Report for 2003ND28B: A Study of Microbial Regrowth Potential of Water in Fargo, North Dakota and Moorhead, Minnesota

- Other Publications:
    - Museus, T. and Khan, E. (2004) Microbial Regrowth Potential of Water in Fargo, North Dakota, and Moorhead, Minnesota. Presented at the Water Resources Management Workshop, March 24, 2004, Mandan, ND.
    - Museus, T. and Khan, E. (2004) Microbial Regrowth Potential of Water in Fargo, North Dakota, and Moorhead, Minnesota. Presented at the Water Resources Management Workshop, March 26, 2004, Devils Lake, ND.
    - Museus, T. and Khan, E. (2004) Microbial Regrowth Potential of Water in Fargo, North Dakota, and Moorhead, Minnesota. Poster presented at the Surface Water Treatment Workshop, April 27-29, 2004, Moorhead, MN. This presentation won first place in the student poster presentation competition

Report Follows

A STUDY OF MICROBIAL REGROWTH POTENTIAL OF WATER IN FARGO, NORTH DAKOTA AND MOORHEAD, MINNESOTA
(Full Renewal)

BACKGROUND

In recent years, water quality scientists and engineers have emphasized on the biodegradability of dissolved organic matter in both raw and treated waters. This is because the biodegradable organic matter (BOM) in treated water can induce the growth or regrowth of microorganisms in the distribution system of drinking water. Residual BOM is usually the most important limiting factor responsible for bacterial regrowth in the water distribution system (Rittmann and Snoeyink, 1984). One of the most effective methods in controlling the bacterial growth in the distribution system is to limit the amount of BOM required for the growth of heterotrophic bacteria in treated water (Servais *et al.*, 1993). Water containing BOM less than a minimum concentration that supports the bacterial growth is usually biologically stable.

BDOC has been used as one of the parameters for quantifying the amount of BOM in water. Servais *et al*. (1989) defined BDOC as the fraction of dissolved organic carbon (DOC) which can be metabolized by bacteria within a period of time. The BDOC test measures the reduction of DOC in a water sample, which is exposed to microorganisms in a period of time (Servais *et al.*, 1987 and 1989). The first BDOC measurement was introduced by Servais *et al*. (1987). It was developed as a batch procedure. A mixed microbial culture from the same environment as the sample was used as an inoculum. Incubation occurred in the dark at 20 ± 0.5°C for a period of 10 to 30 days, and the BDOC was determined by the difference between the initial and final DOCs.

The first BDOC procedure was used specifically for testing the quality of raw water and for designing and monitoring, and optimizing operating conditions of biological activated carbon (ozonation + granular activated carbon) systems. Occasionally, it was used to examine the BDOC removal of other treatment processes such as coagulation and filtration. Interest in BDOC of finished water started to grow when BDOC was linked to the microbial proliferation in the distribution systems. As a result, BDOC is a widely used parameter in the drinking water field.

An alternative to the BDOC procedure called AOC, was invented by van der Kooij *et al*. (1982). AOC is the portion of the organic carbon that can be synthesized to cellular material by a single bacterial strain. In the AOC determination method, a preheated water sample is seeded with a pure strain of *Pseudomonas fluorescens* P17. The sample is incubated at 15°C, and bacterial growth is monitored daily by colony counts (spread plate techniques) until the maximum growth is reached. The incubation period (the number of days to reach the maximum yield) can be from 3 to 30 days depending on the type of the water sample. By concurrently determining the growth yield of bacteria in solutions of known acetate concentration, the maximum growth can be converted into AOC and expressed as μg of acetate-C equivalents/L.

van der Kooij (1987) and van der Kooij *et al*. (1989) included a *Spirillum* strain, NOX, into the procedure as an alternative seed or a dual strain seed due to the inability of *Pseudomonas fluorescens* P17 to metabolize oxalic acid, which is one of the products frequently formed during ozonation. Unlike BDOC, AOC only accounts for the organic carbon used for cell synthesis.

Since the AOC test measures cell growth of a single or dual strain, the test does not guarantee that all the assimilable carbon is measured. The inoculum may not be capable of metabolizing all contaminants. Therefore, the reported AOC value is normally less than the reported BDOC value for the same sample. The AOC method has been widely adopted when the regrowth is a concern.

BDOC has also been related to the regrowth of microorganisms. High BDOC in finished water indicates poor quality and a potential of microbial multiplication. Maintaining a free chlorine residual to prevent the regrowth along the distribution system is a common solution; however, a large amount of chlorine is required. Also, chlorine residual cannot completely inactivate fixed bacteria (Le Chevallier *et al.*, 1988). Controlling microbial dynamics by limiting available substrate (BDOC) is a new and interesting approach (Rittmann and Snoeyink, 1984, Huck, 1990, and Servais *et al*., 1993). Biologically stable water should contain less than 0.15 mg of BDOC/L. At this threshold level, microbial growth is very limited (Servais *et al.*, 1993).

