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Agency

Water Treatment Technology Feasibility Support Document for Chemical Contaminants for the Second Six-Year Review of National Primary Drinking Water Regulations

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Abbreviations and Acronyms

ANSI	American National Standards Institute
atm m^3/m^3	atmospheres-cubic meter (of water) per cubic meter (of air)
BAT	Best Available Technology
DBCP	1,2-dibromo-3-chloropropane
EPA	Environmental Protection Agency
EQL	Estimated Quantitation Level
ETV	EPA's Environmental Technology Verification Program
GAC	Granular Activated Carbon
lbs/1,000 gal	pounds of carbon used per 1,000 gallons of water treated
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
NPDWRs	National Primary Drinking Water Regulations
PAC	Powdered Activated Carbon
POU	Point-of-use
POU-GAC	Point-of-use Granular Activated Carbon
PQL	Practical Quantitation Level
PTA	Packed Tower Aeration
SDWA	Safe Drinking Water Act
SOCs	Synthetic Organic Compounds
TCE	Trichloroethylene
TT	Treatment Technique
VOCs	Volatile Organic Compounds
WHO	World Health Organization
µg/L	micrograms per liter

Executive Summary

The U.S. Environmental Protection Agency (EPA) has completed its second Six-Year Review (Six-Year Review 2) of national primary drinking water regulations (NPDWRs). The 1996 Safe Drinking Water Act (SDWA) Amendments require the U.S. Environmental Protection Agency (EPA or the Agency) to periodically review existing National Primary Drinking Water Regulations (NPDWRs). Section 1412(b)(9) of SDWA reads:

> ...[t]he Administrator shall, not less than every 6 years, review and revise, as appropriate, each primary drinking water regulation promulgated under this title. Any revision of a national primary drinking water regulation shall be promulgated in accordance with this section, except that each revision shall maintain, or provide for greater, protection of the health of persons.

The primary goal of the Six-Year Review process is to identify NPDWRs for possible regulatory revision. Although the statute does not define when a revision is "appropriate," as a general benchmark, EPA considered a possible revision to be "appropriate" if, at a minimum, it presents a meaningful opportunity to:

- improve the level of public health protection, and/or
- achieve cost savings while maintaining or improving the level of public health protection.

For Six-Year Review 2, EPA implemented the protocol that it developed for the first Six-Year Review (USEPA, 2003), including minor revisions developed during the current review process (USEPA, 2009d). EPA obtained and evaluated new information that could affect a NPDWR, including information on health effects (USEPA, 2009f), analytical feasibility (USEPA, 2009b), and occurrence (USEPA, 2009a and 2009e).

This technical support document provides the Agency's findings for its review of treatment feasibility information. EPA identified potential to revise NPDWRs for 23 contaminants. Consequently, EPA reviewed the best available technologies (BATs) and treatment techniques (TTs) specified in NPDWRs, and any emerging technologies, to determine whether treatment performance would pose a limitation to such revisions. This document describes these treatment feasibility reviews.

EPA reviewed the BATs and technologies to meet TTs to determine the potential to achieve concentrations based on estimated quantitation levels (EQLs) or new health effects information. USEPA (2009c) provides a description of the EQLs and USEPA (2009f) identifies the new health-based thresholds. EPA used these thresholds to evaluate potential for meaningful opportunity to improve public health protection. The result of the treatment review is a determination of whether treatment would pose a limitation to revising an NPDWR.

EPA measured technology effectiveness for contaminants for which the enforceable standard is a maximum contaminant level (MCL) based on the following factors:

- Removal efficiency, which is measured as the percentage of the influent concentration removed through treatment

- Qualitative conclusions about treatability from previous EPA rulemakings and other scientific and engineering sources
- Other, technology-specific measures.

Aeration and carbon adsorption are common contaminant removal technologies. In instances when BATs and/or small system compliance technologies include aeration technologies, EPA used Henry's Law constants as indicators of likely treatment effectiveness. Aeration technologies, which include packed tower aeration (PTA), multi-stage bubble aeration, tray aeration, shallow tray aeration, spray aeration, and mechanical aeration, remove contaminants by passing air through the water to be treated. Aeration processes transfer, or "strip," volatile contaminants from the water into the air. Henry's Law constants, which can vary across contaminants, provide measures of the ease with which this stripping occurs.

In instances when BATs and/or small system compliance technologies include carbon adsorption technologies, EPA used bed life and carbon usage rates as indicators of likely treatment effectiveness. Carbon adsorption technologies, which include granular activated carbon (GAC), powdered activated carbon (PAC), and point-of-use granular activated carbon (POU-GAC), remove contaminants through adsorption onto a carbon media. The length of time for which the carbon retains its capacity to absorb target contaminants provides a measure of treatment feasibility and effectiveness.

EPA did not identify limitations of BAT, small system compliance technologies, or emerging technologies to achieve the EQL or health-based thresholds for most of the contaminants regulated through MCLs. **Exhibit ES-1** summarizes these results. For oxamyl, however, data on removal efficiency and a lack of demonstrated treatment effectiveness at low concentrations suggest potential for limitation at concentrations as low as the health-based threshold. Similarly, for 1,2-dichloropropane, treatment to the estimated quantitation level may not be feasible.

EPA established a TT in lieu of an MCL for acrylamide and epichlorohydrin because of the absence of standardized analytical methods for measurement in water. The TT limits the allowable monomer level in products used for water treatment and the dosage of polymers that contain them. EPA established the residual monomer level for each contaminant at the lowest level manufacturers could feasibly achieve at the time of regulation. A system can use third-party or manufacturer's certification in lieu of testing for the residual monomer level.

NSF International (NSF), a third party organization, tests and certifies water treatment chemicals that meet NSF/ANSI Standard 60, *Drinking Water Treatment Chemicals – Health Effects*, which sets out requirements for treatment chemicals based on human health protection (NSF, 1999a). The requirements for acrylamide- and epichlorohydrin-based polymers in Standard 60 are based on EPA's TT standards. Thus, NSF 60 certification of a polymeric coagulant aid containing acrylamide or epichlorohydrin indicates that users are in compliance with EPA's regulation when a product is used as specified (i.e., for the intended purpose and up to the maximum usage level indicated by NSF). EPA obtained NSF data indicating that manufacturers now produce polymers with substantially lower residual monomer content than the TTs require. This new information, viewed in conjunction with regulations and guidelines in other countries, suggests there is potential to revise the TTs to reflect a lower feasible monomer content

Exhibit ES-1. Summary of Treatment Feasibility Review for Contaminants Regulated through MCLs

Contaminant	Current MCL (mg/L)	Threshold Evaluated (mg/L)	BAT	Treatment Limitation Potential
2,4-D	0.07	0.04	GAC[1]	No
Endothall	0.1	0.05	GAC[1]	No
Hexachlorocyclopentadiene	0.05	0.04	GAC and PTA[2]	No
Oxamyl	0.2	0.002	GAC[1,3]	Uncertain
Toluene	1.0	0.6	GAC and PTA[4]	No
Xylenes	10.0	1.0	GAC and PTA[4]	No
Benzene	0.005	0.0005	GAC and PTA[3,4]	No
Chlordane	0.002	0.001	GAC[1]	No
DBCP	0.0002	0.0001	GAC and PTA[5]	No
1,2-dichloropropane	0.005	0.0005	GAC and PTA[4]	Uncertain
Heptachlor	0.0004	0.0001	GAC[1]	No
Heptachlor epoxide	0.0002	0.0001	GAC[1]	No
Hexachlorobenzene	0.001	0.0001	GAC[1]	No
Toxaphene	0.003	0.001	GAC[1]	No
1,1,2-trichloroethane	0.005	0.003	GAC and PTA[4]	No
Vinyl chloride	0.002	0.0005	PTA[4]	No
Carbon tetrachloride	0.005	0.0005	GAC and PTA[4]	No
1,2-dichloroethane (ethylene dichloride)	0.005	0.0005	GAC and PTA[4]	No
Dichloromethane	0.005	0.0005	PTA[4]	No
Tetrachloroethylene	0.005	0.0005	GAC and PTA[4]	No
Trichloroethylene	0.005	0.0005	GAC and PTA[6]	No

