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Small System Compliance Technology List for the Surface Water Treatment Rule and Total Coliform Rule

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1. INTRODUCTION

Section 1.1: Safe Drinking Water Act Implementation

The Safe Drinking Water Act (SDWA) Amendments were signed by the President on August 6, 1996. There are over 70 statutory deadlines in the 1996 SDWA for the Environmental Protection Agency (EPA). The Amendments contain a challenging set of activities for EPA, States, Indian tribes, public water systems, and other stakeholders.

Due to the 1996 SDWA Amendments' emphasis on public information and participation, as well as EPA's desire to seek a broad range of public input, the stakeholder process that was begun during the 1995 drinking water program redirection effort has been greatly expanded. Many of the 70 statutory deadlines have been grouped into twelve project areas. Each of these areas has a broad set of stakeholders that will provide information and comments. In addition to the stakeholders' participation, the National Drinking Water Advisory Council (NDWAC) has formed working groups to address several of the relevant issues. These working groups make recommendations to the full Council, which in turn advises EPA on individual regulations, guidances, and policy matters.

One of the twelve project areas created by the 1996 SDWA is being addressed by EPA's Treatment Technology Team. The mission of the Treatment Technology Team is to identify and/or develop high quality, cost-effective treatment technologies to meet regulation development and program implementation objectives and deadlines. Short-term goals of this team were to prepare: (1) the list of technologies that small systems can use to comply with the Surface Water Treatment Rule (SWTR), completed August 6, 1997; (2) the list of technologies that small systems can use to comply with all of the other National Primary Drinking Water Regulations (NPDWRs), by August 6, 1998; and (3) the list of variance technologies for small systems for the appropriate NPDWRs, by August 6, 1998. Longer-term goals include the identification of: (1) small system compliance and variance technologies for all future regulations; (2) best available technologies (BATs) for larger systems in future regulations; and (3) emerging technologies that should be evaluated as potential compliance or variance technologies for both existing and future regulations. This document relates to the updating of the SWTR and the listing of Total Coliform Rule (TCR) small system compliance technologies. These have been grouped into one publication as they both address microbial contaminants and their indicators in drinking water.

Section 1.2: Small System Technology Definitions

The earlier 1986 SDWA Amendments identified a process for setting maximum contaminant levels (MCLs) as close to the maximum contaminant level goal (MCLG) as is "feasible." The Act states that "... the term "feasible" means feasible with the use of the best technology, treatment techniques and other means which the Administrator finds, after examination for efficacy under field conditions and not solely under laboratory conditions, are available (taking cost into consideration)" [Section 1412(b)(4)(D)]. The technologies that met this feasibility criterion are called "best available technologies" (BATs) and are listed in the final regulations. This process is retained in the amended 1996 SDWA.

The Surface Water Treatment Rule (SWTR) requires compliance with a treatment technique rather than an MCL. Section 1412(b)(7)(A) of the 1986 SDWA listed the conditions under which a treatment technique could be promulgated in lieu of an MCL. When these conditions are met, the Act states that ". . . the Administrator must identify those treatment techniques which, in the Administrator's judgement, would prevent known or anticipated adverse effects on the health of persons to the extent feasible". The TCR, promulgated in 1989, requires compliance with an MCL and specifies treatments and other means for water system compliance.

Before the 1996 SDWA Amendments, cost assessments for the treatment technology feasibility determinations were based upon impacts to regional and large metropolitan water systems. This protocol was established when the SDWA was originally enacted in 1974 [H.R. Rep. No. 93-1185 at 18(1974)] and was carried over when the Act was amended in 1986 [132 Cong. Rec. S6287 (May 21, 1986)]. The service population size categories that EPA has used to make feasibility determinations for regional and large metropolitan water systems has varied among different regulation packages. The most common population size categories used were 50,000 - 75,000 people and 100,000 - 500,000 people. The technical demands and costs associated with technologies that are feasible based on regional and large metropolitan water systems often make these technologies inappropriate for small systems. The 1996 SDWA Amendments attempt to redress this problem in part through the previously described series of small system compliance technologies. This guidance is the part of a series of publications (begun in 1997 for the SWTR) aimed at helping small systems comply with drinking water standards.

Section 1.3: Small System Treatment Technology Requirements

Since large systems were previously used as the basis for all feasibility determinations, the existing BATs for MCL compliance and the treatment techniques require further analysis for small system applications. The 1996 SDWA Amendments specifically require EPA to make technology assessments relevant to the three categories of small systems for both existing regulations (e.g., SWTR and TCR) and future requirements. The three population-based size categories of small systems thus defined are: 10,000 - 3,301 persons, 3,300 - 501 persons, and 500 - 25 persons.

The 1996 SDWA Amendments identify two classes of technologies for small systems: compliance technologies and variance technologies. A "compliance technology" may refer to both a technology or other means that is affordable and that achieves compliance with the MCL and to a technology or other means that satisfies a treatment technique requirement. Possible compliance technologies include packaged or modular systems and point-of-entry (POE) or point-of-use (POU) treatment units [see Section 1412(b)(4)(E)(ii)]. Variance technologies are only specified for those system size/source water quality combinations for which there are no listed compliance technologies [Section 1412(b)(15)(A)]. Thus, the listing of a compliance technology for a size category/source water combination prohibits the listing of variance technologies for that combination. While variance technologies may not achieve compliance with the MCL or treatment technique requirement, they must achieve the maximum reduction or inactivation efficiency that is affordable considering the size of the system and the quality of the source water. Variance technologies must also achieve a level of contaminant reduction that is protective of public health [Section 1412(b)(15)(B)].

The variance procedure for small systems was significantly revised in 1996. Under the 1986 SDWA Amendments systems were required to install a technology before applying for a variance; if they were unable to meet the MCL, they could then apply for a variance. The 1996 Amendments have given the variance option additional flexibility in that variances can be applied for and granted *before* the variance technology is installed, thus ensuring that the system will have a variance before it invests in treatment. Under the 1996 Amendments there is a new procedure available for small systems (systems serving fewer than 10,000): the "small system variance". The difference between a regular variance and a small system variance is the basis for the feasibility (technical and affordability) determination. For the former, large systems are the basis; for the latter, small systems are the basis. If there are no affordable compliance technologies listed by the EPA for a small system size category/source water quality combination, then the system may apply for a small system variance. One of the criteria for obtaining a small system variance is that the system must install a variance technology listed for that size category/source water quality combination [Section 1415(e)(2)(A)]. A small system variance may only be obtained if alternate source, treatment, and restructuring options are unaffordable at the system-level.

There are additional SDWA requirements that affect the listing of variance technologies. Critical in regard to this particular listing are the following: (1) small system variances are not available for any MCL or treatment technique for a contaminant with respect to which a national primary drinking water regulation was promulgated prior to January 1, 1986 [Section 1415(e)(6)(A)]; and, (2) small system variances are not available for regulations addressing microbiological contamination (including contamination by bacteria, viruses, or other organisms) or any indicator or treatment technique for a microbial contaminant [Section 1415(e)(6)(B)]. Therefore, there are **no** variances or variance technologies available for the SWTR and TCR.

In addition, since the SWTR and TCR address microbial contamination, the affordability criteria discussed under the EPA/SDWA affordability project do not apply. For the SWTR and TCR the only screening criterion beyond treatment efficacy will be the ability of small water systems to install and reliably operate the process.

The flow chart in **Figure 1** depicts how the compliance technology and exemption processes may be utilized in decision-making under the SWTR and TCR drinking water regulations.

Insert Fig. 1
(Not available in electronic format)

Section 1.4: Format of the Small System Compliance Technology List for the SWTR and TCR

The 1996 SDWA Amendments do not specify the format for the compliance technology lists. Section 1412(b)(15)(D) states that the variance technology lists can be issued either through guidance or regulations. EPA believes that the compliance technology list may also be appropriately provided through guidance rather than through rule-making. Since the listing provided in this guidance is meant to be informational and interpretative, it does not require any changes to existing rules or the promulgation of new ones. The purpose of this guidance is to provide small systems with information concerning the types of technologies that can be used to comply with the SWTR and TCR requirements; it does not over-ride any of the regulatory requirements.

Both the SWTR and TCR were published in the Federal Register on June 29, 1989. Even though many systems have already installed treatment, there are systems that still need to select a treatment technology to comply with the SWTR and/or the TCR. The importance of meeting the deadlines set forth under the rules further justifies EPA's decision to issue this compliance technology list as guidance.

In summary, EPA has chosen to issue the list through a guidance document because regulation development is unnecessary and could considerably delay publication of the list and/or subsequent updates. Issuing a list in this fashion will allow EPA to provide information to more small systems and regulators in a timely manner as they make treatment technology decisions.

Section 1.5: Content of the Updated Small System Compliance Technology List for the SWTR and TCR

The SDWA does not specify the content of the compliance technology lists. This listing provides greater detail than earlier listings, on the capabilities, applicability ranges, water quality concerns, and operational and maintenance requirements for the identified compliance technologies. This listing also includes, in summary format, tabulations (at end of Chapters 2 and 3) which include details on issues identified by EPA and its stakeholders in their review of draft materials.

Technologies with which the reader may be less familiar are included in the listing, and these are given greater coverage; there are other technologies discussed in Chapter 4 as "emerging" technologies, that is those technologies which indicate a likelihood of success in meeting the specific treatment goals and which require further evaluation. The listing will evolve and be issued annually or as required. The listing will not be product-specific because EPA's Office of Ground Water and Drinking Water does not have the resources to review each product for each potential application and since this would be beyond EPA's purview. Information on specific products may be available through other mechanisms:

(1) EPA's Office of Research and Development and the National Sanitation Foundation (NSF) International are conducting a pilot project under the Environmental Technology Verification (ETV) Program designed to provide treatment purchasers with performance data from independent third

party organizations. The EPA and NSF are cooperatively conducting this project to provide the mechanism for "verification testing" of packaged drinking water treatment systems. This pilot project includes: development of verification protocols and test plans; independent testing and validation of packaged equipment; partnerships among test/verification entities to obtain credible cost and performance data; and preparation of product verification reports for wide-spread distribution. It will be through the distribution of this data by which EPA expects the greatest amount of performance information sharing, leading to efficient and effective technology applications to meet safe drinking water goals. (For more information on this project consult the NSF-ETV Web site http://www.nsf.org/verification/verification.html)

(2) The National Drinking Water Clearinghouse, at West Virginia University, has developed the RESULTS database. RESULTS was designed as an electronic means to access data on small water treatment systems employing both conventional and non-conventional treatment technologies. Information and on-site contacts may be obtained on these treatment applications. (Clearinghouse: phone (304)293-4191, or Web site http://www.ndwc.wvu.edu)

Finally, it is likely that this SWTR and TCR listing may in future years develop in tandem with or eventually merge with the long-term enhanced surface water treatment requirements (LTESWTR). Obviously, as EPA develops information on technologies applicable to small public water systems for microbial control under the SWTR and LTESWTR these efforts may completely merge.

Section 1.6: Stakeholder Involvement

EPA held stakeholder meetings in Washington, D.C., on July 22 and 23, 1997, and May 18 and 19, 1998. Stakeholders at the meetings included representatives of States, public water systems, trade associations, and equipment manufacturers. At the 1998 meeting the proposed draft 1998 listings for SWTR and TCR were presented to stakeholders. Stakeholders were asked to consider the revised compliance technology information, and to provide comments.

Section 1.7: Key Stakeholder Input

The May 18-19, 1998 SWTR/TCR stakeholder discussions centered on EPA's tabulation of listed and "emerging" technologies for the SWTR, and to a lesser extent on TCR technologies. EPA tables provided detailed information on the following technology-specific subject areas: treatment efficacy, including ranges of microbial inactivation; treatment complexity and operator skill levels required; byproducts formed (both chemical and physical byproducts of treatment); raw water quality concerns; and other important limitations of the listed treatments. Stakeholder discussions were very fruitful and resulted in several proposed changes to EPA's draft listing:

- Stakeholders suggested that EPA group several technologies into the "advanced oxidation" heading; and, that modifications to traditional ultraviolet radiation be grouped together as "advanced ultraviolet" treatment. Both groups are considered emerging treatments for small drinking water systems. [Stakeholders generally agreed with EPA that the abovereferenced treatment groups should still be considered "emerging" due to significant gaps in information: such as the the lack of availability of treatment efficacy data and/or operational data in a small systems or drinking water setting. It was also noted that the above-cited EPA/NSF verification program may provide results on the testing of some of the disinfection technologies later in the year, and that results may be available prior to the next listing for the subject microbial regulations.

- EPA was advised to note (in guidance) that bag filters should be handled carefully due to the fragility of the materials, and that seals on cartridge filters can damage and require special attention.
- EPA was advised that in reference to bag and cartridge filtration it would not be advisable to specify maximum raw water turbidity levels (i.e., the 2 to 3 NTU cited). Such limits may be more a function of pretreatment and system economy, and that levels up to 10- 30 NTU have been treated successfully.
- EPA was advised as to the use of ozonation at many small systems in the U.S. and that the International Ozone Association has recently compiled and presented operational case study data (copies of a tabulated listing and presentation by R. Rice at the May 1998 NSF/WHO/PAHO Small Systems Symposium were provided); however, it is generally believed that "advanced" combinations involving ozone have yet to be demonstrated or even practical for small supplies; ozone representatives also pointed out that previously cited cleaning problems have been largely overcome in the past 5 years due to use of pure oxygen feeds (in lieu of air feed) to newer ozone generators.
- It was generally agreed by the participants that an annual update to the SWTR listing of technologies would be appropriate in order to capture any developments in the treatment technology field.
- Relative to the proposed TCR listing of compliance technologies, no specific changes or sustantive comments were received.

