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Part II

Environmental Protection Agency

40 CFR Parts 141 and 142

National Primary Drinking Water Regulations; Radon-222; Proposed Rule

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Parts 141 and 142

[WH–FRL–6462–8]

RIN 2040–AA94

National Primary Drinking Water Regulations; Radon-222

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice of proposed rulemaking.

SUMMARY: In this action, the Environmental Protection Agency (EPA) is proposing a multimedia approach to reducing radon risks in indoor air (where the problem is greatest), while protecting public health from the highest levels of radon in drinking water. Most radon enters indoor air from soil under homes and other buildings. Only approximately 1–2 percent comes from drinking water. The Agency is proposing a Maximum Contaminant Level Goal (MCLG) and National Primary Drinking Water Regulations (NPDWR) for radon-222 in public water supplies. Under the framework set forth in the 1996 amendments to the SDWA, EPA is also proposing an alternative maximum contaminant level (AMCL) and requirements for multimedia mitigation (MMM) programs to address radon in indoor air. Public water systems (PWS) are defined in the Safe Drinking Water Act (SDWA). This proposed rule applies to community water systems (CWS), a subset of PWSs. Under the proposed rule, CWSs may comply with the AMCL if they are in States that develop an EPA-approved MMM program or, in the absence of a State program, develop a State-approved CWS MMM program. This approach is intended to encourage States, Tribes, and CWSs to reduce the health risk of radon in the most cost-effective way. The Agency is also proposing a maximum contaminant level (MCL) for radon-222, to apply to CWSs in non-MMM States that choose not to implement a CWS MMM program. The proposal also includes monitoring, reporting, public notification, and consumer confidence report requirements for radon-222 in drinking water.

DATES: EPA must receive public comments, in writing, on the proposed regulations by January 3, 2000.

ADDRESSES: You may send written comments to the Radon-222, W–99–08 Comments Clerk, Water Docket (MC–4101); U.S. Environmental Protection Agency; 401 M Street, SW., Washington, DC 20460. Comments may be hand-delivered to the Water Docket, U.S. Environmental Protection Agency; 401 M Street, SW., East Tower Basement, Washington, DC 20460. Comments may be submitted electronically to *owdocket@epamail.epa.gov.* Electronic comments must be submitted as an ASCII, WP6.1, or WP8 file avoiding the use of special characters and any form of encryption. Electronic comments must be identified by the docket number W–99–08. Comments and data will also be accepted on disks in WP6.1, WP8, or ASCII format. Electronic comments on this action may be filed online at many Federal Depository libraries.

Please submit a copy of any references cited in your comments. Facsimiles (faxes) cannot be accepted. EPA would appreciate one original and three copies of your comments and enclosures (including any references). Commenters who would like EPA to acknowledge receipt of their comments should include a self-addressed, stamped envelope.

The proposed rule and supporting documents, including public comments, are available for review in the Water Docket at the address listed previously. The Docket also has several of the key supporting documents electronically available as PDF files. For information on how to access Docket materials, please call (202) 260–3027 between 9 a.m. and 3:30 p.m. Eastern Time, Monday through Friday.

FOR FURTHER INFORMATION CONTACT: For general information on radon in drinking water, contact the Safe Drinking Water Hotline, phone (800) 426–4791. The Safe Drinking Water Hotline is open Monday through Friday, excluding Federal holidays, from 9 a.m. to 5:30 p.m. Eastern Time. For technical inquiries regarding the proposed regulations, contact Sylvia Malm, Office of Ground Water and Drinking Water, U.S. Environmental Protection Agency (mailcode 4607), 401 M Street, SW, Washington DC, 20460. Phone: (202) 260–0417. E-mail: *malm.sylvia@epa.gov.* For inquiries regarding the proposed multimedia mitigation program, contact Anita Schmidt, Office of Radiation and Indoor Air, U.S. Environmental Protection Agency, (mailcode 6609J), 401 M Street, S.W, Washington, DC, 20460. Phone: (202) 564–9452. E-mail: *schmidt.anita@epa.gov.* For general information on radon in indoor air, contact the Radon Hotline at 1–800–SOS–RADON (1–800–767–7236).

SUPPLEMENTARY INFORMATION:

Potentially Regulated Entities

Potentially regulated entities include community water systems using ground water or mixed ground and surface water.

The following table lists potentially regulated entities. This table is not intended to be exhaustive, but rather provides a guide for readers regarding entities likely to be regulated by this action. This table lists the types of entities that EPA is now aware of that could potentially be regulated by this action. Other entities not listed in the table could also be regulated. To determine whether your organization is affected by this action, you should carefully examine the proposed applicability criteria in section 40 CFR parts 141.20(b)(1) and Section IV of the preamble. If you have questions regarding the applicability of this action to a particular entity, consult Sylvia Malm who is listed in the preceding **FOR FURTHER INFORMATION CONTACT** section.

Category	Examples of potentially regulated entities
Industry	Privately owned/operated community water supply systems using ground water or mixed ground water and surface water.
State, Tribal, and Local Government.	State, Tribal, or local government-owned/operated water supply systems using ground water or mixed ground water and surface water.
Federal Government.	Federally owned/operated community water supply systems using ground water or mixed ground water and surface water.

Abbreviations Used in This Proposal

AMCL: Alternative Maximum Contaminant Level
BAT: Best Available Technology
BEIR: Committee on the Biological Effects of Ionizing Radiation. The Committee on Health Risks of Exposure on Radon that conducted the National Research Council Biological Effects of Ionizing Radiation (BEIR) VI Study (NAS 1999a). The committee is formed by the Radiation Effect Research/Commission on Life Sciences/National Research Council/National Academy of Sciences.
CFR: Code of Federal Regulations
CWS: Community Water System
EF: Equilibrium Factor
EPA: U.S. Environmental Protection Agency
FR: Federal Register
GAC: Granular Activated Carbon

HRRCA: Health Risk Reduction and Cost Analysis
IOC: Inorganic Contaminant
LSC: Liquid Scintillation Counting
MCL: Maximum Contaminant Level
MCLG: Maximum Contaminant Level Goal
MMM: Multimedia Mitigation
NAS: National Academy of Sciences
NAS Radon in Drinking Water Committee: The Committee on Risk Assessment of Exposure to Radon of the Drinking Water that conducted the National Research Council Risk Assessment of Radon in Drinking Water Study (NAS 1999b). The committee is formed by the Board of Radiation Effect Research of the Commission on Life Sciences of the National Research Council, National Academy of Sciences.
NELAC: National Environmental Laboratory Accreditation Conference
NIST: National Institute of Standards and Technology
NIRS: National Inorganics and Radionuclides Survey
NPDWR: National Primary Drinking Water Regulation
NPRM: Notice of Proposed Rulemaking
NTNC: Non-Transient, Non-Community
OGWDW: Office of Ground Water and Drinking Water
OMB: Office of Management and Budget
PBMS: Performance-Based Measurement System
PE: Performance Evaluation
PT: Proficiency Testing
POE: Point-of-Entry
POU: Point-of-Use
PRA: Paperwork Reduction Act
PWS: Public Water System
pCi/L: Picocuries per Liter
RFA: Regulatory Flexibility Act
SAB: Science Advisory Board
SBA: Small Business Administration
SBO: Small Business Ombudsman
SBREFA: Small Business Regulatory Enforcement and Fairness Act
SDWA: Safe Drinking Water Act
SDWIS: Safe Drinking Water Information System
SIRG: State Indoor Radon Grant
SSCT: Small Systems Compliance Technology
SSVT: Small Systems Variance Technology
SMF: Standardized Monitoring Framework
UMRA: Unfunded Mandates Reform Act
URTH: Unreasonable Risks to Health
WL: Working Level
WLM: Working Level Month

Table of Contents

I. Summary: What Does Today's Proposed Rulemaking Mean for My Water System?

A. Why Is EPA Proposing To Regulate Radon in Drinking Water?

The proposed National Primary Drinking Water Regulation (NPDWR) for radon in drinking water is based on a multimedia approach designed to achieve greater risk reduction by addressing radon risks in indoor air, with public water systems providing protection from the highest levels of radon in their ground water supplies. The framework for this proposal is set out in the Safe Drinking Water Act as amended in 1996 (SDWA), which provides for a multimedia approach for addressing the public health risks from radon in drinking water and radon in indoor air from soil. This statutory-based framework reflects the characteristics uniquely specific to radon among drinking water contaminants: that the relative cost-effectiveness of reducing risk from exposure to this contaminant is substantially greater for a non-drinking water source of exposure—indoor air—than it is from drinking water. Accordingly, SDWA directs the Environmental Protection Agency (EPA) to promulgate a maximum contaminant level (MCL) for radon in drinking water, but also to make available a higher alternative maximum contaminant level (AMCL) accompanied by a multimedia mitigation (MMM) program to address radon risks in indoor air. Further, in setting the MCL, EPA is to take into account the costs and benefits of programs that control radon in indoor air (SDWA 1412(b)(13)(E)).

B. What Is Radon?

Radon's Physical Properties

Throughout this preamble, ''radon'' refers to the specific isotope radon-222. Radon is a naturally occurring gas formed from the radioactive decay of uranium-238. Low concentrations of uranium and its other decay products, specifically radium-226, occur widely in the earth's crust, and thus radon is continually being generated, even in soils in which there is no man-made radioactive contamination. Radon is colorless, odorless, tasteless, chemically inert, and radioactive. A portion of the radon released through radioactive decay moves through air or water-filled pores in the soil to the soil surface and enters the air, while some remains below the surface and dissolves in ground water (water that collects and flows under the ground's surface).

Because radon is a gas, when water that contains radon is exposed to the air, the radon will tend to be released into the air. Therefore, radon is usually present in only low amounts in rivers and lakes. If ground water is supplied to a house, radon in the water will tend to be released into the air of the house via various water uses. Thus presence of radon in drinking water supplies leads to exposure via both oral route (ingesting water containing radon) and inhalation route (breathing air containing both radon and radon decay products released from water used in the house such as for cooking and washing).

Radon itself also decays, emitting ionizing radiation in the form of alpha particles, and transforms into decay products, or ''progeny'' radioisotopes. It has a half-life of about four days and decays into short-lived progeny. Unlike radon, the progeny are not gases, and can easily attach to and be transported by dust and other particles in air. The decay of progeny continues until stable, non-radioactive progeny are formed. At each step in the decay process, radiation is released.

C. What Are the Health Concerns From Radon in Air and Water?

National and international scientific organizations have concluded that radon causes lung cancer in humans. The primary risk is lung cancer from radon entering indoor air from soil under homes. Tap water is a smaller source of radon in air; however, breathing radon released to air from household water uses also increases the risk of lung cancer, and consumption of drinking water containing radon presents a smaller risk of internal organ cancers, primarily stomach cancer.

In most cases, radon in soil under homes is the biggest source of exposure and radon from tap water will be a small source of radon in indoor air.

The U.S. Surgeon General has warned that indoor radon (from soil) is the second leading cause of lung cancer (USEPA 1988b). The National Academy of Sciences (NAS 1999a) estimates that radon from soil causes about 15,000 to 22,000 (using two different approaches) lung cancer deaths each year in the U.S. If you smoke and your home has high indoor radon levels, your risk of lung cancer is especially high. EPA and the U.S. Surgeon General recommend testing all homes below the third floor.

The NAS report mandated by the 1996 SDWA identifies the same unit risk associated with radon in drinking water compared with previous EPA analyses. Based on the NAS risk assessment and an updated EPA occurrence analysis, the Agency estimates that uncontrolled levels of radon in public drinking water supplies cause 168 fatal cancers each year in the U.S. However, radon in domestic drinking water generally contributes a very small part (about 1–2 percent) of total radon exposure from indoor air. The NAS estimated that about 89 percent of the fatal cancers caused by radon in drinking water were due to lung cancer from inhalation of radon released to indoor air, and about 11 percent were due to stomach cancer from consuming water containing radon (NAS 1999b).

D. Does This Regulation Apply to My Water System?

The regulation for radon in drinking water and the multimedia approach proposed in this action would apply to all community public water systems (CWSs) that use ground water or mixed ground and surface water. The proposed regulation would not apply to non-transient non-community (NTNC) public water supplies, nor to transient public water supplies.

E. How Will This Regulation Protect Public Health?

Given the much greater potential for risk reduction in indoor air and years of experience with radon mitigation programs, EPA expects that greater overall risk reduction will result from this proposal than from an approach which solely addresses radon in public drinking water supplies. The proposed regulation for radon in drinking water is intended to promote a more cost-effective multimedia approach to reduce radon risks, particularly for small systems with limited resources, and to reduce the highest levels of radon in drinking water. This determination to have a strong and effective multimedia radon program to address radon in indoor air is consistent with the SDWA framework for multimedia radon programs and the SDWA expectation that EPA would give significant weight to the risk findings of the NAS report, which confirm the health risks of radon in drinking water, and the much greater risks from radon in indoor air arising from soil under homes.

F. How Will the Multimedia Mitigation (MMM) Program Work?

The multimedia mitigation (MMM) program is modeled on the National Indoor Radon Program implemented by EPA, States and others. That program has achieved substantial risk reduction through voluntary public action since the release of the original ''A Citizen's Guide to Radon'' in 1986 (USEPA 1986, 1992b) and the U.S. Surgeon General's recommendation in 1988 that all homes be tested and elevated levels be reduced. The program has been successful in achieving indoor radon risk reduction through a variety of program strategies, which form the basis for EPA's proposed multimedia mitigation program plan criteria. Based on the estimated number of existing homes fixed and the number of new homes built radon-resistant since the national program began in 1986, EPA estimates that under existing Federal and State indoor radon programs, a total of more than 2,500 lives will be saved through indoor radon risk reduction efforts expected to take place through the year 2000. Every year the rate of lives saved increases as more existing houses with elevated radon levels are fixed and as more new houses are built radon-resistant. For the year 2000, EPA estimates that the rate of radon-related lung cancer deaths that will be avoided from mitigation of existing homes and from homes built radon-resistant (in high radon areas) will be about 350 lives saved per year (USEPA 1999i).

The MMM/AMCL approach is intended to provide a more cost-effective alternative to achieve radon risk reduction, by allowing States (or community water systems) to address radon in indoor air from the soil source, while reducing the highest levels of radon in drinking water. It is EPA's expectation that most States will develop State-wide multimedia mitigation programs as the most cost-effective approach. Most of the States currently have indoor radon programs that are addressing radon risk from soil, and can be used as the foundation for development of MMM program plans. EPA expects that State indoor radon programs will implement MMM programs under agreements with the State drinking water programs. The regulatory expectation of community water systems serving 10,000 persons or less is that they meet the alternative maximum contaminant level (AMCL) and be associated with an approved MMM program plan—either developed by the State and approved by EPA or developed by the CWS and approved by the State. Tribal CWS MMM programs, as well as those in States and Territories that do not have drinking water primacy, will be approved by EPA. The same general criteria for State MMM program plans would apply to CWSs in developing local MMM programs in States that do not have such a program, albeit with a local perspective on such criteria and commensurate with the unique attributes of small CWSs. EPA expects that MMM program strategies for CWSs will be less comprehensive than those of State MMM programs, and will need to reflect the local character of the community served by the CWS. Strong public participation in the development of the CWS MMM program plans will help to ensure this, as well as community support for the MMM program. Figures I.1 and I.2 provide a conceptual model for the MCL, AMCL, and MMM programs for small and large systems.

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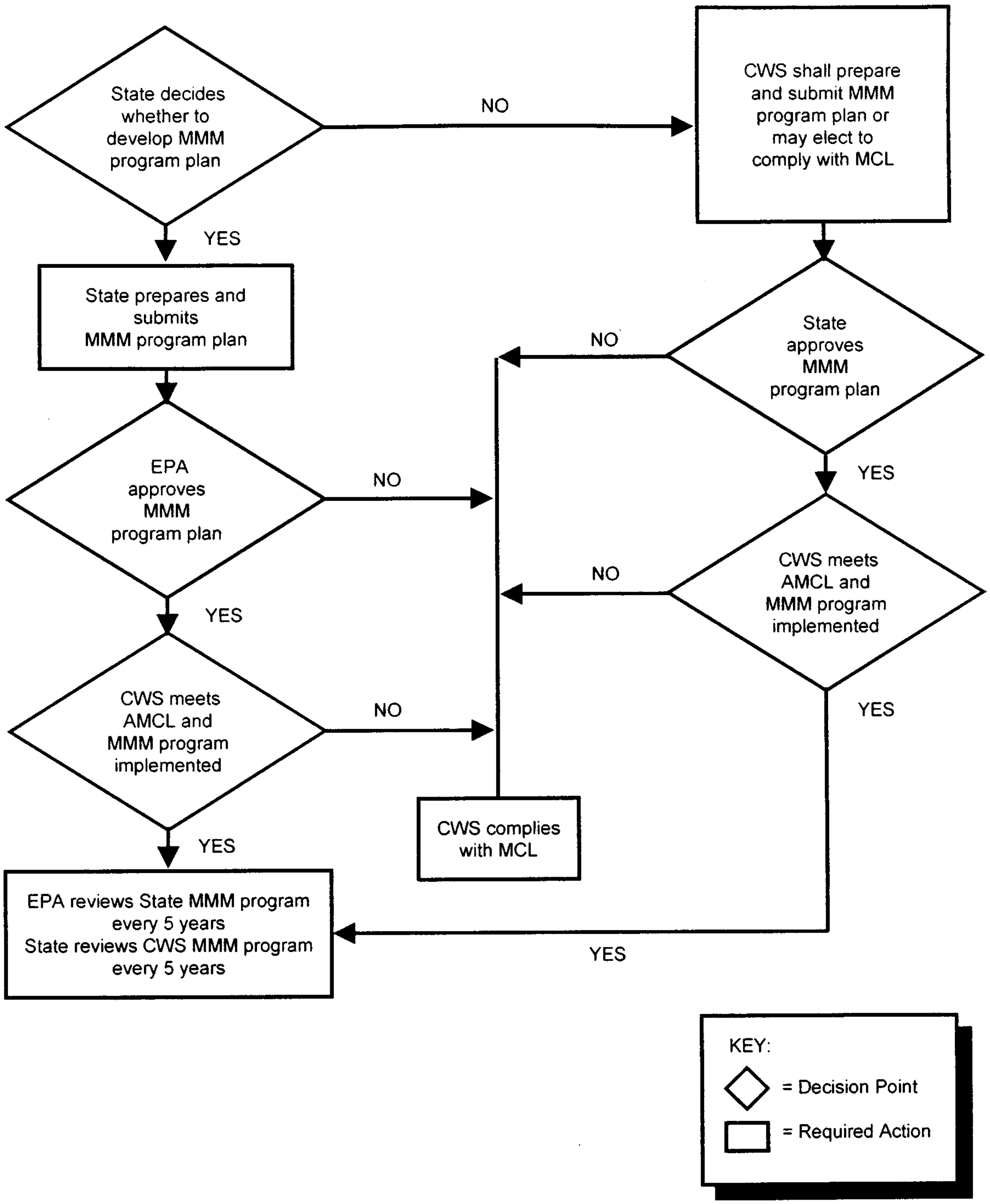
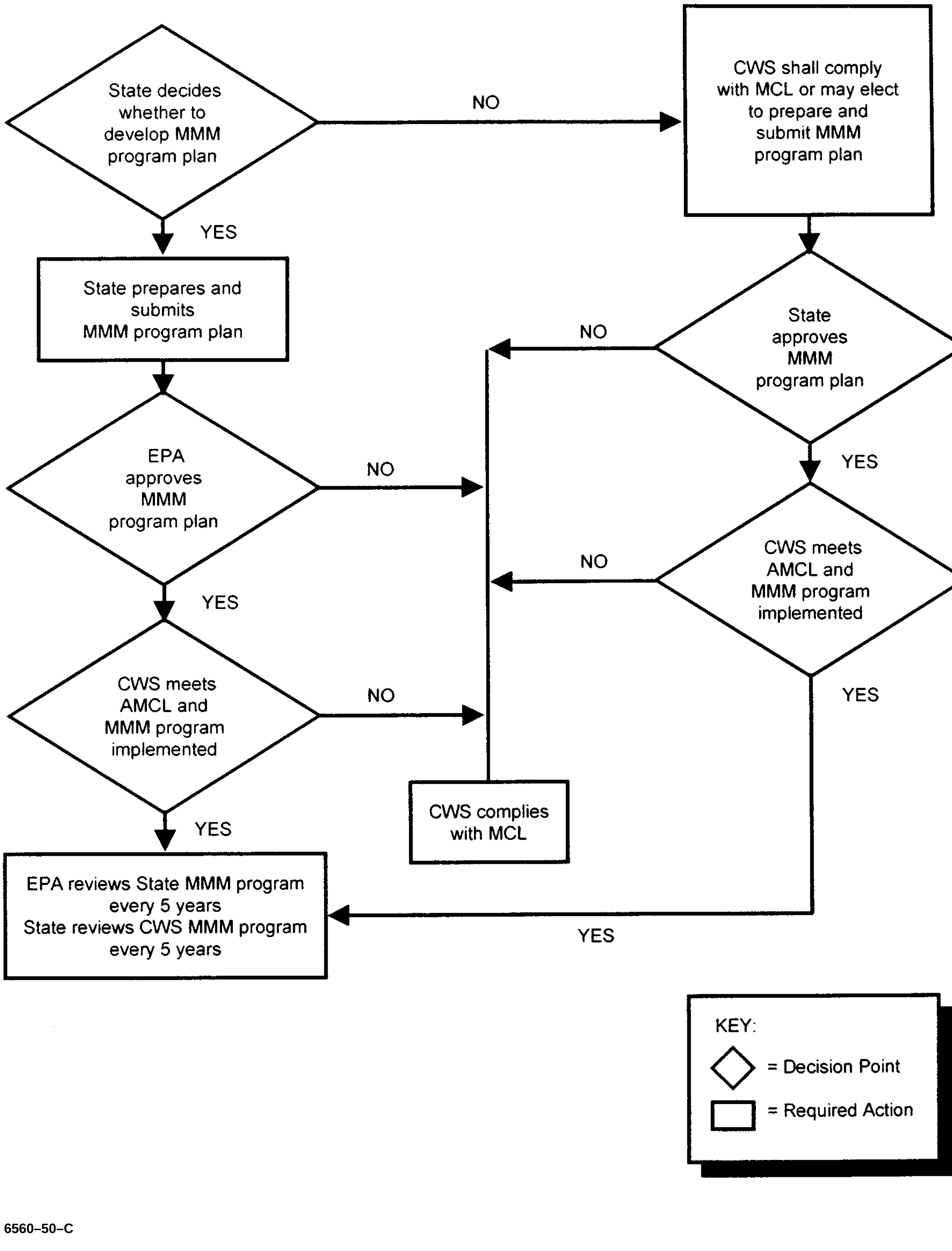
FIGURE I.1
Conceptual Model for the MCL, AMCL, and MMM Program
(Small Systems)



NOTE: The regulatory expectation for small systems is compliance with the AMCL if there is an approved State MMM program, or implementation of a CWS MMM program (in the absence of a State MMM program. Small systems may elect to comply with the MCL instead of implementing an MMM program.

FIGURE I.2
Conceptual Model for the MCL, AMCL, and MMM Program
(Large Systems)



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To meet the requirements of SDWA, the risk reduction benefits expected to be achieved by MMM programs are to be equal to or greater than risk reduction benefits that would be achieved by CWSs complying with the MCL. Under SDWA, this means that if all States implemented MMM programs they would be expected to result in about 62 cancer deaths averted annually, equal to what would be achieved with universal compliance with the MCL at 300 pCi/L. Unlike health risk reduction benefits gained through water treatment, which remain constant from one year to the next, the rate of health benefits from reducing indoor radon is cumulative; that is, it steadily increases every year with every additional existing home that is mitigated and with every new home built radon-resistant. Therefore, MMM programs will use and build on the indoor radon program framework to achieve ''equal or greater'' risk reduction, rather than focusing efforts on precisely quantifying ''equivalency'' to the much more limited risk reduction expected to occur if community water systems complied with the MCL.

G. What Are the Proposed Limits for Radon in Drinking Water?

The proposed regulation provides that States may adopt State-wide MMM programs and the alternative maximum contaminant level (AMCL) of 4000 pCi/L. This is the most effective approach for radon risk reduction and the one EPA expects the majority of States to adopt. If a State has an EPA-approved MMM program plan, CWSs in that State may comply with the AMCL. In the absence of an approved State MMM program plan the regulatory expectation for small CWSs (those serving 10,000 or fewer) is that they comply with a level of 4000 pCi/L in drinking water, and develop and implement a State-approved local MMM program plan to reduce indoor radon risks arising from soil and rock under homes and buildings. Small CWSs may also choose to comply with the MCL of 300 pCi/L (and not develop a local MMM program.)

The AMCL/MMM approach is EPA's regulatory expectation for small CWSs because an MMM program and compliance with the AMCL is a much more cost-effective way to reduce radon risk than compliance with the maximum contaminant level (MCL) of 300 pCi/L. (While EPA believes that the MMM approach is preferable for small systems in a non-MMM State, small CWSs may, at their discretion, choose the option of meeting the MCL instead of developing a local MMM program). Large CWSs (serving a population of more than 10,000) must either comply with the proposed MCL or comply with the AMCL and implement a State-approved CWS MMM program plan (in the absence of an approved State MMM program plan).

If a State has an approved MMM program plan, the standard for radon in drinking water that the State would adopt in order to obtain primacy would be 4000 pCi/L.