1. Small system compliance technologies are: GAC, PAC, and POU-GAC.
2. Small system compliance technologies are: GAC, POU-GAC, PTA, diffused aeration, multi-stage bubble aeration, tray aeration, and shallow tray aeration.
3. Although not currently listed as BAT, promising emerging technologies include: RO, RO followed by GAC, and advanced oxidation (ultraviolet light combined with ozone) followed by GAC.
4. Small system compliance technologies are: GAC, PTA, diffused aeration, multi-stage bubble aeration, tray aeration, and shallow tray aeration.
5. Small system compliance technologies are: GAC, PAC, PTA, diffused aeration, multi-stage bubble aeration, tray aeration, and shallow tray aeration.
6. Small system compliance technologies are: GAC, PTA, diffused aeration, multi-stage bubble aeration, tray aeration, shallow tray aeration, spray aeration, and mechanical aeration.

BAT = best available technologies
DBCP = 1,2-dibromo-3-chloropropane
GAC = granular activated carbon
MCL = maximum contaminant level
Mg/L = milligrams per liter
PAC = powdered activated carbon
POU = point-of-use
PTA = packed tower aeration
RO = reverse osmosis

1 Introduction

The U.S. Environmental Protection Agency (EPA) has completed its second Six-Year Review (Six-Year Review 2) of national primary drinking water regulations (NPDWRs). The 1996 Safe Drinking Water Act (SDWA) Amendments require the U.S. Environmental Protection Agency (EPA or the Agency) to periodically review existing National Primary Drinking Water Regulations (NPDWRs). Section 1412(b)(9) of SDWA reads:

> ...[t]he Administrator shall, not less than every 6 years, review and revise, as appropriate, each primary drinking water regulation promulgated under this title. Any revision of a national primary drinking water regulation shall be promulgated in accordance with this section, except that each revision shall maintain, or provide for greater, protection of the health of persons.

The primary goal of the Six-Year Review process is to identify NPDWRs for possible regulatory revision. Although the statute does not define when a revision is "appropriate," as a general benchmark, EPA considered a possible revision to be "appropriate" if, at a minimum, it presents a meaningful opportunity to:

- improve the level of public health protection, and/or
- achieve cost savings while maintaining or improving the level of public health protection.

For Six-Year Review 2, EPA implemented the protocol that it developed for the first Six-Year Review (USEPA, 2003), including minor revisions developed during the current review process (USEPA, 2009d). EPA obtained and evaluated new information that could affect a NPDWR, including information on health effects (USEPA, 2009f), analytical feasibility (USEPA, 2009b), and occurrence (USEPA, 2009a and 2009e).

This technical support document provides the Agency's findings for its review of treatment feasibility information. EPA identified potential to revise NPDWRs for 23 contaminants. Consequently, EPA reviewed the best available technologies (BATs) and treatment techniques (TTs) specified in NPDWRs, and any emerging technologies, to determine whether treatment performance would pose a limitation to such revisions. This document describes these treatment feasibility reviews.

EPA reviewed treatment feasibility for contaminants regulated through MCLs for which there is potential to revise the MCL due to:

- New health effects assessments suggesting potential for a lower MCLG and potential to set the MCL equal to a lower MCLG is not limited by practical quantitation levels (PQLs)
- Analytical methods review findings indicating the potential for lower PQLs
- A health effects assessment is ongoing, but the MCLG is less than the MCL and there is potential to lower the PQL, which originally limited the MCL

EPA also reviewed the treatment feasibility for two contaminants that are regulated through TTs and are not the subjects of recent or ongoing regulatory action. **Exhibit 1-1** identifies the contaminants included in the review.

Exhibit 1-1. Contaminants Included in this Treatment Technology Feasibility Review

Contaminants regulated through MCLs and potential to revise the MCL	
New health effects assessment indicates potential MCLG decrease, PQL does not currently limit the MCL or there is potential to decrease PQL	
1	2,4-D
2	Endothall
3	Hexachlorocyclopentadiene
4	Oxamyl
5	Toluene
6	Xylenes
New health effects assessment, MCLG = 0, MCL = PQL and there is potential to decrease PQL	
7	Benzene
No new health effects assessment, MCL = PQL and there is potential to decrease PQL	
8	Chlordane
9	1,2-Dibromo-3-chloropropane (DBCP)
10	1,2-Dichloropropane
11	Heptachlor
12	Heptachlor epoxide
13	Hexachlorobenzene
14	Toxaphene
15	1,1,2-Trichloroethane
16	Vinyl chloride
Ongoing health effects assessment, MCL > MCLG and there is potential to decrease PQL	
17	Carbon tetrachloride
18	1,2-Dichloroethane (Ethylene Dichloride)
19	Dichloromethane
20	Tetrachloroethylene
21	Trichloroethylene
Contaminants regulated through TTs and potential to revise the TT	
22	Acrylamide
23	Epichlorohydrin

This document primarily discusses best available technologies (BATs) specified by EPA to meet MCLs and technologies to meet TT-type NPDWRs. It provides supplemental information on small systems compliance technologies and other related treatment information. EPA relies on available scientific and engineering data to support this process. The purpose of this report is to document EPA's evaluation of the potential for BATs to remove contaminants to achieve concentrations comparable to the estimated quantitation level (EQL) or health-based threshold for each contaminant. USEPA (2009c) provides a description of how EPA developed the EQLs or health-based thresholds. EPA used these thresholds to evaluate potential occurrence and exposure effects in addition to treatment feasibility. The end result of each of the following contaminant-specific reviews is a determination of whether treatment would pose a limitation to revising an NPDWR.

Section 2 provides background information on the methods the Agency used to evaluate the effectiveness of treatment technologies for contaminants regulated through MCLs. Section 3 presents the treatment reviews for individual contaminants regulated through MCLs. Finally, section 4 provides a review of the potential to revise TTs for two contaminants (acrylamide and epichlorohydrin) regulated through this method.

2 Measuring Treatment Effectiveness for Contaminants Regulated through MCLs

As discussed above, the treatment analysis in this document uses treatment benchmarks for the contaminants that are based on either an EQL or a health-based threshold, which were developed for the Six-Year Review 2 occurrence analysis (USEPA, 2009c). EPA evaluated technology effectiveness against this benchmark based on the following factors:

- Removal efficiency, which is measured as the percentage of the influent concentration removed through treatment
- Qualitative conclusions about treatability from previous EPA rulemakings and other scientific and engineering sources
- Other, technology-specific measures, discussed in more detail below.

Aeration and carbon adsorption are the most common technologies used for the removal of the contaminants with MCLs in this document. The following discussion describes technology-specific measures that EPA used in evaluating treatment effectiveness for these technologies.

