Removal of Natural Organic Matter in Biofilters [Project #631]

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BACKGROUND
Natural organic matter (NOM) is present in all drinking water sources and is usually quantified by the total organic carbon (TOC) analysis. NOM in drinking water can lead to problems such as the formation of trihalomethanes (THMs) during disinfection with chlorine, regrowth of bacteria in the distribution system, and reduced bed life of granular activated carbon (GAC) adsorbers (Bouwer and Crowe 1988). The TOC concentration in drinking water is of increasing concern to water utilities because of the proposed regulations concerning TOC removal during drinking water treatment in the Disinfectants-Disinfection By-Products (D-DBP) Rule.

Experience in Europe has shown that biological processes can achieve TOC removal efficiencies of 5 to 75 percent. The use of biofiltration for TOC removal could prove very economical, as existing physicochemical treatment processes such as sand filters or GAC beds could serve as biological reactors.

Many U.S. water utilities are committing to the use of ozone as a primary disinfectant or oxidant in response to the proposed regulations for disinfectants and disinfection by-products under the Safe Drinking Water Act (SDWA). Little is known about the relationship between ozonation and biodegradation of natural organic matter in water supplies. Understanding is poor regarding potential problems associated with bacterial regrowth in distribution systems, the potential for a biofilter to remove the biodegradable materials and minimize regrowth problems, and the potential for preozonation and biofiltration to reduce TOC levels in drinking water. This research was performed to help resolve these questions and provide basic design and operational guidelines for biofiltration.

APPROACH
The work described in this report consisted entirely of laboratory studies that were designed to elucidate the relationships among (1) the source and composition of NOM, (2) ozone dose, and (3) TOC removal in batch and continuous-flow column (biofilter) systems.

Four sources of NOM were chosen to represent a broad spectrum of composition. The following parameters were evaluated to characterize the chemical composition of the different NOM sources: pH, TOC concentration, dissolved organic carbon (DOC) concentration, ultraviolet (UV) absorbance (abs) at 254 nm, alkalinity, nutrient concentrations, and apparent molecular weight distribution (AMWD) by ultrafiltration (UF).

Aerobic batch biodegradation studies were conducted to evaluate the biodegradability of the four NOM sources as a function of ozone dose and to determine whether the source of NOM biodegrading bacteria affected the rate or extent of TOC removal in the batch microcosms. Kinetics of TOC biodegradation as a function of NOM source and ozone dose was also evaluated.

Continuous flow biofiltration studies were performed to evaluate the effect of empty bed contact time (EBCT) and NOM source on TOC removal in laboratory-scale biofiltration systems that simulated a rapid sand filter.
RESULTS

The following results were deduced from this project’s experiments.

Characterization of NOM Sources

- Biodegradation in the four raw NOM sources appeared to be limited by the inorganic nutrient concentrations in the sources.
- Relative magnitudes of the UV/TOC ratio were determined for the four raw NOM sources. Higher UV/TOC ratios indicate more unsaturated carbon bonds per mass of organic carbon and perhaps greater complexity and aromaticity of the NOM. Lower UV/TOC ratios tend to indicate more saturated aliphatic character for an NOM source and may result in greater biodegradation of the organic carbon.

Batch Biodegradation Studies

- The biodegradation of organic carbon was significantly affected by the source and composition of the NOM and by the ozone dose.
- Ozonation resulted in some organic carbon removal through direct chemical oxidation.
- The total percent TOC removal that resulted from the combination of direct reaction with O3 and biodegradation increased with increasing ozone dose for the sources that consisted primarily of humic substances.
- The ability to biodegrade complex NOM compounds appeared to be present or inducible in various mixed bacterial populations.
- NOM became more oxidized as the ozone dose was increased.

Biofiltration Studies

- Approximately 6 days were required for TOC removals to stabilize in the initially clean and sterilized biofilters.
- The source or composition of the NOM affected the extent of biodegradation in the biofilters.
- The lack of dependence of TOC removal in the biofilters on EBCT was not in agreement with the majority of results reported in the literature concerning biofiltration.
- Batch experiment results showed biodegradable TOC removal efficiency values ranging from 77 to 100 percent.
- The UV/TOC ratios of the biofilter effluents were consistently higher than the influent values, which indicated preferential biodegradation of the non-UV-absorbing fraction of the TOC.
- The most effective method for maximizing TOC removal was to optimize the coagulant dose.
- Biofiltration is an effective method for removing the biodegradable fraction of TOC. It was able to reduce TOC levels in the pretreated and ozonated waters by 16 to 33 percent.