Under the proposed requirements, an MMM program plan must address four criteria:

1. Public involvement in development of the MMM program plan
2. Quantitative goals for existing homes fixed and new homes built radon-resistant
3. Strategies for achieving goals
4. Plan to track and report results

CWSs must monitor for radon in drinking water according to the requirements described in Section VIII of this preamble, and report their results to the State. If the State determines that the radon level in a CWS is below 300 pCi/L, the system need only continue to meet monitoring requirements and is not covered by the requirements described in Section VI of this preamble, regarding MMM programs.

H. What Is the Proposed Best Available Technology (BAT) for Treating Radon in Drinking Water?

Proposed BAT for Radon Under Section 1412 of the SDWA

High-performance aeration, as described in Section VIII.A of this preamble, is the BAT for all systems. For systems serving 10,000 persons or fewer, the BAT is high-performance aeration and the Small Systems Compliance Technologies, as described in Section VIII.A.

Proposed BAT for Radon Under Section 1415 of the SDWA

BAT for purposes of variances is the same as BAT under Section 1412 of the Act.

I. What Analytical Methods Are Recommended?

EPA is proposing Liquid Scintillation Counting (Standard Method 7500–Rn) and de-emanation (''Lucas Cell'') as the approved methods. The Liquid Scintillation Counting method designated ''D 5072–92'' by the American Society for Testing and Materials (ASTM) is being proposed as an alternate method.

J. Where and How Often Must I Test My Water for Radon?

All CWSs that use ground water must monitor for radon. If your system relies on ground water or uses ground water to supplement surface water during low-flow periods, you must monitor for radon. If you are required to monitor for radon you must collect samples for analysis at each entry point to the distribution system, after treatment and storage. Initially all CWSs using ground water must monitor for radon at each entry point to the distribution system quarterly for one year. (See Section VII.E for discussion of compliance dates). If the results of analyses show that the average of all first year samples at any sample site is above the MCL/AMCL, you must continue monitoring quarterly at that sampling site until the average of four consecutive quarterly samples is below the MCL/AMCL. If the results of analyses show that the average of all first year samples at each sample site is below the MCL/AMCL, you may reduce monitoring to once a year at State discretion at each sample site. If the results indicate that the average of the four quarterly samples are close to the MCL/AMCL (as discussed next), the State may require you to continue monitoring quarterly.

The State may allow you to reduce monitoring for radon to a frequency of once every three-years, if the average from four consecutive quarterly samples is less than ½ the MCL/AMCL and the State determines that your system is reliably and consistently below the MCL/AMCL. However, if a sample collected while monitoring annually or less frequently exceeds the radon MCL/AMCL, the monitoring frequency must be increased to quarterly until the average of 4 consecutive quarterly samples is less than the MCL/AMCL. The State may require the collection of a confirmation sample(s) to verify the result of the initial sample. In the case of reduced monitoring, if the analytical results from any sampling point are found to exceed ½ the MCL/AMCL, the State may require you to collect a confirmation sample at the same sampling point. The results of the initial sample and the confirmation sample(s) will be averaged and the resulting average will be used to determine compliance. States may, at their discretion, disregard samples that have obvious sampling errors.

If, after initial monitoring, the State determines that it is highly unlikely that radon levels in your system will be above the MCL/AMCL, the State may grant a waiver reducing monitoring frequency to once every nine years. In granting the waiver, the State must take into consideration factors such as the geological area of the source water and previous analytical results which demonstrate that radon levels do not occur above the MCL/AMCL. If you are granted a waiver, it remains in effect for a nine year period.

If you monitor for radon after proposal of this rule, you may use the data, at the State's discretion, toward satisfying the initial sampling requirements for radon. Your monitoring program and the methods used to analyze for radon must satisfy the regulations set out in the proposal.

K. May I Use Point-of-Use (POU) Devices, Point-of-Entry (POE) Devices, or Bottled Water To Comply With This Regulation?

POE aeration or granular activated carbon (GAC) would be allowable for use to achieve compliance with MCLs. While these POE technologies are not considered BAT for large systems, they are considered small system compliance technologies (SSCTs), and thus may serve as BAT under Sections 1412 and 1415 of the Act for systems serving 10,000 persons or fewer. Since POU devices are used to treat water at a single tap, radon will be released at unacceptable levels from the other non-treated taps, including the shower head. For this reason, POU devices do not adequately address radon risks and will not be allowed to be used for compliance purposes. Likewise, although bottled water reduces ingestion risk from radon, it does not reduce radon-related inhalation risks from household water. For this reason, compliance determinations based on bottled water consumption cannot be used.

L. May I Get More Time or Use a Cheaper Treatment? Variances and Exemptions

Variances and Exemptions (Section 1415.a of the SDWA)

States and Tribes with primary enforcement responsibility (''primacy'') may issue a variance under Section 1415(a)(1)(A) of the Act to a CWS that cannot comply with an MCL because of source water characteristics on condition that the system install the best available technology. Under Section 1416 of the Act, primacy entities may exempt a CWS from an NPDWR due to ''compelling factors'', subject to the restrictions described in the Act. Primacy entities may require systems to implement additional interim control measures such as installation of additional centralized treatment or POE devices for each customer as measures to reduce the health risk before granting a variance or exemption. The primacy entity must find that the variance or exemption will not pose an ''unreasonable risk to health'', as determined by the State or other primacy entity. Guidance for estimating ''unreasonable risk to health'' (URTH) values for contaminants, including radon, is being developed by EPA and will result in an upcoming publication (a draft of the guidance is expected in the Fall of 1999). Preliminary information regarding URTH values may be found elsewhere (Orme-Zavaleta 1992, USEPA 1998f). States must require CWSs to provide POE devices or other means, as appropriate to the risks present (i.e., no POU or bottled water for volatile contaminants, such as radon), to reduce exposure below unreasonable risk to health values before granting a variance or exemption.

''Small Systems Variances'' (Section 1415(e) of the SDWA)

For NPDWRs proposed after the 1996 Amendments to the Act, EPA is required to evaluate the affordability and technical feasibility of treatment technologies for use as compliance technologies for small systems. Three categories of small systems will be considered: those serving: (1) 25–500, (2) 501–3,300, and (3) 3,301–10,000 persons. If EPA determines that source water conditions exist for one or more small water system size categories such that typical small systems within a given category will not be able to afford and/or implement a technology capable of achieving compliance, then EPA will designate applicable ''small systems variance technologies'' (SSVTs) capable of achieving contaminant levels that are ''protective of public health''. Primacy entities may issue small systems variances to eligible CWSs that install and properly maintain a listed SSVT. For a small system to be eligible for a small systems variance, the primacy entity must determine that the system cannot afford to comply through installing treatment, finding an alternate source of water, or restructuring/consolidating.

EPA has determined that affordable and technically feasible technologies exist for radon removal for all classes of small systems. Under the 1996 SDWA, if EPA lists at least one small systems compliance technology for a given system size category for all source water qualities, then it may not list any small systems variance technologies for that size category, *i.e.*, small systems compliance technologies and variance technologies are mutually exclusive. For this reason, no small system will be eligible for a small systems variance for radon under the SDWA (Section 1415(e)). Small systems may be eligible for general variances (under Section 1415.a of the Act) and/or exemptions on a case by case basis. It is also important to emphasize that the presumptive regulatory expectation for small systems is an MMM program (in the absence of a State MMM program) and compliance with the AMCL of 4000 pCi/L. Thus, for the vast majority of small systems (those with radon levels below 4000 pCi/L), compliance with this proposed rule will not involve any treatment of drinking water.

M. What Are State Primacy, Record Keeping, and Reporting Requirements?

The proposed Radon Rule requires States to adopt several regulatory requirements, including public notification requirements, MCL/AMCL for radon, and the requirements of Subpart R in the proposed rule. In addition, States and eligible Indian tribes will be required to adopt several special primacy requirements for the Radon Rule. The proposed rule includes additional reporting requirements for MMM program plans. The proposed rule also requires States to keep specific records in accordance with existing regulations. These requirements are discussed in more detail in Section IX of this preamble.

N. How Are Tribes Treated in This Proposal?

The proposal provides Tribes the option of seeking ''treatment in the same manner as a State'' for the purposes of assuming enforcement responsibility for a CWS program, and developing and implementing an MMM program (see Section VI.C). If a Tribe chooses not to implement an EPA-approved MMM program, any tribal CWS may develop an MMM plan for EPA approval, under the same criteria described in Section VI.A.

Statutory Requirements and Regulatory History

II. What Does the Safe Drinking Water Act Require the EPA To Do When Regulating Radon in Drinking Water?

The 1996 Amendments to the Safe Drinking Water Act (PL 104–182) establish a new charter for public water systems, States, Tribes, and EPA to protect the safety of drinking water supplies. (For an overview of the general requirements for all drinking water regulations, see Section XVI of this preamble). Among other mandates, Congress amended Section 1412 of the SDWA to direct EPA to take the following actions regarding radon in drinking water.

A. Withdraw the 1991 Proposed Regulation for Radon

Congress specified that EPA should withdraw the drinking water standards proposed for radon in 1991 (see discussion in Section III.D).

B. Arrange for a National Academy of Sciences Risk Assessment

The amendments in Section 1412(b)(13)(B) require EPA to arrange for the National Academy of Sciences (NAS) to conduct an independent risk assessment for radon in drinking water and an assessment of the health risk reduction benefits from various mitigation measures to reduce radon in indoor air.

C. Set an MCLG, MCL, and BAT for Radon-222

Congress specified in Section 1412 (b)(13) that EPA should propose a new MCLG and NPDWR for radon-222 by August, 1999. EPA is also required to finalize the regulation by August, 2000. As a preliminary step, EPA was required to publish a radon health risk reduction and cost analysis (HRRCA) for possible radon MCLs for public comment by February, 1999. As required by SDWA, this analysis addressed: (1) Health risk reduction benefits that come directly from controlling radon; (2) health risk reduction benefits likely to come from reductions in contaminants that occur with radon; (3) costs; (4) incremental costs and benefits associated with each MCL considered; (5) effects on the general population and on groups within the general population likely to be at greater risk; (6) any increased health risk that may occur as the result of compliance; and (7) other relevant factors, including the quality and extent of the information, the uncertainties in the analysis, and factors with respect to the degree and nature of the risk.

D. Set an Alternative MCL (AMCL) and Develop Multimedia Mitigation (MMM) Program Plan Criteria

The amendments in Section 1412(b)(13)(F) introduced two new elements into the radon in drinking water rule: (1) An Alternative Maximum Contaminant Level (AMCL), and (2) radon multimedia mitigation (MMM) programs. If the MCL established for radon in drinking water is more stringent than necessary to reduce the contribution to radon in indoor air from drinking water to a concentration that is equivalent to the national average concentration of radon in outdoor air, EPA is required to simultaneously establish an AMCL. The AMCL would be the standard that would result in a contribution of radon from drinking water to radon levels in indoor air equivalent to the national average concentration of radon in outdoor air. If an AMCL is established, EPA is to publish criteria for State multimedia mitigation (MMM) programs to reduce radon levels in indoor air. Section VI of this preamble describes what a State or public water system must have in their multimedia mitigation program plan.

E. Evaluate Multimedia Mitigation Programs Every Five Years

Once the MMM programs are established, EPA must re-evaluate them no less than every five years (Section 1412(b)(13)(G)). EPA may withdraw approval of programs that are not expected to continue to meet the requirement of achieving equal or greater risk reduction.

III. What Actions Has EPA Taken on Radon in Drinking Water Prior to This Proposal?

A. Regulatory Actions Prior to 1991

Section 1412 of the SDWA, as amended in 1986, required the EPA to publish Maximum Contaminant Level Goals (MCLGs) and to promulgate NPDWRs for contaminants that may cause an adverse effect on human health and that are known or anticipated to occur in public water supplies. On September 30, 1986, EPA published an advance notice of proposed rulemaking (ANPRM) (51 FR 34836) concerning radon-222 and other radionuclides. The ANPRM discussed EPA's understanding of the occurrence, health effects, and risks from these radionuclides, as well as the available analytical methods and treatment technologies, and sought additional data and public comment on EPA's planned regulation.

EPA's Science Advisory Board (SAB) reviewed the ANPRM and the four draft criteria documents that supported it prior to publication of the ANPRM in the **Federal Register**. EPA subsequently revised the criteria documents and resubmitted them to the SAB for review during the summer of 1990. EPA then revised the criteria documents based on this additional round of SAB review and presented a summary of the SAB comments and the Agency's responses in a 1991 Notice of Proposed Rulemaking (NPRM).

B. The 1991 NPRM

On July 18, 1991 (56 FR 33050), EPA proposed a NPDWR for radon and the other radionuclides addressed in the 1986 ANPRM. The 1991 notice, which built on and updated the information assembled for the 1986 ANPRM, proposed an MCLG, an MCL, BAT, and monitoring, reporting, and public notification requirements for radon in public water supplies. The proposed MCLG was zero, the proposed MCL was 300 pCi/L, and the proposed BAT was aeration. Under the proposed rule, all CWSs and NTNCWSs relying on ground water would have been required to monitor radon levels quarterly at each point of entry to the distribution system. Compliance monitoring requirements were based on the arithmetic average of four quarterly samples. The 1991 proposed rule required systems with one or more points of entry out of compliance to treat influent water to reduce radon levels below the MCL or to secure water from another source below the MCL.

The proposed rule was accompanied by an assessment of regulatory costs and economic impacts, as well as an assessment of the risk reduction associated with implementation of the MCL. EPA estimated the following potential impacts from the 1991 proposed MCL:

- An estimated lifetime cancer risk of about two cancers for every 10,000 persons exposed to radon in drinking water.
- Avoidance of about 80 cancer cases per year.
- About 27,000 public water systems affected.
- A total annual cost of about $180 million.

The Agency received substantial comments on the proposal and its supporting analyses from States, water utilities, and other stakeholder groups. EPA has included in Appendix I of this preamble a summary of major public comments on the 1991 NPRM and how EPA subsequently addressed those comments.

C. 1994 Report to Congress: Multimedia Risk and Cost Assessment of Radon

In 1992, Congress directed EPA to report on the multimedia risks from exposure to radon, the costs to control this exposure, and the risks from treating to remove radon. EPA's 1994 Report to Congress (USEPA 1994a) estimates the risk, fatal cancer cases, cancer cases avoided and costs for mitigating radon in water and in indoor air. The Report found that cancer risks from radon in both air and water are high. While radon risk in air typically far exceeds that in water, the cancer risk from radon in water is higher than the cancer risk estimated to result from any other currently regulated drinking water contaminant.

EPA conducted a quantitative uncertainty analysis of the risks associated with exposure to radon in drinking water. This analysis, reviewed by EPA's SAB at the direction of Congress, found that:

• People are exposed to waterborne radon in three ways: (1) From ingesting radon dissolved in water; (2) from inhaling radon gas released from water during household use; and (3) from inhaling radon progeny derived from radon released from water.

• The estimated total U.S. cancer fatalities per year from unregulated waterborne radon via all three routes of exposure were 192, with a range from about 51 to 620.

• The estimated annual cost was $272 million.

The 1994 Report to Congress noted that the regulated industry estimated considerably higher costs than EPA for a 300 pCi/L MCL. For example, in October 1991 the American Water Works Association (AWWA) estimated national costs at $2.5 billion/year (for discussion of this issue, see Section G of the Appendix to this preamble). The final part of the report included the SAB's comments on each analysis presented and an EPA discussion of the issues raised by the SAB.

D. 1997 Withdrawal of the 1991 NPRM for Radon-222

As required by the SDWA as amended, EPA withdrew the MCLG, MCL, and monitoring, reporting, and public notification requirements proposed in 1991 for radon-222 on August 6, 1997 (62 FR 42221). No other provision of the 1991 proposal was affected by this withdrawal.

E. 1998 SBREFA Small Business Advocacy Review Panel for Radon

In 1998, EPA convened a Small Business Advocacy Review Panel to address the radon rule, in accordance with the Regulatory Flexibility Act (RFA) as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA). The Panel of representatives from EPA, the Office of Management and Budget's Office of Information and Regulatory Affairs, and the Small Business Administration's Office of Advocacy reviewed technical background information related to this rulemaking, and reviewed comments provided by small business and government entities affected by this rule. The Panel made recommendations in a final report to the Administrator which included a discussion of how the Agency could accomplish its environmental goals while minimizing impacts to small entities. For additional details, see Section XIV.B of this proposal.

F. 1999 HRRCA for Radon in Drinking Water

EPA published the Health Risk Reduction and Cost Analysis required by the SDWA on February 26, 1999 (64 FR 9559), and took public comment for 45 days. EPA held a one-day public meeting in Washington, D.C. on March 16, 1999, to present the HRRCA and the latest MMM framework, and discuss stakeholder questions and issues. For details of the contents of the HRRCA and EPA's response to significant public comment, see Section XIII of this preamble.

Requirements

IV. To Which Water Systems Does This Regulation Apply?

The SDWA directs EPA to develop national primary drinking water regulations (NPDWRs) that apply to public water systems (PWSs). The statute defines a PWS as a system that provides water to the public for human consumption if such system has at least 15 service connections or regularly serves at least 25 individuals (Section 1401(4)(A)). EPA's regulations at 40 CFR 141.2 define different types of PWSs. A community water system (CWS) serves at least 15 service connections used by year round residents or regularly serves at least 25 year-round residents. A non-community system does not serve year-round residents; rather, it (1) regularly serves at least 25 of the same persons over 6 months of the year (a ''non-transient'' system such as a restaurant or church) or (2) does not serve at least 25 of the same persons over 6 months of the year (a ''transient'' system such as a campground or service station).

The regulation for radon in drinking water and the multimedia approach for reduction of radon in indoor air (MMM program) proposed in this notice applies only to CWSs that use ground water or mixed ground and surface water (see following discussion regarding ''mixed'' supplies). The proposed regulation does not apply to transient water systems because most people who use such facilities do so only occasionally (*e.g.*, travelers). There is no evidence that such short-term exposure to radon would cause acute illness. The data on which health risks from radon were determined for this rulemaking reflect long-term exposure (see chapter 3 of the RIA (USEPA 1999f) HRRCA section that discusses calculation of risk). And, as discussed next in the context of non-transient non-community systems, even workers at transient facilities who regularly drink the water would be expected to have much less exposure than persons served by community water systems. For these reasons, the proposed rule does not cover transient systems.

The proposed regulation also does not apply to non-transient non-community (NTNC) water systems. EPA has determined that the risks posed to persons served by NTNC systems (such as factories, hospitals, and schools with their own drinking water wells) are substantially less than the risks to persons served by community water systems.

The Agency recently completed a preliminary analysis of radon occurrence (using data provided by six States), exposure and risk at NTNC public water systems. Results from this preliminary analysis indicate that even though radon concentrations are likely to be about 60 percent higher at NTNC locations than at locations served by a community water system, the lifetime average risk to individuals who work or attend school in buildings served by a groundwater-based NTNC system is probably about 17 percent of the average risk to a worker (and 6.7 percent of the average risk to a student) exposed in a home served by a community ground water system. The reason that risks are lower in the NTNC setting than the residential setting is that people who are exposed at NTNC locations spend a smaller fraction of their lifetime there than in the home. Further, in the particular case of students most do not spend their entire school years in the same school. EPA also notes that there is limited data in this area, and more information is needed on how water is used in NTNC facilities and on the contribution NTNC water use makes to radon inhalation risk. In addition, the overall population served by NTNC PWSs is relatively small (5.2 million vs. 89.7 million in homes served by CWSs using ground water (USEPA 1999b)).

EPA acknowledges that the SDWA applies to all public water systems. However, EPA believes that limiting the applicability of the radon rule to community water systems where the risk from radon exposure is the greatest meets a major goal of Congress in enacting the 1996 amendments to the Act-to focus regulations on the most significant problems. In the Conference Report adopting the 1996 amendments, Congress finds that ''more effective protection of public health requires—a Federal commitment to set priorities that will allow scarce Federal, State, and local resources to be targeted toward the drinking water problems of greatest public health concerns. '' H. Rep. 104–182, Sec. 3. Moreover, Congress specifically directed EPA in setting the NPDWRs for radon to take into consideration the costs and benefits of control programs for radon from other sources. EPA has used this authority in this proposal to set the MCL at 300 pCi/L and to encourage small systems to implement the MMM program and comply with the AMCL. In both circumstances, EPA took into account the fact that programs to control radon in indoor air promise greater benefits at considerably less cost. EPA believes this cost-effectiveness factor is also relevant in determining the applicability of the radon rule. EPA's preliminary analysis of the risk associated with exposure to radon from NTNC systems is that it is much less than the risk from exposure from CWSs. For this reason, EPA has determined that it is not cost-effective to regulate these systems.

However, it is important to note that this analysis is based on limited occurrence and exposure data. In particular, relatively little is known about the transfer factor for release of radon from water into indoor air at NTNC locations, or about the equilibrium factor affecting the amount of radon in indoor air at such locations. The calculations done by EPA to date have assumed that certain values for these parameters at NTNC locations are similar to those in homes, although the data are limited.

The EPA is soliciting comment on the proposal to exclude NTNC PWSs from the radon regulation. EPA is soliciting comments on the Agency's preliminary analysis of radon exposure in NTNC PWSs, as well as any additional data on key parameters, including data on the release of radon from drinking water in the types of buildings (*e.g.*, restaurants, factories, churches, etc.) supplied by NTNC PWSs, and occurrence of radon in NTNC PWSs. If information by commenters shows a greater opportunity for risk reduction than identified in its initial analysis, EPA may make the final radon rule applicable to NTNC PWSs without further public comment.

With regard to systems using mixed ground and surface water, current regulations require that all systems that use any amount of surface water as a source be categorized as surface water systems. This classification applies even if the majority of water in a system is from a ground water source. Data currently in SDWIS does not identify how many of these mixed systems exist although this information would help the Agency to better understand regulatory impacts. To the extent that systems correctly classified by SDWIS as surface water systems also use ground water that may exceed the MCL/AMCL for radon, the costs and benefits of the current proposal will be underestimated.

EPA is investigating ways to identify how many mixed systems exist and how many mix their ground and surface water at the same entry point or at separate entry points within the same distribution systems. For example, a system may have several plants/entry points that feed the same distribution system. One of these entry points may mix and treat surface water with ground water prior to its entry into the distribution system. Another entry point might use ground water exclusively for its source while a different entry point would exclusively use surface water. However, all three entry points would supply the same system classified in SDWIS as surface water.

One method EPA could use to address this issue would be to analyze Community Water System Survey (CWSS) data then extrapolate this information to SDWIS to obtain a national estimate of mixed systems. CWSS data, from approximately 1,900 systems, breaks down sources of supply at the level of the entry point to the distribution system and further subdivides flow by source type. The Agency could use the national estimate of mixed systems to regroup surface water systems for certain impact analyses when regulations only impact one type of source. The Agency requests comment on this methodology and its applicability for use in regulatory impact analyses.

V. What Is the Proposed Maximum Contaminant Level Goal for Radon?

A. Approach To Setting the Maximum Contaminant Level Goal (MCLG)

Under Section 1412(b)(4) of the SDWA, the EPA must establish maximum contaminant level goals (MCLG) at the level at which no known or anticipated adverse effects on the health of persons occur, and which allow an adequate safety margin. Section 1412(b)(13) requires the Administrator to set an MCLG for radon in drinking water.

B. MCLG for Radon in Drinking Water

As described in Section XII of this preamble, radon is a documented human carcinogen, classified by EPA as a Group A carcinogen (*i.e.*, there is sufficient evidence of a causal relationship between exposure to radon and lung cancer in humans). Radon is classified as a known human carcinogen based on data from epidemiological studies of underground miners. This finding is supported by a consensus of opinion among national and international health organizations. The carcinogenicity of radon has been well established by the scientific community, including the Biological Effects of Ionizing Radiation (BEIR VI) Committee of the National Academy of Sciences (NAS 1999a), the National Institute of Environmental Health Sciences, U.S. Department of Health and Human Services, the World Health Organization's International Agency for Research on Cancer (IARC 1988), the International Commission on Radiological Protection (ICRP 1987), and the National Council on Radiation Protection and Measurement (NCRP 1984). In addition, the Centers for Disease Control, the American Lung Association, the American Medical Association, the American Public Health Association and others have recognized radon as a significant public health problem.

Based on the well-established human carcinogenicity of radon, and of ionizing radiation in general, the Agency is proposing an MCLG of zero for radon in drinking water. This decision is also supported by the NAS' current recommendation for a linear non-threshold relationship between exposure to radon and cancer in humans. In the BEIR VI report (NAS 1999a), the NAS concluded that there is good evidence that a single alpha particle (high-linear energy transfer radiation) can cause major genomic changes in a cell, including mutation and transformation that potentially could lead to cancer. They noted that even if substantial repair of the genomic damage were to occur, ''the passage of a single alpha particle has the potential to cause irreparable damage in cells that are not killed.'' Given the convincing evidence that most cancers originate from damage to a single cell, the committee went on to conclude that ''On the basis of these [molecular and cellular] mechanistic considerations, and in the absence of credible evidence to the contrary, the committee adopted a linear non-threshold model for the relationship between radon exposure and lung-cancer risk. However, the BEIR VI committee recognized that it could not exclude the possibility of a threshold relationship between exposure and lung cancer risk at very low levels of radon exposure.'' The NAS committee on radon in drinking water (NAS 1999b) reiterated the finding of the BEIR VI committee's comprehensive review of the issue, that a ''mechanistic interpretation is consistent with linear non-threshold relationship between radon exposure and cancer risk''. The committee noted that the ''quantitative estimation of cancer risk requires assumptions about the probability of an exposed cell becoming transformed and the latent period before malignant transformation is complete. When these values are known for singly hit cells, the results might lead to reconsideration of the linear no-threshold assumption used at present.'' EPA recognizes that research in this area is on-going but is basing its regulatory decisions on the best currently available science and recommendations of the NAS that support use of a linear non-threshold relationship. For additional information on this issue see Section XII.C.3. ''Biologic Basis of Risk Estimation'' of this preamble.

