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Small System Compliance Technology List for the Surface Water Treatment 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's 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. For six of the project areas (small systems, operator certification, consumer confidence reports, source water protection, contaminant selection, and drinking water State revolving fund), National Drinking Water Advisory Council (NDWAC) working groups have been formed. These working groups will make recommendations to the full Council, which in turn will advise 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. The short-term goals of this team are to prepare: (1) the list of technologies that small systems can use to comply with the Surface Water Treatment Rule (SWTR), by 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. The long-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 first of the short-term goals: the preparation of the list of small system compliance technologies for the SWTR.

Section 1.2: Need for a Small System Technology Requirement

The 1986 SDWA 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 1996 SDWA.

The Surface Water Treatment Rule (SWTR) requires compliance with a treatment technique rule 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 previously described definition of feasible would also apply in the technology determinations for treatment technique rules.

Before the 1996 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 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 Amendments attempt to redress this problem in part through the previously described series of small system compliance technologies; this guidance is the first installment of this series of publications aimed at helping small systems comply.

Section 1.3: Small System Treatment Technology Requirements of the 1996 SDWA

Since large systems were used as the basis for the feasibility determinations, the existing BATs for MCLs and the existing treatment techniques may not be appropriate for small systems. The 1996 SDWA specifically requires EPA to make technology assessments relevant to the three categories of small systems respectively for both existing and future regulations, in addition to the pre-1996 Amendments BAT protocol. The three population-served size categories of small systems defined by the 1996 SDWA are: 10,000 - 3,301 persons, 3,300 - 501 persons, and 500 - 25 persons.

The 1996 SDWA identifies 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)]. The technology class, 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 has been significantly revised under the 1996 SDWA. Under the 1986 SDWA, 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 SDWA, there is a new procedure available for small systems in the two smallest size categories (systems serving less than 3,300): the “small system variance”. EPA approval is required for a small system variance in the largest size category (systems serving between 3,301 and 10,000 persons). 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 some additional requirements for small system variances that affect the listing of variance technologies. 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)]. Nor are small system variances available for a NPDWR for a microbial contaminant (including a bacterium, virus, or other organism) or an indicator or treatment technique for a microbial contaminant [Section 1415(e)(6)(B)]. Variance technologies will not be listed for NPDWRs relevant to these restricted contaminants.

The process for identifying compliance and variance technologies for future regulations was summarized in the preceding paragraphs. The language in the 1996 SDWA Amendments is different for the existing regulations. There are two mandatory lists of compliance technologies that will be developed for the existing rules. By August 6, 1997, the Administrator must list technologies that meet the SWTR for each of the three size categories [Section 1412(b)(4)(E)(v)]. By August 6, 1998, after consultation with the States, the Administrator must issue a list of technologies that achieve compliance with the MCLs or treatment technique requirements for other existing NPDWRs. By August 6, 1998, after consultation with the States, the Administrator must issue guidance or regulations for variance technologies for the existing

NPDWRs for which a small system variance can be granted. Figure 1 summarizes the requirements for compliance and variance technologies and differentiates between existing and future regulations.

FIGURE 1
SMALL SYSTEM REQUIREMENTS
COMPLIANCE VS. VARIANCE TECHNOLOGIES

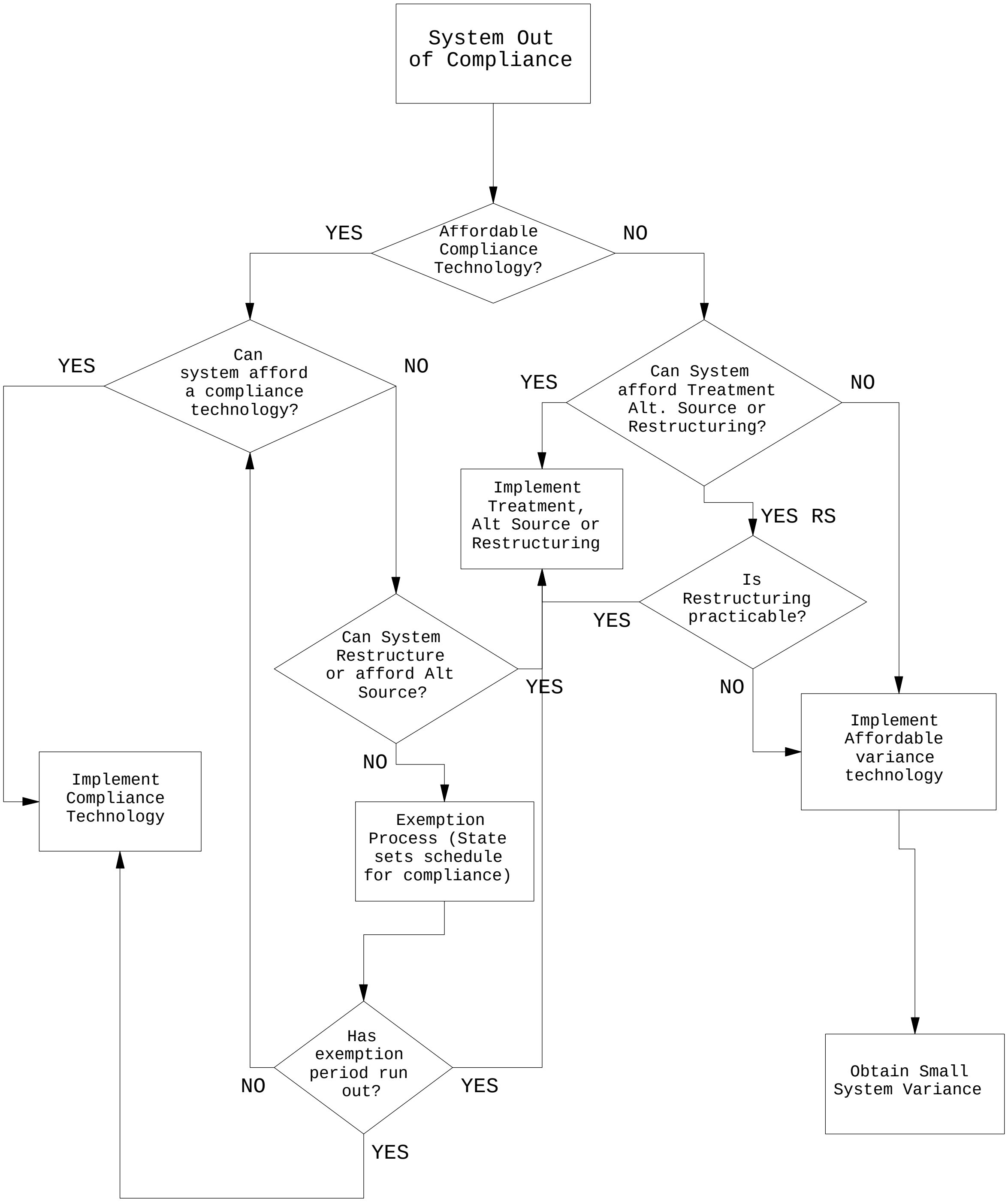
	COMPLIANCE TECHNOLOGY	**VARIANCE TECHNOLOGY**
EXISTING REGULATIONS:		
Meet affordable technology criteria	Not Explicitly Required	Inherently Required
Source Water Quality	GOOD	POOR
Endpoint	MCL	Maximum Reduction that is Affordable
Health Requirements Separate from MCL	NONE	Must be protective of public health
FUTURE REGULATIONS:		
Meet affordable technology criteria	Required	Required
Source Water Quality	GOOD	POOR
Endpoint	MCL	Maximum Reduction that is Affordable
Health Requirements Separate from MCL	NONE	Must be protective of public health

