# Ozone Treatment of Small Water Systems

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# Regulatory Environment Impact on Small Systems

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## Abstract

*The 1996 US Congressional Reauthorization of the Safe Drinking Water Act directed the US EPA to develop regulations that would be applicable to the need of small communities as well as large urban populations. The Congress identified that most small municipal systems treating less than 1 million gallons per day (3.8 megaliter/day), defined as plants that serve less than 10,000 persons have particular challenges due to their size, technical and financial abilities that required special consideration.*

*This paper will report on EPA actions to assure the highest possible water quality to the public from large and small systems while taking into account the special needs of small communities. The Small Systems Compliance Technology Program for the Surface Water Treatment Rule (SWTR), the EPA Environmental Technology Verification (ETV) Packaged Drinking Water Treatment System Pilot project and the impact of the recent Disinfectants and Disinfection Byproducts Rule (D/DBP) will be discussed.*

**Introduction**

The year 1999 marks the 25th anniversary of the enactment of the United States of America Safe Drinking Water Act (SDWA). The SDWA and subsequent amendments (1986 and 1996) have had a significant impact on public health both in the USA and worldwide. The original SDWA charged the United States Environmental Protection Agency (US EPA) to develop and promulgate a number of regulatory initiatives. Subsequent SDWA amendments have carried additional regulatory mandates to the EPA, many of which encourage the use of ozone. The National Primary Drinking Water Rules (NPDWRs) and the establishment of Maximum Contaminant Levels (MCLs) and treatment technique (TT) requirements for specific substances in drinking water has also driven a revolution in treatment technology development, application and analysis.

The EPA lists approximately 171,000 water systems in the United States [1]. The majority of these (158,000) utilize ground water as their source water. These water systems are a combination of Community Water Systems (CWS), Non-Community Transient (NCT) and Non-Community Non-Transient (NCNT) operations. Ground water systems are made up of 44,000 (28%) CWS, 94,000 (60%) NCT and 20,000 (12%) NCNT systems with less than 50% of all ground water systems practicing disinfection.

The 1996 SDWA reauthorization stressed attention to the special needs of small community water systems where previous Rules development focused on large systems. Small drinking water systems are impacted by the December 1998 Disinfectants/ Disinfection By-Products Rule (D/DBP) which became effective 16 February 1999 and will be by the future enactment of the Long Term 1 Enhanced Surface Water Treatment Rule [12] (LT1ESWTR) addressing Cryptosporidium scheduled for November 2000.

**Background [2]**

One of the major regulations which resulted from the original SDWA, from the standpoint of ozone, was the so-called "THM Regulation", promulgated in 1979. This regulation requires large utilities to meet a MCL of 0.010 mg/L (100 µg/L) of the total of the four trihalomethanes (chloroform, chlorodibromomethane, bromodichloromethane, and bromoform).

Prior to promulgation of the THM Regulation in 1979, the U.S. EPA had surveyed waters produced at 80 U.S. water utilities, sampling their finished waters and analyzing for the four THMs. Only two (2) of the surveyed plants used ozone as part of the treatment process. The National Organics Reconnaissance Survey (the NORS) showed THMs levels found at the two ozone plants were the lowest of the other 78 plants. These results, as might be expected, were of great interest to the EPA.

It was then up to the USA to learn from the rest of the world where ozone had been embraced for decades. The result was two EPA sponsored project surveys of selected European and Canadian drinking water treatment plants [3,4]. The surveys reviewed the use of chlorine alternatives, such as chlorine dioxide and ozone as well as other treatment processes. It was during the initial European plant survey project that the survey team observed the process combination of ozonation followed by sand filtration then filtration through granular activated carbon (GAC) before addition of residual disinfectant.

The examination of the European combined ozone and GAC process revealed that, during ozonation, some of the biorefractory organics are converted to more biodegradable materials by chemical oxidation [5]. When these now more readily biodegradable organic molecules pass through the GAC columns, they encounter natural microorganisms, which develop and thrive in GAC in the absence of a residual disinfectant (chlorine, chlorine dioxide, or chloramine). These aerobic microorganisms are capable of rapidly mineralizing the biodegradable organics, converting them to carbon dioxide and water in a few minutes of empty bed contact time (5-10 min EBCT).