In instances when BATs and/or small system compliance technologies include aeration technologies, EPA uses the Henry's Law constant as an indicator of likely treatment effectiveness. Aeration technologies, which include packed tower aeration (PTA), multi-stage bubble aeration, tray aeration, shallow tray aeration, spray aeration, and mechanical aeration, remove contaminants by passing air through the water to be treated. This process transfers, or "strips," volatile contaminants from the water into the air. The Henry's Law constant provides a measure of the ease with which this stripping occurs. The units for the Henry's Law constant in this document are atmospheres-cubic meter (of water) per cubic meter (of air) (atm m^3/m^3); a higher Henry's Law constant indicates greater strippability, and easier contaminant removal by aeration.

In instances when BATs and/or small system compliance technologies include carbon adsorption technologies, EPA uses bed life and carbon usage rates as indicators of likely treatment effectiveness. The use of these indicators is a refinement of the method EPA previously used to assess treatment technology feasibility during First Six-Year Review. Carbon adsorption technologies, which include granular activated carbon (GAC), powdered activated carbon (PAC), and point-of-use granular activated carbon (POU-GAC), remove contaminants through adsorption onto a carbon media. In GAC and POU-GAC, water to be treated passes through a fixed bed of the media; in PAC, the media is mixed into the water to be treated. In either case, the media has a specific capacity for adsorbing a given contaminant. In GAC and POU-GAC, once this capacity is exhausted, the media must be removed and regenerated or replaced with fresh media. In PAC, this capacity influences the quantity, or "dose," of powdered carbon required to remove the contaminant. In either case, the length of time for which the carbon retains its capacity to absorb target contaminants provides a measure of treatment feasibility and effectiveness. For example, a GAC medium will be more useful for a contaminant that it can continue to remove for several months than for a contaminant that exhausts its capacity quickly. With GAC treatment, this length of time is typically called "bed life," and can be measured in months, or in the volume of water treated, called "bed volumes." Another measure of carbon capacity is carbon usage rate, with units of pounds of carbon used per 1,000 gallons of water treated (lbs/1,000 gal). A lower carbon usage rate reflects a greater capacity for the contaminant, and more efficient treatment.

3 Treatment Reviews for Contaminants Regulated Through MCLs

The results of EPA's review of health effects or analytical feasibility indicated the potential to revise the NPDWRs for each of the contaminants in this section. Consequently, EPA reviewed treatment feasibility for each to determine whether treatment feasibility would limit the potential to revise. Each treatment review includes the following:

- The current MCL for the contaminant and the EQL or health-based threshold developed during Six-Year Review 2
- Identification of current BATs and small system compliance technologies
- Where appropriate, identification of new or emerging treatment technologies
- Available information on the treatment effectiveness of these technologies for the contaminant
- Discussion of whether treatment is known to be a limiting concern under the current NPDWR
- A conclusion regarding whether treatment would be expected to be a limiting concern should the Agency revise the NPDWR.

Based on the treatment reviews, EPA did not identify limitations of BAT, small system compliance technologies, or emerging technologies to achieve the EQL or health-based thresholds for most of the contaminants regulated through MCLs. However, for oxamyl, data on removal efficiency and a lack of demonstrated treatment effectiveness at low concentrations suggest potential for limitation at concentrations as low as the health-based threshold. Similarly, for 1,2-dichloropropane, treatment to the estimated quantitation level may not be feasible. **Exhibit 3-1** summarizes these results.

3.1 2,4-D

The current MCL for 2,4-D is 0.07 mg/L and the current BAT is GAC (40 CFR 141.61). Small system compliance technologies include: GAC, PAC, and POU-GAC (USEPA, 1998). The health-based threshold used for the Six-Year Review 2 is 0.04 mg/L (USEPA, 2009f).

According to the World Health Organization (WHO), the achievable GAC removal efficiency for 2,4-D is more than 80%, to concentrations lower than 0.0001 mg/L (WHO, 2006). Carbon usage rates for 2,4-D (0.1224 lbs/1,000 gal) are relatively low compared with other organic contaminants, indicating good treatment feasibility (56 FR 3526, January 30, 1991).

Treatment is not known to be a limiting concern for the current MCL for 2,4-D. The Agency's current assessment is that treatment technology would not pose a feasibility limitation at the health-based threshold of 0.04 mg/L.

Exhibit 3-1. Summary of Treatment Feasibility Review for Contaminants Regulated through MCLs

Contaminant	Current MCL (mg/L)	Threshold Evaluated (mg/L)	BAT	Treatment Limitation Potential
2,4-D	0.07	0.04	GAC[1]	No
Endothall	0.1	0.05	GAC[1]	No
Hexachlorocyclopentadiene	0.05	0.04	GAC and PTA[2]	No
Oxamyl	0.2	0.002	GAC[1,3]	Uncertain
Toluene	1.0	0.6	GAC and PTA[4]	No
Xylenes	10.0	1.0	GAC and PTA[4]	No
Benzene	0.005	0.0005	GAC and PTA[3,4]	No
Chlordane	0.002	0.001	GAC[1]	No
DBCP	0.0002	0.0001	GAC and PTA[5]	No
1,2-dichloropropane	0.005	0.0005	GAC and PTA[4]	Uncertain
Heptachlor	0.0004	0.0001	GAC[1]	No
Heptachlor epoxide	0.0002	0.0001	GAC[1]	No
Hexachlorobenzene	0.001	0.0001	GAC[1]	No
Toxaphene	0.003	0.001	GAC[1]	No
1,1,2-trichloroethane	0.005	0.003	GAC and PTA[4]	No
Vinyl chloride	0.002	0.0005	PTA[4]	No
Carbon tetrachloride	0.005	0.0005	GAC and PTA[4]	No
1,2-dichloroethane (ethylene dichloride)	0.005	0.0005	GAC and PTA[4]	No
Dichloromethane	0.005	0.0005	PTA[4]	No
Tetrachloroethylene	0.005	0.0005	GAC and PTA[4]	No
Trichloroethylene	0.005	0.0005	GAC and PTA[6]	No

1. Small system compliance technologies are: GAC, PAC, and POU-GAC.
2. Small system compliance technologies are: GAC, POU-GAC, PTA, diffused aeration, multi-stage bubble aeration, tray aeration, and shallow tray aeration.
3. Although not currently listed as BAT, promising emerging technologies include: RO, RO followed by GAC, and advanced oxidation (ultraviolet light combined with ozone) followed by GAC.
4. Small system compliance technologies are: GAC, PTA, diffused aeration, multi-stage bubble aeration, tray aeration, and shallow tray aeration.
5. Small system compliance technologies are: GAC, PAC, PTA, diffused aeration, multi-stage bubble aeration, tray aeration, and shallow tray aeration.
6. Small system compliance technologies are: GAC, PTA, diffused aeration, multi-stage bubble aeration, tray aeration, shallow tray aeration, spray aeration, and mechanical aeration.

BAT = best available technologies
DBCP = 1,2-dibromo-3-chloropropane
GAC = granular activated carbon
MCL = maximum contaminant level
Mg/L = milligrams per liter
PAC = powdered activated carbon
POU = point-of-use
PTA = packed tower aeration
RO = reverse osmosis

3.2 Endothall

The current MCL for endothall is 0.1 mg/L and the current BAT is GAC (40 CFR 141.61). Small system compliance technologies include: GAC, PAC, and POU-GAC (USEPA, 1998). The health-based threshold used for the Six-Year Review 2 is 0.05 mg/L (USEPA, 2009f).