The two major concerns regarding technologies for small systems are affordability and technical complexity: per household costs tend to be higher for the smaller system customers for most central treatment technologies, leading to many cases where small systems simply cannot afford to install a prescribed technology, and small systems often do not have access well-trained water system operators. Although the statute is silent concerning the ability of a system to afford compliance technologies for existing regulations, EPA believes the better reading of the statute is that affordability is a key criterion for both existing and future regulations. If the candidate technologies are not evaluated against an affordable technology criterion, then compliance technologies would exist for all of the existing regulations regardless of the source water quality. The existing BATs or treatment techniques would become the compliance technologies for small systems, which was the case prior to the 1996 Amendments. The listing of compliance technologies would prevent the listing of variance technologies, and, as a result, the availability of small system variances. There would, therefore, be no new variances available for small systems with respect to the existing regulations, thus providing no relief to small systems. EPA does not believe that result to be what Congress intended. As a result, EPA will evaluate small system technologies against an affordable technology criterion for all applicable existing regulations.

The flow chart in Figure 2 shows the role of the affordable technology criteria in the treatment technology arena. The primary function of the criteria is to determine whether a system of a given size/source water quality combination should proceed down the compliance or variance technology pathway. The secondary function is to define the universe of technologies within the compliance or variance technology pathway. These affordable technology criteria are different from the affordability criteria to be used by States in granting small system variances under Section 1415(e). The criteria to be used by States, which are due in February 1998, will be applicable to individual systems ("system-level affordability criteria"). Options that States can use for system-level affordability criteria are being developed in the Small System NDWAC Working Group process. In contrast, the affordable technology criteria to be developed under Section 1412(b)(4) can be viewed as "national-level affordability criteria". Technologies that meet the national-level criteria may not be affordable for a particular system within the size category. The role of the system-level affordability criteria is illustrated in Figure 2 as well.

There are several existing regulations for which the candidate technologies will not be evaluated against an affordable technology criterion. As previously mentioned, small system variances are not available for any NPDWR for a microbial contaminant (or indicator) or for regulations promulgated prior to January 1, 1986. The regulations promulgated prior to January 1, 1986 are also exempt; the relevant contaminants are arsenic, beta particle and photon radioactivity, gross alpha particle activity, radium 226, and radium 228. Since small system variances are not available, the system must comply with the NPDWR as before 1996 Amendments. As indicated in Figure 2, alternate source and restructuring are the only other options available for regulations where compliance technologies are unaffordable and small system variances are not available. Because small system variances are not available for the microbial and pre-1986 regulations, EPA has not assessed the affordability of the compliance