EPA received and reviewed additional information from other sources who were not present at the stakeholder meeting, and these are cited as needed within Chapter 2 technology discussions.

Section 1.8: Organization of the Document

This guidance document is organized into chapters describing the small systems compliance treatment technologies for the SWTR and TCR. *Chapter 1* discusses the requirements of the 1996 SDWA Amendments and the approach EPA is following to meet those requirements. *Chapter 2* discusses the technologies that were evaluated including those previously listed by EPA in 1997. The listing is found also in tabular format at the end of the chapter. *Chapter 3* contains the Total Coliform Rule compliance technology listing. *Chapter 4* contains emerging technologies and additional criteria that may require further consideration prior to future technology listings. Appendices contain relavant background information.

2. COMPLIANCE TECHNOLOGY LIST FOR SWTR

Section 2.1: Background of the Surface Water Treatment Rule

The SWTR, published in the Federal Register on June 29, 1989, set national standards for treating public surface water supplies and ground water supplies under the direct influence of surface water. The SWTR includes: (1) criteria under which filtration is required and procedures by which the States are to determine which systems must install filtration; and (2) disinfection requirements. The filtration and disinfection requirements are treatment technique requirements to protect the public against potential adverse health effects of exposure to the protozoa *Giardia lamblia*, viruses, *Legionella*, and heterotrophic bacteria, as well as many other pathogenic organisms that are removed by these treatment techniques. The SWTR also contains certain limits on turbidity as criteria for: (1) determining whether a public water system is required to filter; and (2) determining whether filtration is alone adequate. [Note: additional surface water treatment requirements for small water systems are expected to come into effect under the Long Term Enhanced Surface Water Treatment Rule (LTESWTR), including provisions for control of *Cryptosporidium* through filtration and revised turbidity standards. These will be addressed as in subsequent listings.]

Section 2.2: Technologies Evaluated for the Compliance Technology List

The SWTR enables EPA to issue "log removal credits" to water utilities through requirements for particular water treatments, rather than a requirement for utilities to meet an MCL: a microbial MCL would require the technically difficult feat of monitoring for the microorganisms. Inactivation requirements are 99.9% (3 log) for *Giardia* cysts and 99.99% (4 log) for viruses. The inactivation requirements can be met through disinfection alone or a combination of filtration and disinfection. The 1989 SWTR listed four filtration technologies: conventional filtration including sedimentation; direct filtration; diatomaceous earth filtration; and slow sand filtration. Disinfection treatment is required to follow all of these filtration treatments. The disinfection technologies listed in the 1989 SWTR were chlorine, ozone, chlorine dioxide, and chloramines. Additional filtration and disinfection technologies were subsequently listed by EPA as discussed below.

In 1997 EPA began evaluating information on the originally listed technologies and several alternate technologies (i.e., treatments not listed in the 1989 rule), for SWTR application at small public water supplies. Among the alternative treatments considered were: mixed-oxidant disinfection (on-site oxidant generation); ultraviolet (UV) disinfection; four membrane filtration technologies (reverse osmosis, microfiltration, ultrafiltration, nanofiltration); bag filtration; and cartridge filtration. The Agency presented a proposed listing of these technologies and, after receiving considerable input from its stakeholders, listed all the proposed technologies in August 1997 (EPA 815-R-97-002). In addition, while some small system caveats were included in that listing, the technologies were listed for *all* the SDWA-specified small system size categories. As part of the 1997 listing EPA included abbreviated information on any known limitations regarding each of the compliance technologies; operator skill levels; and other issues that would be important to consider before site-specific choices are made.

EPA undertook the following in 1998: (1) to further organize specific operational characteristics of treatment and data on treatment efficacy, and to specify any other known limitations on the listed treatments; and (2) to determine if other emerging treatments may be considered viable for the SWTR small systems compliance technology listing. The emerging treatments were identified as advanced oxidation (or perozone), pulsed ultraviolet, and ultraviolet oxidation (i.e., UV plus peroxide or ozone).

In identifying the disinfection and filtration compliance technologies in this chapter, EPA discusses disinfection technologies in Section 2.3; pilot testing for filtration treatment systems in Section 2.4; and filtration technologies in Section 2.5; also, a tabular summary of compliance technologies for the SWTR is provided in Section 2.6.

EPA notes that the listing of SWTR technologies is not intended to be a comprehensive or exclusive list. Systems may choose alternative treatment technologies: i.e., technologies not listed which may be found to meet the requirements of the SWTR. EPA lists in Chapter 4 "emerging technologies" that in the future may be evaluated more fully and, if found applicable, would be listed as small systems compliance technologies under SWTR.

The removal and/or inactivation of target or surrogate microorganisms is considered the primary test of a treatment technology's efficacy; however, other factors are considerably important in evaluating treatment including the plausibility of operating the system under a range of conditions. EPA researched available information on each disinfection and filtration treatment type and has written up those listed in this document in accordance with available data. Most references cited are from the published literature except in cases where ongoing research results are mentioned. There is not a single template from which to determine viability of a technology for listing; a certain level of judgement is required when evaluating data on new or emerging technologies. Finally, it is noted that additional pertinent information on each of the disinfection and filtration technologies has been included in a table at the end of this chapter.

Section 2.3: Compliance Technology Evaluation of Disinfection Technologies

Since passage of the 1996 SDWA amendments, several disinfection technologies have been evaluated by EPA as possible compliance technologies. The viability of four disinfection technologies listed in the 1989 SWTR (i.e., free chlorine, ozone, chlorine dioxide, and preformed chloramines) was discussed at length in the 1989 EPA SWTR guidance manual **(3)**, therefore those technology summaries in this report are relatively brief.

CT values required for achieving a certain degree of inactivation for each disinfectant are listed in CT tables in the above-cited SWTR guidance manual. CT refers to the product of the residual disinfectant concentration in mg/L, "C", and the disinfectant contact time in minutes, "T". The disinfectant contact time is defined as the time required for the water being treated to flow from the point of disinfectant application to a point before or at the first customer during peak hourly flow. There is a relationship between CT values and inactivation rates (or log inactivation) for a given disinfectant. Since the determination of log inactivation of a microbiological contaminant is more technically demanding than the calculation of CT, CT is used as a surrogate for log inactivation for a given disinfectant under specific water quality conditions (e.g., temperature, pH). The SWTR and associated guidance provide CT values for free chlorine, ozone, chlorine dioxide, and preformed chloramines that correspond to 1-log inactivation of *Giardia lamblia* cysts. Viruses are generally inactivated at much lower dosages of disinfectant (inactivations of the more resistant surrugate MS-2 bacteriophage are in several cases mentioned in this and other reference material). Where this report mentions information on inactivation of *Cryptosporidium* oocysts it is for informational purposes since the SWTR does not specifically address *Cryptosporidium*.

DISINFECTION TREATMENT TECHNOLOGIES LISTED IN THE ORIGINAL SWTR

Ozone Ozone is a powerful oxidant with high disinfectant capacity. A study found that within a pH range of 6 to 10, at 3 to 10 °C, and with ozone residuals between 0.3 to 2.0 mg/L, bacteriophage MS-2 (a surrogate test organism) and Hepatitis A virus were completely inactivated. Inactivations ranged from >3.9-log to >6-log, and occurred within very short contact periods (i.e., 5 seconds) **(1)**. A 1992 research report describes treatment studies conducted on MS-2, poliovirus, and *Giardia* cysts. It found that MS-2 in natural waters are very sensitive to ozone in comparison to poliovirus type 3. In addition, *Giardia muris* and enteric viruses may be inactivated by ozone (as the primary disinfectant) with 5 minutes contact time and ozone residuals of 0.5 to 0.6 mg/L to 3-log and 4-log removals, respectively. The report concludes that design of ozone as a primary treatment should be based on simple criteria including ozone contact concentrations, competing ozone demands, and a minimum contact time to meet the required cyst and viral inactivation requirements, in combination with USEPA guidance recommendations **(2)**. Viral inactivation CT values for ozone were published in the original USEPA guidance manual for the SWTR **(3)**.

EPA notes that ozonation technology requires careful monitoring for ozone leaks which pose a hazard. Also, use of ozonation may increase biodegradable organics in water which may affect distributed water quality. Additional treatment may be used as necessary. Also, where **bromides** are present in raw water there is an increased potential for formation of disinfection byproducts, i.e., brominated organics and bromate, which should be minimised. Secondary disinfection with chlorine or chloramines may help in this regard, by balancing treatment needs with the need for also protecting distributed water quality.

It has been brought to EPA's attention at stakeholder meetings that recent advancements in ozonation technology include use of high purity oxygen feed systems, rather than ambient air feed systems. Ozonation treatment is therefore said to run cleaner and require less cleaning-related maintenance than had the earlier versions of this technology.

EPA has reviewed survey data submitted by the International Ozone Association and found that ozonation has been applied at many drinking water treatment facilities in the U.S. Ozonation systems with capacities greater than 100,000 gal/day, as well as small water systems serving as little as 500 gal/day, have been documented **(4,5)**. Ozonation, according to these same sources, is often applied for drinking water disinfection as well as for other water treatment objectives, such as for oxidation of dissolved iron and manganese, and control of taste and odor and/or trihalomethanes. Ozonation technology for the subject public water system application is available from a number of suppliers. Ozone treatment is a listed compliance technology for all size categories of public water systems.

References

1. Hall, R.M., and Sobsey, M.D. Inactivation of Hepatitis A Virus and MS2 by Ozone and Ozone-Hydrogen Peroxide in Buffered Water. *Water Science and Technology*, Vol. 27, No. 3-4, pp. 371-378.

2. Finch, G.R., Labatiuk, C.W., Helmer, R.D. and Belosevic, M. *Ozone and Ozone-Peroxide Disinfection of Giardia and Viruses.* Prepared for AWWA Research Foundation, Denver (1992).

3. U.S. Environmental Protection Agency. *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources* (1989 and 1991).

4. Dimitriou, M.A. Letter with attachments attributed to R.G. Rice, from the International Ozone Association to U.S. Environmental Protection Agency, May 23, 1997.

5. Rice, R. *Small (<10,000 persons or < 1 MGD) U.S. Potable Water Treatment Plants Using Ozone- In Operation.* Assembled for the International Ozone Association. March 11, 1998.

Chlorine Chlorine in its several forms is the most widely used disinfectant at public water supplies. Hypochlorites are available in solid (e.g., tablet) or liquid (solution pump-fed) forms. The use of gaseous chlorination (while available) at small water supplies may not be among the best disinfection options due to the hazardous nature of the material. Use of gaseous chlorine places greater demand on the need for isolated plant space, on providing trained and attentive operating staff and their protection from any hazards, and, possibly, on liability issues which may boost insurance costs for small public water systems.

Stakeholders have indicated that provision of adequate CTs for chlorination may be problematic and require additional consideration, particularly where contact time (basins) may be an expensive option for small systems. However, stakeholders agree that all public water supply systems, regardless of size, would benefit from the listing of chlorine for meeting the SWTR. Chlorination technologies for even the smallest public water system applications are available, in gaseous, solid and liquid-feed forms, from a number of suppliers. Cautions regarding use of gaseous chlorine are appropriate, and attention should be paid to staffing and their protection, as noted above. Use of hypochlorite solutions also warrants the following precautions: with time the disinfectant strength of the solution decreases; and, toxic chlorate levels in solution can increase. Awareness regarding the potential for producing elevated levels of halogenated disinfection byproducts, e.g., trihalomethanes, inorganic byproducts, and others, is also essential. Chlorination treatment is a listed compliance technology for all size categories of public water systems.

Reference

1. U.S. Environmental Protection Agency. *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources* (1989 and 1991).

Chloramines Chloramines, while possessing certain advantages over other disinfectants (e.g., long residual effect and low production of disinfection byproducts), have not been widely used in disinfection at small public water systems. Compared to free chlorine and ozone, chloramines possess less potency as a germicidal agent, and would therefore require longer CTs; and, as noted above, stakeholders have informed the USEPA that provision of suitable CTs for such chemical disinfection may be costly and/or problematic and requires adequate consideration.

Chloramine disinfection requires careful monitoring of the ratio of added chlorine to ammonia. Failure to do so can result in odor and taste problems or biological instability of water in the distribution system. Excess ammonia (i.e., low chlorine:ammonia) can promote growth of nitrifying bacteria, which convert ammonia to nitrates and nitrates. Ammonia dose should be tempered by any natural ammonia occurring in raw water **(1)**.

USEPA and stakeholders agree that all public water supply systems, regardless of size, would benefit from the listing of chloramines for SWTR small systems application, with the caveats mentioned above. The Agency has not seen documentation of applied use at small facilities. Chloramination technologies for even the smallest public water system applications may be available from treatment vendors. Chloramination is a listed compliance technology for all size categories of public water systems.

