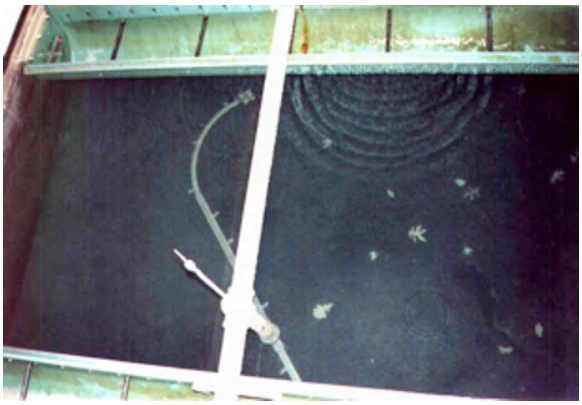
Removal of
Total Organic Carbon

A Technical Review

© 2004 Dr. John T. O'Connor

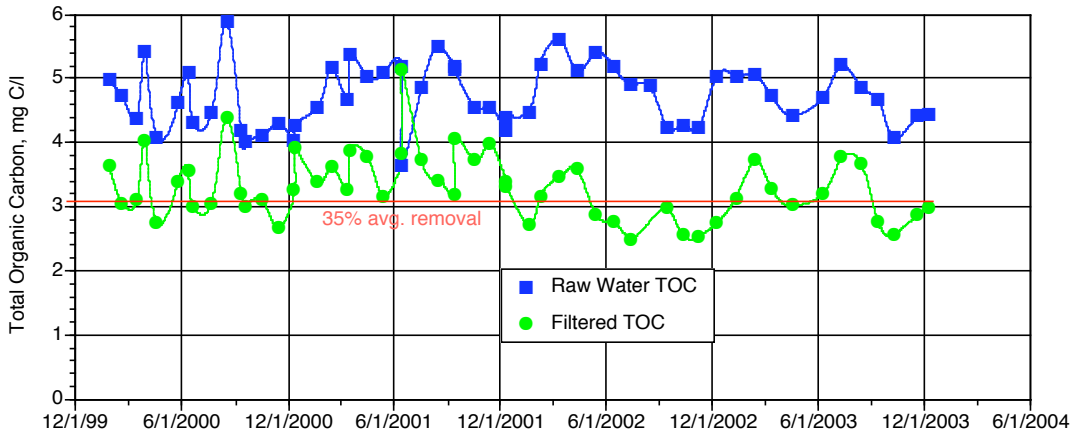


GAC-Capped Filter,Bloomington, Illinois

$H_2O'C$ Engineering
(877) 22-WATER
www.h2oc.com

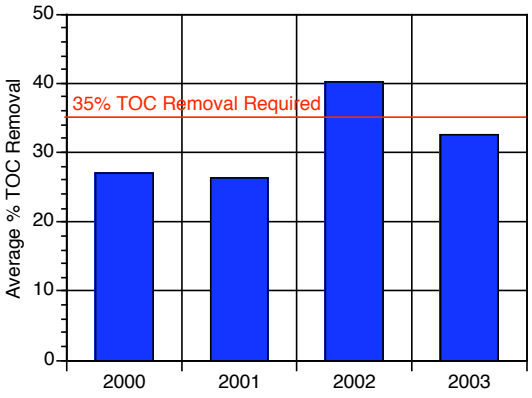
TOC Removal at Kirksville, Missouri

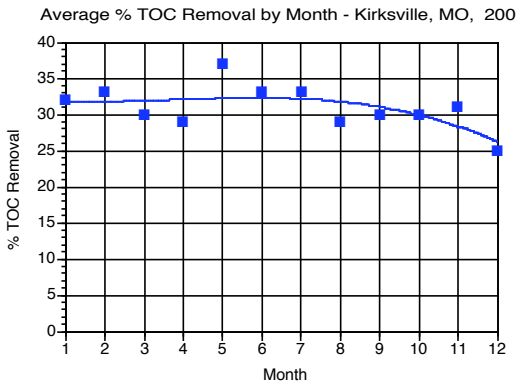
The MDNR has been monitoring Kirksville raw and finished water TOC monthly since January 2000. Over the four year period, 2000-2003, TOC removals averaged 31% whereas USEPA/MDNR require 35% removal for water with an average TOC of 4.73 mg C/l and an alkalinity of 96 mg $CaCO_3$ equivalent/l.