FIGURE 2
AFFORDABLE COMPLIANCE TECHNOLOGIES*

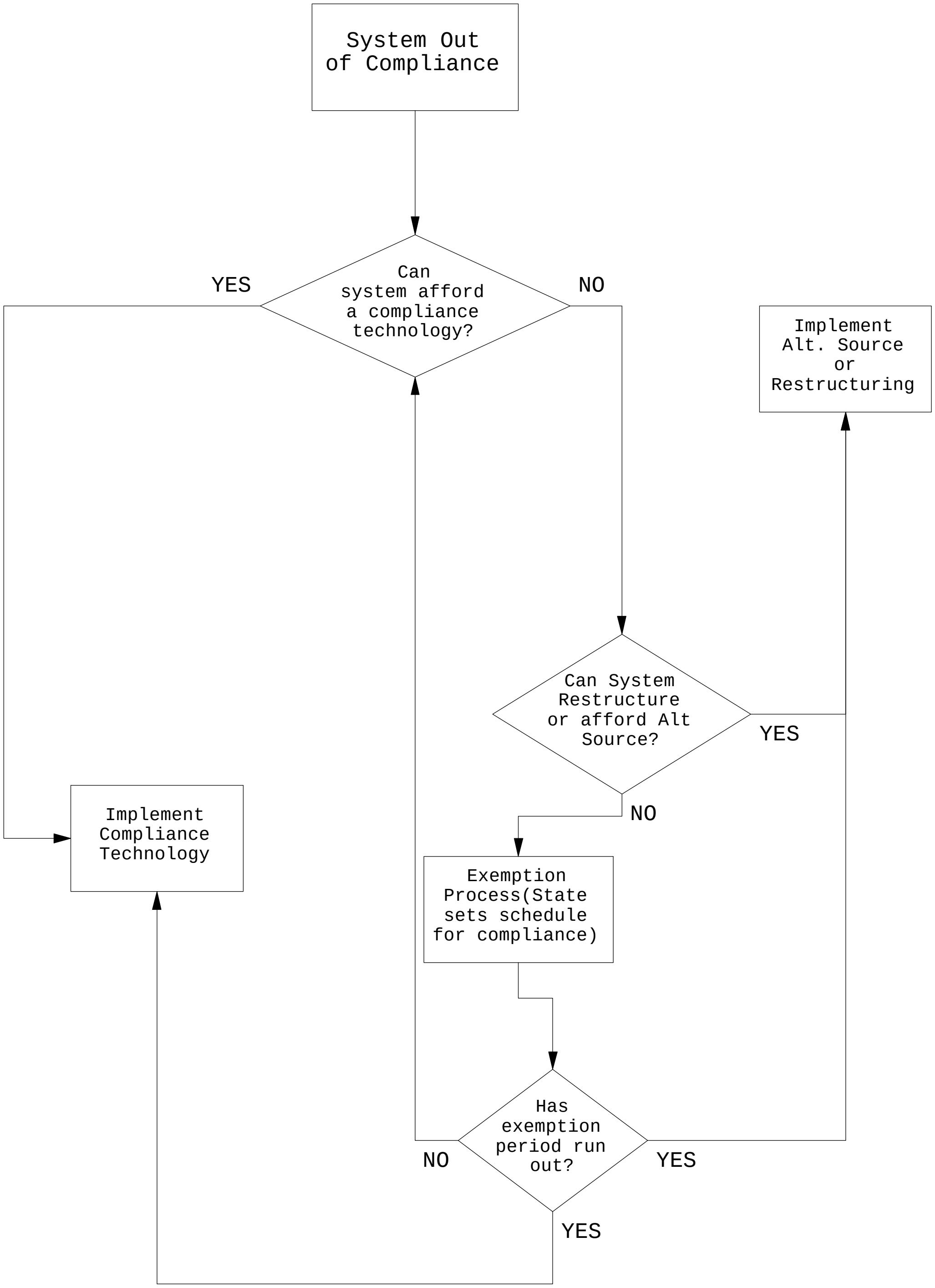


*NOTE: This approach covers all regulations except for microbial contaminants and the pre-1986 regulations (will cover revisions).

technologies for these regulations. The flow chart in Figure 3 shows the simplified process for these regulations.

Since the SWTR is a rule that deals with microbial contaminants (i.e., viruses and *Giardia*), it is not necessary to compare the candidate technologies against affordable technology criteria. For the SWTR, the only screening criterion will be the ability of small water systems to install and reliably operate the process. The disinfection and filtration technology evaluations are found in Chapter 2 of this document.

FIGURE 3
COMPLIANCE TECHNOLOGIES (No affordability)*



*NOTE: This approach covers all microbial regulations (SWTR, Coliform, GWDR, and ESWTR)and the existing arsenic and radionuclide regulations.

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

The 1996 SDWA does 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 requirements; it does not over-ride any of the SWTR requirements.

The SWTR was published in the Federal Register on June 29, 1989. Even though many systems have already installed a treatment technology, there are systems that still need to select a treatment technology to comply with the SWTR. Since technology decisions for these systems will need to be made soon, meeting the August 6, 1997 deadline in the SDWA with respect to this list of technologies provides these systems with valuable information regarding their treatment technology options. The importance of meeting this dead-line further justifies EPA's decision to issue the SWTR 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. Issuing the list without rule-making will allow EPA to meet the deadline and to provide information to more small systems as they make their treatment technology decisions.

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

The SDWA does not specify the content of the compliance technology lists. The initial list is very general and expands the list of technology options listed in the SWTR. This list will be updated in a revised SWTR compliance technology list to be published in August 1998. This second list will provide more detail on the applicability ranges for the identified compliance technologies and may include some new technologies that were not included in the initial list because of the need for further evaluation. The lists will evolve over time, but will not be product-specific. The compliance technology lists 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; nor does EPA feel it would be appropriate to do so.

Information on specific products will be available through another mechanism. EPA's Office of Research and Development has a pilot project under the Environmental Technology Verification (ETV) Program to provide treatment system purchasers with performance data from independent third parties. The EPA and National Sanitation Foundation International (NSF) are cooperatively organizing and conducting this pilot project to allow for verification testing of packaged drinking water treatment systems for meeting community and commercial needs. This pilot project includes development of verification protocols and test plans, independent testing and validation of packaged equipment, conveying and supporting government/industry partnerships to obtain credible cost and performance data, and preparation of product verification reports for wide-spread distribution.

