USGS

**WATER RESOURCES RESEARCH GRANT PROPOSAL**

# Enhanced Removal of DBP Precursors During Precipitative Softening Through Co-Adsorption Processes

**Focus Categories:** TRT, SW, WQL

**Key Words:** Disinfection By-Products, Water Treatment, Softening, Natural Organic Matter, Precipitation

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**Congressional District:** 15th Congressional District

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## Statement of Critical Regional or State Water Problems

The chlorination of drinking water can result in the formation of disinfection by-products (DBPs) such as trihalomethanes and haloacetic acids []. DBPs are probable carcinogens, and short-term exposure can lead to dizziness, headaches, as well as problems associated with the central nervous system. Recent studies have also linked DBPs to increased incidence of miscarriage [], rectal and bladder cancer [, ], and neural tube birth defects []. As a result of the health effects associated with DBPs, as well as microbial pathogens, nearly 40% of water treatment plants in the United States will have to upgrade their systems by 2001 at an estimated cost of $10 billion []. It is estimated that 80% of water treatment facilities will have to make changes to meet regulatory requirements by the year 2005 [].

The upcoming USEPA Disinfectants-Disinfection By-Products (D/DBP) Rule will mandate improvements in water treatment plant performance. Stage I of the D/DBP rule will require water utilities treating surface water, or groundwater influenced by surface water, to reduce the concentration of trihalomethanes (THMs) and haloacetic acids (HAAs) in their finished drinking water to 80 µg/L and 60 µg/L, respectively, or less []. Stage II of the D/DBP Rule, expected to be finalized in 2002, will require further reductions in DBPs (40 µg/L and 30 µg/L for THM and HAA, respectively). In addition to establishing maximum contaminant levels for DBPs, the D/DBP Rule will also specify removal requirements for natural organic matter (or "NOM"), a major precursor to the formation of disinfection by-products.

In the state of Ohio, 125 water treatment plants utilize lime softening for the removal of hardness and turbidity []. To be in compliance with the D/DBP Rule, these and other lime softening plants around the country will be required to remove 20-30% of the natural organic matter present in their source water []. Improvements in the removal of organic matter will most likely be accomplished through alteration of the softening process (so-called "enhanced precipitative softening"), or through the addition of unit operations such as activated carbon. Enhanced softening involves raising the amount of lime added during treatment (roughly 5 to 10 times) and subsequently results in greater chemical costs and the increased production of sludge.

Although enhanced softening results in greater precipitation of $CaCO_3$, previous research indicates that even high dosages of lime (200 mg/L) may be ineffective at removing some DBP precursors, especially low molecular weight humic materials such as fulvic acid []. Adsorption of fulvic acid to $CaCO_3$ precipitates during the softening process is low, primarily due to electrostatic repulsion arising from the high negative charge density of fulvic acid and the negatively charged $CaCO_3$ surface. In addition, $CaCO_3$ particles formed during softening have low surface area (5 $m^2$/g) and therefore minimal sites for humic adsorption, compared to other coagulants such as ferric chloride (230 $m^2$/g). While the formation of $Mg(OH)_2$ during softening can aid in removing DBP precursors, the precipitation of magnesium occurs only at high pH, a condition uncommon in most water treatment plants [].

In this research, we will investigate means to increase the removal of DBP precursors during drinking water treatment. In particular, we will examine whether the adsorption of humic and fulvic acids to $CaCO_3$ precipitates during lime softening can be significantly improved through the "co-adsorption" of synthetic polymers. By co-adsorption, we mean any process by which more than one type of polymer simultaneously or sequentially adsorb to a solid surface. We believe the affinity of disinfection by-product precursors for calcium carbonate precipitates can be improved significantly through co-adsorption, and in particular, by the formation of humic-polymer complexes and/or through the attachment of humic material to polymer-coated $CaCO_3$ surfaces.

**Statement of Results or Benefits**

This research will lead to a better understanding of DBP precursor removal during lime softening, as well as result in a new approach for increasing the removal of organic matter during this process. At a more fundamental level, this work will lead to a better understanding of the factors that control the co-adsorption of multiple species from aqueous solution onto solid supports. We believe this work will represent the first systematic investigation of the effect of co-adsorption processes and organic matter characteristics on the removal of disinfection by-products by lime softening.

Our primary goal is to develop a mechanistic understanding of how co-adsorption may improve the removal of humic materials during lime softening. The purpose of understanding mechanisms is so that we may use this information to rationally design new polymeric additives to enhance water treatment operations. Specific research objectives include; (1) To examine the removal of DBP precursors by lime softening in the presence of a number of different synthetic polymers. (2) To determine the properties of organic matter and synthetic polymer (e.g., molecular weight, charge, hydrophobicity) that influence DBP precursor removal during co-adsorption. (3) To identify the importance of specific co-adsorption mechanisms that influence organic matter removal during softening, such as precipitate surface modification and organic matter/polymer interactions. Furthermore, a significant component of this work will involve the transfer of information to scientists and engineers working in the water treatment field, regulators, and to other water treatment professionals.

We believe application of results generated from this research in the drinking water treatment field will lead to a number of practical benefits. Benefits that may accrue include a reduction in lime softening chemical costs and a reduction in the costs and landfill requirements associated with sludge production. Application of this work should also lead to a decrease in the negative health effects associated with the formation of disinfection by-products during drinking water treatment.