Reference

1. White, G.C. *Handbook of Chlorination and Alternate Disinfectants. Volume 3*. Van Nostrand Co., N.Y., N.Y. (1992).

Chlorine Dioxide Chlorine dioxide, although a powerful oxidant, may be more difficult to handle than other forms of chlorine. Chlorine dioxide requires trained staff to manage its use and is so reactive (thus, is consumed very readily) that it may not provide a residual disinfectant in the distribution system. Photochemical decomposition of ClO2 in reservoirs may increase chlorate concentrations, and other factors including the generation process used and water pH can affect chlorate and chlorite levels. The Agency has not seen documentation of applied use of this technology at small facilities. However, stakeholders have urged USEPA not to exclude this treatment for disinfection. It is noted that chlorine dioxide units for small public water system applications may be available from treatment vendors. Chlorine dioxide is a listed treatment for all categories of public water systems.

ADDITIONAL LISTED DISINFECTION TREATMENT TECHNOLOGIES

UV Radiation Ultraviolet (UV) radiation has been found to be an effective disinfectant in treatment of relatively clean source waters. Historically, UV has been adapted to disinfect reclaimed water, treated sewage, industrial process water, and small groundwater supplies. Simplicity of installation, ease of operation and maintenance, and low costs relative to chemical disinfection, make UV a useful small systems disinfection technology option. Stakeholders have suggested that users of this technology consider UV within the framework of the multiple barrier approach as put forward by the Agency under the SWTR.

UV radiation as a germicidal agent is effectively applied at a wavelength of 253.7 nanometers (or a range of 250-270 nanometers) through application of low-pressure mercury lamps. Other wavelengths are effective in the destruction of chemical contaminants, but this is not addressed in this guidance. UV dose is expressed in units of milliwatt-sec per square centimeter (mW-sec/cm2), the product of the intensity (I) of the UV lamp (mW/cm2) and time (T) of exposure (sec). UV treatment of water is therefore comparable to the CT as described above for chemical disinfection, since UV dose is expressed in terms of the IT values.

The relatively resistant test organisms MS-2 and *Bacillus subtilis* have been inactivated by UV at a level of 3-logs at dosages of approximately 20 to 40 mWsec/cm2, and a level of 4-logs at dosages of approximately 60 to 90 mWsec/cm2. These test results were reported in a 1996 USEPA overview of UV disinfection efficacy, operation, and cost **(1)**. In addition, a recent pilot study on groundwater containing 0.65 ppm iron indicated a 4-log inactivation of MS-2 at 87 mWsec/cm2 **(2)**. These doses would likely inactivate poliovirus, Hepatitis A, and rotavirus. Rotavirus, a UV-resistant virus, was the subject of testing in buffered, distilled water, which yielded 3- and 4-log inactivations at approximately 30 and 40 mWsec/cm2, respectively **(3)**.

Research has confirmed that UV effectiveness is relatively insensitive to temperature and pH differences, and that application of UV as a primary disinfectant (followed by chlorination or chloramination) does not contribute to disinfection by-product formation. In addition, UV application was found not to convert nitrate to nitrite or bromide to bromines or bromates **(3)**.

However, it has long been observed that turbidity, natural organics, iron, calcium hardness, suspended solids, and other factors can reduce UV transmission and cause lamp fouling, thus lowering disinfection effectiveness. Studies have tracked UV performance and transmission, through use of new-generation electronic UV sensors. (Some older UV sensors exhibited erratic readings and a loss of performance over time.) Testing found that correlations may be established between system performance (MS-2 inactivation) and UV sensor readings. This may prove invaluable in maintaining the reliability of UV sensor readings. Bioassay techniques and chemical actinometry were cited by researchers as tools available for obtaining appropriate correlations, and for recalibrating sensors periodically. The same studies found that manual cleaning of fouled UV sleeves and sensors, with commercially-available, 20 percent muriatic acid solution, was effective and not labor-intensive, i.e., requiring one-half to one hour of labor **(2)**.

The UV dose needed for a particular application may vary depending on source water quality.

A suggested lower bound of 38 mWsec/cm2 is based on ANSI/NSF standard 55, which is intended for disinfecting visually clear water pre-filtered for cyst reduction. That dose corresponds to an approximate 4-log rotavirus inactivation, utilizing no multiplier/factor-of-safety. An upper bound of 140 mWsec/cm2 is based on above-cited lab and field study data, i.e., 4-log viral or MS-2 inactivations **(1, 4),** and use of a factor-of-safety or multiplier of 2 to 3.

[Note: Table E-14 of the SWTR Guidance Manual, Inactivation of Viruses by UV, was based on less resistant Hepatitis A virus, at 2- and 3-log inactivations in lab-prepared media. The current guidance may be more conservative in approaching UV design needs.]

Protozoan cysts require greater UV doses for inactivation. For example, one test in a distilled water medium indicated a 2-log inactivation of *Giardia lamblia* at a UV dose of 180 mWsec/cm2 and a 1-log inactivation of *Giardia lamblia* at a UV dose of approximately 40 mWsec/cm2 **(5)**. A factor of safety or multiplier of 2 to 3 applied to this dosage produces a dose of 80 to 120 mWsec/cm2 to achieve a 1-log inactivations of *Giardia lamblia*. As a practical matter, conventional UV systems may not be cost effective for control of *Giardia* at greater than 1-log removal, although advanced ultraviolet treatment systems which may produce 2- to 4-log inactivations of *Cryptosporidium* are being investigated (see Chapter 4) for potential application under the forthcoming EPA Enhanced Surface Water Treatment Regulation.

In addition to pretreatment and/or automatic cleaning systems to remove above-cited dissolved and/or suspended materials, which can impede UV performance, a secondary disinfectant is necessary to provide a residual protection of water in distribution systems. Continuous dose measurement, remote alarms, automatic cleaning of UV components, and annual UV sensor maintenance may also be important design components to prevent deposition or scaling and to minimize on-site operator attention. UV treatment systems appear to be commercially available for drinking water application, within the dose ranges suggested above. Ultraviolet disinfection is a listed technology for all three categories of small public water systems.

[Note: The Agency expects, as data become available, to improve upon and possibly refine the recommended UV doses for meeting viral inactivations requirements. In addition, EPA briefly discusses as "emerging" technologies the following variations on conventional UV treatment: pulsed UV; medium pressure UV; and UV oxidation (i.e., as used in combination with peroxide or ozone (see Chapter 4).]

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On-Site Oxidant Generation (Also known as anodic oxidation and salt brine electrolysis) On-site oxidant generation may be accomplished by an electrolytic process which generates a concentrated solution of oxidants, mainly free chlorine. This process involves passage of an electric current through a continuous-flow brine (salt) solution within a cell. The electrolyzed brine solution containing the concentrated disinfectant is injected into water for treatment. The concentrated solution is diluted approximately one hundred-fold in drinking water treatment.

EPA's previous listing included "mixed oxidant disinfection," and the Agency has decided to characterize this technology in another manner. Recently completed research, as discussed below, has not determined that additional oxidants (other than free chlorine) are produced to a significant degree by the electrolytic action within this process. In its application this treatment is similar to chlorination, however rather than apply commercially available gaseous, solid or liquid forms of chlorine, the process produces a strong disinfectant solution on-site. This treatment method has been successfully tested, applied, and accepted mainly due to the convenience, ease of operation, and basic level of operator skill required.

On-site oxidant generators have been reported to produce multiple oxidants. However, the individual oxidants in solution have proven to be difficult to characterize. Recent research, sponsored by EPA**,** investigated the composition of the generated solutions as well as the analytical techniques available for measurement of the individual species. Lab and full-scale units were studied, and a variety of analytical methods and chemical masking techniques were tested for blocking the interference of free chlorine in the measurement of ozone in solution. The experiments confirmed that chlorine is the primary oxidant in the electrolyzed solution (measured at 200 to 400 mg/L), with ozone, hydrogen peroxide, and chlorine dioxide undetected. Lab-prepared solutions containing free chlorine and ozone were also tested and it was shown that, due to the rapid rate of reaction between the two oxidants (in the millisecond time-scale), any ozone that may be in solution becomes, in a very short time, unavailable for the purpose of disinfection. Based on kinetic studies, ozone levels were calculated by researchers to be less than 0.5 mg/L immediately following generation **(1)**.

It may be assumed until further investigations bear results that units of this type may use various grades of raw material, salt, and this may in turn result in differing amounts of oxidants and associated byproducts in solution. It is noteworthy that this process may also produce chlorate (ClO_3^{-}) and bromate (BrO_3^-) in solution: the former species being a function of free chlorine decomposition, the latter, a human carcinogen, is produced as a result of reactions with bromide in the salt used in preparation of the electrolytic solution. The above-cited study **(1)** reported relatively low levels of chlorite, chlorate and bromate ions in solution in concentrated anolyte liquor (less than 0.05 mg/L chlorite, and 1 to 2 mg/L both chlorate and bromate in full-scale system); the study also detected bromate in finished water but was not specific about concentration.

Researchers have studied the effects on-site electrolysed salt brine disinfection in relation to *Cryptosporidium* oocysts and *Clostridium perfringens* spores as an indicator of oocyst inactivation: at a dosage of 5 mg/L, mixed oxidation achieved greater than 2-log *Cryptosporidium* inactivation at 1-hour contact time **(2)**. A technical report by the Los Alamos Technical Associates, Inc., reported a 4-log inactivation of/ f-2 bacteriophage in water at a relatively short contact time, i.e., CT of 4 **(3)**. In order to provide a complete and useful set of data, studies on inactivation of *Cryptosporidium* are under way by EPA **(4)** and by others, including the American Water Works Research Foundation, with results anticipated in 1999.

On-site oxidant generation for disinfection purposes has been used in full scale water treatment applications at a variety of locations. Field applications have indicated the ease of operation and effectiveness of these systems. Examples of full-scale applications of on-site generation of disinfectants, in several U.S. states, may provide some guidance to interested parties on the use and efficacy of this technology.

Given that on-site generation of oxidants may have advantages over other treatment methods, EPA suggests that small systems consider this disinfection technique for compliance purposes. Given information regarding the disinfectant generated, EPA suggests taking a course of utilizing **chlorination** CT tables when designating chemical dosing for these systems. Additional studies in 1998-99 may yield appropriate data on CT requirements for this technology.

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Section 2.4: Degree of Pilot testing for New Filtration Technologies on the Compliance Technology List

The current SWTR lists four types of filtration technologies and associated requirements. These are described in 40 CFR §141.73(a) - (d): (1) conventional filtration treatment or direct filtration; (2) slow sand filtration; (3) diatomaceous earth filtration; and (4) other (alternative) filtration technologies. A public water system could not use an alternative filtration technology unless it could demonstrate to the State through the use of pilot plant studies or other means that the technology, in combination with disinfection as described under §141.72(b), meets the required three log removal of *Giardia* and four log removal of viruses.

For these alternative filtration technologies, there are typically two stages of evaluation prior to approval. The first stage is to determine if the process effectively removes the contaminants of concern. The second stage is to determine if the individual system can effectively operate the process and to assess site-specific considerations that can affect the technology's performance. Under the SWTR, the filtration processes listed in §141.73(a)-(c) already meet the first stage requirement, but generally require some degree of site-specific testing to meet the second stage. The "other filtration technologies" [§141.73(d)] require pilot testing to meet both criteria.

For alternative filtration technologies on the SWTR compliance technology list, the national-level pilot testing for viability may be waived under §141.73(d). Pilot plant studies are just one mechanism identified in §141.73(d) to demonstrate that the process is capable of meeting the goals of the SWTR. The filtration technology can be demonstrated using "other means" besides pilot testing. Those alternative filtration technologies on the compliance technology list have been determined by EPA to be effective under §141.73(d) and thus do not require national-level pilot testing for viability. This puts new filtration technologies on the same regulatory footing as the technologies listed in §141.73(a) - (c) in terms of national-level pilot testing. A State may still require site-specific pilot testing to assess factors that affect technology performance for all of the compliance technologies. A State may as a practical measure require such testing to demonstrate that a system is capable of operating a given treatment process.

For filtration technologies that are not on the compliance technology list, the existing mechanism in the SWTR for alternative filtration technologies can still be used. Pilot testing for viability could be required for these systems under §141.73(d).

Section 2.5: Compliance Technology Evaluation of Filtration Technologies

Filtration technologies have been evaluated and listed as compliance technologies. Since the viability of the four technologies listed in §141.73(a)-(c) has already been summarized in the SWTR guidance manual, those technology summaries do not contain *all* information previously reported by EPA. (Appendix B contains references published on the filtration technologies listed in the SWTR since 1989.) Seven filtration technologies have been added as compliance technologies for small systems. Summary information on the filtration technologies is included in a table at the end of this chapter.

FILTRATION TREATMENT TECHNOLOGIES LISTED IN THE 1989 SWTR

Filtration is the most commonly used treatment for reducing turbidity and microbial contaminant levels in domestic water supplies. Common drinking water filtration processes involve passing water through a filter media to remove suspended particulate material, larger colloidal materials, and, for some filter media, to reduce levels of smaller colloidal and dissolved contaminants. Examples of suspended particulates include clay and silt, microorganisms, humic and other aggregated organic materials, and aluminum and iron oxide precipitates. Typical filter media include silica sand, diatomaceous earth, garnet or ilmenite, and a combination of coarse anthracite coal overlaying finer sand. Filtration may involve single media, dual media (e.g., coal-sand), and tri-media (e.g., an added third layer of sand). Filtration may be rapid or slow, depending upon the application, and may involve different removal processes, cleaning methods, and operation methods **(1, 2, 3)**.