Section 1.6: Stakeholder Involvement

EPA held a stakeholder meeting on July 22 and 23, 1997. Key stakeholders included States, water systems, and equipment manufacturers. One of the two major topics in this stakeholder meeting was the initial list of compliance technologies for the SWTR. This list was presented in the stakeholder draft of this document (EPA 815-D-97-002). Stakeholders were asked to review this list of compliance technologies for the three size categories of small systems. Stakeholder input resulted in several major changes to the stakeholder draft document: several of the technologies that were not listed or that were listed for a sub-set of the three small systems categories have now been listed for all size categories in this guidance document. In the stakeholder draft, EPA did not list technologies because of treatment techology implementability or performance consistency concerns. The stakeholders indicated that they preferred EPA to list the technologies along with the concerns rather than exclude these technologies from the list. The stakeholders indicated that they wanted the compliance technology list to provide more technology options for individual systems that have the capacity to operate more complex technologies. The stakeholders felt that the consistency concerns could be addressed through the site-specific pilot testing that can be required by the State. EPA agrees with these comments and the final guidance document reflects this change in approach.

The initial list of technologies is not intended to be a comprehensive list: systems may choose any technologies that meet the requirements of the regulations. In addition, the list will be updated in August 1998. The 1997 version of the list includes only those technologies that can be listed based on published data, primarily in peer-reviewed literature. The technologies discussed in Chapter 3 will be reviewed over the next year for inclusion in the updated list. Another goal of the stakeholder meeting was to identify the level of detail necessary to describe variance and compliance technologies and their applicability ranges. Some of the criteria that can be evaluated are discussed in Chapter 3, along with the criteria identified by the stakeholders in the meeting.

Section 1.7: Organization of the Document

This document is organized into several chapters describing the small system compliance technologies for the SWTR. Chapter 1 discusses the requirements of the 1996 SDWA and the approach EPA is following to meet those requirements. Chapter 2 discusses the technologies that were evaluated for the initial compliance technology list. The initial list is found at the end of the chapter. Chapter 3 contains the technologies that require further evaluation over the next year. This chapter also discusses some of the criteria that may be evaluated over the next year for the approved compliance technologies so that applicability ranges can be developed.

2. INITIAL 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, promulgated a NPDWR for public water systems using surface water sources or ground water sources 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 against the potential adverse health effects of exposure to *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, if required, is adequate.

Section 2.2: Technologies Evaluated for the First Compliance Technology List

The SWTR enables EPA to issue “log removal credits” to water utilities through a requirement for particular water treatments, rather than a requirement for utilities to meet an MCL, which 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 SWTR lists four filtration technologies: 1) conventional filtration, including sedimentation; 2) direct filtration; 3) diatomaceous earth filtration; and 4) slow sand filtration. Disinfection treatment is required to follow all of these filtration treatments. The disinfection technologies listed in the SWTR are chlorine, ozone, chlorine dioxide, and chloramine.

The filtration and disinfection technologies identified in the SWTR were evaluated along with other technologies that may achieve the desired inactivation. Filtration processes that function on principles other than those of the listed technologies are referred to as “alternative filtration technologies” (see Section 2.4 for more detail). In addition to the listed filtration technologies in the SWTR, this guidance considers six alternative filtration technologies: ***reverse osmosis filtration, microfiltration, ultrafiltration, nanofiltration, bag filtration, and cartridge filtration***. And, in addition to the SWTR listed disinfection technologies, this guidance considers two new disinfection technologies: ***mixed-oxidant disinfection and ultraviolet radiation***.

The compliance technology guidance list identifies those technologies EPA has found to be effective for small systems from the list of technologies in the SWTR and the additional technologies listed above. The list does not exclude emerging technologies that are found to be as effective as the listed technologies. In this chapter, the disinfection technologies are discussed in Section 2.3 and the filtration technologies are discussed in Section 2.5.

Section 2.3: Compliance Technology Evaluation of Disinfection Technologies

Six disinfection technologies have been evaluated as possible compliance technologies. Since the viability of the four technologies listed in the SWTR has already been summarized in the SWTR guidance manual, their technology summaries are brief.

Inactivation contact time (CT) values for the disinfectants listed in the SWTR were published by USEPA in the 1989 guidance for the SWTR **(3)**. "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 **(5)**. There is a relationship between CT and inactivation percent removal (or log removal) for a given disinfectant. Since the determination of percent removal of a microbiological contaminant is more technically demanding than the calcuation of CT, CT is used as a surrogate for percent removal for a given disinfectant. For example, Table IV-3 (p. 27511) of the SWTR **(5)** shows CT values for free chlorine, ozone, chlorine dioxide, and preformed chloramines that correspond to 1-log removal of Giardia lamblia.

DISINFECTION TREATMENT TECHNOLOGIES LISTED IN THE 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 residual, 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 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. with capacities greater than 100,000 gal/day and some smaller facilities, for disinfection as well as for other water treatment objectives **(4)**. Applications at the smallest water system size category (i.e., systems serving <500) are not plentiful. However, ozonation technology for even the smallest public water system applications is available from a number of suppliers, and is found to be currently in use in relevant systems **(4)**. Ozone treatment, therefore, is a listed technology for all categories of public water systems.

References

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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).

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. U.S. Environmental Protection Agency. 40 CFR Parts 141 and 142. Drinking Water; National Primary Drinking Water Regulations; Filtration, Disinfection; Turbidity, Giardia lamblia, Viruses, Legionella, and Heterotrophic Bacteria; Final Rule. Federal Register, 27486, V. 54, N. 124, June 29, 1989.