VI. What Must a State or Community Water System Have in Its Multimedia Mitigation Program Plan?

Today's proposed rule provides States (as defined in Section 1401 of the SDWA) with alternatives for controlling radon exposure. States can develop a MMM program for the reduction of the higher risk of radon in indoor air together with an alternative MCL (AMCL) of 4000 pCi/L to address the highest levels of exposure from radon in drinking water. If a State does not choose this option, the community water systems (CWS) in that State must develop and implement local MMM program plans or comply with an MCL of 300 pCi/L. See Section VII for information on the regulatory expectations for CWSs.

A. What Are the Criteria?

1. Overview

EPA has identified four criteria that State MMM program plans are required to meet to be approved by EPA. MMM program plans developed by Indian tribes will be reviewed by EPA, according to these same criteria. CWSs developing local MMM programs are also subject to these criteria. These four criteria are: public participation, setting quantitative goals, strategies for achieving goals, and a plan to track and report results.

The criteria are based on a number of factors. Foremost, the criteria reflect the elements found in successful voluntary action programs for radon in indoor air that have been underway for more than a decade. It is estimated that at the end of the year 2000, voluntary programs to test homes and mitigate elevated radon levels in indoor air and to encourage the construction of ''radon-resistant'' new homes will have saved some 2500 lives; and, there is much more that can be done. In the 1999 BEIR VI report (NAS 1999a), NAS concluded that 5,000 to 7,000 cancer cases (using two different methods) could be avoided annually if all homes were below EPA's voluntary radon action level of 4 pCi/L of air. Incorporating these program elements into the criteria required for the MMM programs builds on successful efforts and can be expected to result in an even greater number of lives saved as more States adopt programs and existing programs are strengthened and expanded.

EPA has developed criteria that allow considerable flexibility for those developing and expanding programs. EPA was urged by States and other stakeholders to avoid prescribing the specific elements of the MMM program in a ''one size fits all'' approach. States and CWSs adopting MMM programs will be required to set quantitative goals for mitigating elevated levels of radon in indoor air of existing homes and building radon-resistant new homes, and to initiate strategies to promote and increase these activities. However, there are requirements that will be new to many of the State indoor radon programs. Those adopting MMM programs will be required to involve the public in a number of important (and on-going) ways, and to track and report results from the implementation of the programs. With these additional elements, both the affected public and EPA will be able to assess the success of the MMM programs. Stakeholder input and EPA's experience with the national voluntary program and the State indoor radon programs led EPA to conclude that these criteria will provide the basis for a program that meets the statutory directive for equal or greater risk reduction benefits.

The Agency also considered equity-related issues concerning the potential impacts of MMM program implementation. There is no factual basis to indicate that minority and low income or other communities are more or less exposed to radon in drinking water than the general public. However, some stakeholders expressed more general concerns about equity in radon risk reduction that could arise from the MMM/AMCL framework outlined in SDWA. One concern is the potential for an uneven distribution of risk reduction benefits across water systems and society. Under the proposed framework for the rule, customers of CWSs complying with the AMCL could be exposed to a higher level of radon in drinking water than if the MCL were implemented, though this level would not be higher than the background concentration of radon in ambient air. However, these CWS customers could also save the cost, through lower water rates, of installing treatment technology to comply with the MCL. Under the proposed regulation, CWSs and their customers have the option of complying with either the AMCL (associated with a State or local MMM program) or the MCL. EPA believes it is important that these issues and choices be considered in an open public process as part of the development of MMM program plans. Therefore, EPA has incorporated requirements into the proposed rule that provide a framework for consideration of equity concerns with the MMM/AMCL. First, the proposed rule includes requirements for public participation in the development of MMM program plans, as well as for notice and opportunity for public comment. EPA believes that the requirement for public participation will result in State and CWS program plans that reflect and meet their different constituents' needs and concerns and that equity issues can be most effectively dealt with at the State and local levels with the participation of the public. In developing their MMM program plans, States and CWSs are required to document and consider all significant issues and concerns raised by the public. EPA expects and strongly recommends that States and CWSs pay particular attention to addressing any equity concerns that may be raised during the public participation process. In addition, EPA believes that providing CWS customers with information about the health risks of radon and on the AMCL and MMM program option will help to promote understanding of the health risks of radon in indoor air, as well as in drinking water, and help the public to make informed choices. To this end, EPA is requiring CWSs to alert consumers to the MMM approach in their State in consumer confidence reports issued between publication of the final radon rule and the compliance dates for implementation of MMM programs. This will include information about radon in indoor air and drinking water and where consumers can get additional information.

EPA is encouraging the States to elect to develop and implement State-wide MMM program plans. Since almost all States currently have State indoor radon programs, EPA considers the States to be best positioned to develop strong MMM program plans that, when implemented, will be expected to achieve equal or greater radon risk reduction when compared to compliance with the MCL. For example, a State-wide plan can take into account the within-State variations in indoor radon potential, the differences in radon levels in drinking water, the experienced coalitions and cooperative partners that have been working to promote public action on indoor radon, the technical expertise of State drinking water and indoor radon programs, and many other factors. EPA expects that the States will be best positioned to develop MMM program plans that are robust and credible in terms of the level of public participation in the development and review process, the goals that are to be achieved from implementation of MMM, and the program strategies to be used.

In the development of State MMM program plans meeting EPA's criteria and in the implementation of the State's MMM program plan, EPA expects and strongly recommends that the State's programs responsible for drinking water and for indoor radon coordinate and collaborate on their efforts. This is particularly important because of the uniqueness of the MMM/AMCL approach which addresses radon risk reduction in drinking water and in indoor air in a multimedia manner that is outside the normal regulatory structure for drinking water. Both programs have important responsibilities and roles in making the AMCL and MMM program approach successful in achieving optimal radon risk reduction. To this end, EPA has included as a special primacy requirement (see Section 142.16 of the proposed rule) that States include in their primacy revision application for the AMCL a description of the extent and nature of coordination between the State's interagency programs (*i.e.*, indoor radon and drinking water programs) on development and implementation of the MMM program plan, including the level of resources that will be made available for implementation and coordination between these agencies.

CWSs developing local MMM program plans are also subject to these criteria. CWS MMM program plans developed in the absence of a State program are deemed to be approved by EPA if they meet the same criteria and are approved by the State. States without a MMM program, as a special condition of primacy (see Section 142.16 of the proposed rule), will be required to review and approve local CWS MMM program plans and to submit their process for approving such plans to EPA. The Agency considered an approach under which it would directly review and approve CWS MMM program plans. However, for several reasons, EPA is proposing that States review local MMM program plans. EPA believes that responsibility for such reviews is an appropriate and natural extension of the States' primacy responsibilities for oversight and enforcement of drinking water regulations. State review and approval of local MMM program plans will ensure that all elements of the radon rulemaking—both the MMM program as well as implementation of the AMCL/MCL—are enforced through the State, rather than separating elements of the rule between the Federal and State governments. Dividing responsibility in such a way may complicate implementation of both elements of the radon rule and be confusing to both CWSs and the public. EPA also believes that the States are best positioned to assist CWSs, especially small systems, in the development of local MMM programs plans to review and approve local plans that meet the four criteria. States have a direct and ongoing regulatory relationship with CWSs as a part of their primacy authorities, as well as a major responsibility for public health related policy and programs in the State. In addition, States are aware of and sensitive to local public health needs and concerns, as well as other issues, that may need to be considered in the development and implementation of local MMM programs. For all these reasons, EPA is proposing an approach today that would require the States to review and approve local MMM program plans in accordance with the same criteria used in EPA's review of State MMM program plans. However, EPA solicits comments on other approaches, such as EPA review and approval of local MMM program plans or other options intermediate between sole State or sole Federal responsibility.

EPA anticipates, and recommends, that States would assist CWSs in developing their local MMM program plans and would approve program plans that meet the criteria and that reflect local radon implementation issues as discussed in Section VI.F. In non-MMM States, EPA is also including as a special primacy requirement that States include in their primacy revision application for the MCL a description of the extent and nature of coordination between interagency programs (*i.e.*, indoor radon and drinking water programs) on development and implementation of the State's review and approval process for CWS MMM program plans, including the level of resources will be made available for implementation and coordination between these agencies.

2. Criteria for MMM Program Plans

The following four criteria are required for approval of State MMM program plans by EPA. Local MMM program plans developed by community water systems are deemed to be approved by EPA if they meet these criteria (as appropriate for the local level) and are approved by the State. The term ''State'', as referenced next, includes States, Indian tribes and community water systems. EPA is requesting comment on each of the criteria for approval of State, and CWS, MMM program plans. In particular, EPA is requesting comment on whether the criteria need to be more or less stringent, and the supporting rationale for EPA's consideration of other potentially credible approaches.

(a) Description of Process for Involving the Public. (1) States are required to involve community water system customers, and other sectors of the public with an interest in radon, both in drinking water and in indoor air, in developing their MMM program plan. The MMM program plan must include:

- A description of processes the State used to provide for public participation in the development of its MMM program plan, including the components identified in the following paragraphs b, c, and d;
- A description of the nature and extent of public participation that occurred, including a list of groups and organizations that participated;
- A summary describing the recommendations, issues, and concerns arising from the public participation process and how these were considered in developing the State's MMM program plan; and,
- A description of how the State made information available to the public to support informed public participation, including information on the State's existing indoor radon program activities and radon risk reductions achieved, and on options considered for the MMM program plan along with any analyses supporting the development of such options.

(2) Once the draft program plan has been developed, the State must provide notice and opportunity for public comment on the draft plan prior to submitting it to EPA.

(b) Quantitative Goals. (1) States are required to establish and include in their plans quantitative goals, to measure the effectiveness of their MMM program, for the following:

(i) Existing houses with elevated indoor radon levels that will be mitigated by the public; and,

(ii) New houses that will be built radon-resistant by home builders.

EPA is proposing to require establishing quantitative goals in these two areas because they represent the most direct link to the risk reduction benefits that are the ultimate objective of the MMM programs. In addition, EPA analyses indicate that it is very cost-effective to test and mitigate existing homes with elevated indoor radon levels. It is also very cost-effective to build new homes radon-resistant, especially in higher radon potential areas. In the existing indoor radon program, EPA has been encouraging the States to promote testing and mitigation in all areas of a State. EPA has also encouraged the States to focus on their activities to promote radon-resistant new construction on the highest radon potential areas (Zone 1) where building homes radon-resistant is most cost-effective. However, it is also cost-effective to build homes in medium potential areas (Zone 2), as well as in ''hot'' spots found in most lower radon potential areas (Zone 3).

EPA recognizes the States' (and CWSs') need for flexibility in designing MMM programs reflecting their needs and circumstances, in particular the extent to which opportunities are available for risk reduction in mitigation of existing homes with elevated indoor radon levels or in construction of new homes built radon-resistant. Some States, in particular those with a preponderance of lower radon potential areas (and for CWSs in lower radon potential areas), may find it preferable to focus more heavily on testing and mitigation of existing housing than on radon-resistant new construction.

EPA is requesting comment on whether there are alternative goals that achieve radon risk reduction and the rationale for those goals. EPA is also soliciting comments on the goals outlined in paragraph (b), in particular on the appropriateness of the goals and whether the goals need to be more or less stringent.

(2) These goals must be defined quantitatively either as absolute numbers or as rates. If goals are defined as rates, a detailed explanation of the basis for determining the rates must be included.

EPA is proposing to provide this option, in part, because opportunities available for risk reduction in mitigation of existing homes with elevated indoor radon levels or in construction of new homes built radon-resistant may vary between States and within States. In addition, the level of new home construction may vary from year to year in different parts of a State or in a local jurisdiction. In this situation, it may be more appropriate to set goals for radon-resistant new construction as a rate, rather than absolute numbers, to account for this variability. This may be especially true for CWS developing local MMM program plans where no new home construction is currently taking place but may in the future.

(3) States are required to establish goals for promoting public awareness of radon health risks, for testing of existing homes by the public, for testing and mitigation of existing schools, and for construction of new public schools to be radon-resistant, or to include an explanation of why goals were not established in these program areas.

EPA is proposing that States have this option of defining goals as absolute numbers or as rates because, while awareness of radon health risks is a necessary element and a first step in getting the public to take action on indoor radon, public awareness, in and of itself, does not constitute radon exposure reduction. It does, however, help to facilitate informed choice by the public regarding radon testing and mitigation. Since the level of awareness on the health effects of radon is already high in many States, EPA is proposing to give flexibility to the States on this goal. In the case of radon in schools, many States have undertaken a range of activities to address radon in schools and some have done extensive testing, in some cases passing State legislation requiring the State to test public schools. Therefore, EPA is proposing to give States the option of setting these goals for schools. Although this approach provides flexibility in goal setting, EPA strongly encourages those States which do not have high levels of public awareness on radon and where there has been limited testing of public schools across the State to set goals in these areas. EPA is soliciting comment on whether States should be required to set quantitative goals in all or some of these areas in paragraph (b)(3).

(c) Implementation Plans. (1) States are required to include in their MMM program plan implementation plans outlining the strategic approaches and specific activities the State will undertake to achieve the quantitative goals identified in paragraphs (b)(1) and (b)(2). This must include implementation plans in the following two key areas:

(i) Promoting increased testing and mitigation of existing housing by the public through public outreach and education and during residential real estate transactions.

(ii) Promoting increased use of radon-resistant techniques in the construction of new homes.

(2) If a State has included goals for promoting public awareness of radon health risks; promoting testing of existing homes by the public; promoting testing and mitigation of existing schools; and promoting construction of new public schools to be radon resistant, then the State is required to submit a description of the strategic approach that will be used to achieve the goals.

(3) States are required to provide the overall rationale and support for why their proposed quantitative goals identified in paragraphs (b)(1) and (b)(2), in conjunction with their program implementation plans, will satisfy the statutory requirement that an MMM program be expected to achieve equal or greater risk reduction benefits to what would have been expected if all public water systems in the State complied with the MCL.

(d) Plans for Measuring and Reporting Results. (1) States are required to include in the MMM plan submitted to EPA a description of the approach that will be used to assess the results from implementation of the State MMM program, and to assess progress towards the quantitative goals in paragraphs (b)(1) and (b)(2). This specifically includes a description of the methodologies the State will use to determine or track the number of existing homes with elevated levels of radon in indoor air that are mitigated and the number or the rate of new homes built radon-resistant. This must also include a description of the approaches, methods, or processes the State will use to make the results of these assessment available to the public.

(2) If a State includes goals in paragraph (b)(3) for promoting public awareness of radon health risks; testing of existing homes by the public; testing and mitigation of existing schools; and, construction of new public schools to be radon-resistant; the State is required to submit a description of how the State will determine or track progress in achieving each of these goals. This must also include a description of the approaches, methods, or processes the State will use to make these results available to the public.

B. Why Will MMM Programs Get Risk Reduction Equal or Greater Than Compliance With the MCL?

The National Indoor Radon Program implemented by EPA, States and others, has achieved substantial risk reduction through voluntary public action since the release of the original ''A Citizen's Guide to Radon'' in 1986 (USEPA 1986) (updated: USEPA 1992b) and the U.S. Surgeon General's recommendation in 1988 (US EPA, 1988b) that all homes be tested and elevated radon levels be reduced. The program has been successful in achieving voluntary risk reduction on indoor radon through a variety of program strategies. It is important to keep in perspective the comparatively large potential for risk reduction that can be achieved if all existing homes with indoor radon levels at or above EPA's voluntary action level for indoor radon of 4 pCi/L in the U.S. were mitigated (approximately 6 million homes). In addition there is the potential for significant risk reduction potential if the approximately 1 million new homes built annually in the U.S. were built radon-resistant. Based on the estimated number of existing homes fixed and the number of new homes built radon-resistant since the national program began in 1986, EPA estimates that a total of more than 2,500 lives will be saved through voluntary indoor radon risk reduction efforts expected to take place up through the year 2000. Every year the rate of lives saved increases as more existing houses with elevated radon levels are fixed and as more new houses are built radon-resistant. On average this rate of lives that will be saved from these risk reduction actions increases by about 30 additional lives per year. EPA estimates that for the year 2000, the rate of radon-related lung cancer deaths that will be avoided from mitigation of existing homes and from homes built radon-resistant in high radon areas will be about 350 lives saved per year (USEPA 1999i).

Under the radon provision of SDWA, if all States adopted the AMCL, all State MMM programs together must be expected to result in at minimum about 62 cancer deaths averted annually; equal to what would be achieved with universal compliance with the MCL. Unlike these health risk reduction benefits which remain constant from one year to the next, the rate of health benefits from reducing radon in indoor air, as noted previously, steadily increases every year with every additional existing home that is mitigated and with every new home built radon-resistant. This steady incremental risk reduction offered by mitigation of existing homes with elevated indoor radon and building homes radon-resistant, especially during real estate transactions and through builder and consumer education and State and local adoption of radon-resistant building codes, holds the potential for substantial long-term risk reduction. NAS in their 1999 BEIR VI Report, concluded that up to one third (*i.e.*, 5,000 to 7,000) of their estimated 15,000 to 22,000 annual radon-related lung cancer deaths in the U.S. could be avoided if all homes were below EPA's voluntary radon action level of 4 pCi/L of air (NAS 1999a). This does not include the risk reduction that is achieved from new homes built radon-resistant. The one million new homes on average being built every year represent a significant radon risk reduction opportunity. Therefore, a critical element for MMM is to utilize and build on the indoor radon program framework to achieve ''equal or greater'' risk reduction rather than focusing efforts on precisely quantifying the much more limited risk reduction that will not occur in community water systems complying with the AMCL (*i.e.*, the difference in the risk reduction between the MCL and the AMCL).

C. Implementation of an MMM Program in Non-Primacy States

A State that does not have primary enforcement responsibility for the Public Water System Program under Section 1413 of the SDWA (''primacy'') and where EPA administers the CWS program may still develop a State-wide MMM program plan. EPA would not expect to develop an MMM program plan where the State elects not to develop a State-wide MMM program plan. Accordingly, CWSs in such jurisdictions would be required to comply with the more stringent MCL or develop local MMM program plans for approval by EPA.

The SDWA authorizes all States to develop and submit a MMM program plan to mitigate radon levels in indoor air for approval by the Administrator under Section 1412(b)(13)(G). EPA is proposing that States that do not have primacy may submit a plan to EPA that meets the criteria of 40 CFR 141.302. If the State's plan is approved, the State would be subject to all reporting and compliance requirements of 40 CFR 141.303. Community water systems in States with approved MMM programs would comply with the AMCL of 4000 pCi/L, and would be subject to the requirements for monitoring and analytical methods in 40 CFR 141.20. EPA would continue to administer compliance with the MCL/AMCL, and with monitoring and methods requirements.

D. Implementation of the MMM Program in Indian Country

Under this proposal, States can develop State-wide MMM programs for the reduction of radon in indoor air, and community water systems in such States can then comply with an AMCL of 4000 pCi/L (rather than an MCL of 300 pCi/L). Under Section 1451 of the SDWA, the Administrator of EPA is authorized to treat Indian Tribes in the same manner as States. The proposal provides tribes the option of seeking ''treatment in the same manner as a State'' for the purposes of assuming enforcement responsibility for a community water system program, and developing and implementing an MMM program. If a tribe does not choose to implement an MMM program, any tribal CWS may develop an MMM program plan for EPA approval, under the same criteria described previously.

EPA is proposing to amend the ''treatment as a State'' regulations to allow tribes to be treated in the same manner as States for purposes of carrying out the MMM program. Under this proposal, a tribe would not need to demonstrate that it qualified for treatment in the same manner as a State for any other purpose other than the MMM provisions. Tribes may want to seek treatment in the same manner as a State for this limited purpose to the extent that radon is a significant problem on tribal lands because the MMM program provides an opportunity to focus resources on reducing the higher risk exposure—indoor air—and addressing radon in drinking water at the highest levels of exposure. EPA is proposing to amend the treatment in the same manner as State regulations (40 CFR 142.72 and 40 CFR 142.78) to obtain treatment as a State status solely for the purpose of implementing the MMM authorities. Tribes can, of course, always apply to be treated in the same manner as a State for primacy over the Public Water Supply Program under 40 CFR 142.72.

A tribe applying for authority to develop and implement an MMM program plan that has met the criteria under 40 CFR 142. 72 to be treated in the same manner as a State for any purpose will not need to reestablish that it meets the first two criteria (40 CFR 142.72 (a) and (b)) and needs to provide only information in 40 CFR 142.76 that is necessary to demonstrate that the criteria in 40 CFR 142.72 (c) and (d) are met for the MMM program plan. A tribe whose application for authority to carry out the MMM program is approved must develop and implement a MMM program plan in accordance with 40 CFR 141.302 and 141.303.

E. CWS Role in State MMM Programs

EPA anticipates that CWSs, especially small systems, would have a limited role in State-wide MMM programs. For example, States may develop information brochures on radon that could be distributed locally by CWSs. EPA expects that States will want to consult with CWSs, small and large, in making a determination about the nature and scope of the role, if any, of CWSs in implementing a State-wide MMM program. During EPA's stakeholder process, many States and CWSs agreed that States were best positioned to design and implement effective State-wide MMM programs and that it was not apparent what role CWSs might take in such a program. However, CWSs do have important responsibilities for communicating information on radon to their customers (see Section VI.G).

F. Local CWS MMM Programs in Non-MMM States and State Role in Approval of CWS MMM Program Plans

The regulatory expectation of small community public water systems (CWSs) is that they meet the AMCL and be associated with a MMM program-either developed by the State and approved by EPA or developed by the CWS and approved by the State. EPA strongly recommends that States choose to develop and implement State-wide MMM programs as the most cost-effective approach to manage the health risks from radon. In those cases where States do not elect to do a State-wide MMM program, CWSs would need to notify the State of its intention to develop and submit a local MMM program plan to the State (4 years after publication of the final rule in the **Federal Register**). EPA believes that, in all cases, the regulatory burden of complying with AMCL and implementing a MMM program will be considerably less than complying with the more stringent regulatory level for radon in drinking water. EPA believes that the MMM/AMCL is the appropriate standard for CWSs, especially for small systems, because it results in greater radon risk reduction and makes better use of limited resources. EPA believes that the four criteria for plan approval can be applied to CWS local MMM program plans (as appropriate for the local level), commensurate with the unique attributes of these CWSs and their service areas. As previously discussed in more detail, these four criteria are: public participation, setting quantitative goals, strategies for achieving goals, and a plan to track and report results.

In general, EPA expects that CWSs would be able to meet the four criteria by carrying out a wide range of diverse activities, many of which are well within the expertise of CWSs. However, small CWSs would not necessarily be expected to perform some of the activities entirely on their own. In carrying out certain activities, small CWSs would be expected to seek help from others in order to build upon and take advantage of existing CWS and State networks. The existing State indoor radon programs, for example, operate in large measure through a network of State and local partners such as the American Lung Association, the National Association of Counties, the National Environmental Health Association, the National Safety Council, consumer advocacy groups, non-government organizations, and other local and county governmental organizations. CWSs should be able to use the same networks and their capabilities, and State radon in indoor air programs should help facilitate these contacts. The following provides some additional perspective on the four criteria relative to CWS MMM programs.

Public Participation: Thorough public participation is certainly within the capability of CWSs. Systems are often required in the course of CWS activities, such as operation, maintenance, water bill collection, violation notification, and planning for new facilities, to involve, communicate with, inform, and in other ways interact with the public. Thus, these systems already engage, to a significant degree, in public outreach and communication. EPA expects that such expertise can readily be directed toward the particular public participation requirements associated with MMM programs. Public participating during development of local MMM plans will help ensure greater local support for and implementation of the CWS MMM programs.

Quantitative Goals: EPA notes that the quantitative goals that CWSs, especially small CWSs, typically will need to establish may be rather modest compared to those that would be expected for State-wide programs. The level of risk reduction needed to ensure ''equal or greater'' risk reduction be achieved (as if the MCL were being met) from a local MMM program plan is a function of and takes into account factors such as the size of the population served, level of radon in drinking water, and most importantly, the needs and goals of the community.

Strategies for Achieving Goals: EPA recognizes that promoting public action in the areas of new homes built radon-resistant and mitigation of existing homes with elevated levels of radon in indoor air will be entirely new ventures for CWSs. However, EPA believes CWSs, including small CWSs, will be capable of conducting various activities designed to promote testing and mitigation of existing homes with elevated levels of radon in indoor air and building of new homes to be radon-resistant. Such activities include public education programs, provision of radon test kits, establishing networks with local health and government officials to gain their support and involvement in MMM implementation, meeting with community leaders, customers, local real estate and home building officials and organization, utilizing existing information distribution network employed by CWSs, and other types of activities to promote public action on indoor radon. EPA expects that MMM program strategies for CWSs will be less comprehensive and far reaching than those of State MMM programs, and will need to reflect the local character of the community served by the CWS.

Tracking and Reporting of Results: EPA recognizes that assessing or tracking progress towards meeting these goals also represents a new responsibility for CWSs. However, CWSs may be able to build upon their experience and networks for communicating with customers and identifying their needs or concerns and find ways to collect information about actions taking place in the community. To track homes built or modified to be radon resistant, CWSs may be able to obtain needed information from various local and State programs and offices and other organizations in its network. CWS may also choose to employ contractor support or consultant services to obtain this information or to help track other MMM related activities. EPA also expects the States to provide assistance to CWSs in developing their tracking and assessment approach based on State experience in determining the results of their State indoor radon programs. EPA recognizes that CWSs' options for tracking results may be more limited than those available to the States, and that States should consider such limitations in their five-year review of local programs.