The filtration technologies discussed in this section are used to remove suspended particulate matter from water. For filtration processes that involve the addition of a chemical coagulant, coagulation refers to the complex process of particle aggregation within a water being treated, including coagulant formation, particle destabilization (surface charge alteration of suspended particles), and inter-particle collisions. Flocculation may be considered a part of the coagulation process and refers to the process of promoting inter-particle collisions and thus the aggregation of larger particles (floc). Larger suspended particles may be removed by simple filtration or by sedimentation (gravity settling) or flotation (floc rises to the surface and is skimmed off). Simple filtration involves the physical trapping of suspended particles that are larger than the pore volumes of the filter media; the bulk water passes through unimpeded and leaves the particles behind. As finer suspended particles pass through the filter medium, they are destabilized, resulting in coagulation and adherence to the filter medium **(2, 4)**. In the case of slow sand filtration, which does not involve the addition of coagulants, colloidal and dissolved organic materials may be removed by biological processes in the schmutzdecke ("black layer" or biologically-active layer) and in the filter medium below. In the case of direct filtration, which requires influent water with much less turbidity, the coagulation and flocculation step is followed immediately by filtration. Since there is less aggregated material to remove, sedimentation or flotation is not required to prolong the filter cycle. Some dissolved chemicals may be removed by chemical sorption at the surface of the filter media, especially in the cases of higher surface area filter media (e.g., fine sand and diatomaceous earth), but these processes account for much less of the bulk contaminant removal compared to physical sorption processes **(1, 2, 3, 5)**.

For the purposes of meeting the performance criteria under the SWTR and to protect public health, disinfection treatment is applied following filtration.

In regard to improving the operation of fitration plants, recent advances in telemetry devices have made it possible for a single operator to remotely monitor and operate one or more small water systems within a given area. These "circuit rider" operators can work from a central location, receiving information (including alarms) from the various plants via FAX or modem. Remote control capabilities allow the operator to control certain aspects of the treatment process (e.g., chemical coagulant or disinfection dosage) via modem or other means. This reduces operator costs, and can reduce the amount of chemicals required for treatment **(6)**. These telemetric devices may make technologies that require full-time operator attention more feasible for many small systems. The combined use of package plants and telemetric monitoring may well extend the use of the more complex water treatment technologies to the universe of small systems.

The following technologies are listed in this guidance as compliance technologies for all three size categories of small public water systems; disinfection is assumed to follow filtration treatment. The first four filtration technologies were listed and described in the SWTR **(5)**.

Conventional Filtration and Specific Variations Conventional filtration includes chemical coagulation, rapid mixing, and flocculation, followed by floc removal via sedimentation (or flotation). The clarified water is then filtered. Common filter media designs include sand, dual-media, and tri-media. Design criteria for specific sites are influenced by site-specific conditions and thus individual components of the treatment train may vary in design criteria between systems. Conventional treatment has demonstrated removal efficiencies greater than 99% for viruses and 97 to 99.9% (rapid filtration with coagulation and sedimentation) for *Giardia lamblia* **(5)**.

There are a variety of coagulation/filtration package plants applicable to small systems **(2, 6, 7, 8)**. In package plants that utilize sedimentation, the sedimentation step usually occurs in tube settlers. In "dual-stage filtration" **(8, 9)**, the sedimentation step is replaced by a passive flocculation/clarification step that occurs in an initial "depth clarifier" tank. The clarified water is then passed through a depth filter. Other modes of clarification are possible, including the use of the various upflow and downflow flocculation/filtration processes, also known as "roughing filter" processes. Typically, roughing filters are not as versatile as sedimentation or flotation, but some varieties may perform comparably. One example of a package plant of this type uses a buoyant crushed plastic medium used in an upflow mode as a contact flocculator and roughing filter ahead of a downflow triple-media bed **(2)**. Coagulation/filtration package units have demonstrated the ability to effectively remove turbidity, color, disinfection by-product precursors, viruses, bacteria, and protozoa (e.g., *Cryptosporidium* and *Giardia* cysts) **(6, 7, 8, 9)**.

The dissolved air flotation (DAF) process includes coagulation and flocculation, but instead of gravity sedimentation, the floc is carried up to the water surface by rising air bubbles, where the floc can be skimmed off **(2, 6, 10)**. DAF may be more applicable than other conventional filtration systems for removing particulate matter that does not readily settle, e.g., algae-rich waters, highly colored waters, low turbidity/low alkalinity waters, and cold waters. DAF is less appropriate for very turbid waters due to their higher silt and clay contents. The National Research Council suggests an upper turbidity limit of 30 to 50 NTU for small systems using DAF **(6)**. For lower turbidity waters, DAF performance is comparable to conventional filtration employing sedimentation, and may be superior in removal of turbidity, especially low density turbidity **(11)**.

Conventional filtration is the most widely used technology for treating surface water supplies for turbidity and microbial contaminants, but may be less applicable to the smallest water system size category (those serving 25 to 500 persons) due to relatively high costs and technical complexity. Although conventional filtration has the advantage that it can treat a wide range of water qualities, it has the disadvantage that it requires advanced operator skill and has high monitoring requirements. Thus, small systems without access to a skilled operator should not use conventional treatment, given that waterborne pathogens are acute contaminants and that the disruption of chemical pre-treatment can lead to pathogen introduction into the distribution system **(2, 6, 9)**. The performance of conventional filtration is extremely sensitive to the proper management of the coagulation chemistry involved; if the coagulation step is disrupted or improperly executed, the removal efficiencies for turbidity and microbiological contaminants decrease dramatically in a matter of minutes. For this reason, **EPA suggests that only those systems with full-time access to a skilled operator use conventional filtration.**

Direct filtration Direct filtration has several effective variations; all direct filtration systems include a chemical coagulation step followed by rapid mixing, and all exclude the use of a sedimentation or other clarification step prior to filtration. Following chemical mix, water is filtered through dual- or mixed-media filters using pressure or gravity units. Pressure units, which are used primarily by small systems **(2)**, have the advantage of not requiring repumping for delivery of the filtrate to the point of use. Gravity units have the advantage of allowing easy visual inspection of the filter medium during and after backwash. In addition to the mode of filtration, variations of direct filtration include filter media type and mixing requirements. In-line filtration **(12)** is the simplest form of direct filtration and consists of filters preceded by direct influent chemical feed and static mixing. In general, direct filtration usually requires low turbidity raw water and is attractive because of its low cost relative to conventional treatment **(12, 13)**. The National Research Council **(6)** has suggested that small systems not use direct filtration for waters with average turbidities above 10 NTU or maximum turbidities above 20 NTU. Two other important considerations are color and algae. Since color removal requires coagulant additions in proportion to the degree of color, an upper limit of color is appropriate for direction filtration. An AWWA Committee report **(14)** suggests an upper limit of 40 color units. Algae removal must be evaluated on a case by case basis. Direct filtration has demonstrated removal efficiencies of 90 to 99% for viruses, 50% for *Giardia lamblia* without coagulation, and 95-99% for *Giardia lamblia* with coagulation pre-treatment **(5)**.

Direct filtration has the disadvantage that it requires advanced operator skill and has high monitoring requirements. Thus, small systems without access to a skilled operator should not use direct filtration, given that waterborne pathogens are acute contaminants and that the disruption of chemical pre-treatment can lead to pathogen introduction into the distribution system **(2, 3, 6)**. The performance of direct filtration is extremely sensitive to the proper management of the coagulation chemistry involved; if the coagulation step is disrupted or improperly executed, the removal efficiencies for turbidity and microbiological contaminants decrease dramatically in a matter of minutes. For this reason, **EPA suggests that only those systems with full-time access to a skilled operator use direct filtration**.

<u>Slow sand filtration</u> Slow sand filters are simple, are easily used by small systems, and have been adapted to package plant construction **(6, 7)**. Slow sand filters are similar to single media rapid-rate filters in some respects, but there are crucial differences in the mechanisms employed (other than the obvious difference in flow rate). The *schmutzdecke*, the top-most, biologically active layer of filter, removes suspended organic materials and microorganisms by biodegradation and other processes, rather than relying solely on simple filter straining or physico-chemical sorption. Advantages of slow sand filtration include its low maintenance requirements (since it does not require backwashing and requires less frequent cleaning) and the fact that its efficiency does not depend on actions of the operator. However, slow sand filters do require time for the *schmutzdecke* to develop after each cleaning: during this "ripening period," however, filter performance steadily improves. The ripening period can last from six hours to two weeks, but typically requires less than two days. A two day filter-to-waste period is recommended for typical sand filters **(2)**. Since few remedies are available to an operator when the process is ineffective, particularly if a system has little storage capacity, slow sand filtration should be used with caution and should not be used without pretreatment or process modifications (e.g., GAC layer addition) unless the raw water is low in turbidity, algae, and color **(15)**. Package plant versions with a granular activated carbon layer located beneath the slow sand can adsorb organic materials that are resistant enough to biodegradation to pass through the *schmutzdecke*. When used with source water of the appropriate quality, slow sand filtration may be the most suitable filtration technology for small systems **(6)**. Slow sand filtration has demonstrated removal efficiencies in the 90 to 99.9999% range for viruses and greater than 99.99% for *Giardia lamblia* **(5)**.

<u>Diatomaceous earth (DE) filtration</u> DE filtration, also known as pre-coat or diatomite filtration, can be used to directly treat low turbidity raw water supplies or chemically coagulated, more turbid water sources . DE filters consist of a pre-coat layer of DE, approximately 1/8-inch thick, supported by a septum or filter element. To properly maintain the DE pre-coat layer, and to maintain porosity, treatment is supplemented by a continuous-body feed of diatomite and recycled filtered water. Intermittant operation of DE filters is not advised unless the system recycles water through the filter during production down times. Maintaining the filter in this manner optimizes performance, extends the filtration cycle, and lowers filter maintenance requirements.

Normally the DE filter is backwashed and the septum cleaned after each break in filtration. Then a fresh layer of precoat is applied. If changes in water quality occur, body feed rates may be adjusted immediately and/or a re-precoat may be applied. DE filtration plants can be designed to make such adjustments automatically.

DE filtration is very effective for removing *Giardia* cysts, but filtration studies with plain DE have not indicated a marked capability to remove very small particles, e.g., viruses **(2, 6, 16)**. Some research has shown that specific modifications can lead to 99 percent virus removal **(2)**. In addition, recent studies have indicated excellent removal rates (e.g., 6-log) of *Cryptosporidium* oocysts for DE grades commonly used by smaller systems **(17)** .

Since chemical coagulation is not required, DE filtration is very attractive as a small systems technology and it has been used successfully by small systems for many years. Waters that are low in turbidity, color and other organic matter (disinfection by-product precursors) are most suitable for direct application of DE technology **(6)**.

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ADDITIONAL LISTED FILTRATION TREATMENT TECHNOLOGIES

Membrane Processes

The four treatments listed below are membrane processes, which make use of pressure-driven semi-permeable membrane filters. Membranes are manufactured in a variety of configurations, materials and pore size distributions. The selection of membrane treatment for a particular drinking water application would be determined by a number of factors, such as: targeted material(s) to be removed, source water quality characteristics, treated water quality requirements, membrane pore size, molecular weight cutoff (MWCO), membrane materials and system/treatment configuration **(1)**.

The membrane technologies listed below have been historically employed for specific drinking water uses: (1) *reverse osmosis* treatment in a high pressure mode, in removal of salts from brackish water and seawater; (2) *nanofiltration*, also referred to as membrane softening or low pressure RO, in removal of calcium and magnesium ions (hardness) and/or natural organics and disinfection byproducts control; (3) *ultrafiltration*, characterized by a wide band of MWCs and pore sizes, for removal of specific dissolved organics (e.g., humic substances, for control of disinfection byproducts in finished water) and for removing particulates; and (4) *microfiltration*, as with ultrafiltration utilizing low operating pressures, for removal of particulates including pathogenic cysts **(1, 2).**

Pre-filtration and scale-inhibiting chemical addition may be utilized to protect membranes from plugging effects, fouling and/or scaling, and to reduce operational and maintenance costs. For the purposes of meeting the performance criteria under the SWTR and as a safety measure, a disinfectant is commonly applied following membrane treatment to protect distributed water quality.

Stakeholders have requested that USEPA include the following information as part of the listing of these technologies: (1) the degree of operator skill level, which often depends on water quality and amount of pre- and post-treatment required; (2) higher operator skills are often needed for chemical cleaning of membranes; (3) test piloting of membrane filtration systems may be required; (4) monitoring of membrane integrity, as well as alarm and back-up systems, may be required but that state reviewers should have latitude to decide on such requirements; (5) while the first two listed membrane treatments are absolute barriers to viruses, it should be noted that ultrafiltration and microfiltration are not, therefore the latter two should not be given credit for viral reductions; (6) no distinction is made in terms of membrane configuration type, e.g., spiral bound or other, in this guidance; (7) regarding other treatment goals, microfiltration will pass all organic compounds in water whereas ultrafiltration will capture some organics; and, (8) since designations of membrane absolute or nominal pore size have often been irregularly specified, causing some confusion in interpreting a membrane's exclusion capability, state reviewers may wish to request specific information from manufacturers or suppliers for particular applications.