This particular combination of ozonation followed by GAC filtration was termed Biological Activated Carbon (BAC). By such water treatment combinations of ozone and biofiltration, Europeans were found to be lowering the levels of THM precursors prior to the addition of a residual disinfectant. This observation of the ozone/BAC process benefit and EPA attention caused the US water treatment industry to focus on ozone and chlorine dioxide as oxidants and disinfectants.

With the SDWA Amendments of 1986, EPA notified the water industry that it would be regulating three new microorganisms present in surface waters, Giardia lamblia cysts, enteric viruses, and Legionella bacteria. In addition, the Standard Plate Count microorganism group underwent a name change to Heterotrophic Plate Count (HPC).

The resultant Surface Water Treatment Rule (SWTR) [6], required all systems treating surface waters or ground waters under the direct influence of surface water serving greater than 10,000 persons to demonstrate the ability to attain ***primary disinfection*** of these new microorganisms (primary meaning in the treatment plant). Coincidentally, the term ***secondary disinfection*** was introduced which applied to treated waters in distribution systems.

EPA developed the "CT" concept, which is the arithmetic product of the residual concentration (C, in mg/L) of a disinfectant multiplied by the time (T, in minutes) that the disinfectant is in contact with the water. As long as the product of C x T equals or exceeds a specific number set by the agency for the *Giardia* cysts, the inactivation of a certain percentage of these microorganisms which might be present in the waters being disinfected would be ensured.

Each microorganism specified in the SWTR and its Guidance Manual [7] has a specific set of CT values, which also are a function of pH (particularly for chlorine), and temperature. The lower the required CT value, the more effective is the specific disinfectant, meaning that a specific level of microorganism inactivation can be guaranteed with lower concentrations and/or shorter contact times for the more effective disinfectants. EPA also presented the disinfecting efficiency of any disinfectant in terms of logarithms of microorganism inactivation, or log-inactivation.

Taken by itself, the fact that ozone has the lowest CT values for inactivating Giardia cysts and also enteric viruses, was considerable encouragement for ozone as a result of promulgation (in 1991) of the SWTR.

However, even more encouragement to consider ozone came from EPA during the development of the SWTR. The agency warned those utilities who might seek to attain the higher CT values required for inactivating Giardia cysts and viruses by simply adding additional chlorine and/or additional chlorine contact time. A Disinfectants/Disinfection By-Products (D/DBP) rule was being developed, and halogenated organics would be the primary target of this future regulation. Consequently, even though the primary disinfection requirements of the SWTR certainly can be met by increased use of chlorine, most utilities choosing this approach probably would not be able to meet the requirements of the impending D/DBP rule. Additionally, concerns with haloacetic acids and bromate ion were beginning to surface.

During this period of rapid regulatory change, Cryptosporidium parvum was identified as a potentially more hazardous cyst organism after several high visibility outbreaks. Cryptosporidium parvum represented another dichotomy for the water industry and drinking water regulators. This cyst organism is difficult to remove by filtration because of its small size (~5-µm) and is so resistant to chemical disinfectants that chlorine and chloramine have essentially *no effect* on it. Only chlorine dioxide and ozone have been proven to be effective as individual chemical inactivation of C. parvum.

The effectiveness of ozone on G. lamblia and *C.* parvum did not however shield it from regulatory scrutiny. It was discovered that, at the significantly higher CT levels than required to inactivate C. parvum, ozone has a high potential for bromate ion formation in drinking waters containing bromide ion. The more ozone that must be added over a longer contact period, the more bromate ion formation can be expected, assuming the presence of bromide ion in the original water to be treated.

EPA recognized the D/DBP rule could not be developed and promulgated separately from a revised microbial rule, the Enhanced Surface Water Treatment Rule (ESWTR) which would address, among other items, control of *C.* parvum. EPA could not take the chance of promulgating a D/DBP rule, which might cause some utilities to compromise on disinfection in order to ensure meeting new by-product MCLs.

