The biodegradation step could be implemented as either a biofilter or through constructed wetlands where ample aerobic biodegradation can take place.

If this proves successful on a full-scale plant level, utilities will be able to remove these types of compounds in treated effluent. This could ultimately allow utilities to meet stricter standards of water quality.

Related WERF Research

Project Title	Research Focus
Demonstrating Advanced Oxidation/ Biofiltration for Pharmaceutical Removal in Wastewater (U2R11)	Develops and demonstrates design criteria for UV/H_2O_2 advanced oxidation followed by downstream biofilm-based treatment to remove biologically recalcitrant pharmaceuticals from wastewater effluents.
Understanding Microaerobic Metabolism in a Sustainable World (U1R09)	Focused on evaluating the fate of pharmaceuticals at trace concentrations through bioreactors that either achieve nitrogen removal (anoxic/aerobic, microaerobic with nitrate limitation, microaerobic with nitrate sufficient) or achieve ammonia oxidation but not nitrogen removal (aerobic).

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