CWSs may find it useful to combine efforts with adjacent CWSs for purpose of developing and implementing joint MMM programs, thereby broadening their combined expertise, local infrastructure and institutional bases, and network of partners. EPA also expects that privately-owned, as well as publicly owned, CWSs can avail themselves of these same kinds of networks, partnership, and consultant services. Private systems will generally also be well connected to the municipal entities in the jurisdictions in which they operate.

The report of the Small Business Advocacy Review Panel included a discussion of the concept of a ''model MMM program'' for small systems which would not be required but could provide a workable option for small systems. It might address potential concerns of the smallest systems that anticipate they may lack the resources and expertise to develop an MMM program. As discussed subsequently in Section VI. H., EPA has concerns in general about the appropriateness and applicability of a ''one-size-fits-all'' approach for MMM programs. A model approach, even for small CWSs, would not address the unique, site-specific needs of different CWSs and their associated communities. EPA is requesting public comment on the concept of a model MMM program for CWSs.

As noted previously, EPA is strongly recommending that States choose to develop and implement State-wide MMM programs as the most cost-effective approach to manage the health risks from radon which would preclude the need for water systems to develop such programs on their own. EPA also believes the States which choose not to do an MMM program have an important role, and are the best positioned, to assist CWSs in development of local MMM program plans. EPA will also be providing guidance to assist CWSs, including small CWSs, in the development of local MMM programs. This section has discussed the manner in which the four criteria could be applied to CWSs in non-MMM States. EPA is requesting comment on approaches to applying these criteria to CWSs, especially the smallest CWSs, in view of the capabilities of these systems and their ability to get assistance from others. EPA is also requesting comment on options that may be available to CWSs, particularly, small systems, to develop and implement an MMM program plan.

In summary, EPA recognizes that CWSs do not have the same institutional base and infrastructure, legislative authority, proportionate resource base, or indoor radon program experience as States on which to base development of a local MMM program plan. However, EPA believes that the four criteria for approval are equally applicable to both States and CWSs, and can be applied to CWSs (particularly small CWSs) in a manner that recognizes and accounts for these differences. As discussed previously, the manner in which these criteria are addressed by CWSs in local MMM program plans, and the level and scope of effort, will necessarily differ from that embodied in State plans. States should consider these differences in evaluating CWS MMM program plans and in their five-year review of CWS MMM program implementation. EPA believes that States, in particular, are best positioned to assist CWSs, especially small systems, in the development of local MMM programs that satisfy the four criteria, and expects them to provide such assistance. In evaluating CWS plans, States should exercise flexibility in their review and approval process, especially for small CWSs, recognizing that they will not have the same institutional and resource base or experience and may need to obtain assistance from others.

The Agency expects that most systems in non-MMM States with radon levels between 4,000 pCi/L and 300 pCi/L will develop and submit MMM program plans. However, the Agency recognizes that some CWSs in non-MMM States may elect not to develop a MMM program plan for a variety of reasons. In these cases, certain options are available to small CWSs. They may consider working with one or more other systems for the purposes of developing and implementing an MMM program plan, in order to take advantage of greater institutional capabilities. If a system does not develop an MMM program plan on its own or together with other systems, the system must comply with the MCL of 300 pCi/L through any available means (*e.g.*, blending, use of alternate sources, and treatment).

From a risk communication standpoint, EPA wishes to convey to customers of small CWSs that its regulatory expectation for these systems is that they meet the AMCL and implement an MMM program. However, CWSs can choose to meet the MCL rather than take the MMM approach. If a CWS opts for the MMM/AMCL approach but is unable to develop and successfully implement a State-approved MMM program plan, it may be required as part of an enforcement order, to meet the MCL rather than comply with the MMM/AMCL. The Agency requests comment on this approach for small system MMM programs.

The SDWA provides that EPA will approve local water system MMM program plans and EPA has developed the criteria to be used for approving MMM program plans, as discussed in (A). EPA will review and approve State MMM program plans. CWS MMM program plans that address the criteria and are approved by the State are deemed approved by EPA. The proposed rule requires States that do not have a State-wide MMM program, as a condition of primacy for the radon regulation, to review MMM program plans submitted by CWSs and to approve plans meeting the four criteria for MMM program plans discussed in Section VI.A. of this, including providing notice and opportunity for public comment on CWS MMM program plans. EPA solicits comment on this approach to reviewing and approving local MMM plans. Under SDWA, MMM program plans submitted by CWSs are to be subject to the same criteria and conditions as State MMM program plans. EPA believes that the States are best positioned to assist CWSs, especially small systems, in the development and review of local MMM program plans that meet the four criteria, and to have public health oversight of the progress of the implementation of these local radon risk reduction programs. EPA encourages those States not choosing to develop a State-wide MMM program plan to exercise flexibility in their review and approval of local MMM program plans, especially for small CWSs, recognizing that CWSs will not have the same institutional base, nor the State's program experience on indoor radon, on which to base to local development of a MMM program plan. EPA expects that the State drinking water programs and indoor radon programs will work collaboratively in assisting CWSs that elect to develop and implement local CWS MMM program plans and comply with the AMCL. In non-primacy states, EPA will review and approve local CWS MMM program plans and oversee compliance with the AMCL if the state chooses not to do a state-wide MMM program plan. MMM program plans developed by Indian Tribes or tribal community water systems will be reviewed by EPA. The specific requirements of a CWS in a State with a State-wide MMM program are addressed in Section VI.E. CWSs may choose to meet the MCL.

For those CWSs (both large and small) in non-MMM States that develop local MMM program plans, the State would review the MMM program at least once every 5 years and provide progress reports to the EPA in keeping with the statutory requirements of the SDWA and this Section. (States may also establish interim reporting requirements for the CWS under a MMM program to help ensure adequate progress toward the goals set forth in the local MMM program plan.) Failure of a CWS to develop its MMM program plan by the required regulatory deadline or failure of a CWS to implement its approved MMM program plan (5 years and 5½ years, respectively after the final rule is published) would be a violation of this regulation unless the CWS is complying with the MCL. It is expected that a CWS would be given time to correct any violations relating to its MMM program through an appropriate enforcement action.

G. CWS Role in Communicating to Customers

At a minimum, CWSs have important responsibilities for communicating information on radon to their customers. Under the requirements of the Consumer Confidence Rule (CCR), CWSs will be required to provide key information on the health effects of radon should the level of radon in drinking water exceed the MCL (or AMCL in States with MMM programs). Today's action also updates the standard CCR rule requirements and adds special requirements that reflect the multimedia approach of this rule. The intent of these provisions is to assist in clearer communication of the relative risks of radon in indoor air from soil and from drinking water, and to encourage public participation in the development of the State or CWS MMM program plans. Today's action also proposes to require CWSs to add information to the mandatory yearly report which would inform their customers on how to get involved in developing their State or local CWS MMM program plan. This information would include a brief educational statement on radon risks, explaining that the principal radon risk comes from radon in indoor air, rather than drinking water, and for that reason, radon risk reduction efforts may be focused on indoor air rather than drinking water. This information will also note that many States and systems are in the process of creating programs to reduce exposure to radon, and encourage readers to call for more information. This information would be provided every year until the compliance date for implementation of State MMM programs (or CWS local MMM programs in States without a State-wide MMM program. (See Section X of this preamble for more information on CCR and public notice requirements for radon). EPA is also planning to develop public information materials on radon in drinking water and indoor air as ''tools'' to assist CWSs, as well as the States, Indian tribes, and others, with the risk communication issues associated with the MCL, AMCL, and MMM.

H. How Did EPA Develop These Criteria?

EPA obtained extensive stakeholder input in developing the regulatory criteria for State MMM program plans. Stakeholders participating in this process represented many diverse groups and organizations with an interest in radon, both from the perspective of radon in drinking water and of radon in indoor air. This included State drinking water and State radon program representatives, municipal and privately owned public water system suppliers, local government officials, environmental groups, and organizations representing State health officials, county governments, public interest groups, and others.

As part of the process of getting stakeholder input on development of MMM guidelines and criteria, EPA presented several conceptual framework options for MMM for discussion and consideration. Three preliminary approaches were discussed: (1) To set specific numerical targets in mitigations of existing houses and houses built radon-resistant (as surrogates for lives saved) for each State to meet; (2) to set a level of effort that States must demonstrate would be achieved under their MMM plan; and (3) to set minimum core indoor radon program elements required for all plans.

Under the first approach, specific targets to achieve ''equal'' risk reduction could be set using a variety of approaches and tools and based on a number of factors, such as the level of radon in the drinking water, the number of people served by that system, and other factors. It would also require allocating among the States the total number of lives saved nationally by universal compliance with the MCL (estimated to be about 62 lives saved yearly). The allocation of lives saved by States would likely lead to some State targets being fractions of a life saved yearly, depending on the number of systems, radon levels, and people served. Many stakeholders thought that significant attention would need to be paid to the risk communication challenges of communicating this approach to the public. Although some stakeholders thought this approach might be workable, others did not consider it universally applicable or workable and that it might preclude flexibility and innovation.

The second approach, ''level of effort'', would focus more on a plan for implementation of risk reduction strategies using a point system where different risk reduction strategies (such as public education, radon-resistant new construction code adoption, *etc.*) would be assigned a specific number of points based on potential to achieve health risk reduction. The number of State-specific points that a MMM program plan would have to meet to be approved would require determining the number of systems complying with the AMCL rather than the MCL, the radon levels in their drinking water, and population served. This approach would give States flexibility in choosing the combination of indoor radon risk reduction strategies that best meets the needs of that State by giving them a menu of approaches from different categories of strategies with different assigned points. There are two difficulties in implementing this approach that would need to be addressed. First, it may be difficult to assign in advance a specific quantified value for different strategies in terms of a numerical outcome in risk reduction (*i.e.*, in lives saved or in existing homes mitigated or houses built radon-resistant). EPA requested the National Academy of Sciences (NAS), as part of its assessment of radon in drinking water, to ''prepare an assessment of the health risk reduction benefits associated with various mitigation measures [described in SDWA] to reduce radon levels in indoor air.'' Although the NAS included some review of the States' experience with public education and risk communication, they did not include a quantitative assessment of the ''health risk reduction benefits'' associated with specific ''mitigation measures'' referred to by SDWA. Second, risk communication research has shown, and many stakeholders agreed, that a variety of strategies must be employed simultaneously when trying to get voluntary public actions on preventive health and safety measures. It is often difficult to single out or characterize, for example, the number of people who take voluntary health risk reduction actions because of viewing a particular televised public service announcement separate from other messages, activities, communications, and efforts being implemented by society to reduce that particular public health risk.

Setting specific State risk reduction targets or a level of effort point system were considered in part to address language in the SDWA radon provision that State plans approved by EPA are expected to achieve health risk reduction benefits ''equal to or greater than the health risk reduction benefits that would be achieved if each public water system in the State complied with the maximum contaminant level [MCL]* * *.'' As some stakeholders noted, there are complexities associated with determining risk reduction targets (*e.g.*, in pCi/L) for indoor radon needed to substitute or ''make-up'' for some very small level of risk reduction that would not occur if systems comply with the AMCL. Careful attention would need to be paid to ensuring that this approach did not produce the unintended effect of narrowly focusing or limiting the risk reduction goals of MMM program plans. Some States and other stakeholders were concerned that a complex approach, that may be difficult to communicate to the public, could hamper voluntary public action currently taking place on indoor radon. Some States thought that they may have the data and/or tools that would permit such an approach.

The third conceptual approach was to require MMM program plans to include a set of core program elements, without targets or points, to be determined by EPA. This would require a set of basic program elements that each State MMM program plan would have to incorporate to be approved by EPA. In addition, the States could choose to add additional program elements from a menu of strategies to be provided by EPA. An example of implementation of a core program element might be that each State would have to adopt radon-resistant new construction standards into their State and local building codes, or require testing and mitigation firms to register with the State and report numbers of radon tests and mitigations conducted. Many stakeholders were concerned that this approach might not provide sufficient flexibility needed by the States to reflect their particular needs, including the scope of the radon in drinking water and indoor radon problem, and the varying extent to which the States have been addressing their indoor radon problem through their existing State radon programs.

EPA is soliciting public comment on these three alternative conceptual frameworks for MMM program plans that were examined through the stakeholder process and is also requesting public comment on other potential frameworks and rationale for why and how these would achieve increased radon risk reduction.

While stakeholders had differing views of the three conceptual approaches presented by EPA for discussion purposes, a number of mutual concerns and issues integral to formulation of a conceptual framework for MMM were identified. The following set of broad issues and concerns raised by stakeholders were considered in the development of the required criteria that EPA is proposing.

A uniform approach, that is, a ''one size fits all'' approach to MMM might not provide States with the flexibility they need to custom tailor their plans to their needs. Every State is different in terms of the extent and magnitude of the indoor radon problem, the nature of the existing State indoor radon program, the levels of radon in public water supplies, and many other factors.

Because the SDWA framework for radon permits States to choose to adopt either the MCL or AMCL/MMM option, some stakeholders believed that States might be less inclined to adopt the MMM/AMCL approach if it were considered too complex and difficult to implement and communicate to the public. The approach needs to be simple and straightforward, provide flexibility to accommodate the variety of needs in different States, and encourage innovation at the State and local level.

MMM will be most effective if it is built on and consistent with the foundation and infrastructure of the existing State indoor radon programs. States are better positioned than public water suppliers to achieve radon risk reduction under MMM programs. Most States currently have a voluntary radon program. Some States noted the need for some consistency between the criteria and objectives for MMM program plans and the goals, priorities, and EPA's existing State Indoor Radon Grant (SIRG) program guidance.

States and other stakeholders raised concerns about the potential relationship between MMM and the current State indoor radon programs. Stakeholders strongly encouraged EPA to carefully identify and consider the potential for negative impacts of MMM requirements on current State efforts on indoor radon. In particular there were concerns that attention and resources might be diverted to the MMM program. States might choose not to do a MMM program if the effectiveness or infrastructure of their current indoor radon program might be reduced, or if it does not help States meet the goals of their voluntary programs. This would be counter-productive if it resulted in reduced efforts and diminished infrastructure of a State's voluntary program already achieving indoor radon risk reduction.

Some States felt it was important to have extensive public debate and examination of any program proposed by the State in order to get public support for the AMCL and MMM approach.

A number of stakeholders noted the need for MMM programs to have definable endpoints or goals, show how these endpoints will be attained, and describe how results will be determined. Some States indicated the importance of demonstrating to the public that the program is achieves radon risk reduction.

Stakeholders noted that the level of risk reduction that can be achieved by focusing resources and effort on radon in indoor air is significantly greater than what can be achieved by universal compliance with the MCL. MCL-based risk reduction targets would also be significantly smaller than the risk reduction already being achieved. Therefore it is important to focus on the greater risk reduction potential for radon in indoor air, and on enhancement of indoor radon programs, rather than focus on the smaller risk reduction potential from radon in water.

In developing and deciding on proposed criteria, EPA took into account these stakeholder views and concerns, as well as EPA's goals for MMM and the current approach used by EPA and the States to get indoor radon risk reduction. This information and experience taken together led to the proposed MMM criteria that are based upon three elements: (1) Involve the public in development of MMM; (2) track the level of indoor radon risk reduction that occurs; and, (3) build on the existing framework of State indoor radon programs.

First, stakeholders suggested that extensive public participation in the development of a State MMM program plan is important. One important approach is to involve various segments of the public, from community water system customers to key public health and other organizations, the business community, local officials, and many others. The public needs to be informed about and participate in the MMM development process to ensure that the goals and other elements of the plan will be publicly supported, responsive to the needs of the various stakeholders, and meet public and State goals for reducing indoor radon. Such a process may also result in increased public awareness and voluntary action to reduce the levels of indoor radon. Stakeholder involvement can help States clearly define goals and design the process and strategies for meeting these goals. EPA recognizes that there are a variety of non-quantitative and quantitative approaches, tools, and types of information that can be used to develop goals, but public input is very important to this process. The public involvement in development and examination of plans will help to get support and buy-in from all stakeholders to a set of goals, program strategies, and results measurement, and thus, helps to ensure program success.

Second, a successful MMM program plan needs to include a provision for determining progress on reducing the public's exposure to indoor radon, and for reporting back to the public. In the case of indoor radon, risk reduction results can be evaluated by tracking or in some way determining the level of existing home mitigation and new homes built radon-resistant. A few States already track this information closely. Many do not. EPA believes that there are a variety of approaches currently being used, such as statistically-based surveys; State requirements for tracking testing and mitigation by radon testing and mitigation companies; voluntary agreement by builders to provide information on construction of radon-resistant homes; and other approaches. EPA also recognizes the importance of providing States the flexibility to craft new and innovative approaches for tracking and assessing progress. Through implementation of a State-wide MMM/AMCL approach, States may be able to provide new incentives and opportunities for gathering the information the State will need to demonstrate to the public, and EPA, that progress is being made in getting public action to reduce radon risks.

Third, building MMM on the framework of existing State indoor radon programs takes advantage of the existing programs already working to get public action on indoor radon. Nearly every State currently has a program with existing policies, public outreach and education programs, partner networks and coalitions, and other infrastructure. States have used the State Indoor Radon Grant (SIRG) funds available under Title III of the Toxics Substances Control Act (TSCA) to develop a variety of radon strategies, including distributing information materials to educate the public, maintaining radon hotlines, conducting training programs, providing technical assistance, operating certification programs for the radon industry, setting up regulatory requirements for industry reporting of testing and mitigation, conducting surveys (testing) of homes and schools, working with local governments in high-risk areas to establish incentive programs for radon-resistant new construction, and many other activities. Many of these activities are consistent with the findings of the National Academy of Sciences. They found three factors were most important for motivating the public to test and fix their home: (1) A radon awareness campaign; (2) promoting the widespread voluntary testing by the public of indoor radon levels; and (3) educating the public about mitigation and ensuring the availability of qualified contractors. The reinforcement and augmentation of these types of efforts through MMM programs is expected to result in increased levels of testing and mitigation of existing homes by the public and of homes being built to be radon-resistant.

The ''mitigation measures'' set forth in the 1996 SDWA are similar to those being used in the existing national and State radon programs. Section 1412 (b)(13)(G)(ii) provides that State MMM programs may rely on a variety of ''mitigation measures'' including ''public education, testing, training, technical assistance, remediation grants and loans and incentive programs, or other regulatory or non-regulatory measures''. These represent many of the same strategies that are integral to the indoor radon program strategy, as well as those outlined in the 1988 Indoor Radon Abatement Act.

The risk reduction achieved to date through the national and State radon programs has been achieved primarily through a non-regulatory approach. The SIRG guidance for implementing a program also outlines and recommends indoor radon program priorities, encourages States to develop narrative descriptions of how they intend to address the priority areas, and encourages the establishment of goals for awareness, testing and mitigation of homes and schools, and radon-resistant new construction. Under SIRG, the States are required to submit a list of their activities and workplans for each project that will be done under the grant. While EPA's SIRG guidance requires a list of program activities, it is not currently a Federal requirement under the Indoor Radon Abatement Act of 1988 or under SIRG that State indoor radon programs to: (a) publicly set goals for awareness, testing, mitigation and new construction; (b) develop and implement a strategic plan for action through real estate transactions, new home construction, testing and fixing schools, and getting the public to test and fix their homes; (c) develop and implement approaches to track and measure the results of their strategic plans and activities and report those results to the public; and (d) directly involve the public in the development of the States' program goals and strategic plans. EPA is proposing that, in order to have an approved MMM program plan, States now be required to take these steps.

EPA believes this augmentation of State programs required under the criteria will result in an increased level of risk reduction. States will develop their plans with direct public participation in setting goals, develop strategic plans in key areas, and develop approaches for tracking and measuring results against goals. EPA also expects that substantial and constructive public participation in the development process of the State's MMM program plan is likely to result in a program that meets the public's needs and concerns on an important public health issue, as well as in greater public awareness of the health effects of radon and in increased voluntary action by the public to address their risks from indoor radon. Given EPA's estimate of the expected increase in the yearly rate of lung cancer deaths avoided from the current voluntary program, EPA expects that State MMM program plans meeting these four criteria will achieve equal, or much more likely, greater health risk reduction benefits.

I. Background on the Existing EPA and State Indoor Radon Programs

Implementation of EPA's current national strategy to reduce public health risks from radon in indoor air has focused on using a decentralized management and risk communication approach in partnership with States, local governments and a network of national organizations; a continuum of risk reduction strategies; and, a strong focus on key priorities. Reduction of indoor radon levels has the potential to yield very large risk reduction benefits through pursuit of a wide range of approaches including the availability of relatively inexpensive testing, mitigation, and new construction techniques to reduce the risk from indoor radon. National, State, and local efforts continue to proactively encourage the public to test and fix their homes, promote action on radon in association with real estate transactions, and promote the construction of new homes with radon-resistant techniques through institutional changes such as local adoption of new construction standards and codes.

Prior to 1985 the federal government and only a few States had initiated activities to address indoor radon problems. The initial foundation and scope of State programs was determined by the different needs of the States. For example, some Western States developed programs to assist citizens living on or near uranium mines or mill tailings sites. When very high levels of radon in homes in the area known as the Reading Prong in the Northeastern U.S. were discovered in late 1984, the Agency began to develop and to implement a coordinated national radon program. Some Eastern States situated over the Reading Prong began to develop strong programs in response to homes being found with radon levels in the hundreds and thousands of pCi/L of air. However, there was no coordinated government program, or testing and mitigation industry, to address the risks posed by radon and only a very small fraction of the public was even aware of the problem.

Since then, there has been significant progress in the nation's program to promote voluntary public action to reduce the health risks from radon in indoor air. EPA's non-regulatory Radon Program has established a partnership between federal, State, local and private organizations, as well as private industry, working together on numerous fronts to promote voluntary radon risk reduction. This partnership initially focused programs on increasing public awareness of the problem and providing the public with the necessary resources, including a range of technical guidance and information, to enable them to reduce their health risks through voluntary actions across the nation. Congress endorsed this strategy and strengthened the indoor radon program through the Superfund Amendments and Reauthorization Act of 1986, and again in 1988 through passage of the Indoor Radon Abatement Act. The Superfund Amendments and Reauthorization Act of 1986 (SARA) authorized EPA to conduct a national assessment of radon in residences, schools, and workplaces. The 1988 Indoor Radon Abatement Act (IRAA), an amendment to the Toxic Substances Control Act. established the overall long-term goal of reducing indoor radon levels to ambient outdoor levels, required the development and promotion of model standards and techniques for radon-resistant construction, and established the State Indoor Radon Grant program (SIRG). IRAA also directed EPA to study radon levels in the U.S., evaluate mitigation methods to reduce indoor radon, establish proficiency programs for radon detection devices and services, develop training centers, provide the public with information about radon, and assist States to develop and implement programs to address indoor radon.

Recognizing the importance of working in partnership with the States and leading national organizations, EPA developed a decentralized system for informing the public about the health risks from radon, consisting primarily of State and local governments and key national organizations, with their state and local affiliates, who serve as sources of radon information and support activities to the public. EPA has worked with the States to help establish and enhance effective State indoor radon programs and develop basic State capabilities needed for assisting the public in reducing their risk from indoor radon. EPA developed and transferred technical guidance on radon measurement and mitigation to the States, the private sector, and the public.

A key initiative in this effort to build State Radon Programs has been the State Indoor Radon Grant (SIRG) Program, which provides funding to help States develop and operate effective and self-sustaining radon programs. As of August 1999, forty-five States are currently participating in the SIRG program. These grants have been instrumental in establishing State radon programs or in helping States expand their radon programs more quickly than they otherwise could have.

EPA, the States and national and local partners are using a mixture of diverse strategies that range from the more flexible, such as providing information to the public to encourage the public to act, to more prescriptive, such as providing incentives that give some advantage for taking action, or to adopting policies and requirements that mandate certain actions. As a result, many initiatives are underway today both to actively encourage and motivate homeowners to test and fix their homes as well as to institutionalize risk reduction through testing and mitigation during real estate transactions and through construction of new homes to be radon-resistant.

EPA and the States, working with key national and local organizations, have developed a wide range of channels for delivering information to their members, affiliates and other target audiences. Many organizations have their own ''hotlines,'' journals, brochures, newsletters, press releases, radio and television programs, national conferences, and offer training and continuing education programs. These partners collaborate to urge public action on radon though a wide variety of strategies including information, motivation, incentives, and state and local mandates. The public receives a consistent message on radon from EPA, the States, and a number of other key, respected, and credible sources. Each target audience, like physicians or school nurses or local government officials, becomes in turn a source of information for new target audiences like their patients and local constituents. This approach is comparable to that used to encourage people to take various other voluntary preventive measures to reduce their risk of various health and safety risks. Some of the national organizations that EPA and the States work with include the American Lung Association, the National Association of City and County Health Officials, the National Parent Teacher Association, the Asian American and Pacific County Health Officials, the Association of State and Territorial Health Officials, the National Environmental Health Association, the National Association of County Officials, the Consumer Research Council of Consumer Federation of America, the National Safety Council, and many others.

Many of the publicly available information materials are specialized and designed to encourage specific actions by certain groups, e.g., physicians, homebuilders, real estate agents, home inspectors, home buyers and sellers, and many others. As a result, for example, many home builders are voluntarily using radon resistant new construction techniques and some real estate associations are voluntarily incorporating the use of radon disclosure forms into their regular business practices. Medical and health care professionals are being educated about the health risks of radon and are encouraging their patients to test their homes for radon as a preventive health care measure. Public service announcements by local radio and TV stations encourage the public to act. Other public information materials provide consumers with information on how to test their homes and what options they have for mitigating their radon problem.