On 16 February 1999 both the D/DBP and Interim Enhanced Surface Water Treatment (IESWTR) Rules went into effect with specific compliance dates identified for each rule. EPA promulgated both these rule armed with this advice and consensus of the Reg-Neg stakeholders committee. The International Ozone Association (IOA) had a seat at the table in this breakthrough government/stakeholder rule development process partnership.

## SMALL WATER TREATMENT SYSTEMS

### Definitions

In the United States, the U.S. EPA has defined small water treatment systems as those serving fewer than 10,000 persons. This represents a maximum daily water production of about 1 million gallons (1 mgd) based on average use of 100 gallons per day per person. EPA further subcategorizes water plants into those serving 25-500, 501 to 3,300 and 3,301 to 10,000 persons to better define financial operation and maintenance capabilities.

It is also important to recognize that the U.S. EPA regulates water systems down to those serving 25 or more persons, or systems with 15 or more service connections. Individual homes, or clusters of a few homes serving fewer persons or service connections, are not regulated by the EPA but may be regulated by the individual states. Washington State, for example, considers any installation of two or more homes (except for some farms) taking water from the same source to be a public water purveyor and subject to regulation. In addition, transient facilities, such as “Bed and Breakfast” lodgings or camps and parks are regulated in the same manner as larger community systems, even if the operation involves only one building.

**Figure 1** shows the rate of growth of ozone in U.S. water treatment plants since 1980 through April 1998. The first water treatment plant to utilize ozone continuously in the USA was installed in 1940 in Whiting, Indiana. In 1972, the second plant was installed in Strasburg, Pennsylvania. By 1980, only about 10 U.S. water treatment plants were known to be using ozone.  However, thanks to the Safe Drinking Water Act Amendments of 1986 and subsequent events, interest in ozone treatment of drinking water in the USA began to climb.  As of December 1998, some 264 water plants in the USA were known to be using ozone.

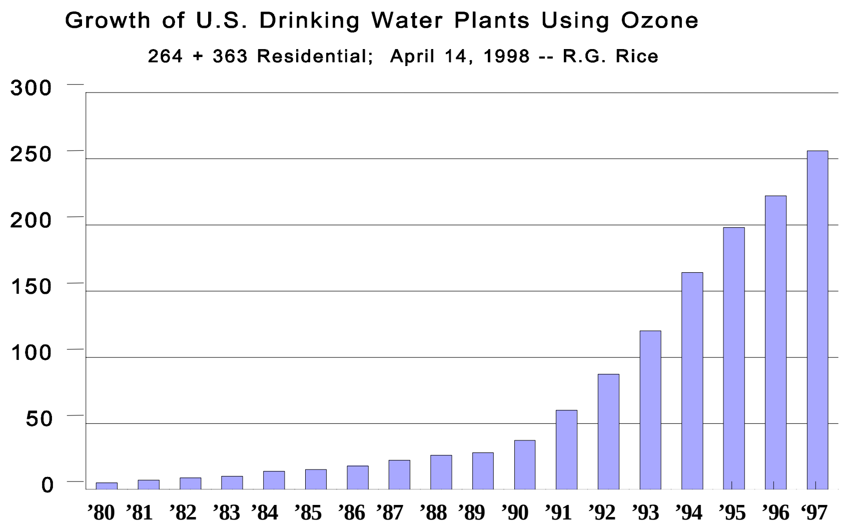
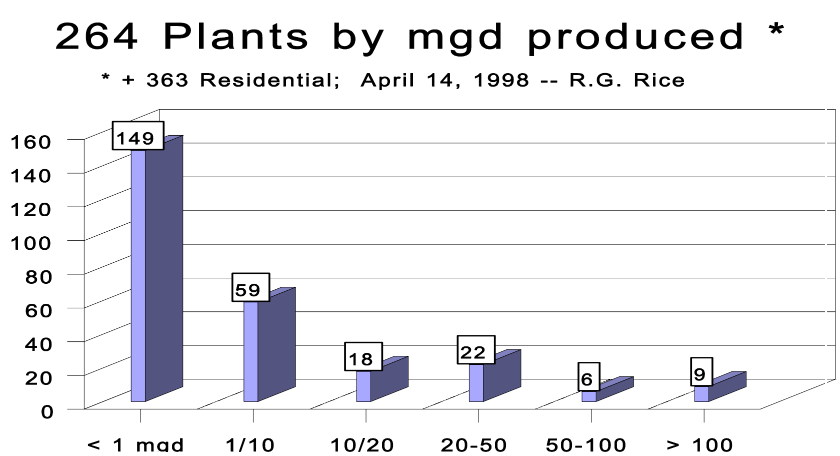