The following membrane processes are listed SWTR technologies for all three categories of small public water systems:

Reverse Osmosis (RO) Filtration RO is a listed technology for all three categories of small public water systems. Due to typical RO membrane pore sizes and size exclusion capability (in the metallic ion and aqueous salt range), RO filtration is effective for removal of cysts, bacteria and viruses **(2, 3)**; however, RO produces the most wasted water, at between 25-50% of the feed.
Disinfection is also recommeded to ensure safety of water.

Nanofiltration (NF) NF is a listed technology for all three categories of small public water systems. Due to typical NF membrane pore sizes and size exclusion capability (1 nanometer range, e.g., organic compounds), NF is effective for removal of cysts, bacteria and viruses. Disinfection is also recommeded to ensure safety of water.

Ultrafiltration (UF) UF is a listed technology for all three categories of small public water systems. Due to typical UF membrane pore sizes and size exclusion capability (e.g., 0.01 micron, molecular/macromolecular range), UF is effective for absolute removal of *Giardia* cysts and partial removal of bacteria and viruses, and when used in combination with disinfection appears to control these microorganisms in water **(4, 5)**. Tests have also shown that filtrate turbidity may be kept consistently at or below 0.1 NTU **(6)**. Due to the importance of disinfection providing a second barrier to contamination, and due to stakeholders' above-mentioned concern regarding maintenance of additional non-membrane treatment for viral inactivation credit, EPA stresses the need for disinfection in conjunction with membrane treatment.

Microfiltration (MF) MF is a listed technology for all three categories of small public water systems. Due to typical MF membrane pore sizes and size exclusion (e.g., 0.1 to 0.2 micron, macro-molecular/microparticle range), MF is effective for absolute removal of *Giardia* cysts and partial removal of bacteria and viruses, and when used in combination with disinfection appears to control these microorganisms in water **(4, 5)**. Tests have also determined that filtrate turbidity may be kept below 0.2 NTU **(7),** typically at or below 0.1 NTU **(6)**. Due to the importance of disinfection providing a second barrier to contamination, and due to stakeholders' above-mentioned concern regarding maintenance of additional non-membrane treatment for viral inactivation credit, EPA stresses the need for disinfection in conjunction with membrane treatment.

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Bag and Cartridge Type Filtration

Bag filtration Bag filtration systems are based on the physical screening process to remove particles. If the pore size of the bag filter is small enough, parasite removal will occur **(1)**. In a bag filtration unit system, water to be treated passes through a bag-shaped filter where the particulates are collected allowing filtered water to pass to the outside of the bag **(2)**. Bag filters are manufactured and supplied by a variety of companies. Bags are available in a variety of material compositions and pore size ratings (typically from 1 to 40 micron). The sizing of the bag filtration component is conditional on the on raw water quality, including the amount of particulate matter and turbidity **(3)**. Unless the quality of the raw water precludes the need for pre-treatment, EPA recommends pretreatment of the raw water using sand or multimedia filters, followed by preliminary bag or cartridge filters of 10 micron or larger pore size, and the use of 1-5 micron filters as final filters to increase particulate removal efficiencies and to extend the life of the filter **(2, 4)**. Contingent on the filter manufacturer, bag filters can accommodate turbidity units from 0.1 to 10.0 NTU and flow between 10 and 50 gpm **(4)**. However, the bag filters will only last a few hours when turbidity consistently exceeds 1 NTU.

Bag filters in combination with cartridge filtration units have been used to remove *Giardia lamblia* at several locations serving small systems **(3, 5)**. Bag filter studies have shown mixed results in the removal of *Cryptosporidium*, ranging from approximately 70% to 99.9% **(1)**. Studies of various membranes using beads as surrogates for *Cryptosporidium* oocysts also showed variability in the removal of this organism **(6)**.

Bag filtration field testing also showed poor to excellent reductions in turbidity. However, this variability might be due to improper installation of the units, leaks or tears in the systems, or local water quality conditions, or as a result of problems with pre-filters **(2, 4)**. In any case, general trends in field experience seems to show that the smaller the pore size rating, the better the filter efficiency.

Stakeholders emphasized that bag filters have been successfully used in water systems across the country. Site-specific pilot testing has been used to determine applicability at individual systems. The stakeholders also identified two other factors that can lead to variability in performance. The bag filter must fit the housing, and different manufacturer's products may not be interchangeable. Some products use nominal pore size ratings rather than absolute pore size ratings, and since nominal pore size ratings refer to some average pore size rather than the largest, particles larger than the nominal pore size may pass through the filter.

Stakeholders have indicated that bags can be fragile and that care must be taken during installation of replacements, to prevent bag tearing. They also noted that monitoring of filter integrity may be needed, but that State reviewers should have the latitude to decide on such requirements.

To further inactivate microorganisms, the final filter effluent would need disinfection to meet the SWTR requirements.

Bag filters have been used successfully in water systems across the country. One key to success is preliminary pilot testing of the process to ensure adequate removals. Pilot testing prior to installation of a bag filter is recommended to address any performance variability factors. **Bag filters are best suited for systems in the first two small system size categories** (i.e., systems serving up to 3,300). However, bag filters are listed as a compliance technology for all three system size categories.

References

1. Goodrich, J.A. and Fox, K. R., "Small System Control of Cryptosporidium for WQA Recertification Credit," *Water Conditioning and Purification* (February 1996): 50-58.

2. New York State Department of Health Bureau of Public Water Supply Protection, *Alternative*

Technology Filtration Study, May 1993.

3. Brandt, B. "'Remote Control' Used to Fight Giardia," *Journal of the American Water Works Association* v 86 n 2 Feb 1994. p 137-138..

4. Smith, G.G., *Small Surface Water Systems Alternate Filtration Report.* Minnesota Department of Health, June 1994.

5. The Greeley-Polhemus Group, Inc. and Malcolm Pirnie, Inc., "Case Studies Assessing Low-Cost, In-Place Technologies At Small Water Systems," Prepared for The Association of State Drinking Water Administrators. July 1992.

6. Goodrich, J.A. et al, "Cost and Performance Evaluations of Alternate Filtration Technologies for Small Systems." Proceedings of the American Water Works Association, Annual Convention, 1995.

Cartridge filtration Cartridge filtration relies on a simple physical screening process to remove particles. Due to materials used and the direction of flow, these are distinct from bag filters. Small pore size openings prevent passage of contaminants through the filter **(1)**. Typical cartridge filters are pressure filters withglass fiber or ceramic membranes, or strings wrapped around a filter element, housed in a pressure vessel **(2)**. The pleating allows for higher surface area for filtration. These filters are manufactured and supplied by a variety of companies with different pore size ratings (0.3 to 80 micron) and materials **(2, 3)**. Similar to bag filtration, these units are very compact and do not require much space.

The pore size rating of the cartridge filtration component used is dependent on the on raw water quality, including the amount of particulate matter and the turbidity **(3)**. Depending on the quality of the raw water, prefiltration of the raw water using sand or multimedia filter, followed by bag or cartridge filters of 10 microns or larger pore size as preliminary filter, and the use of 1-5 micron filters as final filters are recommended to increase particulate removal efficiencies and to extend the life of the filter **(6, 7)**.

Cartridge filters can be used for removal of *Giardia lamblia* **(2, 3, 4)**. Filtration studies conducted by EPA to determine Cryptosporidium removal using beads as surrogates showed that cartridge filtration with 2 micron rated units exhibited log removals of 3.51 and 3.68 **(5)**.

Stakeholders emphasized that cartridge filters have been successfully used in water systems across the country. Site-specific pilot testing was used to determine applicability at individual systems. The stakeholders also identified a factor that can lead to variability in performance. Some products use nominal pore size ratings rather than absolute pore size ratings. Since nominal pore size ratings refer to some average pore size rather than the largest, particles larger than the nominal pore size may pass through the filter.

Stakeholders have noted that cartridge filter seals are subject to damage, and that the housing material may be improperly specified, resulting in leakage and/or other treatment malfunctions; they also have noted that monitoring of filter integrity may need to be required, but that State reviewers should have the latitude to decide on such requirements.

To further inactivate the microorganisms, the final filter effluent would need disinfection to meet the SWTR requirements.

Cartridge filters have been used successfully in water system across the country for up to ten years. One key to success is upfront pilot testing of the process to ensure adequate removals. Pilot testing prior to installation of a cartridge filter is recommended to ensure adequate performance. **Cartridge filters are best suited for systems in the first two small system size categories** (i.e., those serving up to 3,300 people). However, cartridge filters are listed as a compliance technology for all three system size categories.

References

1. Goodrich, J.A. and Fox, K.R. "Small System Control of Cryptosporidium for WQA Recertification Credit." *Water Conditioning and Purification* (February 1996): 50-58.

2. U.S. Environmental Protection Agency. "Very Small Systems Best Available Technology Cost Document". September 1993.

3. Brandt, Barbara "'Remote control' used to fight Giardia," *Journal of the American Water Works Association*. v. 86 n. 2, pp. 137-138. February 1994.

4. The Greeley-Polhemus Group, Inc. and Malcolm Pirnie, Inc. "Case Studies Assessing Low-Cost, In-Place Technologies At Small Water Systems," Prepared for The Association of State Drinking Water Administrators. July 1992.

5. Goodrich, J.A. et al, "Cost and Performance Evaluations of Alternate Filtration Technologies for Small Systems." Proceedings of the American Water Works Association Annual Convention, 1995.

6. New York State Department of Health Bureau of Public Water Supply Protection. *Alternative Technology Filtration* Study, May 1993.

7. Smith, G.G. *Small Surface Water Systems Alternate Filtration Report.* Minnesota Department of Health, June 1994.

<u>Backwashable depth filtration</u> Backwashable depth filters operate in part like cartridge filters in that water flows radially inward allowing the process of particle screening. In one system, bundles of fibers (the filter medium) are rotated and compressed during the filtration mode; monitoring of pressure is used to indicate clogging, which triggers a reverse flow of washwater under pressure; during the backwash cycle the fibers are relaxed, stretched and squeezed to allow for the release of trapped deposits. Tests in Europe have indicated greater than 2-log removal of the relatively small microorganism, *Cryptosporidium* **(1)(2).**

The NSF International protocol for testing backwashable depth filters **(3)** describes the technology as such: a bag filter, cartridge filter, or granular media filter intended to filter uncoagulated water and designed to be backwashed when terminal head loss is attained or turbidity breakthrough occurs. The protocol notes that surface waters of high quality are the most appropriate waters for backwashable depth filters, and that feed water turbidity may not be an adequate indicator of suitability for this treatment. Particulate matter may consist of incompressible and/or compressible substances such as algae or other biological matter (compressible particles being more problematic, affecting frequency of filter backwashing). Therefore, the volume of water treated prior to backwashing may vary greatly depending on the type of particulate matter in source water. NSF also cautions that since backwashable depth filters are not intended to remove viruses, the burden of virus control falls entirely on the disinfection process.

EPA finds that backwashable depth filters, while not used and tested extensively in the U.S., present similar characteristics as the above cited bag and cartridge filters. **These filters may be best suited for systems in the first two small system size categories** (i.e., those serving up to 3,300 people). However, backwashable depth filters are listed as a compliance technology for all three small system size categories.

References

1. Ives, K.J. et al. "An Evaluation of the Effectiveness of the Fibrotex Filter in Removing Cryptosporidial Oocysts from a Surface Water Supply." *Protozoan Parasites and Water.* Edited by W.B. Betts, et al., University of York, United Kingdom (1995).

2. Bernhardt, H. et al. "Investigations of the Retention Efficiency of Fibrotex Filters for *Cryptosporidium* Oocysts Applying Low Turbid Waters from a Water Treatment Plant." *Unpublished* study by Wahnbacktalsperrenverband Siegburg, Universitat Bonn, and Kalsep Ltd.

3. NSF International. Draft NSF Equipment Verification Testing Plan: Backwashable Depth Filtration for the Removal of Microbiological and particulate Contaminants (1998).

Section 2.6: Summary of Compliance Technologies for the SWTR

The following **Tables 1(a) and 1(b),** on disinfection and filtration treatments, respectively, summarize the current listing of small water system compliance technologies for the SWTR. Water system managers and other reviewers should examine the several columns included in this tablulation. The filtration and the disinfection treatment tables each are split into Parts 1 and 2 to accomodate the information categories presented. Limitations included in the tabulation are also described in the text of this chapter, and in references cited. The technologies are listed for *all three* of the subject size categories unless otherwise indicated.

EPA has assigned each technology a level of complexity, reflective of ease of treatment operation and, quite generally, the level of operator skill and knowledge that would be required to run the water treatment plant to meet the subject regulations. If a given treatment is operationally complex, or “advanced,” then the plant operator must have some form of training for such “advanced” treatment.