Incentive programs and initiatives, such as free radon test kits, and builder rebates when builders build homes radon-resistant, are being implemented. States and local jurisdictions are also pursuing a variety of regulatory radon initiatives, such as requiring schools to be tested for indoor radon, requiring disclosure of elevated radon levels in residential real estate transactions, and requiring new homes to be built with radon-resistant new construction features through building codes. These strategies and many others are being used to successfully achieve public action to reduce the health risks from indoor radon.

EPA has consulted with scientists, federal, state and local government officials, public health organizations, risk communication experts, and others to design this program and focus on radon program strategies which have the greatest potential for reducing radon risks through long-term institutional change. In developing strategies for reducing radon risks, EPA and the States have learned from the experience of other successful national public health campaigns, such as the campaigns to promote the use of seat belts. These campaigns have shown that significant public action to voluntarily reduce health risks can be achieved from concerted efforts through a variety of diverse strategies and through the combined efforts of State and local governments, public health organizations, and other public interest groups, grass roots organizations, and the private sector.

Program priorities have been identified to help concentrate and focus efforts of EPA, the States, and local organizations, and others on those activities that are most effective in achieving the overall mission of indoor radon risk reduction. Working with a broad group of stakeholders, EPA established several key priority areas for indoor radon. States and cooperative national organizations have been focusing many of their efforts and activities in these areas.

1. Targeting Efforts on the Greatest Risks First

EPA, the States, and many other public health organizations recommend that all homes be tested and all homes at or above 4 pCi/L be fixed. However, resources have been more heavily focused initially in areas where action produces the most substantial risk reduction, such as on homes and schools in the high radon potential areas and on the increased risk of lung cancer from indoor radon to current and former smokers.

2. Promote Radon-Resistant New Construction

EPA and others encourage programs to promote voluntary adoption of radon-resistant building techniques by builders and the adoption of radon construction standards into national, State and local building codes. Methods (model standards) that establish construction techniques for reducing radon entry in new construction have been developed and published by EPA in collaboration with the National Association of Home Builders. There are currently over 30 major building contractors (some are national firms) who design and construct radon resistant new homes. It is very cost-effective to build new homes radon-resistant, especially in higher radon potential areas. In the existing indoor radon program, EPA has been encouraging the States to promote testing and mitigation in all areas of a State. EPA has also encouraged the States to focus on their activities to promote radon-resistant new construction on the highest radon potential areas (Zone 1) where building homes radon-resistant is most cost-effective. However, it is also cost-effective to build homes in medium potential areas (Zone 2), as well as in ''hot'' spots found in most lower radon potential areas (Zone 3).

3. Promote Testing and Mitigation During Real Estate Transactions

Based on the efforts of EPA, the States, and others, there has been a steady increase in the number of radon tests and mitigations voluntarily done through real estate actions. It is very cost-effective to test and mitigate existing homes with elevated indoor radon levels. Real estate transactions offer a significant opportunity to achieve radon risk reduction. In 1993, EPA published the ''Home Buyer's and Seller's Guide to Radon'' (USEPA 1993f). Hundreds of thousands of copies of the ''Home Buyer's Guide'' have been distributed to consumers. The companion to the ''Home Buyer's Guide'' is the ''Consumer's Guide to Radon Reduction'' (USEPA 1992d) which provides information on how to go about reducing elevated radon levels in a home.

A significant amount of radon testing and mitigation of existing homes takes place during real estate transactions through the combination of home inspections, real estate transfers, and relocation services. Many different groups are in a position to influence buyers and sellers to test and mitigate elevated radon levels. This includes sales agents and brokers, buyers agents, home inspectors, mortgage lenders, secondary mortgage lenders, appraisers, insurance companies, State real estate licensing commissions, real estate educators, relocation companies, real estate press, and others. There are currently no requirements at the federal, State, or local level that a house be tested for indoor radon as part of a real estate transaction. Many State and local governments, however, have passed laws requiring some form of radon disclosure, although the extent and detail of these mandatory disclosure laws varies.

4. Promote Individual and Institutional Change through Public Information and Outreach Programs

Because the health risk associated with indoor radon is controlled primarily by individual citizens, EPA, the States and others have developed a nationwide public information effort to inform the public about the health risks from indoor radon and encourage them to take action. EPA recommends that the public use EPA-listed or State-listed radon test devices and hire a trained and qualified radon contractor to fix elevated radon levels. Early on, EPA established voluntary programs to evaluate the proficiency of these testing and mitigation service companies to provide a mechanism for providing the public with information by publishing updated lists of firms that pass all relevant criteria. Many States have established their own proficiency programs. To help support these efforts, EPA established four self-sustaining Regional Radon Training Centers across the country to train testing and mitigation contractors, State personnel, and others in radon measurement, mitigation, and prevention techniques. In 1998, the Conference of Radiation Control Program Directors (CRCPD), representing State radiation officials, initiated a pilot program through the National Environmental Health Association to establish a privatized national proficiency program to replace EPA's proficiency program which is terminating.

VII. What Are the Requirements for Addressing Radon in Water and Radon in Air? MCL, AMCL and MMM

A CWS must monitor for radon in drinking water in accordance with the regulations, as described in Section VIII of this preamble, and report their results to the State. If the State determines that the system is in compliance with the MCL of 300 pCi/L, the CWS does not need to implement a MMM program (in the absence of a State program), but must continue to monitor as required.

As discussed in Section VI, EPA anticipates that most States will choose to develop a State-wide MMM program as the most cost-effective approach to radon risk reduction. In this case, all CWSs within the State may comply with the AMCL of 4000 pCi/L. Thus, EPA expects the vast majority of CWSs will be subject only to the AMCL. In those instances where the State does not adopt this approach, the proposed regulation provides the following requirements:

A. Requirements for Small Systems Serving 10,000 People or Less

The EPA is proposing that small CWS serving 10,000 people or less must comply with the AMCL, and implement a MMM program (if there is no state MMM program). This is the cut-off level specified by Congress in the 1996 Amendments to the Safe Drinking Water Act for small system flexibility provisions. Because this definition does not correspond to the definitions of ''small'' for small businesses, governments, and non-profit organizations previously established under the RFA, EPA requested comment on an alternative definition of ''small entity'' in the preamble to the proposed

Consumer Confidence Report (CCR) regulation (63 FR 7620, February 13, 1998). Comments showed that stakeholders support the proposed alternative definition. EPA also consulted with the SBA Office of Advocacy on the definition as it relates to small business analysis. In the preamble to the final CCR regulation (63 FR 4511, August 19, 1998), EPA stated its intent to establish this alternative definition for regulatory flexibility assessments under the RFA for all drinking water regulations and has thus used it for this radon in drinking water rulemaking. Further information supporting this certification is available in the public docket for this rule.

EPA's regulation expectation for small CWSs is the MMM and AMCL because this approach is a much more cost-effective way to reduce radon risk than compliance with the MCL. (While EPA believes that the MMM approach is preferable for small systems in a non-MMM State, they may, at their discretion, choose the option of meeting the MCL of 300 pCi/L instead of developing a local MMM program). The CWSs will be required to submit MMM program plans to their State for approval. (See Sections VI.A and F for further discussion of this approach).

SDWA Section 1412(b)(13)(E) directs EPA to take into account the costs and benefits of programs to reduce radon in indoor air when setting the MCL. In this regard, the Agency expects that implementation of a MMM program and CWS compliance with 4000 pCi/L will provide greater risk reduction for indoor radon at costs more proportionate to the benefits and commensurate with the resources of small CWSs. It is EPA's intent to minimize economic impacts on a significant number of small CWSs, while providing increased public health protection by emphasizing the more cost-effective multimedia approach for radon risk reduction.

B. Requirements for Large Systems Serving More Than 10,000 People

The proposal requires large community water systems, those serving populations greater than 10,000, to comply with the MCL of 300 pCi/L unless the State develops a State-wide MMM program, or the CWSs develops and implements a MMM program meeting the four regulatory requirements, in which case large systems may comply with the AMCL of 4,000 pCi/L. CWSs developing their own MMM plans will be required to submit these plans to their State for approval.

C. State Role in Approval of CWS MMM Program Plans

The SDWA provides that EPA will approve CWS MMM program plans. EPA has developed criteria to be used for approving MMM programs. EPA will review and approve State MMM program plans. CWS MMM program plans that address the criteria and are approved by the State are deemed approved by EPA. The proposed rule requires States that do not have a State-wide MMM program, as a condition of primacy for the radon regulation, to review MMM program plans submitted by CWSs and to approve plans meeting the four criteria for MMM programs discussed in Section VI of this preamble, including providing notice and opportunity for public comment on CWS MMM program plans. Under Section 1412(b)(13)(G)(vi) of SDWA, MMM program plans submitted by CWSs are to be subject to the same criteria and conditions as State MMM program plans. EPA will review CWS MMM program plans in non-primacy States, Tribes and Territories that do not have a state-wide MMM program, and approve them if they meet the four required criteria.

D. Background on Selection of MCL and AMCL

The SDWA directs that if the MCL for radon is set at a level more stringent than the level in drinking water that would correspond to the average concentration of radon in outdoor air, EPA must also set an alternative MCL at the level corresponding to the average concentration in outdoor air. Consistent with this requirement, EPA is proposing to set the AMCL at 4000 pCi/L. This level is based on technical and scientific guidance contained in the NAS Report (NAS 1999b) on the water-to-air transfer factor of 10,000 pCi/L in water to 1 pCi/L in indoor air and the average outdoor radon level of 0.4 pCi/L.

The SDWA generally requires that EPA set the MCL for each contaminant as close as feasible to the MCLG, based on available technology and taking costs to large systems into account. The 1996 amendments to the SDWA added the requirement that the Administrator determine whether or not the benefits of a proposed maximum contaminant level justify the costs based on the HRRCA required under Section 1412(b)(3)(C). They also provide new discretionary authority to the Administrator to set an MCL less stringent than the feasible level if the benefits of an MCL set at the feasible level would not justify the costs (SDWA section 1412(b)(6)(A)).

EPA is proposing to set the MCL at 300 pCi/L, in consideration of several factors. First, the Agency considered the general statutory requirement that the MCL be set as close as feasible to the MCLG of zero (SDWA section 1412(b)(4)), and its responsibility to protect public health. In addition, the radon-specific provisions of the amendments provide that, in promulgating a radon standard, the Agency take into account the costs and benefits of programs to control indoor radon (SDWA 1412(b)(13)(E). Although EPA believes that an MCL of 100 pCi/L would be feasible, EPA believes that consideration of the costs and benefits of indoor radon control programs allows the level of the MCL to be adjusted to a less stringent level than the Agency would set using the SDWA feasibility test. The proposed MCL of 300 pCi/L takes into account and relies on the unique conditions of this provision and the reality it reflects that the great preponderance of radon risk is in air, not water, and the much more cost-effective alternative to water treatment is to address radon in indoor air through the MMM program. The Agency recognizes that controlling radon in air will substantially reduce human health risk in more cost-effective ways than spending resources to control radon in drinking water. If most states adopted the MMM/AMCL option, EPA estimates the combined costs for treatment of water at systems exceeding the AMCL, developing a MMM program, and implementing measures to get risk reduction equivalent to national compliance with the MCL (62 avoided fatal cancer cases and 4 avoided non-fatal cancer cases per year) at $80 million, which is substantially less than the $407.6 million cost of achieving the MCL. EPA expects that most states will adopt the AMCL/MMM program option

While EPA believes it is appropriate to acknowledge the more cost-effective control program to a certain extent in setting the MCL, the Agency does not believe the cost-effectiveness is the sole determining factor. Rather, EPA believes the absolute level of risk to which members of the public may be exposed is also a key consideration in determining a standard that is protective of public health.

The Agency proposed an MCL of 300 pCi/L in 1991 based, in part, on its assessment of the health risk posed by radon in drinking water. It should be noted that the overall magnitude of risk estimated by the Agency at that time is in agreement with the overall risk of radon in drinking water currently estimated by the National Academy of Sciences (NAS 1999b). The Agency has a long-standing policy that drinking water standards should limit risk to within a range of approximately 10^{-4} to 10^{-6} and is thus proposing to use the flexibility provided by the authority in 1412(b)(13)(E) to propose an MCL of 300 pCi/L, which is approximately at the upper bound of the Agency's traditional risk range used for the drinking water program (representing an estimated 2 fatal cancers per 10,000 persons).

As noted earlier, the Administrator must publish a determination as to whether the benefits of the proposed MCL justify the costs, based on the Health Risk Reduction and Cost Analysis prepared in accordance with SDWA § 1412(b)(3)(C). Accordingly, the Administrator has determined that the benefits of the proposed MCL of 300 pCi/L justify the costs. The benefits of the proposed MCL, include about 62 avoided fatal lung cancer cases and 4 avoided non-fatal lung cancer cases annually. EPA has used a valuation of $5.8 million ($1997) to value the avoided fatal cancers and a valuation of $536,000 ($1997) to value the avoided non-fatal cancers. Multiplying these valuations by the estimated cancer cases avoided (62 fatal, 3.6 non-fatal) yields a benefits estimate of $362 million per year. The cost to achieve national compliance with an MCL of 300 pCi/L is estimated at $407.6 million per year. EPA expects the actual cost of the proposed rule to be significantly lower, since the expectation is that most systems will not need to comply with the MCL of 300 pCi/L. Costs would be about $80 million per year if the AMCL/MMM option is widely adopted by States.

There are also some potential non-quantified benefits, including customer peace of mind from knowing drinking water has been treated for radon and reduced treatment costs for arsenic for some water systems that have problems with both contaminants, and non-quantified costs, including increased risks from exposure to disinfection byproducts, permitting and treatment of radon off-gassing, anxiety on the part of residents near treatment plants and customers who may not have previously been aware of radon in their water, and safety measures necessary to protect treatment plant personnel from exposure to radiation. However, in this case it is not likely that accounting for these non-quantifiable benefits and costs quantitatively would significantly alter the overall assessment. Taking both quantified and non-quantified benefits into account, EPA has determined that the costs are justified by the benefits. Accordingly, the new authority to set a less stringent MCL if benefits do not justify costs is not applicable and has not been used in this proposal.

Although the central tendency estimate of monetized costs exceeds the central tendency estimate of monetized benefits, the determination that benefits justify costs is consistent with the legislative history of this provision, which makes clear that this determination whether benefits ''justify'' costs is more than a simple arithmetic analysis of whether benefits ''exceed'' or ''outweigh'' costs. The determination must also ''reflect the non-quantifiable nature of some of the benefits and costs that may be considered. The Administrator is not required to demonstrate that the dollar value of the benefits are greater (or lesser) than the dollar value of the costs.'' [Senate Report 104–169 on S. 1316, p. 33] The determination is based on the analysis conducted under SDWA § 1412(b)(3)(C), in the Health Risk Reduction and Cost Analysis (HRRCA) published for public comment on February 26, 1999 (64 FR 9559), revised in response to public comment, and available as part of the Regulatory Impact Analysis (1999n) in the public docket to support this rulemaking. The costs and benefits of the proposed rule, and the methodologies used to calculate them, are discussed in detail in section XII of this preamble and in the Regulatory Impact Analysis (1999n).

In making this determination, EPA also considered the special nature of the radon standard, which provides an alternate MCL of 4000 pCi/L for states or water systems that adopt a MMM program designed to produce equal or greater risk reduction benefits to compliance with the MCL by promoting voluntary public action to mitigate radon in indoor air. As noted previously, mitigation of radon in indoor air is much more cost-effective than mitigation of radon in drinking water. If most states adopted the MMM/AMCL option, EPA estimates the combined costs for treatment of water at systems exceeding the AMCL, developing a MMM program, and implementing measures to get risk reduction equivalent to national compliance with the MCL (62 avoided fatal cancer cases and 4 avoided non-fatal cancer cases per year) at $80 million, which is substantially less than the $407.6 million cost of achieving the MCL.

In its valuation of costs and benefits for the MMM program, EPA has assumed that adopting the MMM approach will achieve only benefits equivalent to those for meeting the MCL and has calculated the costs and benefits of the proposed rule on this basis. However, EPA expects that adoption of MMM programs will be widespread as a result of this rule and that the actual benefits realized will be far greater than those associated with meeting the MCL. In addition, EPA fully expects most States to follow the MMM approach, therefore CWSs below the AMCL will incur minimal costs and a much smaller subset of CWSs will incur costs to meet the AMCL. Thus, costs for meeting the MCL are a theoretical worst case scenario which the Agency believes will not occur, particularly since the regulatory expectation for water systems serving 10,000 people or fewer would be that they meet the 4000 pCi/L AMCL, along with implementation of a local MMM program. Although in some cases small CWSs may choose to meet the MCL of 300 pCi/L through water treatment, this is voluntary and not a requirement of the proposed regulation.

The Agency also considered the costs, benefits, and risk reduction potential of radon levels at 100 pCi/l, 500 pCi/L, 1000 pCi/L, 2000 pCi/L and 4000 pCi/L. As table VII.1 illustrates, the costs and benefits increase as the radon level increases. The quantified costs somewhat exceed the quantified benefits at each level, but the benefit-cost ratios are similar. However, the difference between costs and benefits becomes somewhat larger as the various MCL options become more stringent, with the largest difference at 100 pCi/L. When the uncertainty of the estimates is factored in, there is overlap in the benefit and cost estimates at all evaluated options. For more information on this analysis, please refer to the Regulatory Impact Analysis (RIA) for this proposal (USEPA, 1999n).

TABLE VII.1.—EVALUATION OF RADON LEVELS

Radon level (pCi/L)	Fatal cancer cases avoided	Individual fatal lifetime cancer risk	Cost per fatal cancer case avoided ($M)	Total national costs[1] $M	Monetized benefits[1] $M	Benefit-cost ratio
4000	2.9	26.8 in 10,000	14.9	43.1	17.0	0.4
2000	7.3	13.4 in 10,000	9.5	69.7	42.7	0.6
1000	17.8	6.7 in 10,000	7.3	130.5	103	0.8
500	37.6	3.35 in 10,000	6.8	257.4	219	0.9
300	62.0	2.0 in 10,000	6.6	407.6	362	0.9
100	120.0	0.67 in 10,000	6.8	816.2	702	0.9

[1] Water Mitigation only; assuming 100% compliance with MCL. Source: revised HRRCA.

Some commenters recommended that EPA give serious consideration to setting an MCL at the AMCL level (4000 pCi/L), or at least at a level substantially above 300 pCi/L, in order to control radon levels in drinking water at a level more comparable to outdoor background levels. This approach was also discussed by the Small Business Advocacy Review Panel convened for this rule under the RFA as amended by SBREFA. (A copy of the Panel's final report is available in the docket for this rule making, (USEPA, 1998c).)

As noted earlier, EPA's interpretation of the standard-setting requirements of the SDWA for radon are that they rely primarily upon the general standard-setting provisions for National Primary Drinking Water Regulations, with some additional radon-specific provisions. The general provisions require that the MCL be set as close as feasible to the MCLG. The radon-specific provisions direct the Administrator to take into account the costs and benefits of control programs for radon from other sources. As discussed, EPA is interpreting these general and radon-specific authorities to propose an MCL above the feasible level, near the upper end of the risk range traditionally used by the Agency in setting drinking water standards. In addition, EPA believes that the extensive statutory detail enacted on multimedia mitigation illustrates a congressional preference for cost-effective compliance through the AMCL/MMM program approach. EPA notes that the equal or greater risk reduction required to be achieved through the AMCL/MMM option would be diminished as the MCL approaches the AMCL of 4,000 pCi/L and that fewer States and CWSs would select this option. Further, the AMCL/MMM approach would be eliminated entirely if the MCL were set at the AMCL.

As noted previously, EPA believes the proposed MCL of 300 pCi/L, in combination with the proposed AMCL and MMM approach, accurately and fully reflects the SDWA provisions. The Agency recognizes , however, that some stakeholders may have strong views about the appropriateness of setting an MCL at a higher level. Accordingly, EPA requests comment on the option of setting the MCL closer to or at the AMCL level of 4000 pCi/L. In this connection, the Agency also requests comments on and the rationale for how such alternative options could be legally supported under the SDWA and in the record for this rulemaking, in light of the considerations EPA has applied for the MCL it proposes.

EPA solicits comment on the proposed MCL and AMCL and the Agency's rationale, and on other appropriate MCLs given these considerations, and the rationale for alternative levels. In the final rule, the Agency may select a higher or lower option from those analyzed in the HRRCA for the final radon rule without further public comment.

E. Compliance Dates

The proposed time line for compliance with the radon rule is described next and illustrated in Figure VII.1.

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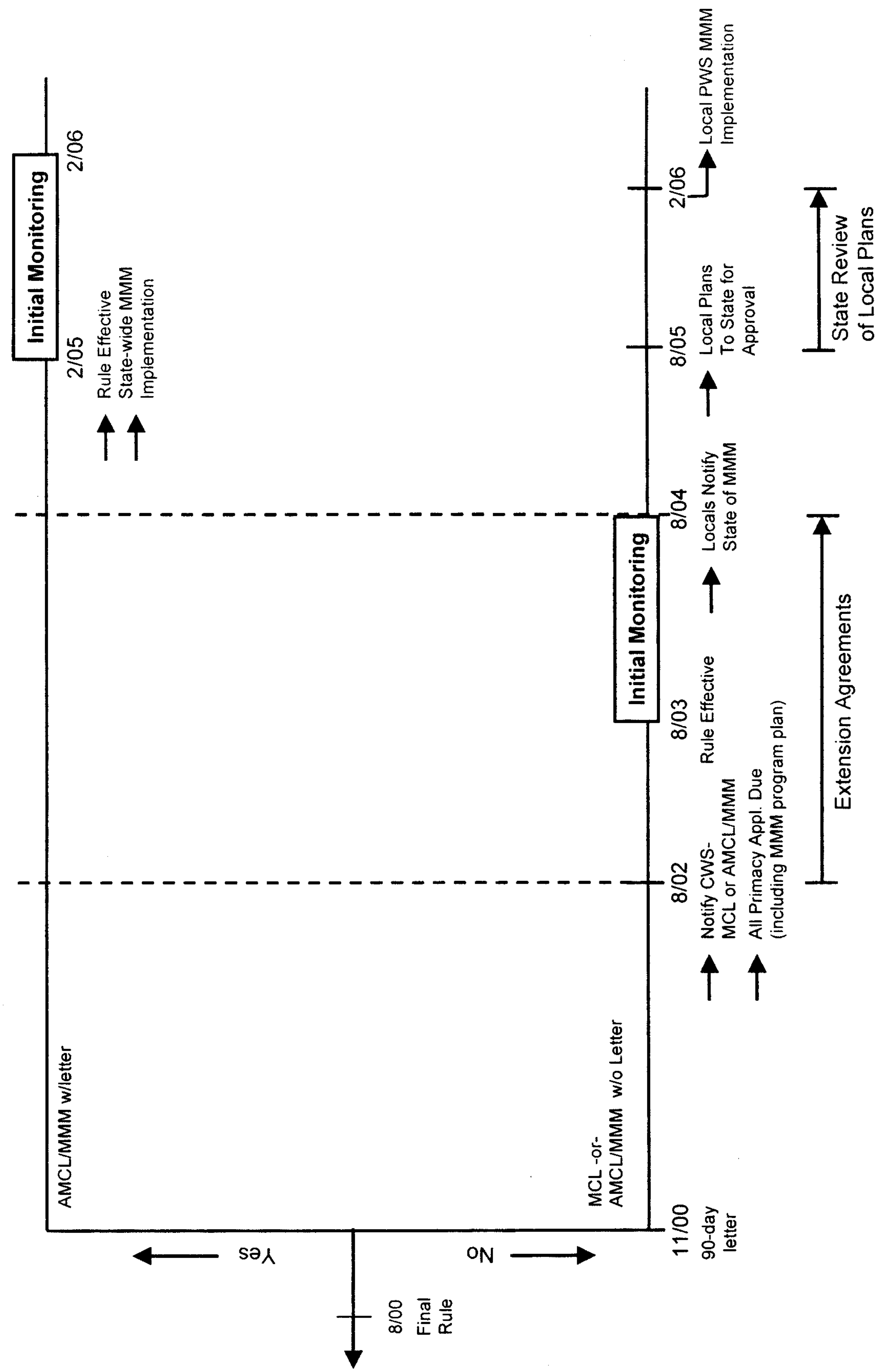
FIGURE VII.1

Timeline for Compliance (Radon)



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States are required to submit their primacy revision application packages by two years from the date of publication of the final rule in the **Federal Register**. For States adopting the AMCL, EPA approval of a State's primacy revision application is contingent on submission of and EPA approval of the State's MMM program plan. Therefore, EPA is proposing to require submission of State-wide MMM program plans as part of the complete and final primacy revision application. This will enable EPA to review and approve the complete primacy application in a timely and efficient manner in order to provide States with as much time as possible to begin to implement MMM programs. In accordance with Section 1413(b)(1) of SDWA and 40 CFR 142.12(d)(3), EPA is to review primacy applications within 90 days. Therefore, although the SDWA allows 180 days for EPA review and approval of MMM program plans, EPA expects to review and approve State primacy revision applications for the AMCL, including the State-wide MMM program plan, within 90 days of submission to EPA.