In order minimize AOC and BDOC in finished water, some water treatment plants employ biological filtration in their treatment trains. The biological filtration usually consists of ozonation and filtration. The purpose of ozonation is to destruct complex organic to simpler molecules which can be used by microorganisms in the filter. For some treatment plants, the ozonation portion of the biological filtration also serves as primary disinfection, and taste and odor control. Increases in BDOC and AOC after ozonation have been well documented (Janssens *et al.*, 1984, Servais *et al.,* 1987, and Volk *et al.*, 1993). The BDOC and AOC increases during ozonation are removed in the filter which contains media (activated carbon or sand) covered by attached microorganisms (biofilm).

DESCRIPTION OF THE CRITICAL STATE OR REGIONAL WATER PROBLEM

BDOC and AOC have been used to examine the regrowth potential of water throughout the world. Furthermore, AOC is included in the latest *Standard Methods* (1998). However, the regrowth potential of water in Fargo, North Dakota and Moorhead, Minnesota has never been evaluated; BDOC and AOC values of water in Fargo and Moorhead have not been reported. The ultimate goal is to minimize the concentrations of these two parameters in treated water provided by the Fargo and Moorhead water treatment plants which in turn will benefit public health by limiting the number of microorganisms in tap water. Collecting BDOC and AOC data is a first step to achieve the ultimate goal. The data will also indicate the degree of susceptibility of drinking water of Fargo and Moorhead to microbial proliferation.

It is crucial that BDOC and AOC of water in Fargo and Moorhead are studied because of the nature of high total organic concentrations in the influent and effluent and the use of ozonation at both treatment plants (Figure 1). BDOC and AOC tend to be high with these two conditions. The influent (from the Red River for the Fargo plant and the Red River blended with groundwater at 85%:15% for the Moorhead plant) and effluent total organic carbon (TOC) concentrations at both plants are sometimes as high as 8 to 10 mg/L and 1 to 2 mg/L, respectively. BDOC is a portion of total organic concentrations. Although water with high total organic concentrations does not necessarily contain large amounts of BDOC, positive linear relationships have been frequently observed between the two parameters (Servais *et al.*, 1987 and Khan *et al*. 1998b). As stated previously, ozonation of water with organics results in BDOC and AOC increases and their removal relies on the performance of subsequent treatment which normally is filtration. Currently, BDOC and AOC removal abilities of the filtration units at the Fargo and Moorhead plants are not known because the two parameters have not been measured.