The tables characterize the skill level for each listed technology, ranging from basic, through intermediate and advanced. For a unit technology that requires “basic operator skill”, an operator with minimal experience in the water treatment field can perform the necessary system operation and monitoring if provided with written instruction. “Intermediate operator skill” implies that the operator understands the principles of water treatment and has a knowledge of the regulatory framework. “Advanced operator skill” implies that the operator possesses a thorough understanding of the principles of system operation, including water treatment and regulatory requirements. If pretreatment is required at a given site, it may be assumed that the required operator skill levels will increase; likewise, if certain features of a treatment train advance technologically, such that operation is simplified or automated, then skill level may decrease. Further information on skill levels may be found in publications by the American Water Works Association, and in protocols developed by the NSF International under the previously-cited treatment verification program.

The SWTR compliance technology list includes new technological, operational, and other information not listed previously by EPA. Information is provided on important raw water parameters, chemical and physical byproducts produced, and other possible limitations that should be considered in selection and design of treatment. The following tabulation is meant for quick reference regarding the listed compliance treatment technologies. It should be recognized that site-specific conditions may preclude certain applications, and that conditions may necessitate other forms or variants of the listed treatment to maximize control of the subject microbiological contaminants.

Table 1a. SURFACE WATER TREATMENT COMPLIANCE TECHNOLOGY TABLE
DISINFECTION TECHNOLOGIES (Part 1)

Unit Technologies	Removals: Log Giardia & Log Virus w/CT's indicated in ( )[1]	Complexity: Ease of Operation (Operator Skill)	Raw Water, Pretreatment & Other Water Quality Issues
Free Chlorine	3 log (104) & 4 log (6)	Basic	Better with high quality. Pretreatment may be needed to reduce disinfection byproduct (DBP) precursors; and/or to reduce pH, turbidity, and/or chlorine dose. If high potential for DBPs, chloramination may be best for distribution protection. Where Fe/Mn high, sequestration or physical removal may be needed.
Ozone	3 log (1.43) & 4 log (1.0)	Intermediate	Better with high quality. pH 7 to 9 and/or above normal temperatures may increase cyst inactivations. Pretreatment may control DBP formation; and Fe/Mn may necessitate sequestration or physical removal.
Chloramines	3 log (1850) & 4 log (1491)	Intermediate	Better with high quality. Excess ammonia (low Cl2 to N ratio) can promote growth of nitrifying bacteria in filters, which convert ammonia to nitrates and nitrites; nitrification in covered reservoirs also likely. Ammonia dose should be tempered by natural ammonia levels in water.
Ultraviolet Radiation	1 log Giardia (80-120) & 4 log viruses (90-140) mWsec/cm2 doses in parentheses[2]	Basic	Relatively clean source water required. UV adsorption (e.g., Fe, NOM) and scattering constituents (e.g., particles) affect dosage for microbial inactivation, and therefore system design/cost. Data indicate strong correlation between dose required and iron; bench-scale studies using microbial surrogate recommended.[3]
On-Site Oxidant Generation	Research pending on CT values	Basic	Better with high quality. Other factors: Chlorine production rates may vary; CT based on chlorination is suggested. See also *Free Chlorine.*

[1]CT (Concentration x Time), in mg-min/L, based upon 1989 Surface Water Treatment Rule Guidance Manual. Temp. 10 C, mid-pH range, unless otherwise indicated.

[2]UV dose is product of mW/cm2 (intensity) x sec (time); bases of viral inactivation ranges are rotavirus and MS-2 tests (see text).

[3]Unpublished research results of Malley et al. (1997-98) suggest correlations; groundwater principally studied.

Chlorine Dioxide	3 log (23) & 4 log (25)	Intermediate	Better with high quality. DBPs include chlorite and chlorate. Photochemical decomposition of ClO_2 in uncovered reservoirs may increase chlorate concentrations in water. Generation process, pH, and other factors, can affect chlorate/chlorite levels.

Table 1a. SURFACE WATER TREATMENT COMPLIANCE TECHNOLOGY TABLE
DISINFECTION TECHNOLOGIES (Part 2)

Unit Technologies	Disinfection Byproducts Concerns	Other Limitations
Free Chlorine	Trihalomethanes, haloacetic acids, aldehydes, inorganic byproducts, others.	Fe and Mn demand, pH and other factors influence dose. DBP production **should be monitored** where precursors occur. Providing adequate CT (**time/storage)** may be a problem for some supplies. Chlorine gas requires special caution in handling and storage, and operator training.
Ozone	Organic acids, aldehydes, AOC, and others. If bromide present, brominated organics and bromate.	Ozone leaks represent hazard: air monitoring required. Ozone used as primary disinfectant (i.e., no residual protection). Biodegradable organics may affect distributed water quality. Personnel time requirements for system cleaning may be fairly substantial.
Chloramines		Long CT. Requires care in monitoring of ratio of added chlorine to ammonia.
Chlorine Dioxide		Storage and handling precautions: exposure to heat, sunlight, or UV light may decrease product strength; spillage would require rapid recovery/sumps, and access to water for cleanup.
On-site Oxidant Generation	Chlorate (ClO_3^-), bromate (BrO_3^-), and chlorinated THMs	Research will determine CT values appropriate for electolyzed salt brine. Other oxidants (other thatn chlorine) not detected in solution by significant research effort.
Ultraviolet Radiation	NA	No disinfectant residual protection for distributed water. Periodic calibration of UV sensors and other special maintenance may be required.

Table 1b. SURFACE WATER TREATMENT COMPLIANCE TECHNOLOGY TABLE
FILTRATION TECHNOLOGIES (Part 1)

Unit Technologies	Removals: Log Giardia & Log Virus	Raw Water, Pretreatment & Other Water Quality Issues
Conventional Filtration and Specific Variations on Conventional	2-3 log *Giardia* & 1 log viruses	Wide range of water quality. DAF more applicable for removing particulate matter that doesn't readily settle: algae, high color, low turbidity (up to 30-50 NTU) and low-density turbidity. Prior to filtration: chemical coagulation, rapid mix, flocculation, sedimentation or flotation (depth clarifiers or roughing filters may replace sedimentation).
Direct Filtration	0.5 log *Giardia* & 1-2 log viruses (and 1.5-2 log Giardia with w/coagulation)	Suggested limits: average turbidity 10 NTU; maximum turbidity 20 NTU; 40 color units; algae on a case-by-case basis[4]. Prior to filtration: chemical coagulation and rapid mixing.
Slow Sand Filtration	4 log *Giardia* & 1-6 log viruses	"Schmutzdecke" formation prerequisite. Pretreatment or process modifications required if raw water high in turbidity, color, and/or algae.
Diatomaceous Earth Filtration	Very effective for *Giardia* (2 to3-log) and *Cryptosporidium* (up to 6-log); low bacteria and virus removal	Low turbidity, low color water; low organic DBP precursors. Pretreatment may be used to decrease turbidity and DBP precursors, although chemical coagulation is not typically necessary.

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[4]National Research Council, Committee on Small Water Supply Systems. "Safe Water From Every Tap: Improving Water Service to Small Communities." National Academy Press, Washington, D.C. (1997).

Reverse Osmosis	Very effective, absolute barrier (cysts and viruses)	May require conventional or other pretreatment for surface water to protect membrane surfaces: may include turbidity or Fe/Mn removal; stabilization to prevent scaling; reduction of dissolved solids or hardness; pH adjustment.[5]
Nanofiltration	Very effective, absolute barrier (cysts and viruses)	Very high quality or pretreatment required (e.g., micro- or ultra-filtration to reduce fouling/extend cleaning intervals).[6] See also Reverse Osmosis pretreatments, above.
Ultrafiltration	Very effective *Giardia*, >5-6 log[7]; Partial removal viruses (disinfect for virus credit)	High quality or pretreatment required (e.g., microfiltration). TOC rejection generally low, so if DBP precursors are a concern, NF may be preferable.
Microfiltration	Very effective *Giardia*, >5-6 log; Partial removal viruses (disinfect for virus credit)	High quality or pretreatment required. Same note as for ultrafiltration regarding TOC.
Cartridge/ Bag/Backwashable Depth Filtration	Variable *Giardia* removal & Disinfection required for virus removal	Very high quality or pretreatment required, due to low particulate loading capacity. Depending on raw water quality, sand or multi-media prefilter, and 10 micron preliminary filter prior to 1 to 5 micron filter, recommended. See also NSF protocols.

[5]Ref. "Recommended Standards for Water Works." Policy Statement on Reverse Osmosis Treatment by the Great Lakes-Upper Mississippi River Board of State Public Health & Environmental Managers (1997).

[6]Ref. Chellam, S. Et al., "Effect of Pretreatment on Surface Water Nanofiltration." JAWWA, October 1997 (Vol. 89, Issue 10). And, Lozier, J., et al, "Integrated Membrane Treatment in Alaska," JAWWA, October 1997 (Vol. 89, Issue 10). It is noted that the use of microfiltration as pretreatment may not result in removal of all foulants, i.e., nanofilters may require more frequent chemical cleaning than when ultrafilter is used as pretreatment.

[7]Ref. Adham,S.S, Jacangelo, J.G., and Laine, J.M. "Characteristics and Costs of MF and UF Plants." JAWWA, May 1996.

Table 1b. SURFACE WATER TREATMENT COMPLIANCE TECHNOLOGY TABLE
FILTRATION TECHNOLOGIES (Part 2)

Unit Technologies	Complexity: Ease of Operation (Operator Skill Level)	Secondary Waste Generation	Other Limitations/Drawbacks
Conventional Filtration and Specific Variations on Conventional	Advanced	Sludge (varying solids %), backwash, filter to waste	High monitoring requirements; full-time operator or "circuit rider" attention.
Direct Filtration	Advanced	Filter backwash	High monitoring requirements; full-time operator or "circuit rider" attention.
Slow Sand Filtration	Basic	Filter cake. Filter to waste (2-day) each ripening period	Algae (especially seasonal blooms) in raw water can clog filters and cause variations in run length. Not very effective in removal of DBP precursors or color. Most effective on high quality source water, i.e., those of low turbidity, algae and color.
Diatomaceous Earth	Intermediate	Diatomaceous filter residue (substantial amounts)	Intermittent operation of DE filters not advised unless the system recycles water through the filter: this will extend the filtration cycle and lower filter maintenance. Low raw water turbidity/color water.
Reverse Osmosis	Intermediate: increases with pre/post-treatment and membrane cleaning needs.	Briney waste. High volume, e.g.,25 to 50 percent. May be toxic to some species	Bypassing of water (to provide blended/stabilized distributed water) **cannot** be practiced at risk of increasing microbial concentrations in finished water. Post-disinfection required under regulation, and recommended as a safety measure and for residual maintenance. Other post-treatments may include degassing of CO_2 or H_2S, and pH adjustment.
Nanofiltration	Intermediate: increases with pre/post-treatment and membrane cleaning needs.	Concentrated waste. 5 to 20 percent volume	Disinfection required under regulation, and recommended as a safety measure and residual protection.

Ultrafiltration	Basic:increases with pre/post-treatment and membrane cleaning needs.	Concentrated waste. 5 to 20 percent volume. Waste may include sand, silt, clays, cysts, algae, viruses and humic material (Ref. 2).	Disinfection required for viral inactivation.
Microfiltration	Basic:increases with pre/post-treatment and membrane cleaning needs.	Low volume waste may include sand, silt, clays, cysts, and algae.	Disinfection required for viral inactivation.
Cartridge/Bag/Backwashable Depth Filtration	Basic	Discarding of cartridges and filters. Backwashable depth filters may be equipped with inactivation devices to disinfect waste.	Requires relatively pure raw water. Care must be taken not to damage clean cartridges, or tear bags, upon installation. Cartridge replacement may be frequent, increasing O&M requirements. Algae and fragments of biological material may disrupt filter. Disinfection is required for viral inactivation, i.e., disinfection CxT, following filtration. May be more applicable to systems serving fewer than 3,300.

3. COMPLIANCE TECHNOLOGIES FOR THE TOTAL COLIFORM RULE

EPA promulgated the total coliform rule (TCR) in June 1989. The TCR contains a listing of "best technologies, treatment techniques, or other means available for achieving compliance with the maximum contaminant level (MCL) for total coliforms" [from 40 CFR Ch. 1, §141.63 (d)]. Listed as best techniques under TCR are:

- Protection of wells from contamination (ground water)
- Maintenance of disinfection residual for distribution
- Proper maintenance of distribution systems
- Filtration and/or disinfection
- State WHPP (ground water)

At the time these techniques were codified, no specific notation as to applicability to categories of public water system size was included. However, with passage of the Safe Drinking Water Act of 1996, EPA is to specify compliance technologies for three small water system size categories, defined by the Act as those serving 10,000 - 3,301 persons; 3,300 - 501 persons; and 500 - 25 persons.

As mentioned in Chapter 1, there are no variance provisions for regulations that control microbiological contamination.

Following presentation at the May 1998 meeting with stakeholders of EPA's proposed TCR compliance technology listing, which essentially is the same as the above-cited 1989 listing, EPA has not received substantive comments on this listing. Therefore, the Agency is listing the same treatment techniques and other means for small systems compliance as were codified in the 1989 rule.