In proposing GAC as the BAT for endothall, EPA concluded that GAC is effective in removing synthetic organic compounds (SOCs) including endothall (55 FR 30370, July 25, 1990), based on model predictions that took into account endothall's chemical/physical characteristics. Subsequent treatability studies in support of the final EPA rulemaking demonstrated that GAC was as effective as predicted by the model (57 FR 31776, July 17, 1992).

Treatment is not known to be a limiting concern for the current MCL for endothall. The Agency's current assessment is that treatment technology would not pose a feasibility limitation at the health-based threshold of 0.05 mg/L.

3.3 Hexachlorocyclopentadiene

The current MCL for hexachlorocyclopentadiene is 0.05 mg/L and the current BATs are GAC and PTA (40 CFR 141.61). Small system compliance technologies include: GAC, POU-GAC, PTA, diffused aeration, multi-stage bubble aeration, tray aeration, and shallow tray aeration (USEPA, 1998). The health-based threshold used for the Six-Year Review 2 is 0.04 mg/L (USEPA, 2009f).

EPA has categorized hexachlorocyclopentadiene among the more volatile SOCs (55 FR 30370, July 25, 1990). For the volatile SOCs, properly designed PTA facilities can achieve removal efficiencies of 90% to more than 99% (55 FR 30370, July 25, 1990). For hexachlorocyclopentadiene, Henry's Law constants reported in several sources are high, ranging from 0.6701 to 1.105 atm m^3/m^3, indicating good treatment feasibility (Sander, 1999). EPA has concluded that GAC also is effective in removing SOCs including hexachlorocyclopentadiene (55 FR 30370, July 25, 1990).

Treatment is not known to be a limiting concern for the current MCL for hexachlorocyclopentadiene. The Agency's current assessment is that treatment technology would not pose a feasibility limitation at the health-based threshold of 0.04 mg/L.

3.4 Oxamyl

The current MCL for oxamyl is 0.2 mg/L and the current BAT is GAC (40 CFR 141.61). The health-based threshold used for the Six-Year Review 2 is 0.002 mg/L (USEPA, 2009f). Small system compliance technologies include: GAC, PAC, and POU-GAC (USEPA, 1998). In addition, EPA's Environmental Technology Verification (ETV) Program recently verified the performance of several POU devices for removal of chemical contaminants including oxamyl. The emerging technologies tested in the ETV verifications included reverse osmosis, reverse osmosis followed by GAC, and advanced oxidation (ultraviolet light combined with ozone) followed by GAC (NSF, 2005a, 2005b, 2005c, 2006, 2007a).

GAC removal efficiency for oxamyl ranges from 85% to 95%, depending on design parameters (USEPA, 1990). The ETV test of a POU device using advanced oxidation followed by GAC verified that the GAC filter component of the device removed greater than 98% of oxamyl from an influent concentration of 1.1 mg/L (NSF, 2005c).

The ETV tests of POU devices using reverse osmosis verified that the reverse osmosis components of these devices removed 99% or more of oxamyl from influent concentrations of 0.98 to 1.1 mg/L. Because of the high removals using the reverse osmosis components alone, the verifications did not test the GAC components of those devices that included the technology for oxamyl removal (NSF, 2005a, 2005b, 2006, 2007a).

Treatment is not known to be a limiting concern for the current MCL for oxamyl. Given the above data on removal efficiency (85% to 98% for GAC and 99% for reverse osmosis) and a lack of demonstrated treatment effectiveness at low concentrations, however, treatment technology could pose a limitation at concentrations as low as the health-based threshold of 0.002 mg/L.

3.5 Toluene

The current MCL for toluene is 1 mg/L and the current BATs are GAC and PTA (40 CFR 141.61). Small system compliance technologies include: GAC, PTA, diffused aeration, multi-stage bubble aeration, tray aeration, and shallow tray aeration (USEPA, 1998). The health-based threshold used for the Six-Year Review 2 is 0.6 mg/L (USEPA, 2009f).

According to the WHO, the achievable air stripping removal efficiency for toluene is more than 80%, to concentrations lower than 0.001 mg/L (WHO, 2006). For PTA, field studies performed in three States demonstrated a removal efficiency of greater than 96% for toluene and other contaminants, with initial concentrations of up to 0.6 mg/L (Ram et al., 1990 as cited in USEPA, 1998). Performance studies employing diffused aeration to treat toluene and other contaminants have demonstrated 50% to 90% removal efficiencies (USEPA, 1985 as cited in USEPA, 1998). For toluene, Henry's Law constants reported in several sources are relatively high, ranging from 0.126 to 0.314 atm m^3/m^3, indicating good treatment feasibility (Sander, 1999; Cummins and Westrick, 1987). EPA has categorized toluene as a contaminant with good strippability (56 FR 3526, January 30, 1991).

According to the WHO, the achievable GAC removal efficiency for toluene is more than 80%, to concentrations lower than 0.001 mg/L (WHO, 2006). Carbon usage rates for toluene (0.3050 lbs/1,000 gal) are higher than for other organic contaminants (56 FR 3526, January 30, 1991). Although EPA found that GAC may be more than twice as expensive as PTA for large systems on a dollar per household per year basis, if off-gas control of PTA is necessary, then costs between PTA and GAC are more competitive (56 FR 3526, January 30, 1991).

Treatment is not known to be a limiting concern for the current MCL for toluene. The Agency's current assessment is that treatment technology would not pose a feasibility limitation at the health-based threshold of 0.6 mg/L.

3.6 Xylenes

The current MCL for total xylenes is 10 mg/L and the current BATs are GAC and PTA (40 CFR 141.61). Small system compliance technologies include: GAC, PTA, diffused aeration, multi-stage bubble aeration, tray aeration, and shallow tray aeration (USEPA, 1998). The health-based threshold used for the Six-Year Review 2 is 1 mg/L (USEPA, 2009f).

According to the WHO, the achievable air stripping removal efficiency for xylenes is more than 80%, to concentrations lower than 0.005 mg/L (WHO, 2006). Performance studies for diffused aeration used to treat xylenes and other contaminants have demonstrated 50% to 90% removal efficiencies (USEPA, 1985 as cited in USEPA, 1998). For xylenes, Henry's Law constants reported in several sources are relatively high, ranging from 0.0973 to 0.341 atm m^3/m^3, indicating good treatment feasibility (Sander, 1999; Cummins and Westrick, 1987). EPA has categorized xylenes as a contaminant with good strippability (56 FR 3526, January 30, 1991).

According to the WHO, the achievable GAC removal efficiency for xylenes is more than 80%, to concentrations lower than 0.005 mg/L (WHO, 2006). One case study, cited in the U.S. Army Corps of Engineers' *Adsorption Design Guide,* shows GAC removal efficiencies for xylenes of greater than 99% at influent concentrations of 0.2 to 0.5 mg/L (U.S. Army Corps of Engineers, 2001). Carbon usage rates for xylenes (0.2148 to 0.3718 lbs/1,000 gal) are higher than for other organic contaminants (56 FR 3526, January 30, 1991). Although EPA found that GAC may be more than twice as expensive as PTA for large systems on a dollar per household per year basis, if off-gas control of PTA is necessary, then costs between PTA and GAC are more competitive (56 FR 3526, January 30, 1991).

Treatment is not known to be a limiting concern for the current MCL for xylenes. The Agency's current assessment is that treatment technology would not pose a feasibility limitation at the health-based threshold of 1 mg/L.