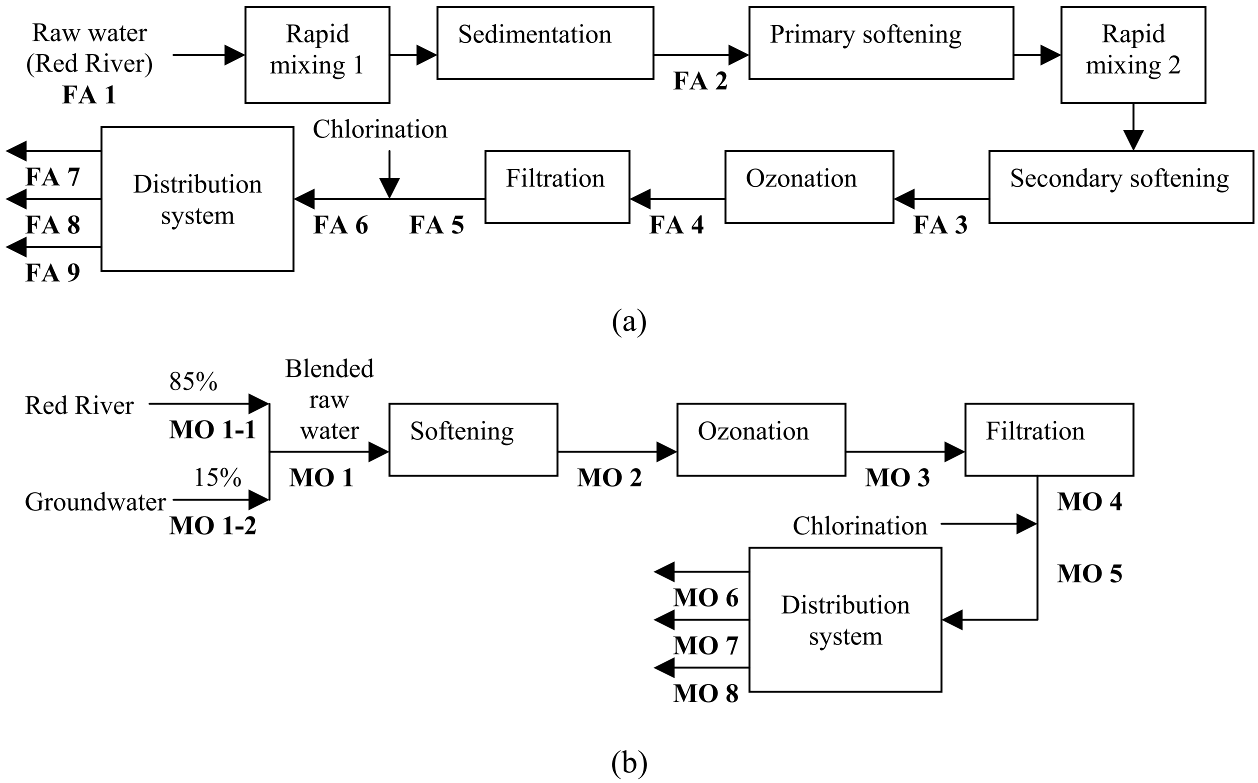

Figure 1 Simplified schematic diagrams for (a) the Fargo Water Treatment Plant and (b) the Moorhead Water Treatment Plant.

SCOPE OF STUDY AND OBJECTIVES

The main scope of this study is to collect BDOC and AOC data of water in Fargo and Moorhead in order to achieve the following objectives:

1) To evaluate the microbial regrowth potential of water especially finished water and tap water,
2) To predict the regrowth occurrence in the distribution systems by comparing AOC and BDOC in finished water and those in tap water, and
3) To compare BDOC and AOC removal of the Fargo and Moorhead plants which are different mainly in the presence and absence of the rapid mixing-sedimentation process.

METHODOLOGY

Sampling

Sampling began since November 1, 2003 and will continue until October 31, 2004. Samples are collected from one treatment plant and accompanying distribution system biweekly. The plants are alternated weekly. Sampling locations are listed in Table 1 and the samples are analyzed for AOC, BDOC, UV_{254}, TOC and pH.

Parameter tested

Each sample will be analyzed for pH, ultraviolet absorbance at 254 nm (UV_{254}), TOC, DOC, BDOC, and AOC. UV_{254} is used to relatively measure the amount of organic compounds that are aromatic in structure or have conjugated unsaturated bonds. It is known that a decrease in UV_{254} indicates less refractory organics (more BDOC).

Table 1 Sample identification and collection locations.

Fargo water systems		Moorhead water systems	
Sample no.	Sampling location	Sample no.	Sampling location
FA 1	Raw water (Red River)	MO 1	Blended raw water
FA 2	After sedimentation	MO 1-1	Raw water (Red River)
FA 3	After secondary softening	MO 1-2	Raw water (Groundwater)
FA 4	After ozonation	MO 2	After softening
FA 5	After filtration	MO 3	After ozonation
FA 6	After chlorination (treated water)	MO 4	After filtration
FA 7	Holiday Inn Hotel	MO 5	After chlorination (treated water)
FA 8	North Dakota State Universtiy	MO 6	Stop and Wash Convenience Store
FA 9	Hector International Airport	MO 7	Busch Agricultural Resources Inc.
		MO 8	Oasis Convenience Store

* Sample will only be collected when utilized as a source for raw water

Analyses

pH is measured using a pH meter (Orion model SA520). UV_{254} is determined following the procedure listed in *Standard Methods* (1998), using a spectrophotometer (Thermo Spectronics model Genesys 10 UV Scanning). TOC and DOC is analyzed according to the procedure described in *Standard Methods* (1998), using a TOC analyzer (Tekmar-Dohrmann model Phoenix 8000). For DOC analysis, the samples are filtered through a glass fiber filter (Whatman, GF/F) prior to TOC determination. BDOC is evaluated in accordance with a modified protocol by Khan *et al.* (1998a) which is simpler and more accurate than the original method (Servais *et al*., 1987). AOC is determined according to *Standard Methods* (1998).

FACILITIES, EQUIPMENT AND INSTRUMENTS

Facilities

This research will be conducted mainly in the Environmental Engineering laboratory facilities of the Department of Civil Engineering and Construction, North Dakota State University. The main laboratory facility occupies about 2,650 square feet of the second floor of the Civil and Industrial Engineering Building. An additional laboratory with an approximate area of 240 square feet is located on the first floor of the Engineering Technology Building. These two facilities have general apparatus (glassware) basic support services (gas, water, air, fume hoods, distilled and deionized water). Included in the main facility are offices for research assistants and storage spaces.