Figure 1. Growth of U.S. drinking water plants using ozone. [2]

In **Figure 2**, the 264 operating water plants are broken down by size, in terms of mgd of water production.  Of interest is the fact that 149 of these plants – well over half – produce less than 1 mgd (e.g., serve fewer than 10,000 persons).  These fact alone makes it clear that ozone is not just for big water systems and ozone must be affordable for small systems.

Figure 2. 264 ozone plants by MGD of water produced. [2]




**Ozone Applications in Small Water Systems**

Since over half of the plants using ozone are small, many are using ozone to treat groundwaters. In these instances, ozone is used primarily for disinfection (bacteria and viruses) and for oxidation of such typical groundwater contaminants as iron, manganese, sulfide and nitrite ions and sometimes color. Most of the much larger water plants using ozone treat surface waters and apply ozone for primary disinfection (Cryptosporidium, Giardia and virus inactivation), for oxidation of iron, manganese, taste and odor, color, for coagulation assistance, and for lowering levels of disinfection by-product (DBP) precursors. The current trend is for small community systems to use ozone for the same purposes as the larger plants.

**Current EPA Regulatory Impact on Small Systems**

**Compliance Technology Program**

The Safe Drinking Water Act Amendments of 1996 included three statutory deadlines to identify small system treatment technologies that could meet the water quality requirements of existing drinking water regulations. In August 1997, EPA issued a list of compliance technologies for the Surface Water Treatment Rule [8]. In August 1998, EPA published a list of compliance technologies for all the other pre-1996 National Primary Drinking Water Rules [9] (NPDWRs). Also in 1998, EPA released a list of variance technologies and a guidance manual titled, "Variance Technology Findings for Contaminants Regulated Before 1996.

Small system affordability, operational capability and process performance where key concerns voiced by Congress to EPA with the 1996 SDWA reauthorization. A compliance technology is one that is affordable and or achieves either the MCL or treatment technique requirement, (point-of-entry, point-of-use or modular systems treatment units). Variance technologies may be approved for use in specific instances where there are no approved compliance technologies. A variance technology may not achieve the MCL or TT compliance; they must achieve a minimum reduction efficiency that is affordable to assure a level of contaminant reduction that is protective of public health (POPH).

These POPH levels will be based on Unreasonable Risk to Health (URTH) criteria for short-term (7 year) Vs the MCL (70 year) exposure. EPA's approval of variance technologies or systems to a POPH level for a specific small system is an interim step to having the small system meet the MCLs and is only available for five specific contaminants.

Ozone was listed in 1997 as a compliance technology for primary disinfection requirements of the SWTR. Ozone was also listed as a compliance technology in the 1998 for certain other pre-1996 National Primary Drinking Water Rules (NPDWRs). This primarily covered the inclusion of ozone with chlorine as a best available technology (BAT) for inorganic oxidation. Work still must be done before ozone will be listed as a BAT for SOC and VOC contaminants. EPA intends to update each Variance Technology list annually.

**Disinfectants/Disinfection By-products Rule[10]**

While small systems had been included under the broad reach of the SDWA, only large systems providing water to greater than 10,000 people were included under the 1979 THM Regulation. It was not until 1998 and the promulgation of the D/DBP Rule that most small systems had to pay attention to THMs which the larger water systems had to be in compliance with 1982. In December 1998, Stage 1 of the D/DBP Rule, EPA lowered the TTHM standard, added total haloacetic acids, bromate ion, etc., and now apply them and specific microorganisms to the lists of substances to be regulated for small systems (less than 10,000 population). Cryptosporidium is not included for small systems with this rule but will be with the promulgation of the Long Term 1 SWTR due November 2000.

