143t Cyanobacterial Toxins: Treating the New Generation of Water Contaminants

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Problem Statement

Cyanobacteria, also known as blue-green algae, are found globally in all types of aquatic environments, including water distribution systems. The increase in the frequency of appearance of algal blooms worldwide can be attributed to elevated nutrient levels (i.e., nitrates and phosphates) from the overuse of fertilizers and detergents. Cyanobacterial blooms mainly impart color, odor and taste to water. Some specific genera are also capable of releasing toxic compounds that dramatically diminish the quality of water. Studies have shown that up to 50% of the recorded blooms can be expected to be toxic. Approximately fifty species of cyanobacteria contain and release toxins as a metabolic byproduct and also during "cell death" (lysis). Cyanotoxins can cause irritations of mammalian organs, including skin (irritant toxins and dermatotoxins), cell damage (cytotoxins), liver damage (hepatotoxins), or disturb the proper function of the nerves (neurotoxins). These compounds have low lethal doses, within the range of 50-300 μg/kg, impacting mammalian health significantly and sometimes permanently. Cyanotoxins can indirectly affect organisms by entering the food chain, since they bioaccumulate in fish and shellfish tissues. The relatively recent discovery of cyanotoxins in drinking water supply systems and resources has established them as part of the new generation of drinking water contaminants that require treatment. The lack of guidelines or regulations on cyanobacteria and cyanotoxins in terms of maximum contaminant level (MCL) and best available technology (BAT) for their detection, is the rate limiting step towards the confrontation of these new emerging water contaminants. Regardless of the lack of regulations, the research interest for the treatment of these toxins has been growing exponentially in the past few decades and is mainly targeted towards microcystin-LR (MC-LR), a hepatotoxin released from a variety of cyanobacteria.

Treatment of MC-LR

Several methods have been tested for the inactivation (chlorination), removal (activated carbon adsorption) and degradation (chemical oxidation with hydroxyl radical-based processes such as, ozonation, Fenton reagent (FR) and titanium dioxide photocatalysis) of MC-LR. Especially for the latter case, none reported mineralization efficiency exceeding 10%. Frequently used methods in drinking water trains like coagulation, flocculation, and sedimentation are very efficient for the removal of algal cells and part of the toxins. However, it has been reported from pilot plant studies that the application of mechanical force during water treatment can increase the number of cells that undergo lyses and hence increase the overall soluble toxin concentration. Chemical treatment with compounds like potassium permanganate and copper sulfate was also tested for controlling the rate of phytoplankton blooming in water resources. The inhibition of the blooms was successful; unfortunately these chemicals increase the rate of release of MC-LR from the cells resulting in an increased soluble toxin concentration.

Approach adopted

In this study Sulfate Radical-based Advanced Oxidation Technologies (SR-AOTs) were used for the degradation of MC-LR. Radical generation was achieved with the coupling of oxidants such as peroxymonosulfate (PMS) and persulfate, catalysts including cobalt and other transition metals, and UV radiation. Sulfate radicals are generated with the catalyzed decomposition of the oxidants with radiation, catalyst or both. Previous studies of our group on the destruction of recalcitrant contaminants with the Co/PMS system have indicated wide range of functional pH, low catalyst dose requirements (true catalytic system) and high mineralization and purification efficiencies.

Important Findings

The decomposition of PMS can result in the formation of sulfate, hydroxyl and peroxymonosulfate radicals depending on the oxidation pathway. Control experiments in the absence of catalyst and oxidant demonstrated the high stability of MC-LR. Cobalt (0.1 mg/L) or PMS (10/1 molar ratio of oxidant to contaminant) alone did not show any degradation of the toxin. Degradation occurred only when both oxidant and catalyst were present. Moreover, the initial rate of degradation increased with increasing oxidant ratio. From the results obtained so far sulfate radicals were observed to degrade MC-LR at concentrations as high as 2000 ppb in sort time periods making it a promising technology for the treatment of biological toxins. The study showed that SR-AOTs as well as similar hydroxyl radical-based AOTs (HR-AOTs) were efficient technologies for the destruction of biological toxins in water and can be used to handle unexpected events caused by cyanobacterial toxins contamination as a result of eutrophication in lakes or as rapid response technologies in cases of intentional contaminantion of water.