The following **Table 2** contains some explanatory comments regarding each of the treatments and other means listed. The comments are only meant as additional guidance in that certain codes of practice may be useful in addressing a problem; or in terms of pointing out where additional constituents in water may need additional attention (e.g., iron and manganese, ammonia, THM precursors).

It is also necessary to note that determining application of a treatment technique or other means to comply would be highly dependent upon what factors are contributing to an MCL violation. For example, faulty maintenance procedures and/or a leaking pipeline that may have triggered an MCL violation would obviously require a different technological response than where a compromised well structure has been found to be the cause of microbiological pollution. In addition, depending on the number and types of faults that are found, a system may need to implement more than one compliance technology to adequately safeguard its water system.

Table 2: TOTAL COLIFORM RULE COMPLIANCE TECHNOLOGIES	
40 CFR Ch. 1 §141.63(d) Best Technologies or Other Means to Comply (Complexity Level Indicated)	**Comments/Water Quality Concerns**
Protection of wells from contamination, i.e., placement and construction of well(s) (Basic)	Ten States Standards and others (AWWA A100-90) apply; setback distances and protective vadose zones; interfacing with other programs essential (e.g., source water protection program).
Maintenance of a disinfection residual for distribution system protection (Intermediate)	Source water constituents may affect disinfection: Fe/Mn, organics, ammonia, other factors may affect dosage and water quality. TTHM production and corrosion (Pb/Cu) may be issues. Biofilm formation and other deposits in pipes may affect water quality. TCR remains unspecific on type/amount of disinfectant, as each type differs in concentration, time, temperature, pH, interaction with other constituents, etc.
Proper maintenance of distribution system: pipe repair/replacement, main flushing programs, storage/ reservoir and O&M programs (including cross-connection control/ backflow prevention), and maintenance of positive pressure throughout (Intermediate)	O&M programs particularly important for smaller systems needing to maintain water purity. States may vary on distribution protection measures. See also Appendix C EPA memorandum (Issue #2) in reference to cross-connection control as proper maintenance; and EPA's Cross-Connection Control Manual (# EPA 570/9-89-007).
Filtration and/or Disinfection of surface water or other groundwater under direct influence (Subpart H/SWTR); or disinfection of groundwater (Basic thru Advanced)	Same issues as cited above under maintaining disinfection residual; *pretreatment* requirements affect complexity of operation. Refer to SWTR Compliance Technology List; and other regulations under development.
Groundwaters: Compliance with State Well-Head Protection Program (Intermediate)	EPA/State WHPP implementation (per §1428 SDWA): may be used to assess vulnerability to contamination, and in determination of sampling and sanitary survey frequencies.

4. "EMERGING" TECHNOLOGIES AND ISSUES FOR FURTHER CONSIDERATION

Section 4.1: Emerging Technologies

In 1997 EPA listed additional new or "emerging" technologies that merit further consideration as small system compliance technologies under the SWTR and/or TCR. The Agency stated that if found to be viable, these newer technologies would be incorporated in forthcoming lists. Identified were the following emerging treatments or means to comply:

- Advanced oxidation or perozone
- Pulsed ultraviolet
- Ultraviolet oxidation
- Point-of-entry (POE) devices*****

*****NOTE: POE treatment as a centrally managed treatment option was considered by EPA, however, the Agency feels that POE application for addressing microbial contamination would be very limited due to the concern for disinfecting water properly (following filtration) and the complexity of monitoring POE systems individually.

Stakeholders at the May 1998 meeting agreed that this listing of technologies should remain very inclusive, and that the emerging technologies should be investigated as more data on their use become available. Stakeholders also advised that EPA should not be overly "prescriptive" in this listing on specific factors that would impinge on site-specific designs. The listing should, therefore, continue to develop as a tool for State regulatory personnel and small water system managers in their decision making.

EPA reviewed available information and industry-supplied data on the above emerging treatment technologies, and determined that current data do not support the listing of the "advanced ultraviolet" and "advanced oxidation" type processes in this context. In most cases, while appropriate in treating water contaminated with other substances (such as organic contaminants), these treatments have not yet found use at water systems for inactivating the target microorganisms. **Two main reasons are cited for not listing these as compliance technologies at this time:**

(1) The Agency has not reviewed data on inactivation by these advanced processes of *Giardia* cysts and viruses subject to the requirements of the SWTR.

(2) These processes may not have been tested/piloted in the field for meeting the subject regulatory requirements. This may be due to a lack of penetration into and/or acceptance within the small systems market at this time, or due to a perception that advanced treatments are not necessary, or may be burdensome to operate for smaller systems, given that simpler, single-oxidant treatment technologies have proven effective for the purposes stated.

The following is a brief summary of information EPA has reviewed on the above-mentioned advanced treatment technologies. It should be noted that the Agency would continue to accept and review data that may indicate progress in application of these treatments for control of microorganisms in water.

ADVANCED ULTRAVIOLET TREATMENTS

Pulsed Ultraviolet (UV) Pulsed ultraviolet radiation treatment is application of UV technology to a water column via repeated high intensity bursts (or "high power density" pulses **(1)**) of radiation, as opposed to continuous wave UV application which typically applies constant but lower levels of power and irradiation. Tests on this technology have centered on efficacy of pulsed-UV treatment in treating oocysts of *Cryptosporidium* **(2)(3) (4)**, and to some extent on inactivation of bacteria **(5)**. A study presented in 1997 indicated that a pulsed UV system had produced an approximate 2-log inactivation of *Cryptosporidium* oocysts **(4).** EPA has not viewed data on *Giardia* inactivation, or small systems applications of this technology; American Water Works Association Research Foundation research results may be of assistance in determining pulsed UV efficacy, likely targeting *Cryptosporidium* in water.

(1) LaFrenz, R. *Application of Pulsed UV for Water Disinfection*. Innovatech, Inc. Presented at AWWA Water Quality Technology Conference, 1997.

(2) *Cryptosporidium Testing Using Pulsed UV Light.* US Centers for Disease Control, Atlanta Georgia, February 10, 1994.

(3) Lorenzo-Lorenzo, M.J. et al. *Effect of Ultraviolet Disinfection of Drinking Water on the Viability of* Cryptosporidium parvum *Oocysts.* Journal of Parasitology. 79(1)67-70 (1993).

(4) Clancy, J.L. et al. *Inactivation of* Cryptosporidium parvum *Oocysts in Water Using Ultraviolet Light.* Clancy Environmental Consultants, University of Arizona, and United Water- N.J. in collaboration: Presented at the AWWA International Symposium on *Cryptosporidium* and Cryptosporidiosis, Newport Beach CA (March 1997).

(5) Bank, H.L. et al. *Bactericidal Effectiveness of Modulated UV Light*. Applied and Environmental Microbiology, 56(12)3888-3889.

Ultraviolet Oxidation This treatment is the combination of ultraviolet and a strong chemical oxidant such as hydrogen peroxide (or ozone). One study indicates 3-4 log reductions of coliphages, at doses of 10 mmol/L H2O2 and ultraviolet at 0.8 W/L (no time indicated) **(1)**. One stakeholder reported that the combination of UV and ozone has been in use overseas, though apparently not in the U.S. Ultraviolet oxidation appears to have been applied more so in non-drinking water settings, e.g., in control of organic compounds in wastewater. Testing on *Giardia* cysts (for characterizing of dosing requirements) have apparently not been conducted. This treatment combination may be useful in pre-oxidizing iron, manganese, and/or Arsenic (III) in raw water and providing disinfection credit.

(1) Rajala R.L., et al. *Effect of Advanced Oxidation Processes on Inactivation of Coliphages,* Water Science and Technology (1995).

Other Ultraviolet Variations Other modifications of the conventional or continuous wave UV application include:

- ! A medium pressure lamp system using a collimated beam was been pilot tested in an advanced wastewater treatment application, at the Montreal wastewater plant. Fecal coliforms were inactivated (over 3-logs) at doses of approximately 35 mWs/cm2, and other factors were investigated such as turbidity, particle size distribution, UV transmittance, dissolved organics and iron. Photoreactivation and dark repair mechanisms were found to increase microbial counts at higher UV doses **(1)**.

- ! An advanced ultraviolet cryptosporidium inactivation device incorporates within its design two chambers that successively screen/trap microorganisms and irradiate them while trapped, at successive doses of 4,000 mWs/cm2 (i.e., total dose approx. 8,000 mWs/cm2). Results of testing have been presented to EPA and others: the tests indicate that greater than 4-log (99.99%) of *Cryptosporidium* oocysts were inactivated by the process in a full-scale "pilot" test; results also indicated a need to assess the maximal levels of inactivation, which may exceed 4-log, and to demonstrate the efficacy and applicability of the treatment in real world applications, i.e., beyond the test's carefully controlled trial conditions **(2)**. An additional challenge test using *E.coli* bacteria *and B. subtilis* (more resistant bacterial endospores) on this same device resulted in a 4.9 log reduction in *E. Coli*, and a 1.3 log reduction in *B. subtilis* **(3).** AWWA's *Opflow* **(4)** monthly included an article on a demonstration of the UV treatment unit (and ozonation) at a plant in Wisconsin.

- ! Additional research has been conducted on medium-pressure UV systems, and on pulsed UV using xenon lamps. Also, thin film UV designs are being considered , possibly for reduction of dose and power requirements. More research may result in more efficient designs for SWTR or enhanced SWTR applications.

(1) Cairns, W.L., Sakamoto, G., Comair, C.B., and Gehr, R. *Assessing UV Disinfection of a Physico-chemical Effluent by Medium Pressure Lamps Using a Collimated Beam and Pilot Plant."* Trojan Technologies, DigiPen Computer Graphics, and McGill University in collaboration: Presented at the WEF Specialty Conference on Effluent Disinfection Systems. New Jersey (May 1993).

(2) Clancy, J.L. et al. *Inactivation of* Cryptosporidium parvum *Oocysts in Water Using Ultraviolet Light.* Clancy Environmental Consultants, University of Arizona, and United Water- N.J. in collaboration: Presented at the AWWA International Symposium on *Cryptosporidium* and Cryptosporidiosis, Newport Beach CA (March 1997).

(3) *Evaluation of the Disinfection Capabilities of the Safe Water Solutions L.L.C.* Cryptosporidium *Inactivation Device.* Clancy Environmental Consultants, report commissioned by Safe Water Solutions L.L.C. (December 1996).

(4) Johnson, R.C. *Getting the Jump on* Cryptosporidium *with UV.* Opflow: American Water Works Association, v.23, no.10 (October 1997).

ADVANCED OXIDATION PROCESSES

Advanced oxidation processes (AOPs) are oxidation processes that generate highly reactive hydroxyl radicals. Hydroxyl radicals are produced by an accelerated the ozone decomposition rate, through the addition of hydrogen peroxide (H2O2) and/or ultraviolet (UV) light to ozonated water. The most commonly used AOP is the combination of hydrogen peroxide and ozone, also referred to as peroxone or perozone (see above section on ultraviolet oxidation for more information on the UV-chemical oxidation disinfection process).

Peroxide-ozone treatment has primarily been used to treat organics in water such as taste and odor compounds and chlorinated organics. Metropolitan Water District (MWD) of Southern California conducted extensive research into the removal of geosmin and 2-methylisoborneol (MIB). MWD also performed studies on the inactivation of microorganisms using the peroxone process. The inactivation rates were comparable to ozone at hydrogen peroxide to ozone ratios ranging from 0.2-0.3. *E. coli*, MS2 and f2 coliphages were inactivated at rates greater than 5 $\log_{10}$, and hetrotrophic plate count (HPC) bacterium was inactivated at approximately 1.2-2.5 $\log_{10}$. In other studies, inactivation of Giardia muris cysts using peroxone was also comparable to ozone. The inactivation rate for *Giardia muris* was 2.3 ± 0.2 $\log_{10}$, suggesting that peroxone is slightly more potent in inactivating this microbe than ozone. This advanced process may also be of use in lowering brominated disinfection byproducts where bromides are present.

Regarding raw water quality, higher levels of alkalinity affect the ozone residual, increasing microorganism inactivations. Finch, et al., indicates O3 dose, pH, turbidity and temperature all affect advanced oxidation efficiency. Also, above 0.5:1 application rate (hydrogen peroxide to ozone) there is no apparent benefit; and as a precaution, above a 1:1 ratio of hydrogen peroxide to ozone the toxicity of H2O2 is an issue.

Since the primary components in the peroxone system are ozone and hydrogen peroxide, it has the same limitations as ozone. Peroxone can only be used as a primary disinfectant due to its high reactivity rate; it does not maintain an appreciable residual level. Performance is based upon an optimal hydrogen peroxide to ozone ratio of less than 0.5. Peroxone treatment may also have some small system limitations because ozone must be generated at the point of use due to its instability, and hydrogen peroxide is considered a hazardous material requiring secondary containment storage facilities.

Advanced oxidation is considered an emerging technology. The majority of advanced oxidation research as been for treatment of organics. Because of peroxone's oxidative properties, a system which uses ozone as the primary disinfectant may want to consider advanced oxidation if they need to treat organics as well. More studies will have to be performed before advanced oxidation becomes a common technology for disinfection.

(1) Roy Wolfe, et al. Inactivation of *Giardia muris* and Indicator Organisms Seeded in Surface Water. ES&T, 1989

(2) Roy Wolfe, et al. Disinfection of Model Indicator Organisms in a Drinking Water Pilot Plant by using PEROXONE. Applied & Environmental Microbiology, 1989.