Laboratory equipment and instruments

The facilities contain most basic instruments and are well-equipped for conducting the proposed research. Examples of the basic instruments available are turbidimeters, pH meters, dissolved oxygen (DO) meters, ozone generators, a respirometer, phase contrast microscopes, conductivity meters, ion selective probes, vacuum pumps, ovens, furnaces, incubators, an autoclave, centrifuges, balances, refrigerators, water baths, cooling units, distillation and digestion systems for chemical oxygen demand (COD), nitrogen, and phosphorus analyses. Available major instruments in the main facility include a purge and trap gas chromatograph, with a mass selective detector (GC/MSD), two scanning UV-VIS spectrophotometers, and a TOC analyzer.

PROGRESS TO DATE

Literature review has been performed to learn background information about the topic. The background information that has been reviewed assisted in the experiment design and processes that need to be followed. Preliminary testing has been performed and results of the BDOC analysis can be seen in Figure 1 below. The preliminary AOC data are not available due to problems with the test method. The test method for AOC is very meticulous and leaves a lot or room for error and contamination. The problems that occurred have been corrected and I am confident that the results will be correct in the near future. The sampling and testing will continue until October 31, 2004. From October 31, 2004 to March of 2005 a thesis will be written and defended. In the original proposal sampling was to start on March 1, 2002, but was delayed due to my inexperience with test procedures and equipment that was required to complete each method. Also, more time was spent on practice testing and literature reviews than originally planned for.

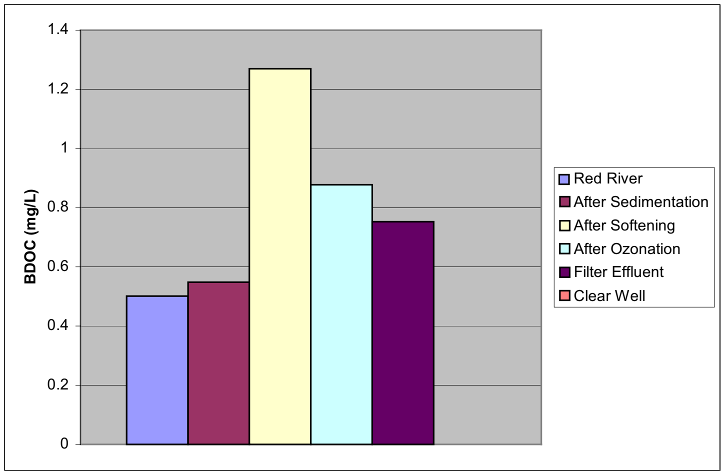

Figure 1: BDOC, Fargo Water Treatment Facility

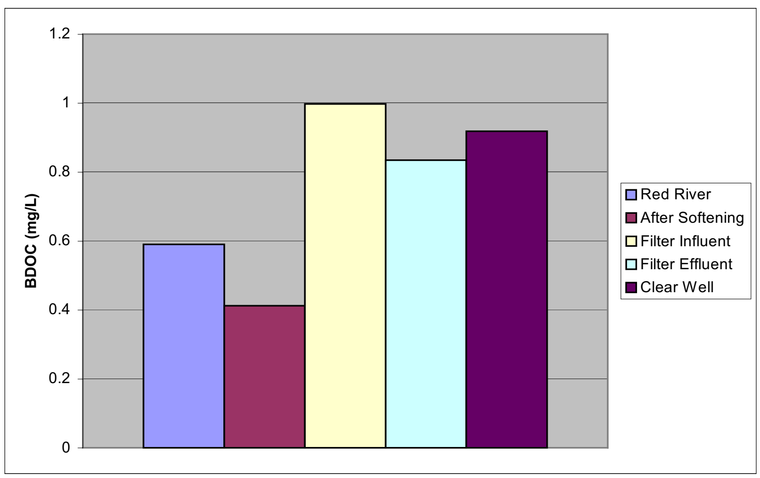

Figure 2: BDOC, Moorhead Water Treatment Facility

ANTICIPATED RESULTS AND BENEFITS ("DELIVERABLES")

This research will greatly benefit the water treatment facilities and public health because it will indicate how biologically stable the water in Fargo and Moorhead is. If the finished water produced by the Fargo and Moorhead plants has high regrowth potential (containing high BDOC and AOC), first it has to be known and then studied in more detail on strategies to minimize BDOC and AOC which will help to protect water consumers more from possible microbial contact that may cause adverse health effects. Furthermore, the results of this research will indicate whether blending the Red river water with groundwater as practiced at the Moorhead plant and the rapid mixing-sedimentation process used by the Fargo plant have any effect on BDOC and AOC in finished water.

In addition to the synopsis, abstract, and summary of progress, the findings on this project will be presented at a national or regional conference and will be submitted for publication in a peer review journal. The M.S. thesis generated from this research, which will also make available to public electronically on the internet, will contain all the information on the project including raw data and will serve as a final report.

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