Chlorine Chlorination 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 informed the USEPA that provision of adequate CTs for chlorination may be problematic and require additional consideration. However, stakeholders agree that all public water supply systems, regardless of size, would benefit from the listing of chlorination disinfection. 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. Chlorination treatment is a listed technology for all 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).

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. 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. 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 problematic and require consideration.

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 treatment for all categories of public water systems.

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 (and thus, is consumed very readily) that it may not provide a residual disinfectant in the distribution system. 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.

DISINFECTION TREATMENT TECHNOLOGIES NOT LISTED IN THE SWTR

UV Radiation Ultraviolet (UV) radiation has been found to be an effective disinfectant in 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. (The Agency does not wish to imply that this wavelength is the only useful band of radiation for disinfection purposes, but it does represent, at this time, the most efficacious UV specification for disinfection while other bands are more useful for destruction of chemical contaminants.) UV dose is typically expressed in units of milliwatt-sec per square centimeter (mW-sec/cm2), which is the product of the intensity of the UV lamp (mW/cm2) and time of exposure (sec). UV dosage in treating water in this manner is comparable to "CT" values provided for chemical disinfectants.

The relatively resistant test organisms MS-2 and *Bacillus subtilis* have been inactivated by

UV at a rate of 3-logs at dosages of approximately 20 to 40 mWsec/cm2, and a rate 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)**.

UV effectiveness is relatively insensitive to temperature and pH differences, while turbidity, iron, suspended solids, and other factors can reduce UV transmission, thus lowering disinfection effectiveness. The UV dose chosen for a particular application may vary depending on the source water quality. The 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, and which approximates the above cited 4-log rotavirus inactivation utilizing no multiplier. The upper bound of 140 mWsec/cm2 is based on above-cited lab and field study data (4-log viral or MS-2 inactivations) **(1, 3)** and use of factors of safety, i.e., multipliers 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 rigorous (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 **(4)**. A factor of safety (i.e., 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*.

In addition to pretreatment to remove dissolved and/or suspended materials that may impede UV performance, a secondary disinfectant may be necessary to provide a residual for protection of water in distribution pipes. Continuous dose measurement with remote alarm systems and automatic cleaning of UV components may also be important in design to prevent deposition or scaling and to reduce 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, as expressed above in the form of a range for meeting viral inactivations requirements. In addition, *USEPA would like to review data as they become available on pulsed UV applications (for cyst and/or viral inactivations), UV in combination with oxidants, and other information which may expand this guidance.*]

References

1. U.S. Environmental Protection Agency. *Ultraviolet Light Disinfection Technology in Drinking Water Application: An Overview.* Office of Water. EPA 811-R-96-002 (1996).

2. Snicer, G.A., Malley, J.P., Margolin, A.B. and Hogan, S.P. *Evaluation of Ultraviolet (UV) Technology for Groundwater Disinfection.* Prepared for AWWA Research Foundation, Denver (1997).

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Mixed-oxidants Mixed-oxidant disinfection, which involves the on-site electrolytic generation of mixed disinfectants, is an emerging approach to disinfection. The process can also be referred to as “anodic disinfection”. The process involves the generation of ozone, chlorine dioxide, hypochlorite ion, hypochlorous acid, and elemental chlorine from the passage of an electric current through a continuous-flow brine (salt) solution. The solution containing these oxidants is then injected into the raw water for treatment. While this suite of disinfectants would be expected to be very effective, the relative amounts of the individual oxidants are difficult to characterize. Chemical analysis of the oxidants in a given sample requires techniques usually found only in chemical research laboratories **(1)**.

The National Research Council **(1)** suggests that mixed-oxidant disinfection is not appropriate for small systems attempting to comply with the Surface Water Treatment Rule because of analytical difficulties and lack of data for evaluating the effectiveness of this process. Given that mixed-oxidant disinfection has several advantages over chlorination (discussed below) and that the lack of information regarding the exact speciation of the generated oxidants can be overcome by taking the conservative approach of using chlorine CT tables (discussed below), EPA suggests that small systems may want to consider mixed-oxidant disinfection.

Compared to the use of a single oxidant, the use of multiple oxidants can be more effective. This is due to several factors: (1) different oxidants have different ranges of conditions where they are most effective; (2) different oxidants have different residual durability; and (3) combinations of oxidants can act synergistically as disinfectants. Thus, mixed-oxidants are more effective against a broader spectrum of microorganisms when used properly **(2)**. The increased effectiveness and reaction rate of mixed-oxidants as compared to chlorination is due to the combined action of ozone, chlorine dioxide, and chlorine **(2, 3, 4)**. Both ozone and chlorine dioxide are considered stronger oxidants than chlorine **(2, 3)**. Studies have also shown that the use of mixed-oxidants is more potent in inactivation of microorganisms than ozone or chlorine alone. Another advantage of mixed-oxidant disinfection is that research indicates that mixed-oxidant disinfection may produce fewer disinfection by-products, such as trihalomethanes (THMs), than other chlorination systems **(3)**.

According to Goodrich and Fox **(5)**, the contact time for mixed-oxidant disinfection should fall between that of ozone and chlorine used together. Mixed-oxidants have been shown in laboratory and pilot tests to be capable of between 3-log to 6-log inactivation for parasitic microorganisms (4 hours contact time and 5 ppm residual) **(3)**, and *Giardia* inactivation of 3-log to 4-log **(6)**. In one pilot study, effluent turbidity improved from 0.3-0.5 NTU range to 0.2 to 0.35 NTU range after mixed-oxidant mixture treatment **(3)**. However, mixed-oxidants may not be reliable for removing turbidity and are only able to effect slight reductions in color.