Average TOC removals at Kirksville have been found to vary each year. In 2002, average TOC removals exceeded 40% while, in 2003, removals declined to 32.5%. An incremental TOC removal of just 0.12 mg C/l would have allowed Kirksville to achieve compliance that year.

With the exception of December, a plot of four-year average % TOC removals by month shows little seasonal variation. This might indicate that high summer temperatures did not result in significant algal blooms or growths of microorganisms.





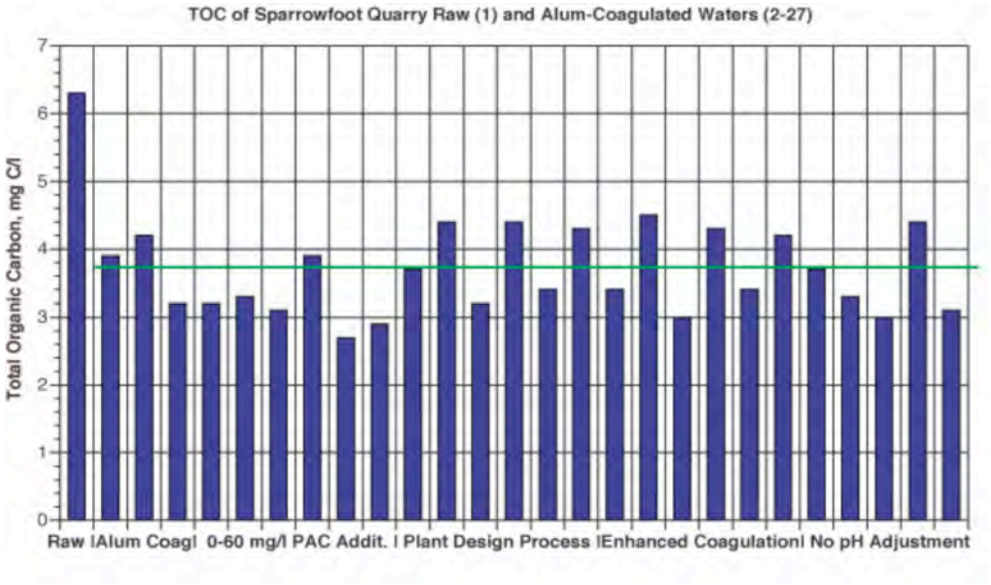
Despite the inability of its treatment process to consistently remove 35% of the influent TOC, Kirksville routinely meets the MCls for TTHM and HAA.

Case Study: Evaluation of Enhanced Coagulation at Clinton, Missouri (H_2O'C Engineering, 1997)

Prior to construction of a new water treatment plant at Clinton, MO in 1997, extensive, replicate studies of TOC removal were conducted to evaluate proposed alternative processes for the effective control of excessive DBP formation. Conventional alum coagulation (1) was compared with (2) alum plus powdered activated carbon (PAC), (3) the proposed plant design process and (4) enhanced coagulation. Finally, comparative tests were conducted where (5) no pH adjustment was made.

Both conventional alum coagulation (40 mg/l) and enhanced coagulation at pH 6.3 consistently removed approximately 40% of the source water TOC (6.3 mg C/l).. PAC additions to 60 mg/l increased TOC reductions to 50%. Particulate organic carbon was measured at 21%. The initial alkalinity of the Sparrowfoot Quarry water, 110 mg $CaCO_3$ equivalent/l, was reduced to 40 during 'enhanced' coagulation.

Enhanced coagulation did not offer any additional TOC reduction benefit compared with conventional coagulation.



Know your TOC! - Fractionation of TOC in Relation to Treatment

Although the effort, energy and resources being spent regulating TOC reduction and promoting enhanced coagulation is subject to debate, properly-directed assessments of the nature and reactions of TOC fractions in drinking water sources may lead to a better understanding of their relation to both health and aesthetic concerns. The following is a conceptual outline of procedures that a water utility could utilize to assess their water's DBP-forming response as a function of various conventional and advanced processes directed at TOC reduction.

Aeration for Removal of Purgeable Organic Carbon from Source Waters

Head-space-free sampling (no bubbles) allows for a rough analytical assessment of the potential removal of the more volatile constituents of the TOC. While at least one regulatory agency has required the aeration of a large lake water supply, no data is yet available as to its effect aeration has on either TOC concentrations or tastes-and-odors.