3.7 Benzene

The current MCL for benzene is 0.005 mg/L and the current BATs are GAC and PTA (40 CFR 141.61). The EQL used for the Six-Year Review 2 is 0.0005 mg/L (USEPA, 2009c). Small system compliance technologies include: GAC, PTA, diffused aeration, multi-stage bubble aeration, tray aeration, and shallow tray aeration (USEPA, 1998). In addition, EPA's ETV Program recently verified the performance of several POU devices for removal of chemical contaminants including benzene. The emerging technologies tested in the ETV verifications included reverse osmosis, reverse osmosis followed by GAC, and advanced oxidation (ultraviolet light combined with ozone) followed by GAC (NSF, 2005a, 2005b, 2005c, 2006, 2007a).

EPA pilot studies using PTA at more than 30 sites showed greater than 99% volatile organic compound (VOC) removals to be achievable. Based on these and other studies, EPA concluded that PTA systems designed using reasonable engineering practices could achieve 99% removal of nine VOCs, including benzene, under all anticipated circumstances. Removal could be as high as 99.9% under optimum conditions (50 FR 46902, November 13, 1985). For benzene, Henry's Law constants in several sources are relatively high, ranging from 0.0584 to 0.341 atm m^3/m^3, indicating good treatment feasibility (Sander, 1999; Crittenden, 1988; Cummins and Westrick, 1987).

EPA has concluded that GAC can achieve a high level of removal of most VOCs. Although carbon usage rates are significantly higher for benzene than other VOCs, EPA concluded that removal is still feasible using GAC (50 FR 46902, November 13, 1985). One case study cited in the U.S. Army Corps of Engineers' *Adsorption Design Guide* shows a GAC removal efficiency for benzene of greater than 99% at an influent concentration of 0.4 mg/L (U.S. Army Corps of Engineers, 2001). The ETV test of a POU device using advanced oxidation followed by GAC verified that the GAC filter component of the device removed greater than 99% of benzene, from an influent concentration of 0.44 mg/L (NSF, 2005c).

The ETV tests of POU devices using reverse osmosis verified that the reverse osmosis components of these devices removed 85% to greater than 99% of benzene, from influent concentrations of 0.68 to 1.1 mg/L. Because of the high removals using the reverse osmosis components alone, the verifications did not test the GAC components of those devices that included the technology for benzene removal (NSF, 2005a, 2005b, 2006, 2007a).

Treatment is not known to be a limiting concern for the current MCL for benzene. The Agency's current assessment is that treatment technology would not pose a feasibility limitation at the EQL of 0.0005 mg/L.

3.8 Chlordane

The current MCL for chlordane is 0.002 mg/L and the current BAT is GAC (40 CFR 141.61). The EQL used for the Six-Year Review 2 is 0.001 mg/L (USEPA, 2009c). Small system compliance technologies include: GAC, PAC, and POU-GAC (USEPA, 1998).

According to the WHO, the achievable air stripping removal efficiency for chlordane is more than 80%, to concentrations lower than 0.0001 mg/L (WHO, 2006). Carbon usage rates for chlordane (0.0379 lbs/1,000 gal) are lower than for other organic contaminants, indicating good treatment feasibility (56 FR 3526, January 30, 1991).

Treatment is not known to be a limiting concern for the current MCL for chlordane. The Agency's current assessment is that treatment technology would not pose a feasibility limitation at the EQL of 0.001 mg/L.

3.9 1,2-Dibromo-3-chloropropane (DBCP)

The current MCL for DBCP is 0.0002 mg/L and the current BATs are GAC and PTA (40 CFR 141.61). The EQL used for the Six-Year Review 2 is 0.0001 mg/L (USEPA, 2009c). Small system compliance technologies include: GAC, PAC, PTA, diffused aeration, multi-stage bubble aeration, tray aeration, and shallow tray aeration (USEPA, 1998).

The Henry's Law constant (0.00486 atm m^3/m^3) for DBCP is at least an order of magnitude lower than for other contaminants such as benzene (Cummins and Westrick, 1987). EPA has categorized DBCP as a contaminant with difficult strippability (56 FR 3526, January 30, 1991).

Carbon usage rates for DBCP are significantly lower (0.0448 lbs/1,000 gal) than for other organic contaminants, indicating good treatment feasibility (56 FR 3526, January 30, 1991). The City of Redlands, California, operates a GAC treatment plant to remove DBCP and trichloroethylene (TCE) from groundwater. The carbon adsorbers typically operate for 18 months between reactivations (GWRTAC, 2001). Thus, while both aeration and carbon adsorption are BATs, adsorption may, in some cases, be the preferred treatment.

Treatment is not known to be a limiting concern for the current MCL for DBCP. The Agency's current assessment is that treatment technology would not pose a feasibility limitation at the EQL of 0.0001 mg/L.

3.10 1,2-Dichloropropane

The current MCL for 1,2-dichloropropane is 0.005 mg/L and the current BATs are GAC and PTA (40 CFR 141.61). Small system compliance technologies include: GAC, PTA, diffused aeration, multi-stage bubble aeration, tray aeration, and shallow tray aeration (USEPA, 1998). The EQL used for the Six-Year Review 2 is 0.0005 mg/L (USEPA, 2009c).

Performance studies for diffused aeration used to treat 1,2-dichloropropane and other contaminants have demonstrated 50% to 90% removal efficiencies (USEPA, 1985 as cited in USEPA, 1998). For 1,2-dichloropropane, Henry's Law constants reported in several sources are moderately high, ranging from 0.0481 to 0.136 atm m^3/m^3, indicating good treatment feasibility (Sander, 1999; Cummins and Westrick, 1987). EPA has categorized 1,2-dichloropropane as a contaminant with average strippability (56 FR 3526, January 30, 1991).

According to the WHO, the achievable GAC removal efficiency for 1,2-dichloropropane is more than 80%, to concentrations lower than 0.001 mg/L (WHO, 2006). Carbon usage rates for 1,2-dichloropropane (0.2857 lbs/1,000 gal) are somewhat higher than for other organic contaminants (56 FR 3526, January 30, 1991). Although EPA found that GAC may be more than twice as expensive as PTA for large systems on a dollar per household per year basis, if off-gas control of PTA is necessary, then costs between PTA and GAC are more competitive (56 FR 3526, January 30, 1991).

Treatment is not known to be a limiting concern for the current MCL for 1,2-dichloropropane. However, given the above data (removal efficiency 50% to 90% for aeration, with only moderately high Henry's Law constants; removal efficiency more than 80%, to concentrations lower than 0.001 mg/L, for GAC), treatment technology could pose a feasibility limitation at the EQL of 0.0005 mg/L.

3.11 Heptachlor

The current MCL for heptachlor is 0.0004 mg/L and the current BAT is GAC (40 CFR 141.61). Small system compliance technologies include: GAC, PAC, and POU-GAC (USEPA, 1998). The EQL used for the Six-Year Review 2 is 0.0001 mg/L (USEPA, 2009c).

Carbon usage rates for heptachlor are significantly lower (0.0556 lbs/1,000 gal) than for other organic contaminants, indicating good treatment feasibility (56 FR 3526, January 30, 1991).

Treatment is not known to be a limiting concern for the current MCL for heptachlor. The Agency’s current assessment is that treatment technology would not pose a feasibility limitation at the EQL of 0.0001 mg/L.

3.12 Heptachlor Epoxide

The current MCL for heptachlor epoxide is 0.0002 mg/L and the current BAT is GAC (40 CFR 141.61). Small system compliance technologies include: GAC, PAC, and POU-GAC (USEPA, 1998). The EQL used for the Six-Year Review 2 is 0.0001 mg/L (USEPA, 2009c).