Mixed oxidants have been used in full scale water treatment applications, including disinfection, at a variety of locations. There are examples of full-scale applications of mixed-oxidant disinfection in several U.S. states **(3)**, which may provide some guidance to interested small water systems on use and efficacy of the technology.

Since mixed-oxidant production has not yet been adequately characterized for the full-scale units, EPA recommends that the CT tables for chlorine should be used for this technology until more CT information is available specific to this technology. This is a conservative recommendation that could be revised when this list is updated in August 1998. EPA recognizes that this approach undermines one of the advantages of this technology, namely the shorter required contact time. However, given the potential benefits of reduced disinfection by-product concentrations and improved disinfection capabilities, this approach may prove worthwhile for many small systems. Future research should provide sufficient data on the speciation of oxidants produced by the full-scale units to remove the need to use the conservative CT approach, making mixed-oxidant disinfection a more viable small system disinfection 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 approved filtration technologies. They are described in 40 CFR §141.73(a) - (d): a) conventional filtration treatment or direct filtration; b) slow sand filtration; c) diatomaceous earth filtration; and d) other filtration technologies. A public water system could not use the fourth option unless it could demonstrate to the State through the use of pilot plant studies or other means that the filtration technology, in combination with the disinfection treatment, meets the 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/inactivates 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 the “other filtration technologies” on the SWTR compliance technology list, the Federal-level pilot testing for viability can 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 Federal-level pilot testing for viability. This puts these new filtration technologies on the same footing as the technologies listed in §141.73(a) - (c) in terms of Federal-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 also still require testing to demonstrate that the system is capable of operating the process for all the compliance technologies.

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

Ten filtration technologies have been evaluated as possible compliance technologies. Since the viability of the four technologies listed in §141.73(a)-(c) has already been summarized in the

SWTR guidance manual, the technology summaries are brief. Appendix B contains references published on the filtration technologies listed in the SWTR since 1989. Six alternative filtration technologies have also been evaluated as compliance technologies.

FILTRATION TREATMENT TECHNOLOGIES LISTED IN THE 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. Familiar 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 over-all 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 commonly applied following filtration.

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

Conventional filtration Conventional filtration includes pre-treatment steps of chemical coagulation, rapid mixing, and flocculation, followed by floc removal via sedimentation or flotation. After clarification, the water is then filtered. Common filter media 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 a sedimentation step, 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 other conventional filtration performances, 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)**. It is reiterated that 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.

Recent advances in telemetry devices or remote monitoring and control devices have made it possible for a single operator to monitor and operate several small water systems within a given area. These "circuit rider" operators can work from a central location while receiving information (including alarms) from the various plants via FAX or modem. Remote control capabilities allow the circuit rider operator to control certain aspects of the treatment process, e.g., chemical coagulant dosage or disinfection dosage via a modem or equivalent means. This reduces operator costs to a single system and can reduce the amounts of chemicals required for treatment **(6)**. These telemetric devices may make those technologies requiring a full-time operator more feasible for many small systems. The combined use of package plants and telemetric monitoring and control may well extend many of the more complex water treatment technologies to the universe of technologies appropriate for small systems.

Direct filtration Direct filtration has several effective variations, but all include a pre-treatment of chemical coagulation followed by rapid mixing. The water is then filtered through dual- or mixed-media using pressure or gravity filtration 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. Besides the mode of filtration, variations of direct filtration include filter media 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)**.

It is reiterated that 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.

Slow sand filtration 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 functional mechanisms (other than the obvious difference in flow rate): the "schmutzdecke" removes suspended organic materials and microorganisms by biodegradation and other biological processes, instead of relying solely on simple filtration 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 cleaning, during which the filtration performance steadily improves; this interval is called the "ripening period". 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, 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 filter 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)**.

Diatomaceous earth (DE) filtration DE filtration, also known as pre-coat or diatomite filtration, can be used to directly treat low turbidity raw water supplies. DE filters consist of a layer of DE (about 1/8-inch thick) supported on a septum or filter element. This pre-coat layer is subject to cracking and must be supplemented by a continuous-body feed of diatomite to maintain porosity of the filter. Problems inherent in maintaining the filter cake have limited the use of DE filtration. DE filtration that does not recycle filtered water may not be appropriate for small systems that filter intermittently, since the filter cake must be changed and the septum must be cleaned after each break in filtration.

DE filtration is very effective for removing Giardia cysts, but filtration with plain DE has indicated the inability to remove very small particles, e.g., viruses **(2, 6, 16)**. Research has shown that modifications can lead to 99 percent virus removal **(2)**. Since chemical coagulation is not required, DE filtration is very attractive as a small systems technology and 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 suitable for DE filtration **(6)**.

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FILTRATION TREATMENT TECHNOLOGIES NOT LISTED IN THE SWTR

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 (MWC), 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 often depends on amount of pre- and post-treatment required, which in turn depends upon raw water quality; (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) designations of membrane absolute or nominal pore size have often been irregularly applied by the industry, therefore state reviewers may wish to request such information from manufacturers or suppliers.

The following 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)**.

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.

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 apprears adequate for removal/inactivation of these microorganisms **(4, 5)**. Tests have also shown that filtrate turbidity may be kept consistently at or below 0.1 NTU **(6)**.

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 adequate for removal/inactivation of these microorganisms **(4, 5)**. Tests have also determined that MF filtrate turbidity may be kept below 0.2 NTU **(7)** and typically at or below 0.1 NTU **(6)**.