Newly Replaced Aerator at Morton, IL

GAC-Capped Sand Filter at Bloomington, IL

Physical Removal of Particulate Organic Carbon

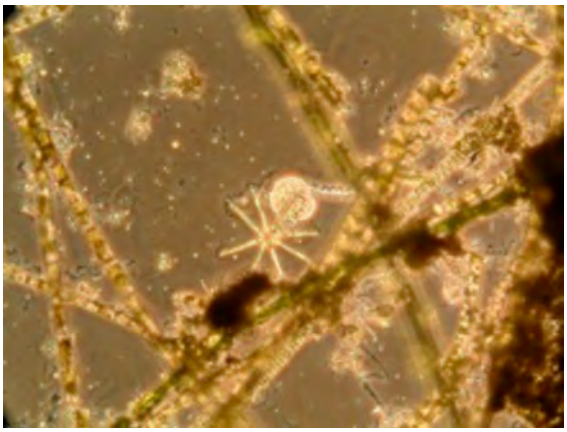
USEPA has cited separation of dissolved (or filtrable) organic carbon from particulate matter using 0.45 µm membranes. However, separations using membranes with smaller pore sizes may more accurately reflect the particle size removals that are actually being achieved by conventional coagulation and filtration. A sequence of membrane separations may indicate both the potential for further increasing particle removals and for reducing TOC by additional or enhanced coagulation.

Biotic Particles

Direct microscopic observation and enumeration of the particles present in source and finished waters can provide insight not currently available at most U.S. water treatment plants. Currently, monitoring of physical removal processes relies primarily on turbidity (light scattering), a measurement that offers no information on the type, size, shape or number of particles either removed or remaining following treatment.

Microscopic observation allows for a more comprehensive and quantitative assessment of the types and number of particles encountered in an individual water supply. For surface waters, this may vary widely on a seasonal basis. Since most surface waters contain 1 to 10 million bacterial cells per milliliter, the effectiveness of physical removal processes can be readily evaluated by direct enumeration of bacterial cells. These micrometer-sized, biotic particles are, in themselves, sources of organic carbon.

Epifluorescence Microscopy



Lake Water Algae and Bacteria

Sorption of Dissolved Organic Compounds

Following the removal of the particulate fraction, a series of jar and small column tests may be used to assess that fraction of dissolved organic carbon, remaining after physical treatment, that can be economically removed by adsorbents, such as powdered or granular activated carbon. Such a testing program would aid utilities in focussing on operationally and economically efficient treatment techniques that might be appropriate for removal of each fraction of the organic material present in their particular water source.

GAC and Sand Totes at Lake Bloomington

TOC Removal by Water Treatment Processes at the Bloomington Water Treatment Plant

An cold weather evaluation (31 January 2001) of the overall removal of total organic carbon (TOC) by the Bloomington water treatment plant processes showed that a 43 percent reduction was achieved. This reduction substantially exceeds the 25 percent TOC removal required under the provisions of the USEPA Long Term 1 Enhanced Surface Water Treatment Rule.

The following table shows that most of the TOC removal takes place during the softening process. This is, probably, the result of iron coagulation plus the entrainment of the particulate organic matter in calcium carbonate and magnesium hydroxide precipitates. As viewed under the microscope, much of the particulate organic matter present in the Lake water is in the form of algal and bacterial cells as well as organic debris, slime and detritus.

Despite the presence of a GAC cap on the filter, little additional removal of organic matter was evident following softening by precipitation with lime. The remaining dissolved portion of the organic matter, DOC, was not reduced significantly under these winter operating conditions.

Since the observed TOC removal processes appear highly effective at low influent water temperatures, comparable or better removals may be expected as water temperatures rise.

TOC Removal by Water Treatment Processes at Bloomington, IL

Sampling Point	TOC, mg C/l	Removal
Rapid Mix Basin	6.10	Influent
Claricone (5 mgd)	3.54	42 %
Claricone (7 mgd)	3.64	-
Recarb. - Influent	3.48	-
Recarb. - Middle	3.56	-
Recarb. - Effluent	3.49	-
Filter 13 - Influent	3.46	-
Filter 13 - Effluent	3.46	43 %