Carbon usage rates for heptachlor epoxide are significantly lower (0.0271 lbs/1,000 gal) than for other organic contaminants, indicating good treatment feasibility (56 FR 3526, January 30, 1991). EPA has categorized heptachlor epoxide as a strongly adsorbed organic contaminant (54 *FR* 22062, May 22, 1989).

Treatment is not known to be a limiting concern for the current MCL for heptachlor epoxide. The Agency’s current assessment is that treatment technology would not pose a feasibility limitation at the EQL of 0.0001 mg/L.

3.13 Hexachlorobenzene

The current MCL for hexachlorobenzene is 0.001 mg/L and the current BAT is GAC (40 CFR 141.61). Small system compliance technologies include: GAC, PAC, and POU-GAC (USEPA, 1998). The EQL used for the Six-Year Review 2 is 0.0001 mg/L (USEPA, 2009c).

EPA has categorized hexachlorobenzene among moderately adsorbed contaminants, exhibiting an intermediate carbon usage rate (55 FR 30370, July 25, 1990). The agency concluded that GAC is effective in removing SOCs including hexachlorobenzene (55 FR 30370, July 25, 1990).

Treatment is not known to be a limiting concern for the current MCL for hexachlorobenzene. The Agency’s current assessment is that treatment technology would not pose a feasibility limitation at the health-based threshold of 0.0001 mg/L.

3.14 Toxaphene

The current MCL for toxaphene is 0.003 mg/L and the current BAT is GAC (40 CFR 141.61). Small system compliance technologies include: GAC, PAC, and POU-GAC (USEPA, 1998). The EQL used for the Six-Year Review 2 is 0.001 mg/L (USEPA, 2009c).

Carbon usage rates for toxaphene are significantly lower (0.0432 lbs/1,000 gal) than for other organic contaminants, indicating good treatment feasibility (56 FR 3526, January 30, 1991).

Treatment is not known to be a limiting concern for the current MCL for toxaphene. The Agency's current assessment is that treatment technology would not pose a feasibility limitation at the EQL of 0.001 mg/L.

3.15 1,1,2-Trichloroethane

The current MCL for 1,1,2-trichloroethane is 0.005 mg/L and the current BATs are GAC and PTA (40 CFR 141.61). Small system compliance technologies include: GAC, PTA, diffused aeration, multi-stage bubble aeration, tray aeration, and shallow tray aeration (USEPA, 1998). The health-based threshold used for the Six-Year Review 2 is the current MCLG of 0.003 mg/L (USEPA, 2009c).

EPA indicates that 1,1,2-trichloroethane may be among the less volatile organic chemicals (55 FR 30370, July 25, 1990). Still, for 1,1,2-trichloroethane, Henry's Law constants reported in several sources are moderately high, ranging from 0.0314 to 0.0487 atm m^3/m^3, indicating good treatment feasibility (Sander, 1999).

For carbon adsorption, EPA has categorized 1,1,2-trichloroethane among moderately adsorbed contaminants, exhibiting an intermediate carbon usage rate (55 FR 30370, July 25, 1990).

Treatment is not known to be a limiting concern for the current MCL for 1,1,2-trichloroethane. The Agency's current assessment is that treatment technology would not pose a feasibility limitation at the health-based threshold of 0.003 mg/L.

3.16 Vinyl Chloride

The current MCL for vinyl chloride is 0.002 mg/L and the current BAT is PTA (40 CFR 141.61). Small system compliance technologies include: GAC, PTA, diffused aeration, multi-stage bubble aeration, tray aeration, and shallow tray aeration (USEPA, 1998). The EQL used for the Six-Year Review 2 is 0.0005 mg/L (USEPA, 2009c).

EPA pilot studies at more than 30 sites showed that PTA can achieve greater than 99% VOC removals. Because vinyl chloride is more easily removed by aeration than other VOCs, EPA concluded that PTA systems designed using reasonable engineering practices could achieve 99.9% removal of vinyl chloride under most circumstances (50 FR 46902, November 13, 1985). Case studies using spray aeration demonstrated greater than 99% removal for vinyl chloride and other contaminants, with initial concentrations of 100 to 200 mg/L (USEPA, 1985 as cited in USEPA, 1998). For vinyl chloride, Henry's Law constants reported in several sources are very high, ranging from 0.889 to 265 atm m^3/m^3, indicating very good treatment feasibility (Sander, 1999; Crittenden, 1988; Cummins and Westrick, 1987; Rauschert Industries, undated).

Treatment is not known to be a limiting concern for the current MCL for vinyl chloride. The Agency's current assessment is that treatment technology would not pose a feasibility limitation at the EQL of 0.0005 mg/L.

3.17 Carbon Tetrachloride

The current MCL for carbon tetrachloride is 0.005 mg/L and the current BATs are GAC and PTA (40 CFR 141.61). Small system compliance technologies include: GAC, PTA, diffused aeration, multi-stage bubble aeration, tray aeration, and shallow tray aeration (USEPA, 1998). The EQL used for the Six-Year Review 2 is 0.0005 mg/L (USEPA, 2009c).

EPA pilot studies at more than 30 sites showed that PTA can achieve greater than 99% VOC removals. Based on these and other studies, EPA concluded that PTA systems designed using reasonable engineering practices could achieve 99% removal of nine VOCs, including carbon tetrachloride, under all anticipated circumstances. Removal could be as high as 99.9% under optimum conditions (50 FR 46902, November 13, 1985). For carbon tetrachloride, Henry's Law constants reported in several sources are high, ranging from 0.204 to 1.36 atm m^3/m^3, indicating good treatment feasibility (Sander, 1999; Crittenden, 1988; Cummins and Westrick, 1987; Rauschert Industries, undated).

EPA indicates that GAC can achieve high level of removal (up to 99.9%) of VOCs, including carbon tetrachloride, under all anticipated conditions (50 FR 46902, November 13, 1985). Case studies cited in the U.S. Army Corps of Engineers' *Adsorption Design Guide* show GAC removal efficiencies for carbon tetrachloride of greater than 99.9%, at influent concentrations of 1.0 to 135 mg/L (U.S. Army Corps of Engineers, 2001).

Treatment is not known to be a limiting concern for the current MCL for carbon tetrachloride. The Agency's current assessment is that treatment technology would not pose a feasibility limitation at the EQL of 0.0005 mg/L.

3.18 1,2-Dichloroethane (Ethylene Dichloride)

The current MCL for 1,2-dichloroethane is 0.005 mg/L and the current BATs are GAC and PTA (40 CFR 141.61). Small system compliance technologies include: GAC, PTA, diffused aeration, multi-stage bubble aeration, tray aeration, and shallow tray aeration (USEPA, 1998). The EQL used for the Six-Year Review 2 is 0.0005 mg/L (USEPA, 2009c).

EPA pilot studies using PTA at more than 30 sites showed greater than 99% VOC removals to be achievable. Based on these and other studies, EPA concluded that PTA systems designed using reasonable engineering practices could achieve 99% removal of nine VOCs, including 1,2-dichloroethane, under all anticipated circumstances. Removal could be as high as 99.9% under optimum conditions (50 FR 46902, November 13, 1985). For 1,2-dichloroethane, Henry's Law constants reported in several sources are moderately high, ranging from 0.023 to 0.0639 atm m^3/m^3, indicating good treatment feasibility (Sander, 1999; Crittenden, 1988; Cummins and Westrick, 1987).