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Bag and Cartridge 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, parasitic removal will occur **(1)**. In a bag filtration unit system, water to be treated passes through a bag-shaped filtration unit where the particulates are collected on the bag's filter media while allowing the filtered water to pass to the outside of the bag **(2)**. Bag filters are manufactured and supplied by a variety of companies with different micron ratings (typically from 1 to 40 micron) and material compositions. The sizing of the bag filtration component is conditional on the on raw water quality, including the amount of particulate matter and the turbidity **(3)**. Unless the quality of the raw water precludes pre-treatment, EPA recommends prefiltration 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 use to remove *Giardia lamblia* at several locations serving small populations **(3, 5)**. Bag filter studies have shown mixed results in the Cryptosporidium removal rates ranging from approximately 70% to 99.9% **(1)**. Studies of various membranes using beads as surrogate for cryptosporidium also showed variability in the removal rates **(6)**.

Bag filtration field test results of these units also showed excellent to poor turbidity reductions. However, these variabilities might be due to improper installation of the units, due to leaks or tears in the systems, due to local water quality conditions, or as a result of problems with pre-filters **(2, 4)**. In any case, general trends in these field experiences seem 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 was 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 manufacturers products may not be interchangeable. 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. The stakeholders also 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 microorganisms, the final filter effluent would need additional disinfection to meet the SWTR requirements.

Bag filters have been used successfully in water systems across the country for up to ten years. 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 the performance variability factors. Bag filters are best suited for systems in the first two small system size categories (25 - 500 and 501 - 3,300). However, bag filters are listed as a compliance technology for all three system size categories.

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Cartridge filtration Cartridge Filtration, similar to bag filtration, relies on the physical screening process to remove particles. If the pore size of the filter is small enough, parasites will not pass through the filter **(1)**. Typical cartridge filters are pressure filters with pleated fabrics, membranes, or strings wrapped around a filter element and 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 micron 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 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. The stakeholders also 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 additional 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 (25 - 500 and 501 - 3,300). However, cartridge filters are listed as a compliance technology for all three system size categories.

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Section 2.6: Tables of Compliance Technologies for the SWTR

The following tables contain the initial list of compliance technologies for the SWTR for the three small system size categories. The three population size categories of small public water systems as defined in the SDWA are those serving: 10,000 - 3,301 persons, 3,300 - 501 persons, and 500 - 25 persons. The technologies are listed for all three size categories; however, systems should examine the "Limitations" column before selecting a technology. This column contains information that could limit the applicability of the technology for some systems within a size category or categories. The limitations are more extensively described in the text for each technology.

Water treatment plant operator skills vary with each piece of unit technology. The tables for filtration and disinfection technologies include a skill level for each technology ranging from basic to advanced. For a piece of 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. The “operator skill level required” column in the tables refers to the skill level needed for the *unit* technology. If pretreatment is required, the required operator skill levels will likely increase.

These lists will be updated in August 1998 and may include new technologies or additional information.

SWTR COMPLIANCE TECHNOLOGY TABLE: *Disinfection*			
Unit Technologies[1]	**Limitations (See footnotes)**	**Raw Water Quality Range**[2]	**Operator Skill Level Required**[2]
Free Chlorine	a	All, but better with high quality	Basic
Ozone	N/A	All, but better with high quality	Intermediate
Chloramines	b	All, but better with high quality	Basic
Chlorine Dioxide	c	All, but better with high quality	Intermediate
Mixed-Oxidant Disinfection	N/A	All, but better with high quality	Basic to Intermediate
Ultraviolet (UV) radiation	N/A	Visual clarity; suspended and dissolved materials can impede performance[3]	Basic

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[1] New technologies in bold.

[2] National Research Council (NRC). Safe Water From Every Tap: Improving Water Service to Small Communities. National Academy Press. Washington, DC. 1997.

[3] U.S. Environmental Protection Agency. *Ultraviolet Light Disinfection Technology in Drinking Water Application: An Overview.* Office of Water. EPA 811-R-96-002 (1996).

SWTR COMPLIANCE TECHNOLOGY TABLE: *Filtration*

Unit Technologies[1]	**Limitations (See footnoes)**	**Raw Water Quality Range[2]**	**Operator Skill Level Required[2]**
Conventional Filtration (includes dual-stage and dissolved air flotation)	d	Wide Range	Advanced
Direct Filtration (includes In-line Filtration)	d	High quality	Advanced
Diatomaceous Earth Filtration	e	Very high quality or pre-treatment	Intermediate
Slow Sand Filtration	f	Very high quality or pre-treatment	Basic
Reverse Osmosis Filtration	N/A	Requires pre-filtration for surface waters	Advanced
Nanofiltration	N/A	Very high quality or pre-treatment	Basic
Ultrafiltration	N/A	Very high quality or pre-treatment	Basic
Microfiltration	N/A	High quality or pre-treatment	Basic
Bag Filtration	g	Very high quality or pre-treatment	Basic
Cartridge Filtration	g	Very high quality or pre-treatment	Basic

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[1] New technologies in bold.

[2] National Research Council (NRC). Safe Water From Every Tap: Improving Water Service to Small Communities. National Academy Press. Washington, DC. 1997.