EPA is proposing that CWSs begin their initial monitoring requirements (one year of quarterly monitoring) for radon by 3 years after publication of the final rule in the **Federal Register**, except for CWSs in States that submit a letter to the Administrator committing to develop an MMM program plan in accordance with Section 1412 (b)(13)(G)(v). For CWSs in these States, one year of quarterly monitoring is proposed to begin 4.5 years after publication of the final rule. The proposed rule allows systems to use grandfathered data collected after the proposal date to satisfy the initial monitoring requirements provided the monitoring and analytical methods employed satisfy the regulations set forth in the rule and the State approves. Systems opting to conduct early monitoring will not be considered in violation of the MCL/AMCL until after the initial monitoring period applicable to their State (*i.e.,* 4 years after publication of the final rule, 5.5 years after publication of the final rule).

The routine and reduced monitoring requirements were developed to be consistent with the Standardized Monitoring Framework (SMF) and the Phase II/V monitoring schedule. EPA believes this is valuable for States and systems by providing sampling efficiency and organization, therefore, EPA has tried to adapt the compliance dates so that States and systems can make a smooth transition into the SMF following the initial monitoring requirements. The necessity to complete the initial monitoring in a timely manner is driven by the need for systems in non-MMM States to evaluate their compliance options, including development of a local MMM program and compliance with the AMCL), and for systems in MMM States to ensure compliance with the AMCL.

EPA feels it is important to set time constraints on implementation of the MMM plans to ensure the equal or greater risk reduction resulting from multimedia mitigation. Therefore, the rule must allow the systems in non-MMM States enough time to develop their MMM program plan with technical assistance from the State and submit the plan for State approval. In addition, the State must have sufficient time to review and approve the local plans. If the compliance determination for a system in a non-MMM State exceeds the MCL during the initial monitoring period, the proposed rule requires these systems to notify the State of their intention to develop a local MMM program at the completion of initial monitoring, 4 years after publication of the final rule. The local MMM program plans must be submitted to the State for approval by 5 years after of publication of the final rule (*i.e.,* 12 months after the completion of initial monitoring) and the States have 6 months from the submittal date to review and approve or disapprove the plan. The system will begin implementation of their MMM program 5.5 years after publication of the final rule (*i.e.,* 1.5 years after the completion of initial monitoring). If the State fails to review and disapprove the local MMM program in the time allowed, the system will begin implementation of the submitted plan. If the system fails to comply with these compliance dates, a MCL violation will apply from the date of exceedence. If the compliance determination for a system choosing to comply with the MCL exceeds the MCL following the completion of the initial monitoring period, the system will have the option to submit a local MMM plan to the State within 1 year from the date of the exceedence and begin implementation 1.5 years from the date of the exceedence or incur a MCL violation.

Implementation of State-wide MMM programs must begin 3 years after publication of the final rule, unless the State submits a letter to the Administrator committing to develop an MMM program plan in accordance with Section 1412 (b)(13)(G)(v) of the SDWA. States submitting this letter must implement their State-wide MMM program plan by 4.5 years after publication of the final rule. EPA feels it is extremely important that the MMM program plans be completed on a schedule that allows States sufficient time to begin implementation by the compliance date to ensure that equal or greater risk reduction benefits are provided.

EPA recognizes potential issues may arise as a result of the proposed initial monitoring schedule. The potential issues include lab capacity and a temporary deviation from the SMF schedule. EPA is requesting comment on alternatives to avoid or lessen the impact of these issues and other issues not listed here.

EPA considers the proposed monitoring schedule to be acceptable since the proposed rule affects one contaminant and applies to a smaller universe of water systems (NTNCWSs, transient systems, and CWSs relying solely on surface water are not covered by the rule) which decreases the number of systems effected, and therefore lessens the impacts of the potential issues. An alternative initial monitoring scenario which was considered would specify early monitoring requirements for systems serving more than 10,000 people. This scenario would put additional burden on the States and systems to monitor early and it would not substantially ease the workload since the number of systems serving greater than 10,000 that use groundwater or groundwater under the direct influence of surface water is relatively small.

Initial monitoring could be phased in over a period of two or three years, but EPA does not feel it is appropriate to extend the initial monitoring period due to the necessity to evaluate the need to develop and implement local MMM program plans. In MMM States, systems must be in compliance with the AMCL in a timely manner to ensure the maximum risk reduction.

In consideration of all these factors, EPA is proposing to require the initial monitoring over a one-year period as specified earlier. However, systems opting to conduct early monitoring will not be considered in violation of the MCL/AMCL until after the initial monitoring period applicable to their State (*i.e.,* 4 years after publication of the final rule, 5.5 years after publication of the final rule). However, CWSs opting to conduct early monitoring will not be considered in violation of the MCL/AMCL until after the initial monitoring period applicable to their State (*i.e.,* 4 years after publication of the final rule, 5.5 years after publication of the final rule. It is EPA's strong recommendation that all States choose to adopt the AMCL and implement an MMM program. But some States may elect to adopt the MCL or may decide later to adopt the AMCL/MMM approach. In these states, the initial monitoring will be required to begin by 3 years after publication of the final rule, whereas in States submitting the 90-day letter committing to develop an MMM program plan will begin initial monitoring 4.5 years after publication of the final rule.

VIII. What Are the Requirements for Testing for and Treating Radon in Drinking Water?

A. Best Available Technologies (BATs), Small Systems Compliance Technologies (SSCTs), and Associated Costs

1. Background

Section 1412(b)(4)(E) of the Act states that each national primary drinking water regulation which establishes an MCL shall list the technology, treatment techniques, and other means which the Administrator finds to be feasible for purposes of meeting the MCL. In addition, the Act states that EPA shall list, if possible, affordable small systems compliance technologies (SSCTs) that are feasible for the purposes of meeting the MCL. In order to fulfill these requirements, EPA has identified best available technologies (BAT) and SSCTs for radon.

(a) Proposed BAT. Technologies are judged to be BAT when they are able to satisfactorily meet the criteria of being capable of high removal efficiency; having general geographic applicability, reasonable cost, and a reasonable service life; being compatible with other water treatment processes; and demonstrating the ability to bring all of the water in a system into compliance. The Agency proposes that, of the technologies capable of removing radon from source water, only aeration fulfills these requirements of the SDWA for BAT determinations for this contaminant. The full range of technical capabilities for this proposed BAT is discussed in the EPA Technologies and Costs document for radon (USEPA 1999h). Table VIII.A.1 summarizes the BAT findings by EPA for the removal of the subject drinking water contaminants, including a summary of removal capabilities.

TABLE VIII.A.1—PROPOSED BAT AND ASSOCIATED CONTAMINANT REMOVAL EFFICIENCIES

High Performance Aeration[1].	Up to 99.9% Removal.

Note: (1) High Performance Aeration is defined as the group of aeration technologies that are capable of being designed for high radon removal efficiencies, *i.e.,* Packed Tower Aeration, Multi-Stage Bubble Aeration and other suitable diffused bubble aeration technologies, Shallow Tray and other suitable Tray Aeration technologies, and any other aeration technologies that are capable of similar high performance.

Granular activated carbon (GAC) can also remove radon from water, and was evaluated as a potential BAT and a potential small systems compliance technology for radon. Since GAC removes radon less efficiently than it does organic contaminants, it generally requires designs that use larger quantities of carbon per volume of water treated to remove radon compared to contaminants for which GAC is BAT. This requirement for larger carbon amounts translates to much higher treatment costs for GAC radon removal. In fact, full-scale application of GAC for radon removal has been limited to installations at the household point-of-entry and for centralized treatment for very small communities (AWWARF 1998a). EPA has determined that the requirements for radon removal render it infeasible for large municipal treatment systems, and it is therefore not considered a BAT for radon. However, GAC and point-of-entry (POE) GAC may be appropriate for very small systems under some circumstances, as described next (USEPA 1999h, AWWARF 1998a, AWWARF 1998b).

(b) Proposed Small Systems Compliance Technologies. The 1996 Amendments to SDWA recognize that BAT determinations may not address many of the problems faced by small systems. In response to this concern, the Act specifically requires EPA to make technology assessments relevant to the three categories of small systems respectively for both existing and future regulations. These requirements are in addition to EPA's obligation, unchanged by the SDWA as amended in 1996, to designate BAT. 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. These evaluations include assessments of affordability and technical feasibility of treatment technologies for each class of small system. Table VIII.A.2, ''Proposed Small Systems Compliance Technologies (SSCTs) and Associated Contaminant Removal Efficiencies'', lists the proposed small systems compliance technologies for radon and summarizes EPA's findings regarding affordability and technical feasibility for the evaluated technologies. EPA has interpreted the SSCTs as equivalent to BATs under Section 1415 of the Act, for the purposes of small systems (those serving 10,000 persons or fewer) applying to primacy agencies for Section 1415(a) variances.

TABLE VIII.A.2.— PROPOSED SMALL SYSTEMS COMPLIANCE TECHNOLOGIES (SSCTS)[1] AND ASSOCIATED CONTAMINANT REMOVAL EFFICIENCIES

Small systems compliance technology	Affordable listed small systems categories[2]	Removal efficiency	Operator level required[3]	Limitations (see footnotes)
Packed Tower Aeration (PTA)	All Size Categories	90– > 99.9% Removal	Intermediate	(a)
High Performance Package Plant Aeration (*e.g.*, Multi-Stage Bubble Aeration, Shallow Tray Aeration).	All Size Categories	90– > 99.9% Removal	Basic to Intermediate.	(a)
Diffused Bubble Aeration	All Size Categories	70 to > 99% removal	Basic	(a, b)
Tray Aeration	All Size Categories	80 to > 90%	Basic	(a, c)
Spray Aeration	All Size Categories	80 to > 90%	Basic	(a, d)
Mechanical Surface Aeration	All Size Categories	> 90%	Basic	(a, e)
Centralized granular activated carbon	May not be affordable, except for very small flows.	50 to > 99% Removal	Basic	(f)

TABLE VIII.A.2.— PROPOSED SMALL SYSTEMS COMPLIANCE TECHNOLOGIES (SSCTS) [1] AND ASSOCIATED CONTAMINANT REMOVAL EFFICIENCIES—Continued

Small systems compliance technology	Affordable listed small systems categories [2]	Removal efficiency	Operator level required [3]	Limitations (see footnotes)
Point-of-Entry (POE) granular activated carbon.	May be affordable for systems serving fewer than 500 persons..	50 to > 99% Removal	Basic	(f, g)

Notes: [1] The Act (Section 1412(b)(4)(E)(ii)) specifies that SSCTs must be affordable and technically feasible for small systems.
[2] This section specifies three categories of small systems: (i) those serving 25 or more, but fewer than 501, (ii) those serving more than 500, but fewer than 3,301, and (iii) those serving more than 3,300, but fewer than 10,001.
[3] From National Research Council. Safe Water from Every Tap: Improving Water Service to Small Communities. National Academy Press. Washington, DC. 1997.
Limitations: (a) Pre-treatment to inhibit fouling may be needed. Post-treatment disinfection and/or corrosion control may be needed.
(b) May not be as efficient as other aeration technologies because it does not provide for convective movement of the water, which reduces the air:water contact. It is generally used in adaptation to existing basins.
(c) Costs may increase if a forced draft is used. Slime and algae growth can be a problem, but may be controlled with chemicals, e.g., copper sulfate or chlorine.
(d) In single pass mode, may be limited to uses where low removals are required. In multiple pass mode (or with multiple compartments), higher removals may be achieved.
(e) May be most applicable for low removals, since long detention times, high energy consumption, and large basins may be required for larger removal efficiencies.
(f) Applicability may be restricted to radon influent levels below around 5000 pCi/L to reduce risk of the build-up of radioactive radon progeny. Carbon bed disposal frequency should be designed to allow for standard disposal practices. If disposal frequency is too long, radon progeny, radium, and/or uranium build-up may make disposal costs prohibitive. Proper shielding may be required to reduce gamma emissions from the GAC unit. GAC may be cost-prohibitive except for very small flows.
(g) When POE devices are used for compliance, programs to ensure proper long-term operation, maintenance, and monitoring must be provided by the water system to ensure adequate performance.

(c) Approaches for Listing Small Systems Compliance Technologies (SSCTs). EPA has considered several options for the listing of SSCTs in the proposed rule for radon. The issue is how to list SSCTs with BAT in the rule, while at the same time allowing for flexible and timely updates to the list of SSCTs in the future.

EPA would like to establish a procedure that allows SSCT lists to be updated by guidance, rather than through the more resource intensive and time-consuming process of rule-making. For example, under today's proposal, EPA is including SSCT lists in the rule. This approach fully satisfies the requirements in Section 1412(b)(4)E(ii) of the Act, which states that EPA shall include SSCTs in lists of BAT for meeting the MCL. Since BATs are explicitly listed in rules, it is consistent to explicitly list SSCTs. Also, Section 1415(a) of the Act requires that BAT be proposed and promulgated with NPDWRs to satisfy the provisions for ''general variances'' (variances under Section 1415(a)); therefore, SSCTs must be listed in the rule if small systems are to be allowed to use them as BAT in satisfying the provisions for general variances.

Regarding updates to the list of SSCTs, Section 1412(b)(9) of the Act states that EPA shall review and revise, as appropriate, all promulgated NPDWRs every six years. However, since revisions of NPDWRs follow the normal rule-making process of proposing, taking public comment, and finalizing the rule, the process can be very time-consuming. While EPA believes that this six year review cycle is sufficient for updates to lists of BAT, it is unlikely to be sufficient for updates to lists of SSCTs, since recent improvements in package plant technologies, POE/POU devices, and remote monitoring/control technologies have been fairly rapid and future improvements seem imminent. For this reason, EPA seeks comment on this approach or alternate approaches that would allow for more timely updates to the list of SSCTs.

In support of an approach to SSCT list updates that is less formal and more expeditious than rulemaking, EPA notes that new Section 1412(b)(4)(E)(iv) allows the Administrator, after promulgating an NPDWR, to ''supplement the list of technologies describing additional or new or innovative treatment technologies that meet the requirements of this paragraph for categories of small public water systems.'' This provision does not contain any reference to or require rulemaking to update the SSCT list, in contrast with the earlier 1994 House version (in H.R. 3392) of this provision that specifically required revisions of the list to be made ''by rule.''

Under one alternative, EPA would publish only an initial list of SSCTs with the BAT list in 40 CFR 141.66. EPA would also state in the rule that updates to the list of SSCTs would be done through guidance published in the **Federal Register** or through updates to the SSCT guidance manual. This process would be consistent with the process already used for listing SSCTs for the currently regulated drinking water contaminants (USEPA 1998g). A similar alternative approach would simply ''list'' SSCTs in Section 141.66 by referencing EPA guidance, which would be published separately and which could be updated periodically as needed outside of the normal rule-making process. Finally, EPA could publish both the initial list and the updates solely in a **Federal Register** notice or as guidance; however, under this last approach, only the promulgated BAT listed in the rule (which would not include SSCTs) would be available for small systems seeking a general variance under Section 1415(a) of the Act. EPA solicits comments on the suggested approaches for the listing of SSCTs and on the equivalency of SSCTs with BAT for the purposes of small systems applying for variances under Section 1415 of the Act.

(d) Small Systems Affordability Determinations. The affordability determinations that are used for listing SSCTs are discussed in detail in recent EPA publications (USEPA 1998i, USEPA 1998e). It should be noted that aeration is one of the least expensive treatment technologies for drinking water (USEPA 1993d, NRC 1997) and has been determined to be affordable for all three small systems size categories. For the smallest size category (serving 25 to 500 persons), EPA cost estimates indicate that typical annual household

costs for aeration (80% removal efficiency, with disinfection and scaling inhibitor) are $190 per household per year ($/HH/yr). For systems installing aeration only, household costs for the smallest system size category are $114 per household per year. Case studies (n=9, USEPA 1999h) for systems with aeration serving between 25 and 500 persons showed annual household costs ranging from $5 to $97 per household per year, with an average of $45 per household per year. Costs reported in these case studies included all pre- and post-treatments added with aeration. The ''national average per household cost'' estimated in the Regulatory Impact Analysis is $260 per household per year for 25–500 persons. This average per household cost is higher than the estimated per household costs for systems using aeration since these average costs include not only aeration, but also the more expensive compliance alternatives (GAC, regionalization, and ''high side'' PTA). Note that the cost for the 25–500 category is a weighted average of the per household costs for the 25–100 and 101–500 categories reported in Table 7–2 of the Regulatory Impact Analysis. Also note that monitoring costs of approximately $4.00 per household per year ($270 per system) are included in the national average per household costs, but not in the aeration treatment per household costs reported.

Granular activated carbon (GAC) may be affordable only for very small flows. EPA's GAC-COST model estimates indicate that GAC may not be affordable for the smallest size category (25–500 persons served) in whole. Annual household costs are estimated to be approximately $800 to > $1000 per household per year. However, case studies of small systems using GAC to remove radon for very small flows (populations served < 100 persons) show annual household costs ranging from $46 to $77 per household per year. The large discrepancy between modeled costs and full-scale case study costs is probably due to the fact that the model design assumptions are more typical of larger systems, whereas the designs used in the case studies are much simpler. The American Water Works Association Research Foundation (AWWARF 1998a) similarly concludes that EPA's cost estimates for radon removal by GAC are over-estimates (ibid., p. 190) and that GAC can be cost competitive with aeration for very small systems (*ibid*., Chapter 8). Examples of estimates of POE-GAC capital costs are shown in the next section, ''Treatment Costs''.

2. Treatment Costs: BAT, Small Systems Compliance Technologies, and Other Treatment

(a) Modeled Treatment Unit Costs. Total production costs associated with the various technological options for radon reduction, such as packed tower aeration and diffused bubble aeration installations, have been examined (USEPA 1999h). For systems that are currently disinfecting, ninety-nine percent reduction of radon by PTA is estimated to cost from $2.48/kgal (dollars per 1,000 gallons treated) for the smallest systems, defined as those serving 100 persons or fewer, to $ 0.12/kgal for large systems, defined as those serving up to 1,000,000 persons. Eighty percent reduction of radon by PTA without disinfection is estimated to range from $2.10/kgal to $0.08/kgal for the same system sizes. For those systems adding disinfection because of the addition of aeration treatment, disinfection treatment costs for very small systems are estimated at an additional $1.40/kgal and costs for large systems are estimated at an additional $0.07/kgal. Aeration production costs have been adjusted to include costs that account for the addition of a chemical stabilizer (orthophosphate) by 25 percent of small systems (those serving 10,000 persons or fewer) and by 15 percent of large systems. In other words, the production costs shown are weighted averages that simulate the installation of aeration without chemical stabilizers by a fraction of the systems and with chemical stabilizers by the remaining fraction. Chemical stabilizers are used to minimize fouling from iron and manganese and/or to reduce corrosivity to the distribution system. Chemical addition cost estimates include capital costs for feed systems and operations and maintenance costs for the processes involved. Table VII.A.3 summarizes total production costs for system size categorizes for 80 percent radon removal. Further details on costing assumptions and breakdown of the unit treatment costs can be found in the RIA (USEPA 1999h).

TABLE VIII.A.3.—TOTAL PRODUCTION COST[1] OF CONTAMINANT REMOVAL BY BAT FOR 80 PERCENT RADON REMOVAL (DOLLARS/1,000 GALLONS, LATE 1997 DOLLARS)

	Population Served					
	25–100	100–500	500–1,000	1,000–3,300	3,300–10,000	>10,000
Aeration[2]	2.06	0.71	0.39	0.22	0.15	0.08–0.10
Aeration + disinfection	3.44	1.09	0.69	0.40	0.22	0.09–0.12
Granular Activated Carbon (GAC)	0.34	2.16	2.16	NA	NA	NA
GAC + disinfection	1.71	2.54	2.46	NA	NA	NA
POE GAC + UV disinfection	16.99	14.03	NA	NA	NA	NA

Notes:

[1] Cost ranges are estimated from cost equations found in the radon Technologies and Costs document (EPA 1999h), as used in the radon HRCCA (64 FR 9559).

[2] Aeration costs are weighted to include chemical inhibitor costs (Fe/Mn and corrosion control) for 25 percent of small systems and 15 percent of large systems.

(b) Case Studies of Treatment Unit Costs. Case studies for aeration and GAC are reported in detail in the radon Technologies and Costs document (USEPA 1999h). Total production costs for aeration case studies ranged from an average of $0.82/kgal for systems serving 25—100 persons (n = 4, standard deviation = $0.32/kgal, average population = 58) to $0.19/kgal for systems serving 100—3,300 persons (n = 11, standard deviation = $0.22/kgal, average population = 873). Total production costs for GAC ranged from $1.50/kgal for systems serving fewer than 100 persons (n = 2, standard deviation = $0.48/kgal, average population = 55) to $0.40/kgal for a system serving approximately 23,000 persons. Production costs for two POE GAC installations ranged from $0.21/

kgal to $0.75/kgal. It should be noted that these POE GAC costs do not include the additional monitoring costs that would apply in a compliance situation. Annual monitoring costs are generally negligible compared to annual treatment costs for centralized treatment (<2.5 percent for very small systems to <1 percent for large systems), and may be significant in the case of POE treatment (USEPA 1998g). For this reason, the POE GAC case study production costs may under-estimate true POE GAC costs. In general, the case studies suggest that EPA's modeled unit costs may be conservative for small systems. Since it is true that the radon case studies are not necessarily a random sample of all systems that will be impacted by the future radon rule, it may be argued that the typical reported costs may differ significantly from the typical costs of compliance. However, the costs of aeration from the radon case studies overlap nicely with the costs reported in the VOCs case studies, which should represent typical costs of compliance. Given this fact and the large number of case studies used, EPA has confidence that the case studies represent a best estimate of costs of treatment for compliance purposes. It should be noted that these reported case study costs are total costs and include all pre- and post-treatments added with the radon treatment process.

(c) Treatment Cost Assumptions and Methodology. The general assumptions used to develop the treatment costs include costs for: chemicals and general maintenance, labor, capital amortized over 20 years at a 7 percent interest rate, equipment housing, associated engineering and construction, land for small systems (design flow < 1 mgd per well), and power and fuel (USEPA 1998h, USEPA 1998g, USEPA 1999h). Costs were updated to December 1997 dollars using a standard construction cost index (Engineering News-Record Construction Cost Index). Process capital costs for aeration technologies were calculated using updated cost equations from the Packed Tower Column Air Stripping Cost Model (USEPA 1993e). Process capital costs for granular activated carbon and total capital costs for iron and manganese sequestration/corrosion control, and disinfection were calculated using standard EPA models (as described in USEPA 1998e and USEPA 1999a). Construction, engineering, land, permitting, and labor costs were estimated based upon recommendations from an expert panel comprised of practicing water design and costing engineers from professional consulting companies, utilities, State and Federal agencies, and public utility regulatory commissions (USEPA 1998i). GAC disposal costs are included in the GAC-COST O&M model. All cost estimates include capital costs for equipment housing and land for small systems (design flows < 1.0 MGD). It was assumed that all treatment installations would include disinfection. Capital and operating & maintenance costs for iron and manganese (Fe/Mn) sequestration by the addition of zinc orthophosphate were included for 25 percent of small systems and 15 percent of large systems. Pre- and post-treatment assumptions are explained in more detail later.

(d) ''Decision Tree''. Compliance costs were estimated assuming that non-compliant water systems would choose from a variety of compliance options, including installing a suitable treatment train, finding an alternate source of water, purchasing water from a near-by water utility, and using best management practices, like blending or ventilated storage. The modeled proportions of systems choosing a compliance pathway (the ''decision tree'') is based on the assumption that systems will choose the most cost-effective alternative, given the fact that site-specific factors (*e.g.*, a well located in a suburban residential area) may force some systems to choose an option that is more expensive than the least cost alternative. The modeled proportions were assumed to vary by system size and water quality. More details on these assumptions are found in the Health Risk Reduction and Cost Analysis supporting this proposal (64 FR 9559).

(e) Iron and Manganese Assumptions. Treatment costs assume that 25 percent of small systems and 15 percent of large systems installing aeration will need to add an additional chemical inhibitor (*e.g.*, orthophosphate, polyphosphates, silicates, *etc.*) to minimize the formation of iron/manganese (Fe/Mn) precipitates and carbonate scale; to reduce bio-fouling from the growth of Fe/Mn oxidizing bacteria (See, *e.g.*, Faust and Aly 1998); and to reduce water corrosivity. Although zinc orthophosphate was assumed to be universally used, this was done as a simplifying costing assumption, and should not interpreted as suggesting that zinc orthophosphate is the appropriate inhibitor choice for all circumstances. Uncertainty analyses were performed in national cost estimates to simulate a range of choices of chemical inhibitors by systems and to simulate a range in the percentages of systems requiring the addition of an inhibitor. It is reiterated that, for the purposes of iron/manganese control and corrosion control, other chemical inhibitors may be more appropriate than zinc orthophosphate on a case by case basis.

(f) Iron and Manganese Occurrence. Tables VIII.A.4 and VIII.A.5 show the estimated co-occurrence of radon with dissolved iron and manganese in raw ground water for various radon and Fe/Mn levels. It can be seen from these tables (based on the U.S. Geological Survey's National Water Information System database, ''NWIS'') that the majority of ground water systems will be expected to have Fe/Mn source water levels below the secondary MCLs (SMCLs) for iron (greater than 85 percent of GW samples have less than the SMCL of 0.3 mg/L) and manganese (greater than 75 percent of GW systems have less than the SMCL of 0.05 mg/L). Since Fe/Mn precipitation inhibitors are appropriate for treating combined Fe/Mn levels up to around 1–2 mg/L (Faust and Aly 1998, USEPA 1999h), this data indicates that the vast majority of ground water systems (greater than 95 percent) will be expected to be in situations where inhibitors are sufficient for handling iron and manganese problems. The cost estimates conservatively assume that inhibitors will also be used by systems with source water below the SMCLs for iron and manganese. Systems with Fe/Mn levels above 1–2 mg/L may require oxidation/filtration or a similar removal technology. However, it should be noted that Fe/Mn levels this high may cause very noticeable nuisance problems, including ''red water'', noticeable turbidity, laundry and sink staining, and interference with the brewing of tea and coffee. It is likely that many systems with source water Fe/Mn levels this high will have already addressed this problem.