(3) Rajala, R.L. et al. Effect of Advanced Oxidation Processes on Inactivation of Coliphages. Wat. Sci. Tech., 1995.

(4) McGuire, M.J., et al. Treating Water with Peroxone: A Revolution in the Making. WATER/Engineering & Management, May 1988.

(5) Finch, G.R. et al. Ozone and Ozone-Peroxide Disinfection of Giardia and Viruses. AWWARF & AWWA, 1992.

Section 4.2: Additional Issues for Consideration

EPA will continue to seek, through voluntary submittal by stakeholders of on-going treatment evaluations, and through other developmental activities, new information that may be useful to users of this guide. It is anticipated that many of the technology issues discussed in this listing will be clarified when further information is available. EPA particularly seeks information on treatment availability; design and operational factors including raw water concerns and byproducts issues, system management, and of course on treatment efficacy.

EPA will also keep abreast of other efforts underway in the fields of equipment testing, certification, on-site verification, State-developed or other independently developed protocols for equipment tests, operational issues, and other related concerns. The Agency is committed to continuing its dialogue with stakeholders, both in terms of identifying issues and resolving them.

Finally, it should be noted that this listing may be viewed as a transitional listing as EPA considers further regulations that will impact large, and small, water supplies; EPA has begun this transition by including in this listing data that will be of greater import to systems as they prepare to provide the next level of control of microbial pathogens in water, namely enhanced surface water treatment needs and inactivation/removal of oocysts such as *Cryptosporidium*, which is to be addressed in later EPA rules. Research in this area is moving rapidly, and results of national survey data will be forthcoming. These are expected to be of use in regard to determining suitable compliance technologies for meeting the enhanced surface water treatment requirements.

APPENDIX A

RELEVANT PARTS OF SECTIONS 1412 OF THE REVISED SAFE DRINKING WATER ACT
(SECTION 1412(b)(4)(E)(ii) thru (v) as amended in 1996)

SEC. 105. TREATMENT TECHNOLOGIES FOR SMALL SYSTEMS.

Section 1412(b)(4)(E) (42 U.S.C. 300g-1(b)(4)(E)) is amended by adding at the end the following:

``(ii) List of technologies for small systems.--The Administrator shall include in the list any technology, treatment technique, or other means that is affordable, as determined by the Administrator in consultation with the States, for small public water systems serving--

``(I) a population of 10,000 or fewer but more than 3,300;

``(II) a population of 3,300 or fewer but more than 500; and

``(III) a population of 500 or fewer but more than 25;

and that achieves compliance with the maximum contaminant level or treatment technique, including packaged or modular systems and point-of-entry or point-of-use treatment units. Point-of-entry and point-of-use treatment units shall be owned, controlled and maintained by the public water system or by a person under contract with the public water system to ensure proper operation and maintenance and compliance with the maximum contaminant level or treatment technique and equipped with mechanical warnings to ensure that customers are automatically notified of operational problems. The Administrator shall not include in the list any point-of-use treatment technology, treatment technique, or other means to achieve compliance with a maximum contaminant level or treatment technique requirement for a microbial contaminant (or an indicator of a microbial contaminant). If the American National Standards Institute

has issued product standards applicable to a specific type of point-of-entry or point-of-use treatment unit, individual units of that type shall not be accepted for compliance with a maximum contaminant level or treatment technique requirement unless they are independently certified in accordance with such standards. In listing any technology, treatment technique, or other means pursuant to this clause, the Administrator shall consider the quality of the source water to be treated.

``(iii) List of technologies that achieve compliance.--Except as provided in clause (v), not later than 2 years after the date of enactment of this clause and after consultation with the States, the Administrator shall issue a list of technologies that achieve compliance with the maximum contaminant level or treatment technique for each category of public water systems described in subclauses (I), (II), and (III) of clause (ii) for each national primary drinking water regulation promulgated prior to the date of enactment of this paragraph.

``(iv) Additional technologies.--The Administrator may, at any time after a national primary drinking water regulation has been promulgated, supplement the list of technologies describing additional or new or innovative treatment technologies that meet the requirements of this paragraph for categories of small public water systems described in subclauses (I), (II), and (III) of clause (ii) that are subject to the regulation.

``(v) <<NOTE: Records.>> Technologies that meet surface water treatment rule.--Within one year after the date of enactment of this clause, the Administrator shall list technologies that meet the Surface Water Treatment Rule for each category of public water systems described in subclauses (I), (II), and (III) of clause (ii).''.

APPENDIX B

ADDITIONAL REFERENCES ON SWTR-APPROVED FILTRATION TECHNOLOGIES

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Fogel, Doug. “Removing Giardia and Cryptosporidium by slow sand filtration”. American Water Works Association Journal, v. 85 (Nov. '93) p. 77-84.

Fulton, George P. "Diatomaceous earth filtration for reduced risk water treatment." PUBLIC WORKS v. 126 (Nov. '95) p. 34-6.

Gifford, John S. et al. "Synergistic effects of potassium permanganate and PAC in direct filtration systems for THM precursor removal." WATER RESEARCH v. 23 (Oct. '89) p. 1305-12.

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Knocke, William R. et al. "Examining the reactions between soluble iron, DOC, and alternative oxidants during conventional treatment." AMERICAN WATER WORKS ASSOCIATION JOURNAL v. 86 (Jan. '94) p. 117-27.

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Leland, David E. Slow sand filtration in small systems in Oregon. American Water Works Association Journal, v. 82 (June '90) p. 50-9.

Logsdon, Gary S. et al. "Testing direct filtration for the treatment of high-turbidity water." AMERICAN WATER WORKS ASSOCIATION JOURNAL v. 85 (Dec. '93) p. 39-46.

Ongerth, Jerry E. "Evaluation of treatment for removing Giardia cysts.” AMERICAN WATER WORKS ASSOCIATION JOURNAL v. 82 (June '90) p. 85-96.

Nieminski, Eva C. et al. "Removing Giardia and Cryptosporidium by conventional treatment and direct filtration." AMERICAN WATER WORKS ASSOCIATION JOURNAL v. 87 (Sept. '95) p. 96-106.

Peer, George J. et al. "Spiking tests prove DE filtration works for high Giardia concentrations."

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Randall, Nick. “A small town helps itself--to time-tested slow sand filter technology”. Public Works, v. 122 (Aug. '91) p. 104-6.

Rees, Robert H. et al. "Let diatomite enhance your filtration.” CHEMICAL ENGINEERING v. 97 (Aug. '90) p. 76-9.

Rees, Robert. "Diatomites cut filtration costs.” POLLUTION ENGINEERING v. 22 (Apr. '90) p. 67-8+.

Riesenberg, F., Walters, B., Steele, A., and Ryder, R. Slow sand filters for a small water system. American Water Works Association Journal, v. 87 (Nov. '95) p.48-56.

Schuler, Peter F. et al. "Diatomaceous earth filtration of cysts and particulates using chemical additives." AMERICAN WATER WORKS ASSOCIATION JOURNAL v. 82 (Dec. '90) p. 67-75.

Schuler, Peter F. Slow sand and diatomaceous earth filtration of cysts and other particulates. Water Research, v. 25 (Aug. '91) p. 995-1005.

Spencer, Catherine M. et al. "Improving precursor removal." AMERICAN WATER WORKS ASSOCIATION JOURNAL v. 87 (Dec. '95) p. 71-82.

Tobiason, John E. et al. "Pilot study of the effects of ozone and PEROXONE on in-line direct filtration." AMERICAN WATER WORKS ASSOCIATION JOURNAL v. 84 (Dec. '92) p. 72-84.

VanArnam, David G. et al. "Diatomaceous-earth water filtration." WATER/ENGINEERING & MANAGEMENT v. 136 (Oct. '89) p. 35-6.

Visscher, Jan Teun. Slow sand filtration: design, operation, and maintenance. American Water Works Association Journal, v. 82 (June '90) p. 67-71.

Walton, Harris G. "Diatomite filtration: why it removes Giardia from water." WATER/ ENGINEERING & MANAGEMENT v. 136 (Oct. '89) p. 38.

Wiesner, Mark R. et al. "Cost estimates for membrane filtration and conventional treatment." AMERICAN WATER WORKS ASSOCIATION JOURNAL v. 86 (Dec. '94) p. 33-41.

APPENDIX C

MEMORANDUM REGARDING TCR TECHNOLOGIES

MEMORANDUM

SUBJECT: Clarification of Issues Concerning the Revised Total Coliform Rule

FROM: Michael B. Cook, Director
Office of Drinking Water (WH-550D)

TO: Water Supply Branch Chiefs
Environmental Services Division Directors
Quality Assurance Officers
Regions-I-X

Several Regions and States have requested clarification on parts of the revised total coliform rule, promulgated June 19, 1989. These clarifications appear below.

1. ISSUE: Why is it the total coliform rule does not distinguish between transient non-community water systems and non-transient non-community water systems like some rules regulating chemical contaminants?

Regulations on chemical contaminants generally deal with chronic exposure, i.e., lifetime exposure; this differs from microbiological regulations where a single exposure may result in illness. Moreover, the vast majority of non-community water systems will sample fewer than five times per month, and thus be required to have a sanitary survey every 5 years (with some exceptions), the same as like-sized community water systems. For such systems, sanitary surveys are more important for protecting public health than monitoring. Thus, it is less important to differentiate between the two types of non-community water systems.

2. ISSUE: Is a cross-connection control program included as a best available means for achieving compliance with the MCL?

§141.63(d) identifies the best technology, treatment techniques, or other means available for achieving compliance with the MCL for total coliforms. This list includes paragraph (3) in that section, "Proper maintenance of the distribution system including appropriate pipe replacement and repair procedures, main flushing programs, proper operation and maintenance of storage tanks and reservoirs, and continual maintenance of positive water pressure in all parts of the distribution system..." EPA considers this statement as including a cross-connection control program.

3. ISSUE: Where is a fourth repeat sample collected?

§141.21(b)(2) states that a system which has a total coliform-positive sample must collect at least one repeat sample from the sampling tap where the original total coliform-positive sample was taken, and at least one repeat sample at a tap within five service connections upstream and at least one repeat sample at a tap within five service connections downstream of the original sampling site. EPA did not specifically state that a system required to take a fourth repeat sample by §141.21(b)(1) was to take it within five service connections of the original sample, but that was implied in the rule in §141.21(b)(2), and was the Agency's intention (see definition of repeat sample in the preamble on 54 FR 27553, column 1, first paragraph).

4. ISSUE: Where are additional sets of repeat samples collected?

§141.21(b)(4) states that if one or more samples in a set of repeat samples 4-s total coliform-positive, the system must collect an additional set of repeat samples. The rule, however, is not clear on where the additional set is to be collected, five adjacent service connections from the original total coliformpositive tap or the repeat total coliform-positive tap (assuming only one repeat sample is total coliform-positive). EPA believe's that this situation would generally occur only when the distribution system is contaminated, and consequently will allow the system to decide on which of the two taps to center the second set of repeat samples.

5. ISSUE: If a system has a fecal col'iform-positive sample and all repeat samples are total coliform-negative, does that system have an acute violation of the MCL for total coliforms?

§141.63(b) specifies the MCL for total coliforms, based upon the presence of fecal coliforms or E. coli. Based upon this paragraph, if a system has a total coliform-positive routine sample which is also fecal coliform-positive (or E. colipositive), and all repeat samples are total coliform-negative, then the system has not violated the MCL in §141.63(b).

6. ISSUE: Invalidation of total coliform-positive samples.

§141.21(c)(1) lists the conditions under which a State may invalidate a total coliform-positive sample. A State may invalidate such a sample only on a case-by-case basis for eadh instance; the State may not invalidate total coliform-positive samples prospectively or generically.

7. ISSUE: MCL violations for persistent violators of monitoring or reporting requirements.

No EPA rule, including the revised total coliform rule, states that systems which repeatedly violate specified monitoring or reporting requirements are, as a consequence, in violation of the MCL. However, States should not be discouraged from choosing such an approach.

8. ISSUE: Collection of a routine sample(s) the next month by a small system after the State waives the requirement for five samples the next month after a total coliform-positive sample.

§141.21(b)(5)(ii) states that when a State waives the requirement for a system which collects fewer than five routine samples/month to collect at least five routine samples during the next month after a total coliform-positive sample, the system must still take at least one routine sample before the end of the next month, unless the State has determined that the system has corrected the contamination problem before the system took the set of repeat samples. EPA did not intend to suggest by this statement that systems could ignore the routine monitoring frequency requirements specified under §§141.21(a)(2)-(3). A system must still collect the number of routine samples specified by §§141.21(a) (2)-(3).

9. ISSUE: Mixed Medium ONPG-MUG (MMO-MUG) test

To date, the only commercially available formulation of the approved MMO-MUG test of which EPA is aware is the Autoanalysis Colilert Test. Other methods which are identical in formulation and procedure would also be acceptable. Variations in formulation or procedure of the MMO-MUG test that was approved in the Federal Register (54 FR 27544; June 29, 1989) should be submitted to EPA's Environmental Monitoring Systems Laboratory in Cincinnati for review.