Characterization of Natural Organic Matter and Its Relationship to Treatability [Project #603]

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BACKGROUND
Natural organic matter (NOM) occurs ubiquitously in both surface waters and groundwaters and consists of both humic (i.e., humic and fulvic acids) and nonhumic components. NOM in general and certain of its constituents in particular are problematic in water treatment. From a regulatory perspective, concerns focus upon the role of NOM constituents as disinfection by-product (DBP) precursors. The premise of this study is that the "fingerprints," or signatures, of NOM in raw or untreated water sources provide insight into treatment process selection and applicability. It is hypothesized that problematic NOM fractions can be targeted for removal or transformation.

APPROACH
The analytical protocol for this study included:

• characterization of bulk NOM and various NOM fractions

• characterization of NOM according to size as dissolved (DOM), colloidal (COM), or particulate (POM) organic matter using sequential membrane filtration

• fractionation of DOM by apparent molecular weight (AMW) using ultrafiltration (UF) and gel permeation chromatography (GPC)

• fractionation of DOM according to humic and nonhumic character using adsorption chromatography by XAD-8 resin isolation

Bulk NOM and various fractions from seven different source waters were measured by dissolved organic carbon (DOC), ultraviolet light absorbance (UV-254), fluorescence, chlorine demand, and DBP formation tests. Both 96-hour DBP formation potential (DBPFPP) tests and 24-hour simulated distribution system (SDS) DBP tests were performed for trihalomethanes (THMs), haloacetonitriles (HANs), and haloacetic acids (HAAs). In addition to NOM-related parameters, each source water was characterized according to pH, bromide ion (Br\(^-\)), alkalinity, hardness, turbidity, organic nitrogen, and ammonia.

All sources were subjected to bench-scale evaluations of treatment processes capable of NOM removal or transformation. These processes included ozone oxidation, chemical coagulation, lime softening, and carbon adsorption. Two water sources were studied within the context of pilot-scale studies. Along with the assessment of NOM and its relationship to treatability, issues related to the biodegradability of NOM were addressed. Both bench-scale and pilot-scale evaluations were conducted to evaluate the impact of ozonation, alum coagulation, and GAC adsorption on biodegradable properties.
RESULTS
Significant source-related differences in NOM were observed among the various source waters. Less significant seasonal variations in NOM were measured, with more variation in amounts (i.e., concentrations) than in specific characteristics. Source waters contained comparable amounts of NOM in mid-AMW ranges (1,000 to 5,000 Daltons), with the relative dominance of NOM in lower-AMW (1,000 Daltons) and higher-AMW (5,000 Daltons) ranges varying from source to source. The humic fraction varied between 42 and 56 percent of the NOM in the various sources.

In raw and treated waters, lower-AMW NOM was slightly more reactive than higher-AMW NOM in forming some DBPs (THMs, HANs). The normalized chlorine (Cl2) demands (Cl2:DOC) of lower-AMW NOM and higher-AMW NOM were comparable. The nonhumic fraction was almost as reactive as the humic fraction in forming DBPs, and the normalized chlorine demands of the humic and nonhumic fractions were comparable. The fate of Br- through fractionation steps tended to obscure clear DBP trends with respect to the reactivity of NOM with chlorine.

Coagulation and softening can be used to target higher-AMW NOM (1,000 Daltons), humic NOM, and NOM of a relatively nonpolar and lower-acidity character, although DBP formation may vary from fraction to fraction. Use of ozonation alone for NOM oxidation is not realistic. Subsequent biological treatment, however, may provide an opportunity for removal of the biodegradable fraction of NOM. GAC adsorption may provide an opportunity to target problematical NOM fractions not amenable to control by coagulation or ozonation. Coupling of ozonation with GAC (i.e., biologically activated carbon) creates an increased opportunity for removal of biodegradable NOM. Because Br- is not removed by coagulation or adsorption, DBP control strategies based on NOM removal and transformation should concurrently address the fate of Br- through a treatment process.

NOM characterization of a raw or untreated water source can provide designers and operators with additional insight into treatment process selection and operation, and treated water characterization can confirm process performance. Therefore, a multitiered characterization scheme has been formulated as an aid to the water-industry users of the report: surrogate characterization (Tier 1), quantitative characterization (Tier 2), supplemental characterization (Tier 3), and research-oriented characterization (Tier 4).