Limitations Footnotes to SWTR Compliance Technology Tables
a. Chlorine is available in several forms: solid, liquid, and gaseous. Gaseous chlorine, due to its hazardous nature, requires special handling and storage care. Special training of operators is recommended.
b. Chloramine disinfection requires careful monitoring of the ratio of added chlorine to ammonia. Chloramines also possess less potency than other disinfectants and thus need longer CTs.
c. The process of generating chlorine dioxide is complicated and requires intermediate operator skill. Because of this complexity and the high monitoring requirements, this technology may not be appropriate for many small water systems.
d. Involves coagulation. Coagulation chemistry requires advanced operator skill and extensive monitoring. A system needs to have direct full-time access or full-time remote access to a skilled operator to use this technology properly.
e. Filter cake should be discarded if filtration is interrupted. For this reason, intermittent use is not practical. Recycling the filtered water can remove this potential problem.
f. Water service interruptions can occur during the periodic filter-to-waste cycle, which can last from six hours to two weeks.
g. Site-specific pilot testing prior to installation of a bag or cartridge filter likely to be needed to ensure adequate performance.

3. ISSUES FOR CONSIDERATION IN UPDATED SWTR COMPLIANCE TECHNOLOGY LIST

Section 3.1: Technologies/Issues under consideration for August 1998 SWTR Compliance Technology List

The initial list of SWTR compliance technologies can be found in Section 2.6. As noted in Section 1.4, the initial list is general and does not provide detail on applicability ranges for the compliance technologies. EPA is considering adding information on applicability ranges and other considerations that should be evaluated prior to selecting a disinfection or filtration technology when the list is updated in August 1998. The level of detail on these factors will be discussed at an upcoming stakeholder meeting. Some of the factors that could be incorporated into the list of compliance technologies include:

- <u>Influent water quality requirements or pretreatment requirements</u>- Many of the technologies will not operate effectively if influent qualities are not within a certain criteria designed for the unit. As a result, pretreatment may be necessary with certain waters.

- <u>Log Removal Credits</u>- The guidance manual for the SWTR listed log removal credits for the technologies listed in the SWTR. The compliance technology guidance identifies several new technologies for small systems. Ranges of log removal credit for the new technologies could be developed to supplement the information in the SWTR guidance manual.

- <u>Complexity or ease of operation and maintenance</u>- In many small systems situations, the user or the operator will not be trained or qualified for complex water treatment operations. This can result in inadequate system assembly and use. The performance of a technology can be negatively impacted if it is difficult to construct or assemble or to operate and maintain. Performance of many technologies will be reduced dramatically if the system is not constructed, operated, or maintained as specified by the manufacturer.

- <u>Secondary waste generation</u>- The volume and type of waste produced by the process is another factor that small systems need to consider when selecting a treatment process. Small system waste disposal options could be developed for each of the compliance technologies.

- <u>Other technology limitations and drawbacks</u>- A discussion on the by-products produced by the disinfection technologies could be added to the compliance technology list. A discussion on the energy requirements and fouling/scaling problems could be added for membranes technologies. Chemical handling requirements could also be discussed.

The initial group of technologies, listed in section 2.6, includes only those technologies where published data are available, and where the review of the literature shows high performance efficiencies. Listed below are additional “new” technologies that merit consideration for small system application. These technologies will be evaluated and if found to be viable, will be incorporated in the updated list.

- **<u>Advanced oxidation or perozone:</u>** Ozone is a powerful oxidizing agent and the use of ozone with peroxide, another strong oxidant, appears promising. However, the generation of ozone on site might be a potential roadblock for this technology for the smallest systems.

- **<u>Pulsed ultraviolet:</u>** Another variation of the ultraviolet technology. Manufacturers have indicated the effective use of this technology for Cryptosporidia inactivation.

- **<u>Ultraviolet oxidation:</u>** Simultaneous use of ultraviolet and oxidizing agents such as peroxide may enhance the ultraviolet process.

- **<u>Point-of-entry (POE) devices:</u>** Section 1412(b)(4)(E)(ii) states that POU devices cannot be listed as a compliance technology for any MCL or treatment technique requirement for a microbial contaminant (or an indicator of a microbial contaminant). However, POE devices are not prohibited from being used as a compliance technology for a microbial contaminant. There are several difficulties that would need to be overcome for this to become a viable option. For example, how would disinfection be applied? The National Resource Council **(1)** recommends that disinfection not be applied with a POE device given the importance of disinfection. Since disinfection follows filtration in good engineering practice, the application of POE filtration devices as SWTR compliance technologies presents a dilemma. If POE devices were considered for SWTR compliance, what would be the minimum monitoring frequency to ensure health protection? The required frequency of monitoring may well make POE devices impractical as SWTR compliance technologies.

Section 3.2: Additional Factors or New Technologies Identified by Stakeholders

EPA held a stakeholder meeting on July 22 and 23, 1997. Key stakeholders included States, water systems and equipment manufacturers. The stakeholders had two general comments on the 1997 compliance technology list that will be incorporated into the updated list. The first comment concerned the need for more detail regarding the operator skill level required for each unit process, especially when pretreatment is required. The second comment concerned the need for more detail on the maintenance requirements for each process. These factors and those discussed in Section 3.1 will be examined in the future and will discussed in the updated list.

The stakeholders also had a general comment that is not specific to the compliance technology list for the SWTR. The stakeholders requested that EPA develop a protocol for data submissions from a variety of sources. These sources include: manufacturers, States, existing databases, the EPA/NSF ETV project, and other sources. EPA agrees that having a standard format will facilitate both data submission and data analysis. EPA also emphasizes the need for additional data relevant to identifying new technologies and to providing additional detail regarding the technologies already on the list.

APPENDIX A

RELEVANT PARTS OF SECTIONS 1412 OF THE REVISED (1996) SDWA

Insert Page 1

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APPENDIX B

REFERENCES ON SWTR-APPROVED FILTRATION TECHNOLOGIES SINCE 1989

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