TABLE VIII.A.4.— CO-OCCURRENCE OF RADON WITH DISSOLVED IRON IN RAW GROUND WATER[1, 2] (4188 SAMPLES)

Radon (pCi/L)	Dissolved Fe (mg/L) (percent)					
	ND	<0.3	0.3–1.5	1.5–2.5	>2.5	Totals
ND	0.67	0.36	0.21	0.02	0.31	1.57
<100	2.17	1.72	0.53	0.12	0.48	5.02
100–300	7.55	10.20	2.67	1.34	1.74	23.50
300–1,000	18.89	22.61	[3] 3.08	0.57	1.31	46.46
1,000–3,000	6.42	9.05	0.74	0.10	0.62	16.93
>3,000	2.10	3.82	0.31	0.02	0.26	6.51
Totals	37.80	47.76	7.54	2.17	4.72	100.00

Notes:
[1] Based on analyses as described in USEPA 1999c.
[2] The USGS National Water Information System (NWIS) database was used for this analysis.
[3] Shaded area denotes region where radon level is above MCL and dissolved iron is above 0.3 mg/L, the secondary MCL for iron.

TABLE VIII.A.5.—CO-OCCURRENCE OF RADON WITH DISSOLVED MANGANESE IN RAW GROUND WATER [1, 2] (4189 SAMPLES)

Radon (pCi/L)	Dissolved Mn (mg/L) (percent)				
	ND	<0.02	0.02–0.05	>.050	Totals
ND	0.69	0.26	0.05	0.57	1.57
<100	2.67	0.84	0.36	1.15	5.02
100–300	8.00	5.97	2.20	7.33	23.50
300–1,000	21.99	11.84	3.17	[3] 9.48	46.48
1,000–3,000	6.45	5.90	1.24	3.34	16.93
>3,000	1.43	3.39	0.53	1.17	6.52
Totals	41.23	28.20	7.55	23.04	100.00

Notes: [1] and [2]: See Table VIII.A.4.
[3] Shaded area denotes region where radon level is above MCL and dissolved manganese is above 0.05 mg/L, the secondary MCL for manganese.

A similar analysis of the National Inorganic and Radionuclides Survey (NIRS) database, which sampled finished ground water, suggests that greater than 81 percent of GW systems sampled have dissolved Fe/Mn levels less than 0.3 mg/L and greater than 97 percent of systems sampled have levels less than 1.5 mg/L (USEPA 1999h). Table VIII.A.6 compares combined Fe/Mn levels predicted by the NIRS database to occur in finished ground water with levels predicted by NWIS to occur in raw ground water. This table is consistent with expectations that the vast majority of ground water systems will have combined Fe/Mn levels below 1–2 mg/L and that a significant fraction of ground water systems with Fe/Mn levels above the SMCL are already taking measures to reduce Fe/Mn levels.

TABLE VIII.A.6.—CO-OCCURRENCE OF RADON WITH DISSOLVED COMBINED IRON AND MANGANESE IN RAW AND FINISHED GROUND WATER

Ground water type	Percent of samples with dissolved combined Fe and Mn (mg/L) (percent)		Data sources
	<0.3	<1.5	
Finished Ground Water	>81, >93	>97 >99	NIRS,[1] AWWA Water:/ Stats [2]
Raw Ground Water	>85, >71	>95 >88	NWIS,[3] AWWA Water:/Stats

Notes:
[1] ‘‘National Inorganics and Radionuclides Survey’’: See USEPA 1999c for references.
[2] American Water Works Association, ‘‘Water:/Stats, 1996 Survey: Water Quality’’.
[3] USGS, National Water Information System.

An analysis of the American Water Works Association (AWWA) ‘‘Water:/Stats’’ database corroborates these conclusions: average Fe/Mn levels in finished water from 442 ground water systems showed that greater than 93 percent of the systems had combined Fe/Mn levels less than 0.3 mg/L and greater than 99 percent of systems had combined Fe/Mn levels less than 1.5 mg/L (AWWA 1997); average Fe/Mn levels in raw ground water from 433 systems showed that greater than 71 percent of systems had combined Fe/Mn levels less than 0.3 mg/L and greater than 88 percent of systems had Fe/Mn levels less than 1.5 mg/L. While this analysis does support the conclusions from NIRS and NWIS, it should be noted that the AWWA ‘‘Water:/Stats Survey’’ is skewed towards large ground water systems: only 3.4 percent of the systems surveyed serve fewer than 10,000 persons, whereas at the national level, greater than 95 percent of ground water systems serve fewer than 10,000 persons. In comparison, NIRS was designed to be nationally representative of contaminant occurrence in CWSs, while NWIS is a ''data bank'' in which the U.S. Geological Survey stores water contaminant data from its various studies. While the data in NWIS was not collected as part of a designed national survey (and hence can not be claimed to be necessarily nationally representative), it is arguably nationally representative based on its large sample size and its wide distribution of sample collection locations (USEPA 1999c).

(g) Disinfection Assumptions. It was assumed that all systems adding treatment would include disinfection. Since a significant fraction of ground water systems already disinfect, the percentage of systems that would have to add disinfection was estimated from a ''disinfection-in-place baseline'', as described in the Radon Health Risk Reduction and Cost Analysis published on February 26, 1999 (64 FR 9559). It should be noted that this baseline is nationally representative. Some States will, of course, have higher proportions of ground water systems with disinfection-in-place (*e.g.*, those States that require that ground water systems disinfect) and some will have lower proportions. Since the cost estimates being calculated are at the national level, EPA believes that this assumption is valid since this will over-estimate costs for systems in some States and under-estimate costs for systems in other States, with the respective cost errors tending to cancel at the national level. As a simplifying cost assumption, chlorination was assumed for all systems adding disinfection. The actual choice of disinfection technology should, of course, be made on a case by case basis. The fact that many systems will choose disinfection systems other than chlorination and that some systems will not add disinfection at all is captured in the uncertainty analysis, described later in this section.

(h) Comparison of Modeled Costs with Real Costs from Case Studies. Figure VIII.A.1 compares modeled total capital costs against case studies of actual aeration treatment installations for radon and VOCs found in the literature and gathered by EPA. It should be noted that these case studies include all pre- and post-treatments capital costs and costs for land, housing structures, permits, and all other capital added with the aeration process. If EPA's assumptions regarding pre- and post-treatments were seriously flawed, this comparison would demonstrate the fact. As can be seen, EPA's models fit the data fairly well and, in fact, Figure VIII.A.2 shows that the ''typical cost model'' rather closely approximates a power fit through the capital cost data for the larger systems and significantly over-estimates capital costs for small systems.

The ''PTA Cost Model'' represents EPA's best estimate of the costs of constructing and operating a PTA system under the associated design assumptions (steel shell, below-ground concrete clearwell, structure, etc.). This design was intended to be fairly typical of those systems serving more than 500 persons and up to 1,000,000 persons. The ''High Side PTA Cost Model'' represents EPA's best estimate of the costs of constructing and operating a PTA system under the same basic treatment design, but including significantly higher land, structure, and permitting costs. This model was intended to be fairly typical of systems that are ''land-locked'' in suburban or urban areas where land costs, building codes, and permitting demands may be much higher than for typical situations. The ''Low Side PTA Cost Model'' represents EPA's best estimate of the costs of constructing and operating a PTA system using designs more typical of very small systems, including package plant installations. This model is described in the Radon Technologies and Costs Document (USEPA 1999h). As can be seen in Figure VIII.A.1, the PTA Cost and High Side PTA Cost models are representative of the systems with design flows greater than 0.1 MGD. All of these models tend to over-estimate costs for those systems with smaller design flows.

The relative percentages of non-compliant systems modeled by the low-, typical-, and high-side costs are shown in the ''decision tree'' in Table 7–3 of the Regulatory Impact Assessment supporting this proposal. As part of the uncertainty analysis (described later in this section), these decision tree percentages were varied significantly. The results and assumptions are presented in detail in Section 10.8.3 of the Regulatory Impact Assessment. Based on a sensitivity analysis of the relative impacts of all the cost elements studied, the variance in the decision tree percentage values had much less of an impact on national costs compared to the variance in the treatment unit costs ($/kgal).

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Figure VIII.A.1 Total Capital Costs: Aeration Cost Case Studies. (Late 1997 Dollars)

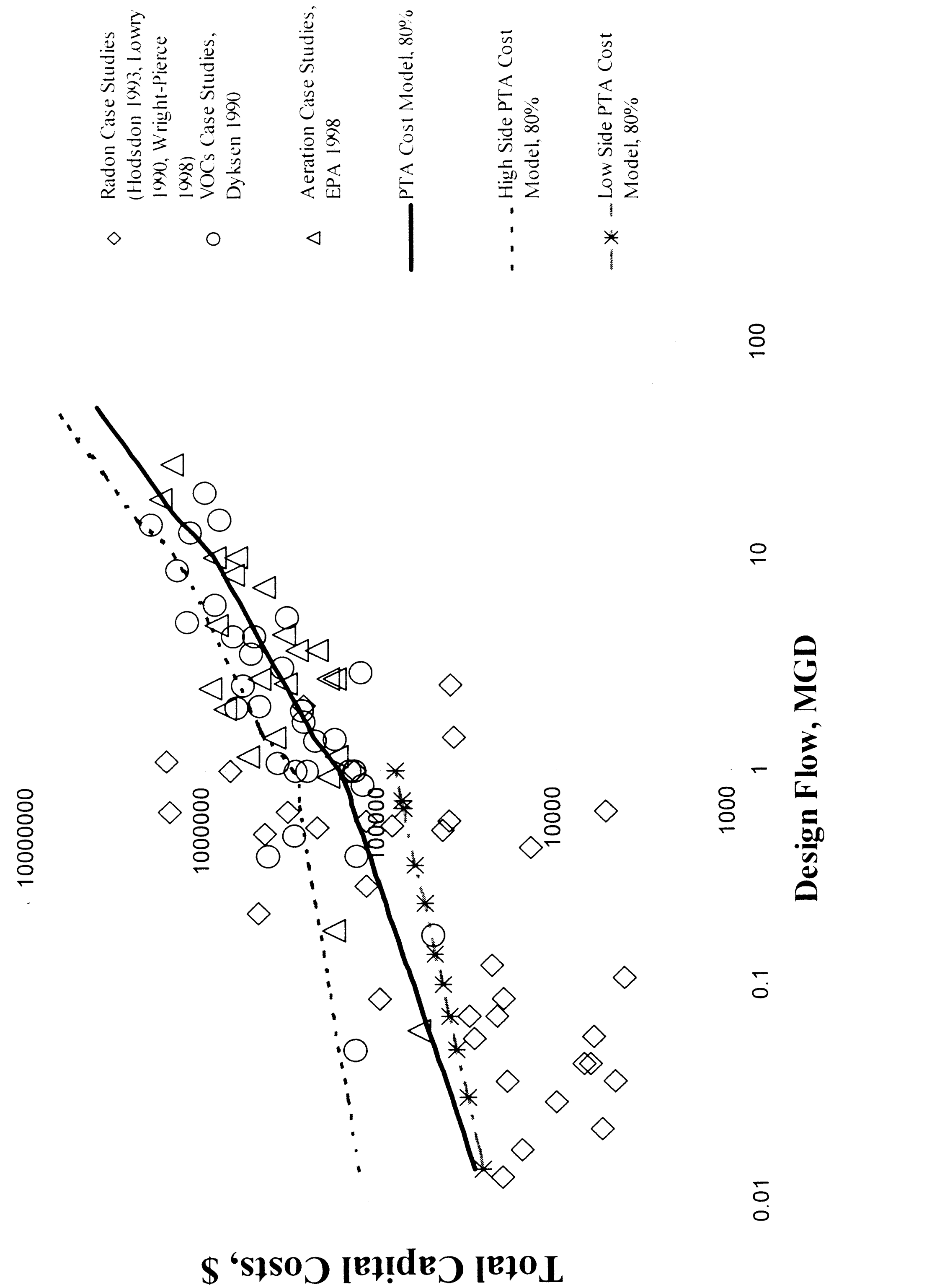

Figure VIII.A.2. Total Capital Costs: Comparison of EPA's Capital Costs Estimates to Literature Estimates. (Late 1997 Dollars)

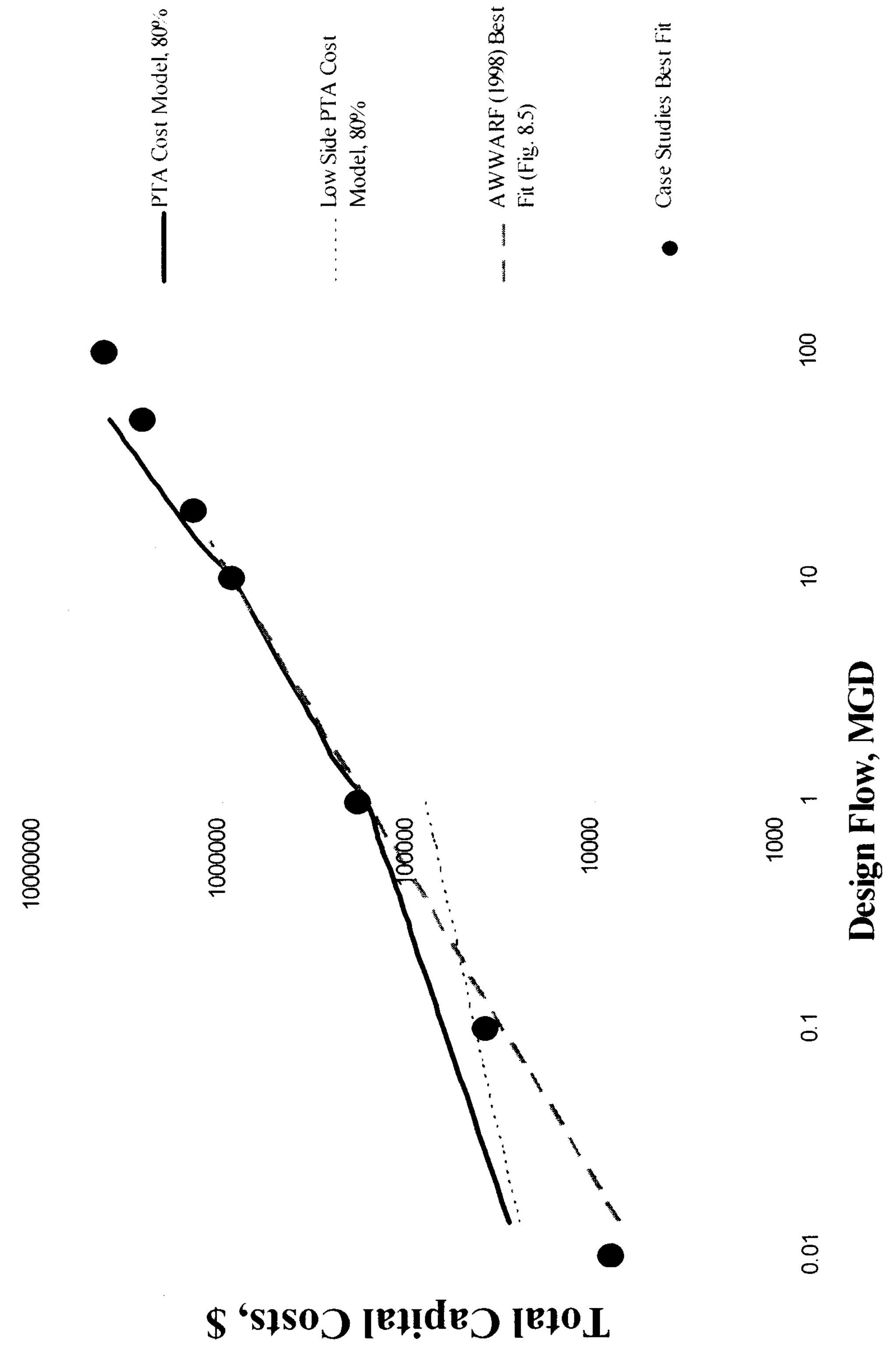

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Figure VIII.A.2 compares the EPA aeration capital cost models against best fits to aeration capital cost case studies from the Radon Technologies and Costs Document (which includes aeration installations for VOCs) and to capital costs for radon case studies as reported by American Water Works Association Research Foundation (AWWARF 1998b). In general, EPA's unit cost estimates are supported by the case studies cited previously and by the findings reported by the AWWARF (AWWARF 1998b).

Figure VIII.A.3 shows that EPA's modeled operations and maintenance (O&M) costs are representative of the case study cost data. It should be noted that EPA is modeling incremental O&M aeration costs (additional O&M costs due to the addition of radon treatment) and that many of the radon case studies and all of the VOCs case studies report total O&M costs, which include O&M costs not related to the removal of radon. For this reason, the case study O&M costs would be expected to be considerably higher than the modeled costs, especially for the larger systems (which tend to have other processes in place that require substantial O&M costs). For example, most of the case studies using disinfection already had disinfection in place before adding aeration for radon. Since it is very difficult to separate the individual components of O&M costs without detailed site-specific information, these disinfection O&M costs are included in the O&M costs shown even though they are not related to treatment added for radon. As described previously, EPA did model O&M costs for disinfection and sequestration for iron and manganese and did include these in its national cost estimates. Figure VIII.A.3 compares modeled O&M costs for aeration with and without disinfection. Modeled O&M costs for iron/manganese stabilization and corrosion control are included through a weighting procedure that simulates 25 percent of small systems and 15 percent of large systems adding a chemical inhibitor. EPA solicits public comment and data on treatment costs and performance for the removal of radon from drinking water.

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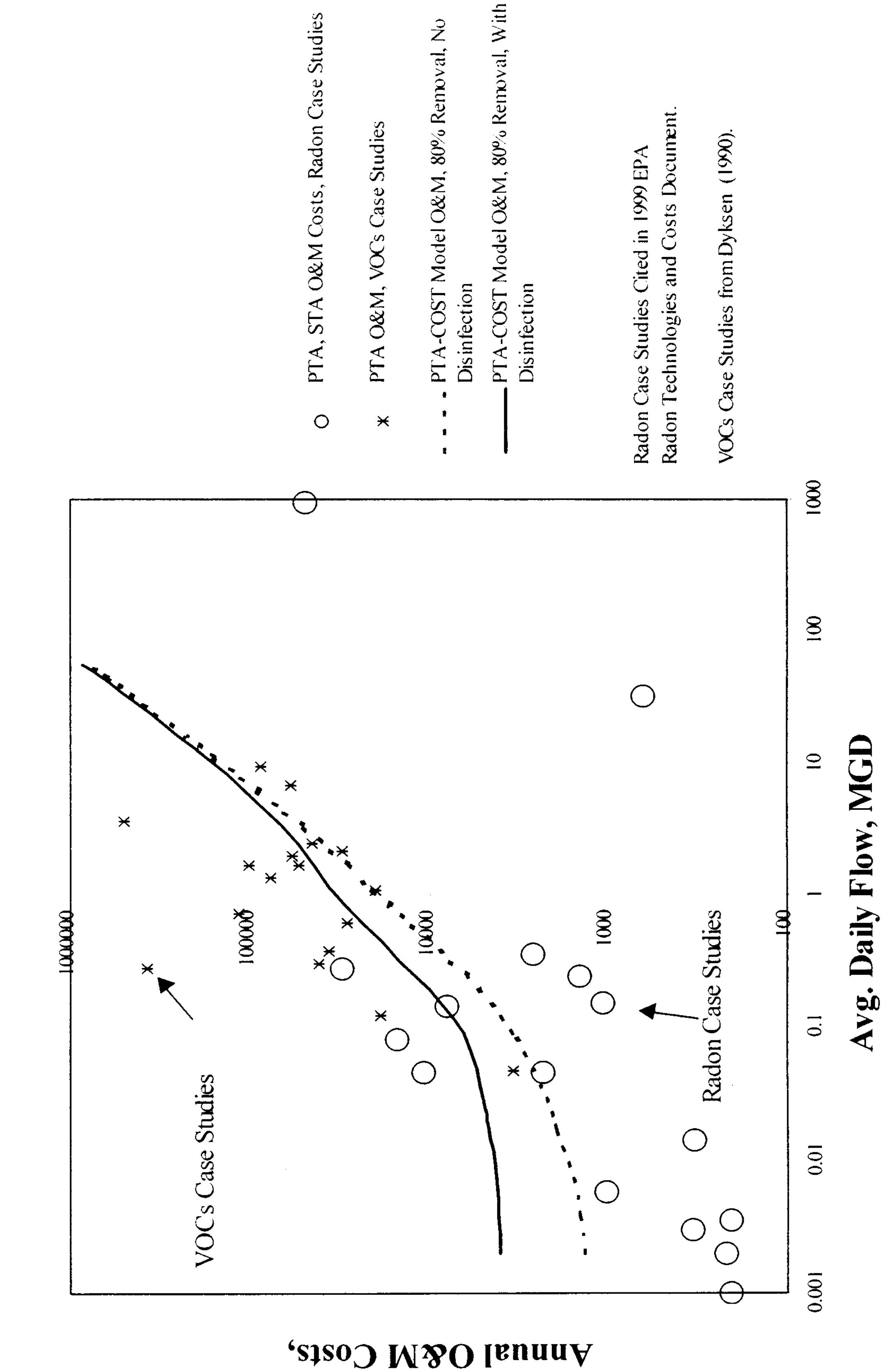
Figure VIII.A.3 Annual O&M Costs: Aeration Cost Case Studies.
(Late 1997 Dollars per Annum)



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Figures VIII.A.4 and VIII.A.5 compare the modeled capital costs and O&M costs for GAC against actual costs reported in case studies (USEPA 1999a, AWWARF 1998b). As can be readily seen, EPA's modeled costs are significantly higher than the actual costs, especially so for very small flows. To account for this discrepancy, EPA used the best fit through the case study data to generate a calibrated GAC model for capital and O&M costs. EPA calculated GAC treatment costs based on this model and did an uncertainty analysis on GAC costs assuming that while the modeled costs were typical, they could be as high as the GAC–COST predictions. This procedure is described in more detail in the radon HRRCA.

EPA also estimated point-of-entry GAC (POE–GAC) costs for very small systems. While capital and standard maintenance costs may be affordable ($100–$350 per household per year), monitoring costs can make POE–GAC much more expensive. EPA estimates (USEPA 1998g) that monitoring costs alone can be as much as $140 per household per year. A ''high end'' estimate for POE–GAC is $1,000 per household per year. If more cost-effective monitoring and maintenance program schemes are devised, these costs may be considerably lower.

In general, treatment costs may vary significantly depending on local circumstances. For example, costs of treatment will be less than shown if contaminant concentration levels encountered in the raw water are lower than those used for the calculations or if an existing clearwell can be retrofitted for aeration. However, costs of treatment will be higher if oxidation/filtration pre-treatment is required for iron and manganese removal or if water must be piped from the well-head to an off-site area for treatment.