EPA estimates that 140 million people will have increased protection under the D/DBP Rule. The EPA is rolling out the D/DBP Rule in two stages. In both stages, MCLs are to be set for the four trihalomethanes (THMs), six haloacetic acids, for bromate ion, and for chlorite ion (a by-product of chlorine dioxide use). In addition, maximum residual levels (MRLs) for chlorine, chlorine dioxide and chloramine are established. There will be no MRL for ozone, because it will not be present in finished drinking water as it leaves the treatment plant, due to its short half-life.

MCLs to be attained for all water treatment systems for the by-products listed in the D/DBP rule are as follows:

| | Stage 1 | Stage 2 |
|---|---|---|
| Total THMs (TTHMs) | 80 µg/L | 40 µg/L |
| Total of 6 haloacetic acids (THAAs) | 60 µg/L | 30 µg/L |
| Bromate Ion | 10µg/L | to be determined |

The current European Community (EC) Bromate ion limit is set at 25 mg/L.

Stage 2 MCLs are currently under negotiation during a Reg-Neg 2 process, which began organizationally in December 1998 and is schedule for promulgation in May 2002. The Reg-Neg process will depend on data collected under the Information Collection Rule (ICR) and on-going public and private sector research. This paper assumes that the Stage 2 MCLs for TTHMs and THAAs are 50% of Stage 1 based on EPA comments.

With the promulgation of the D/DBP rule, EPA estimated that as many as 3,615 small surface water systems and 8,324 small ground water systems would be affected and that ozone was a potential treatment technology. EPA developed National cost estimates for identified potential treatment techniques, and included these in the 16 December 1998 Federal Register announcement of the D/DBP Rule.

The costs appointed to small ozone treatment systems are viewed as overly conservative and unrepresentative of actual costs. The IOA PAG and Water Quality Association

(WQA) have ozone committees working together to survey existing installations to provide more accurate information to the EPA to support small system education.

**Environmental Technology Verification Program[11]**

EPA initiated the Environmental Technology Verification (ETV) Program to support development, understanding and appropriate use of packaged water treatment technologies for small systems. This program is designed to expedite acceptance at both the federal and state level of new and innovative technologies to meet current and future regulation.

EPA contracted NSF International to manage the program, which will develop specific test protocals, approve test plans and qualify Field Testing Organizations (FTO) for verification of packaged plant performance. EPA ETV packaged plant performance verification will present confirmation of manufacturers product performance claims under specified conditions. Individual states can use this performance verification report to determine whether the technology will be approved for use with or without additional onsite testing. This should reduce time to market for new treatment processes or packaged systems that will benefit the small systems market.

EPA also has made matching funding available under the current ETV program ending 30 June 1999. A manufacturer can be reimbursed 75% of the test expenses, up to $100,000 for an approved test program. This dramatically lowers the investment hurdle that manufacturers face in gaining new technology acceptance. In the case of ozone inactivation of Cryptosporidium, these matching funds would go a long way toward covering testing and in particular animal infectivity studies.

The ETV Program has developed Microbial Inactivation and SOC protocols where ozone and or advanced oxidation processes would be tested. IOA PAG members provided comment on the draft protocols. Final protocols should be published in June 1999.

**Conclusions**

- Regulatory activities are driving change in the drinking water industry to provide added protection to the public health.
- Ozone has been identified and listed as an affordable, compliance technology for surface water disinfection and specific oxidation applications.
- The D/DBP Rule has raised concerns with potential creation of bromate ion in systems utilizing ozone in the treatment process.
- The EPA Environmental Technology Verification program was created to verify product performance that will assist in the development and acceptance of packaged water treatment systems which can include ozone for disinfection and SOC reduction.
- The IOA PAG and Water Quality Association will work together to gather additional installation and operating ozone plant survey data to support EPA regulatory development.

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**Key Word**

**Regulation, Ozone, EPA, Drinking Water, Disinfectants and Disinfection Byproducts, Environmental Technology Verification Program, Enhanced Surface Water Treatment, Compliance Technology**