EPA has concluded that GAC can achieve a high level of removal of most VOCs. Although carbon usage rates are significantly higher for 1,2-dichloroethane than other VOCs, EPA concluded that removal is still feasible using GAC (50 FR 46902, November 13, 1985).

Treatment is not known to be a limiting concern for the current MCL for 1,2-dichloroethane. The Agency's current assessment is that treatment technology would not pose a feasibility limitation at the EQL of 0.0005 mg/L.

3.19 Dichloromethane

The current MCL for dichloromethane is 0.005 mg/L and the current BAT is PTA (40 CFR 141.61). Small system compliance technologies include: GAC, PTA, diffused aeration, multi-stage bubble aeration, tray aeration, and shallow tray aeration (USEPA, 1998). The EQL used for the Six-Year Review 2 is 0.0005 mg/L (USEPA, 2009c).

EPA has categorized dichloromethane among the more volatile SOCs (55 *FR* 30370, July 25, 1990). For the volatile SOCs, properly designed PTA facilities can achieve removal efficiencies of 90% to 99% or more (55 *FR* 30370, July 25, 1990). For dichloromethane, Henry's Law constants reported in several sources are moderately high, ranging from 0.0341 to 0.132 atm m^3/m^3, indicating good treatment feasibility (Sander, 1999). For GAC, EPA has concluded that the technology is capable of removing SOCs, but is a more costly technique than PTA for dichloromethane (55 *FR* 30370, July 25, 1990).

Treatment is not known to be a limiting concern for the current MCL for dichloromethane. The Agency's current assessment is that treatment technology would not pose a feasibility limitation at the EQL of 0.0005 mg/L.

3.20 Tetrachloroethylene

The current MCL for tetrachloroethylene is 0.005 mg/L and the current BATs are GAC and PTA (40 CFR 141.61). Small system compliance technologies include: GAC, PTA, diffused aeration, multi-stage bubble aeration, tray aeration, and shallow tray aeration (USEPA, 1998). The EQL used for the Six-Year Review 2 is 0.0005 mg/L (USEPA, 2009c).

EPA pilot studies at more than 30 sites showed that PTA can achieve greater than 99% VOC removals. Based on these and other studies, EPA concluded that PTA systems designed using reasonable engineering practices could achieve 99% removal of nine VOCs, including tetrachloroethylene, under all anticipated circumstances. Removal could be as high as 99.9% under optimum conditions (50 FR 46902, November 13, 1985). According to the WHO, the achievable air stripping removal efficiency for tetrachloroethylene is more than 80%, to concentrations lower than 0.001 mg/L (WHO, 2006). Field studies of PTA performed in three States demonstrated a removal efficiency of greater than 96% for tetrachloroethylene and other contaminants, with initial concentrations of up to 0.6 mg/L (Ram et al., 1990 as cited in USEPA, 1998). Performance studies employing multiple tray aeration to treat tetrachloroethylene and other contaminants have demonstrated 50% to 90% removal efficiencies (USEPA, 1985 as cited in USEPA, 1998). For tetrachloroethylene, Henry's Law constants reported in several sources are high, ranging from 0.214 to 1.20 atm m^3/m^3, indicating good treatment feasibility (Sander, 1999; Cummins and Westrick, 1987; Rauschert Industries, undated). EPA has categorized tetrachloroethylene as a contaminant with good strippability (56 FR 3526, January 30, 1991).

According to the WHO, the achievable GAC removal efficiency for tetrachloroethlyene is more than 80%, to concentrations lower than 0.005 mg/L (WHO, 2006). Case studies cited in the U.S. Army Corps of Engineers' *Adsorption Design Guide* show GAC removal efficiencies for tetrachloroethylene of greater than 99.9%, at influent concentrations of 4.5 to 170 mg/L (U.S. Army Corps of Engineers, 2001). EPA has concluded that GAC can achieve a high level of removal (up to 99.9%) of VOCs, including tetrachloroethlyene, under all anticipated conditions (50 FR 46902, November 13, 1985). Carbon usage rates for tetrachloroethylene (0.1144 lbs/1,000 gal) are relatively low compared with other organic contaminants, indicating good treatment feasibility (56 FR 3526, January 30, 1991).

Treatment is not known to be a limiting concern for the current MCL for tetrachloroethylene. The Agency's current assessment is that treatment technology would not pose a feasibility limitation at the EQL of 0.0005 mg/L.

3.21 Trichloroethylene

The current MCL for trichloroethylene is 0.005 mg/L and the current BATs are GAC and PTA (40 CFR 141.61). Small system compliance technologies include: GAC, PTA, diffused aeration, multi-stage bubble aeration, tray aeration, shallow tray aeration, spray aeration, and mechanical aeration (USEPA, 1998). The EQL used for the Six-Year Review 2 is 0.0005 mg/L (USEPA, 2009c).

EPA pilot studies at more than 30 sites showed that PTA can achieve greater than 99% VOC removals. Based on these and other studies, EPA concluded that PTA systems designed using reasonable engineering practices could achieve 99% removal of nine VOCs, including trichloroethylene, under all anticipated circumstances. Removal could be as high as 99.9% under optimum conditions (50 FR 46902, November 13, 1985). Field studies of PTA performed in three States demonstrated a removal efficiency of greater than 96% for trichloroethylene and other contaminants, with initial concentrations of up to 0.6 mg/L (Ram et al., 1990 as cited in USEPA, 1998). Performance studies employing multiple tray aeration to treat trichloroethylene and other contaminants have demonstrated 50% to 90% removal efficiencies (USEPA, 1985 as cited in USEPA, 1998). Other case studies using spray aeration demonstrated greater than 99% removal for trichloroethylene and other contaminants, with initial concentrations of 100 to 200 mg/L (USEPA, 1985 as cited in USEPA, 1998). For trichloroethylene, Henry's Law constants reported in several sources are relatively high, ranging from 0.116 to 0.552 atm m^3/m^3, indicating good treatment feasibility (Sander, 1999; Crittenden, 1988; Cummins and Westrick, 1987; Rauschert Industries, undated).

Case studies cited in the U.S. Army Corps of Engineers' *Adsorption Design Guide* show GAC removal efficiencies for trichloroethylene of greater than 99.9%, at influent concentrations of 3 to 50 mg/L (U.S. Army Corps of Engineers, 2001). EPA has concluded that GAC can achieve a high level of removal (up to 99.9%) of VOCs, including trichloroethylene, under all anticipated conditions (50 FR 46902, November 13, 1985). The City of Redlands, California, operates a GAC treatment plant to remove trichloroethylene and DBCP from groundwater. The carbon adsorbers typically operate for 18 months between reactivations (GWRTAC, 2001).

Treatment is not known to be a limiting concern for the current MCL for trichloroethylene. The Agency's current assessment is that treatment technology would not pose a feasibility limitation at the EQL of 0.0005 mg/L.

4 Review of Treatment Techniques for Acrylamide and Epichlorohydrin

Acrylamide and epichlorohydrin are introduced in drinking water primarily as impurities in polymers and copolymers used for water treatment and in contact surfaces used in storage and distribution systems. EPA proposed drinking water regulations for acrylamide and epichlorohydrin in 1989 (54 *FR* 22062, May 22, 1989) and promulgated final drinking water regulations in 1991 (56 FR 3526, January 30, 1991). As both these contaminants are classified as probable human carcinogens (B2), EPA established the MCLGs for both at zero. EPA has regulated these contaminants using a treatment technique requirement in lieu of a MCL because of the absence of standardized analytical methods for their measurement in water. The NPDWR limits the allowable monomer level in products used for water treatment and the dosage of polymers that contain them. EPA selected this option because methods are available for measurement of residual monomer in polymer products and these levels are routinely measured by manufacturers. These levels are:

- Acrylamide: 0.05% residual acrylamide in polymers/copolymers and maximum dosage of 1 ppm (or equivalent)
- Epichlorohydrin: 0.01% residual epichlorohydrin in polymers/copolymers and maximum dosage of 20 ppm (or equivalent).

The residual monomer level for each contaminant was considered to be the lowest level manufacturers could feasibly achieve at the time EPA promulgated the regulation (54 *FR* 22062, May 22, 1989). A system can use third-party or manufacturer's certification in lieu of testing for the residual monomer level.

NSF International (NSF), a third party organization, tests and certifies water treatment chemicals that meet NSF/ANSI Standard 60, *Drinking Water Treatment Chemicals – Health Effects*, which sets out requirements for treatment chemicals based on human health protection (NSF, 1999a). The requirements for acrylamide- and epichlorohydrin-based polymers in Standard 60 are based on EPA's treatment technique requirements. Thus, NSF 60 certification of a polymeric coagulant aid containing acrylamide or epichlorohydrin indicates that users are in compliance with EPA's regulation when a product is used as specified (i.e., for the intended purpose and up to the maximum usage level indicated by NSF).

EPA obtained data during Six-Year Review 2 indicating that potential improvements in the technology or manufacturing now allow production of the polymer with lower residual monomer content. This new information viewed in conjunction with regulations and guidelines in other countries suggests there is potential for EPA to revise its TT requirement to reflect a lower feasible monomer content.

4.1 Improvements in Manufacturing

In 2007, NSF provided EPA with results of NSF analyses between January 2005 and June 2007 of acrylamide monomer in polyacrylamides and free epichlorohydrin in polyamines.[1] NSF performed the analyses for approval of these products against NSF/ANSI Standard 60. **Exhibit 4-1** provides a summary of the results. The Appendix contains the data NSF provided to EPA.

Residual levels in the products tested and certified are well below the residual levels in the current TTs. The mean concentration among acrylamide tests is about one-fifth the residual level in the current TT, and the 90th percentile result is one-half the residual level in the current TT. All analyses for residual epichlorohydrin were non-detects, with a detection limit equal to one-fifth the residual level in the current TT.

Exhibit 4-1. Summary of NSF International Product Testing Results for Acrylamide and Epichlorohydrin

Contaminant	Number of Analyses and Detections[1]	Detection Limit (mg/kg)	Summary of Results (mg/kg)					Current TT (mg/kg)[3]
			Maximum	90th Percentile	Mean[2]	Median[2]	Minimum	
Acrylamide[4]	66 [45]	10	420	250	98	60	10	500
Epichlorohydrin[5]	84 [0]	20	NA	NA	NA	NA	NA	100

NA = not applicable – all results are below the detection limit.
1. Total number of analyses appears first. The number of results above the detection limit appears second, in brackets.
2. Includes nondetected values for acrylamide, assumed to be 10 mg/kg.
3. TT residual monomer content converted from percent to mg/kg; 1 mg/kg = $1/10^6$ = 0.000001 = 0.0001%.
4. Method: Per Skelly and Husser (1978).
5. Method: Per section B.4.3.1 in NSF 60-2005.

4.2 Regulations and Guidelines in Other Countries

Regulations in other areas of the world are generally more stringent than the current EPA NPDWR for acrylamide and epichlorohydrin in drinking water. **Exhibit 4-2** provides a comparison of recommendations and guidelines used elsewhere to EPA's current regulations.

Canada has no national regulations regarding acrylamide or epichlorohydrin. However, many provinces require NSF 60 certification for additives used in drinking water treatment (Lemieux, 2007). The residual monomer and dosage requirements for NSF 60 certification are based on those in EPA's current NPDWR.

[1] NSF did not provide any confidential business information such as which manufacturers were included in the analyses. NSF only provided vectors of testing results.

Exhibit 4-2. Comparison of Acrylamide and Epichlorohydrin Drinking Water Guidelines

Country/Region	Regulation or Guideline	Acrylamide	Epichlorohydrin
US EPA	Residual Monomer	0.05%	0.01%
	Maximum Dosage	1 mg/L	20 mg/L
	Expected Concentration in Water[1]	0.5 µg/L	2 µg/L
Canada	NSF 60 certification required in many provinces; see text below		
United Kingdom[2]	Residual Monomer	0.02%	0.002%
	Maximum Dosage	0.25 mg/L (average) 0.5 mg/L (maximum)	2.5 mg/L (average) 5 mg/L (maximum)
	Expected Concentration in Water[1]	0.05 µg/L (average) 0.1 µg/L (maximum)	0.05 µg/L (average) 0.1 µg/L (maximum)
European Union[3]	Concentration in Water	0.1 µg/L	0.1 µg/L
WHO[4]	Concentration in Water	0.5 µg/L	0.4 µg/L
Australia[5]	Concentration in Water	0.2 µg/L	0.5 µg/L

1. The expected monomer concentration in water is the product of the maximum dosage and the residual monomer level, using the worst-case assumption that all residual monomer remains in finished water.
2. DWI (2007) and Ashworth (2007). The UK limits both the average and the maximum polymer dose.
3. OJEC (1998). The concentration is “the residual monomer concentration in the water as calculated according to specifications of the maximum release from the corresponding polymer in contact with the water.”
4. WHO (2006). The World Health Organization’s recommendation for epichlorohydrin is a provisional guideline value because there is evidence of a hazard, but the available information on health effects is limited (WHO, 2004).
5. NHMRC (2004). The guideline value for epichlorohydrin is below the limit of determination; improved analytical procedures are required for this compound.

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Appendix: Monomer Data from NSF International

In 2007, NSF International (NSF) provided EPA with the results of NSF analyses of acrylamide monomer in polyacrylamides and free epichlorohydrin in polyamines certified to NSF/ANSI Standard 60. The analyses were performed between January 2005 and June 2007. The data that NSF provided is reproduced here.

NSF determined the residual acrylamide content in 66 samples of commercial polyacrylamides, using the method described by Skelly and Husser (1978) with a detection limit of 10 mg acrylamide per kg polymer. NSF provided only a vector of test results; it did not provide manufacturer or product names or any other competition-sensitive information. **Exhibit A-1** provides a frequency distribution for the data that NSF provided to EPA.

Exhibit A-1. NSF International Data on Acrylamide Monomer in Polyacrylamide

Measurement (mg/kg)	Number of Samples
ND[1]	21
10	2
20	1
30	2
40	6
60	2
70	3
80	2
90	2
100	3
110	1
120	1
140	3
150	2
170	2
180	2
210	2
220	2
280	1
320	2
340	1
360	1
410	1
420	1

ND = nondetect.
1. Detection limit was 10 mg/kg.

NSF provided EPA with measurements of the amount of residual epichlorohydrin in 84 samples of commercial polyamines, using the method described in section B.4.3.1 of NSF 60-2005 with a detection limit of 20 mg epichlorohydrin per kg polymer. NSF provided only a vector of test results, with no manufacturer or product names or other competition-sensitive information. None of the 84 measurements found epichlorohydrin in a concentration greater than the detection limit.