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Figure VIII.A.4 Total Capital Costs: GAC Case Studies

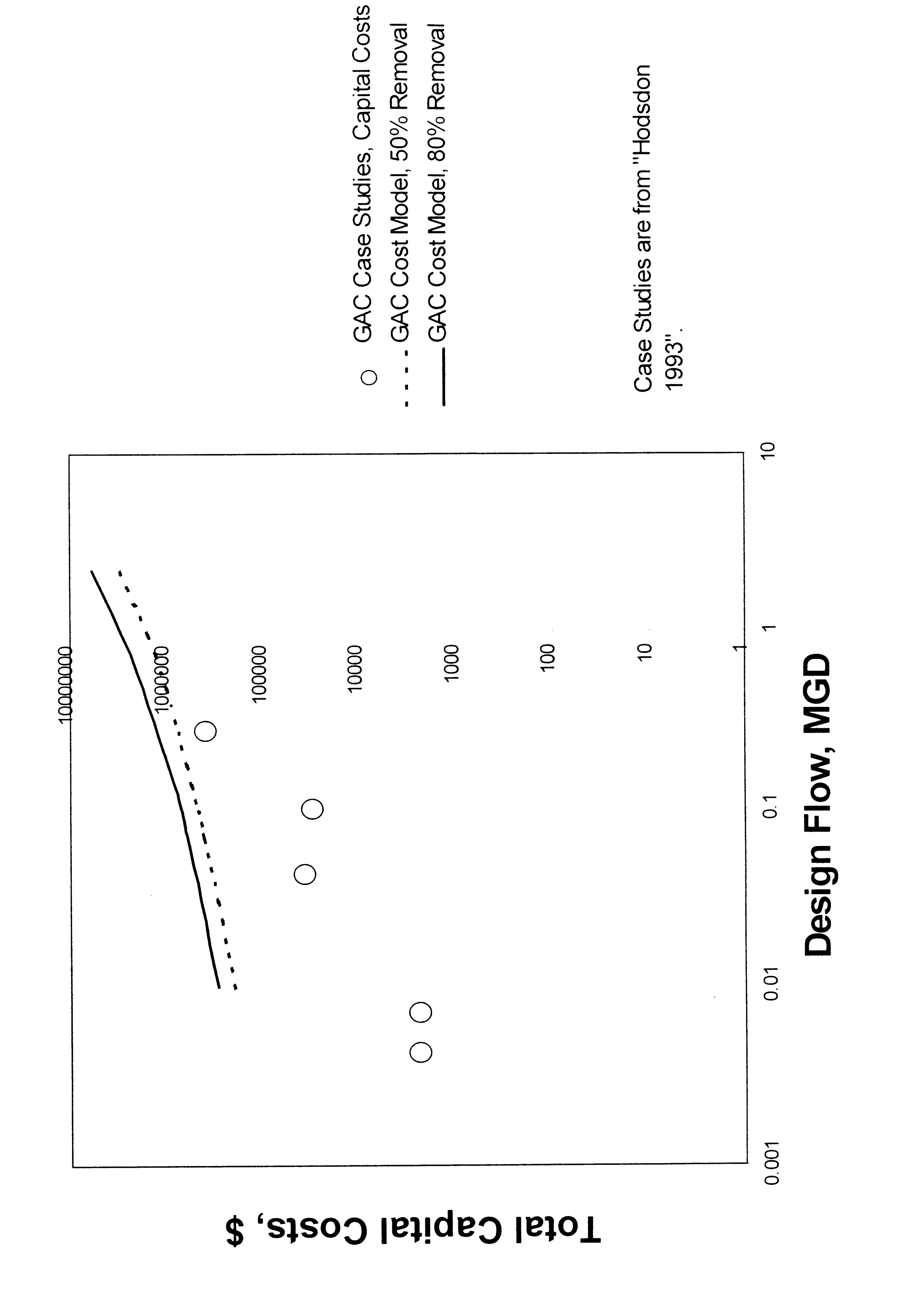
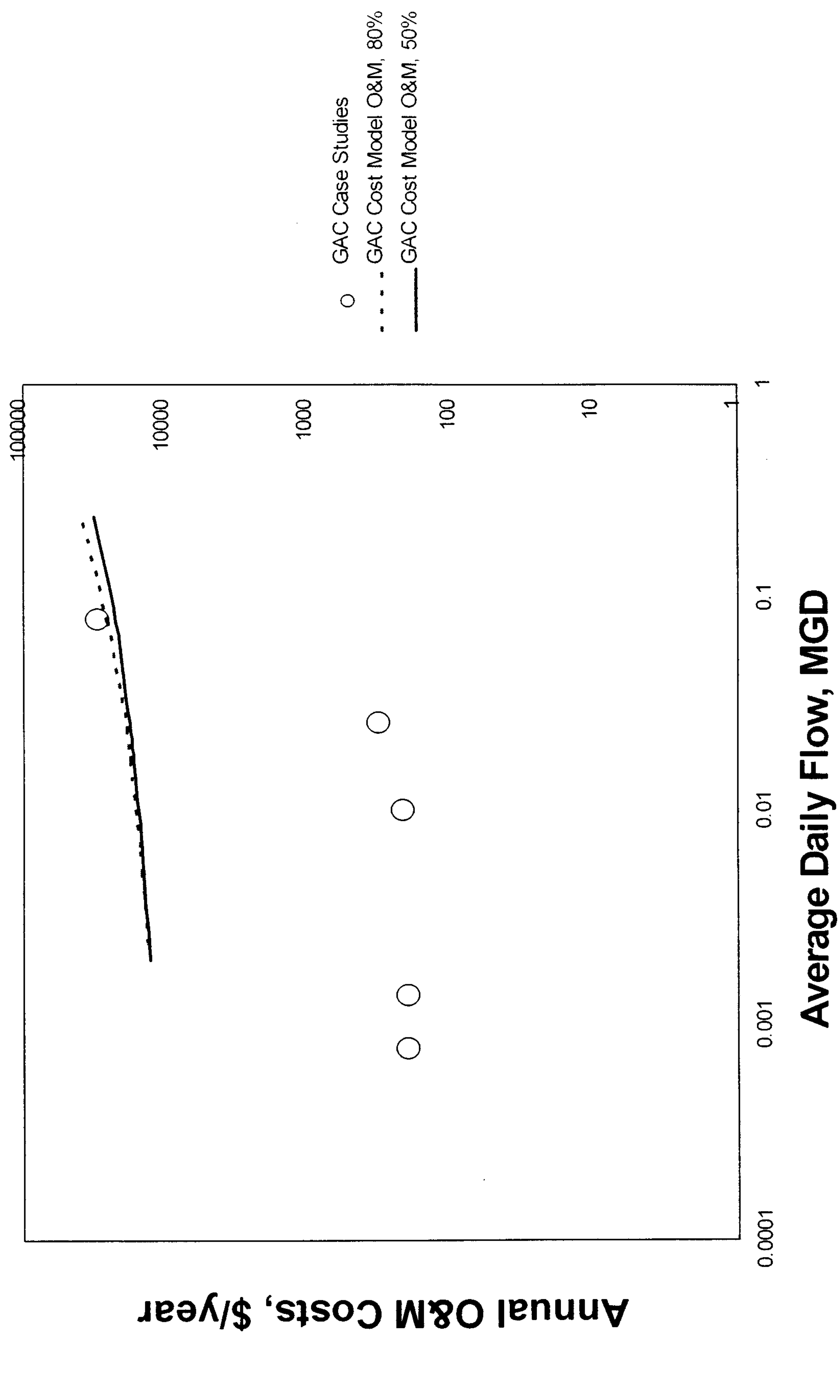


Figure VIII.A.5 Annual O&M Costs: GAC Case Studies



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(i) Uncertainty Analysis for Treatment Costs. To estimate the uncertainty in national treatment costs, EPA estimated credible ranges and distributions of values for the most important factors (inputs) affecting costs. Distributions of selected inputs were then used in a Monte Carlo analysis to explore the uncertainty in national costs. The cost factors that were analyzed include:

- Numbers of systems in the various size categories;
- The distribution of the numbers of sources (wells) per system in each size category;
- Distributions of populations served in each size category;
- Annual household water consumption;
- Proportions of systems and wells exceeding radon limits; and
- Unit costs of radon treatment technologies (aeration and GAC).

Each of these inputs was modeled using probability distributions that reflect the spread in the available data. In some cases, (distributions of populations served, daily household water consumption, unit costs) variability was estimable from SDWIS, the CWSS, or other sources. In the case of the numbers of systems of different sizes, the estimated variability was greatest for the smallest systems, less for the moderate size systems, and the numbers of the largest systems (serving greater than 100,000 customers) was assumed to be known with certainty. The variation in the proportions of systems and sources above radon limits was estimated based on EPA's recent analysis (USEPA 1999l) of inter- and intra-system radon variability in radon levels.

In addition to these inputs, the estimated percentages of systems choosing particular treatment technologies (the ''decision tree'') were allowed to vary as well. Three decision tree matrices were used, corresponding to a central tendency estimate of the proportions of systems choosing specific mitigation technologies, and to lower- and higher-cost distributions of technology selection. When the simulation was run, the central tendency matrix was selected in 80 percent of the iterations, and the low- and high-cost decision matrices were selected in ten percent of the iterations each.

The variability in the estimated mitigation costs was examined using a conservative test case in which all systems above an MCL of 300 pCi/L were assumed to mitigate to comply with the MCL. The results of the analysis are described in detail in the radon Health Risk Reduction and Cost Analysis. In general, the distribution of cost estimates, even with all the variables included in the Monte Carlo analysis, is much narrower than the corresponding distribution of risk and benefit results. For this hypothetical scenario, the fifth percentile cost estimate is $455 million per year, while the 95th percentile estimate is $599 million per year (only 32 percent higher). The compactness in spread in national costs relative to the spread in national benefits is primarily due to the fact that the variability in the individual cost model inputs is low relative to the variability in some of the inputs (*e.g.,* individual risk) to the benefits model.

(j) Potential Interactions Between the Radon Rule and Upcoming and Existing Rules Affecting Ground Water Systems: Aeration and GAC are BAT for more than 25 and 50 currently regulated contaminants, respectively. Both technologies have been well-demonstrated and the secondary effects of each technology are well understood (See, e.g., Cornwell 1990, Umphres and Van Wagner 1986, AWWA 1990). These technologies are also used to remove other contaminants from drinking water, including taste and odor causing compounds. The Community Water System Survey (USEPA 1997a) indicates that 2 to 5 percent of ground water systems serving fewer than 500 persons currently have aeration treatment in place. Of systems serving more than 500 persons, 10–25 percent of these systems have aeration treatment at one or more entry points.

In the case of aeration, these secondary effects include carbon dioxide release (pH increase), oxygen uptake, and potential bacterial density increases, all of which potentially impact other existing and future drinking water regulations that pertain to ground water. In the case of GAC treatment, potential bacterial density increases are of concern. These potential interactions are described in a following section. (Concerns that are specific to radon removal and secondary effects due to other contaminants, *e.g.,* radium and uranium, are discussed in part 3 of this Section.)

(k) Ground Water Rule: Since the treatment techniques applicable to the removal of radon, *i.e.*, aeration, GAC, and/or ventilated storage, may result in increases in microbial activity (NAS 1999b, Spencer et al. 1999), it is important that water systems determine whether post-treatment disinfection is necessary. The ''Ten States Standards'' (GLUMRB 1997) suggest that disinfection should follow ground water exposure to the atmosphere (*e.g.,* aeration or atmospheric storage). The Ten State Standards also suggest that systems using GAC treatment implement ''provisions for a free chlorine residual and adequate contact time in the water following the [GAC] filters and prior to distribution.'' While EPA is not requiring that disinfection be used in conjunction with any treatment for radon, it is including costs for disinfection with treatment in accordance with good engineering practice. Cost assumptions for disinfection, including clearwell sizing for 5–10 minutes of contact time, are consistent with 4-log viral inactivation for ground water, which is expected to be consistent with requirements in the upcoming Ground Water Rule.

It should be noted that air is not a significant pathogen vector and thus aeration does not necessarily increase pathogenic risk for ground water users. However, bacterial activity can increase upon aeration and/or treatment with GAC. In the case of aeration treatment, bacteria that oxidize iron and/or sulfide may proliferate because of the oxygen increase; in the case of GAC treatment, bacteria may proliferate since the GAC surface tends to accumulate organic matter and nutrients that support the bacteria. In either case, heterotrophic plate count limits may become high enough to be of concern and for this reason disinfection may be necessary (USEPA 1999h, NAS 1999b).

(l) Disinfectants and Disinfection Byproducts (D/DBP) Rule: Commonly used disinfection practices for ground water systems include chlorination and, especially for small systems with limited distribution systems, ultraviolet (UV) radiation. Disinfection is used by many ground water systems because it decreases microbial risks from microbial contamination of ground water (NAS 1999b). However, there is a trade-off between a reduction in microbial risks and the risks introduced from disinfection by-products. Various disinfectant by-products (DBPs) can be formed depending on the disinfectant used, the disinfectant concentration and contact time, water temperature, the levels of DBP pre-cursors like natural organic materials and bromide, *etc.* For example, chlorination by-products like trihalomethanes can result from the interaction between chlorine chemical species and naturally occurring organic materials (NOM) and bromate can result from the ozonation of waters with sufficiently high levels of naturally occurring bromide ion.

Ground water systems tend to have significantly lower trihalomethane (THM) organic precursors than surface waters, although this is not always the case. Total organic carbon (TOC) is often used as a surrogate for formation of one important class of DBPs, total trihalomethanes (THM), since the THM formation potential of chlorinated waters correlates with TOC. As reported in the proposed Disinfectants and Disinfection Byproducts Rule (July 29, 1994: 59 FR 38668), a survey of surface waters showed TOC levels at the 25th, 50th, and 75th percentiles of 2.6, 4.0, and 6.0 mg/L, respectively; ground waters showed TOC levels at the same percentiles of ''non-detect'', 0.8, and 1.9 mg/L, respectively. Nationally, typical ground waters have low TOC levels. However, some areas of the U.S., e.g., the Southeastern U.S. (EPA Region 4), have some aquifers with high TOC levels.

One approach for the minimization of DBP formation in drinking water is to employ a disinfectant other than chlorine. Primary disinfection with chloramination, ozonation, or UV radiation are examples. However, other considerations may apply. For example, ozonation of ground water with sufficiently high bromide levels may result in significant levels of the DBP bromate. If a residual is required, it may be necessary to add secondary chlorination to maintain a residual in the distribution system. Other strategies include reducing the precursor concentration prior to chlorination, removal of THMs after their formation, and the installation of a second chlorination point in the distribution system. This last approach allows much lower chlorination levels to be used for primary chlorination, which greatly reduces THM formation.

While these strategies may be employed to minimize the formation of DBPs and, thereby reducing potential DBP risks and avoiding MCL violations for the DBP rule, there are other reasons to expect minimal interactions between the radon rule and the D/DBP rule. Namely, EPA expects that the radon rule will not result in a large percentage of systems adding disinfection because of the need to treat for radon. Since the primary regulatory option for small ground water systems is the MCL/MMM option (MCL = 4000 pCi/L) and less than one percent (1%) of small systems have radon levels that high, EPA does not expect many small systems to add treatment for radon in response to the radon rule, resulting in a very small percentage of small systems adding disinfection. Roughly half of all small systems already half disinfection in place already, further suggesting minimal small system impact from the radon rule. While EPA also expects that many large systems will also adopt the MCL/MMM option, EPA estimates that 95–97 percent of large ground water systems are already disinfecting, and thus would not have to add disinfection if treating for radon. For the expected small minority of systems that do add chlorination disinfection with radon treatment, the trade-off between a reduction in risks from radon exposure to an increase in risk from disinfection by-products will need to be carefully considered by the system installing treatment and strategies to minimize DBP formation should be implemented (NRC 1997, NAS 1999b, Spencer *et al.* 1999).

(m) Lead and Copper Rule: For several reasons, it is expected that few systems already in compliance with the Lead and Copper Rule will experience direct cost impacts because of the Radon Rule. Systems serving fewer than 50,000 persons do not have to modify corrosion control practices if the lead and/or copper contaminant trigger levels are not exceeded. For the reasons explained next, aeration is not expected to result in increased lead and copper levels in the vast majority of cases. While larger systems will have to include radon treatment into their over-all ''optimal corrosion control'' plans as they are updated, aeration tends to reduce or maintain corrosivity levels and should not result in measures beyond those included in the national costs for the proposed radon rule.

Aeration of ground water for radon treatment tends to raise the pH of water (Kinner *et al.* 1990, as cited by NAS 1999b, Spencer *et al.* 1999), since it tends to remove dissolved carbon dioxide, which forms carbonic acid when dissolved in water. In a study of VOCs removal by aeration, the American Water Works Association (AWWA 1990) reported that the net effect of aeration was ''no increase in corrosivity'': The reduction in carbon dioxide levels resulted in higher pH and in increased stability of carbonate minerals that serve to protect distribution systems, negating the corrosive effects of increased oxygen levels. The NAS concludes (NAS 1999b and references cited within Spencer *et al.* 1999) that studies suggest that corrosivity tends to decrease with aeration, but that a minority of systems that aerate may have to add a corrosion inhibitor to stabilize the impacts of the increased oxygen levels. As described previously, EPA has assumed in its national costs that, of the systems that install aeration, 25 percent of small systems and 15 percent of large systems will add chemical inhibitors for the dual purposes of corrosion control and the control of iron and manganese.

(n) Arsenic Rule: It is expected that there will be no significant negative relationships between compliance measures for the Arsenic and Radon Rules. In fact, one of the few expected impacts is beneficial: aeration plus disinfection may serve to pre-oxidize As(III) to the more readily removable As(V) form. However, the benefits estimated in this notice do not reflect this potential benefit.

3. Descriptions of Technologies and Issues

(a) Aeration. Aeration techniques for removal of radon from drinking water include active processes such as diffused bubble aeration (DBA), packed tower aeration (PTA), simple spray aeration, slat tray aeration, and free fall aeration, with or without spray aerators. Passive aeration processes such as free-standing, open air storage of water for reduction of radon may be effective for systems requiring lower removal efficiencies. Additional removal of radon via radioactive decay (into the daughter products of radon) may also occur in storage tanks and in pipelines which distribute drinking water, reducing radon by approximately 10 to 30 percent, within 8 to 30 hour detention periods. Although all of these aeration processes may be effective, depending on site specific conditions, only active aeration processes are considered BAT. Site specific considerations that may influence an individual water system's choice of treatment include source water quality (including concentrations of radon and other contaminants removed or otherwise affected by aeration), institutional or labor constraints, wellhead location, seasonal climate (*e.g.*, temperature), site-specific design factors, and local preferences. Identical treatment designs may achieve different radon removal efficiencies at individual water systems, depending upon these factors. A design for a technology may be altered to increase the radon removal efficiency, *e.g.*, an increase in the technology's air:water ratio (the respective flows of air and water being mixed) may increase the radon removal efficiency to account for local conditions that depress the radon removal efficiency. In some cases, the removal efficiency requirement may be high enough that only high performance aeration technologies (*e.g.*, packed tower aeration) will achieve the desired removals.

High performance aeration technologies, *e.g.*, packed tower aeration (PTA) and package plant aerators with high air:water ratios like shallow tray aeration (STA) or multi-stage bubble aeration (MSBA), provide the most efficient transfer of radon from water to air, with the ability to remove greater than 99 percent of radon from water. A supply which requires a smaller reduction of radon, *e.g.*, 50 percent, could opt to install one of these technologies and treat 50 percent of its source water and subsequently blend the treated with raw water, or it may design a shorter packed tower to achieve compliance with the MCL, both of which are significantly cheaper than treating the entire flow to 99 percent radon removal. Other advantages of high performance aeration include: removal of hydrogen sulfide, carbon dioxide, and VOCs, and oxidation of iron and manganese. Full-scale PTA, STA, and MSBA installations have been constructed for the removal of radon for very small up to medium sized-systems (AWWARF 1998b, USEPA 1999a). In addition to these case studies, full-scale aeration facilities for VOCs removal for medium to large-sized systems have been reported in the literature (AWWA 1990). Since radon is more easily air stripped than most volatile organic compounds, and high performance aeration technologies have been shown to be efficient forms of aeration for VOC removal (Kavanaugh and Trussell 1989, Dyksen *et al.* 1995), these technologies are appropriate as BAT for radon.

Treatment issues regarding aeration have been discussed in the literature (*e.g.*, Dihm and Carr 1988, Kinner et al. 1990b, Dell'Orco et al. 1998, AWWARF 1998b) and by EPA (USEPA 1999d). These issues include the potential for bacteria fouling (*e.g.*, iron/manganese/sulfide oxidizing bacteria), iron and manganese chemical precipitation and scaling, and corrosivity changes. Bacteria fouling and Fe/Mn scaling may clog or otherwise impede operations at an aeration facility, requiring preventative maintenance and/or periodic cleaning. Regarding corrosivity, the aeration process tends to reduce carbon dioxide levels (and raise pH, which tends to decrease corrosivity) and introduce oxygen (which tends to increase corrosivity). Whether or not corrosivity increases or decreases depends on site specific factors. In general, the degree to which these treatment issues may occur depends on the source water quality, ambient water and air temperatures, pre- and post-treatments added or in place, the type of aeration used, and other factors. To account for the cost impacts of dealing with Fe/Mn/carbonate scaling, EPA has included the capital and operation and maintenance costs of pre-treatment with a scalant stabilizer (which also may serve as a corrosion inhibitor, depending upon the type of corrosivity). Pre-/Post-treatment with a disinfectant to control biological fouling and to provide four-log viral deactivation (assuming a five minute contact time at 1.0–1.5 mg/L chlorine) has also been assumed in cost estimates. EPA assumed that those groundwater systems without disinfection already in place will add disinfection when aerating.

The PTA process involves the use of packing materials to create pore spaces that greatly increase the air:water contact time for a given flow of air into water. In counter-current PTA, the water is pumped to the top of the tower, then distributed through the tower with spray nozzles or distribution trays. The water flows downward against a current of air, which is blown from the bottom of the tower by forced or induced draft. The air space at the top of the tower is continually refreshed with ventilators. This design results in continuous and thorough contact of the water with ambient air. The factors that determine the radon removal efficiency are the air:water ratio (the ratio of air blown into the bottom of the tower and the water pumped into the top of the tower), the type and number of packing material, the internal tower dimensions, the water loading rate, the radon level in the influent and in the ambient air, and the water and air temperatures. A typical packed tower aeration installation consists of: (1) the tower: a metal (stainless steel or aluminum), fiber-glass reinforced plastic, or concrete tower with internals consisting of packing material with supports and distributors, (2) a blower or blowers, (3) effluent storage, which is generally provided as a concrete clearwell (airwell) below the tower; very small systems may use metal or plastic storage tanks, and (4) effluent pumping. Pumping into the tower is performed either through modification or replacement of the original well pump.

Commercially available high performance package plant aerators (USEPA 1999a, AWWARF 1998b) include multi-stage bubble aerators (MSBA), shallow tray aerators (STA), and other high air:water ratio designs. MSBA units typically consist of shallow (typically less than 1.5 feet deep) high-density polyethylene tanks partitioned into multiple stages with stainless steel or plastic dividers. Each stage is provided with an aerator, each of which is connected to the air supply manifold. STA units typically consist of one to six stacked tray modules (each 18 to 30 inches deep). Water is pumped through each tray as air is blown through diffusers at the bottom of the tray, creating turbulent mixing of the air and water. These package plant aerators have several distinct advantages: they are low-profile and compact (small footprint), are considered straightforward to install, and are relatively easy to maintain.

Other varieties of active aeration include diffused bubble aeration, which involves the bubbling of air into the water basin (of varying depth and design) via a set of air bubble diffusors. Forms vary from designs with shallow depth tanks containing thousands of diffusers to ''low technology'' designs involving bubbling air into a storage tank via a perforated hose connected to a blower. Some forms of diffused bubble aeration can remove up to 99.9 percent of radon from drinking water; simpler varieties can remove from 80 to > 90 percent of radon. One of the main advantages of diffused bubble aeration is its potential for making use of existing basins for the aeration process, which substantially reduces construction costs. Even if the aeration basin must be newly constructed, this process can be more cost effective than PTA for small systems. The disadvantages of diffused aeration include the requirement for increased contact time, the impracticality of large air-to-water ratios because of air pressure drops, and overall less efficient mass transfer of radon from water. The level of contact between air and water achievable in a packed tower aerator is difficult to obtain in a simple diffused air system (*i.e.*, forms like MSBA can achieve comparable contacts).

The Radon Technology and Cost document (USEPA 1999h) summarizes treatability studies for four diffused bubble aeration installations. One of the case studies involves a full-scale diffused aeration plant in Belstone, England, which provided a long-term radon removal efficiency of 97 percent. This plant (design flow of 2.5 mgd) was designed with an air:water ratio, using 2,800 air diffusers, each designed to supply a maximum of 0.8 cubic feet per minute, and a 24-minute retention time. In a field test of a diffused bubble aeration system, Kinner et al. (1990) report that removals of 90 to 99 percent were achieved at air-to-water ratios of 5 and 15, respectively.

Spray aerators direct water upward, vertically, or at an angle, dispersing the water into small droplets, which provide a large air:water interfacial area for radon volatilization. In single pass mode, depending upon the air:water ratio, removal efficiencies of >50 to >85 percent can be achieved. In multiple pass mode, 99 percent removals can be achieved. Most of the advantages cited previously for diffused aeration also apply to spray aeration. Disadvantages include the need for a large operating area and operating problems during cold weather months when the temperature is below the freezing point. Costs associated with this option (for all sizes of water treatment plants) have not been developed by EPA, but case studies (USEPA 1999a, AWWARF 1998b) indicate that it is cost-competitive with other small systems aeration technologies.

EPA has evaluated other, less technology-intensive (''low-technology''), options which may be suitable for small water systems, and which may cost less than the options described previously to install and operate (Kinner et al. 1990b, USEPA 1999a, AWWARF 1998b). These options include: atmospheric storage, free fall with nozzle-type aerator, bubble aerators, blending, and slat tray aerators. Limited data concerning these low-technology alternatives are reviewed in USEPA 1999a and AWWARF 1998b. Case studies show that atmospheric storage with a detention time of nine hours resulted in removals of 7–13 percent and a detention time of 30 hours in removals of around 35 percent. Dixon and Lee (1987) report that blending 6.34 MG of well water with a radon level of 1079 pCi/L with 18.34 MG of surface water resulted in effluent water with 226 pCi/L. Other storage case studies (detention times ranging from 8 to 23 hours) show that free-fall into a tank, free-fall with simple bubble aeration, simple spray aeration with free-fall, and simple bubble aeration remove 50–70 percent, 85–95 percent, 60–70 percent, and 80–95 percent of radon, respectively. More detail on an example will illustrate the simplicity of the treatment involved: the case study for ''free-fall with simple bubble aeration'' cited previously involved the introduction of water through two feet of free fall into a tank equipped with garden hose (punctured) bubble aerators, where the air was supplied by a laboratory air pump. Kinner et al. (1990b) concluded that very effective radon reduction can be achieved by simple aeration technologies that may be easily applied in small communities.

(i) *Evaluation of Radon Off-Gas Emissions Risks.* Since this notice contains a proposal to reduce radon concentrations in drinking water by setting an MCL, and the EPA is proposing aeration as BAT for meeting the MCL, the Agency undertook an evaluation of risks associated with potential air emissions of radon from water treatment facilities due to aeration of drinking water. In the first evaluation (USEPA 1988a, 1993a), EPA used radon data from 20 drinking water systems in the U.S. which, according to the Nationwide Radon Survey (1985), contained the highest levels of radon in drinking water and affected the largest populations and/or drinking water communities. EPA estimated the potential annual emissions (in pCi radon/yr) from these facilities, assuming 100 percent radon removal.

These radon emissions estimates were used as inputs to the AIRDOS-EPA model, which is a dispersion model that can be used to estimate the concentration of radon at a point some distance from the point source (*e.g.*, a packed tower vent). This model is the predecessor to the newer CAP–88–PC model, which combined AIRDOS with the DARTAB model, which estimates the total lifetime risk to individuals and the total health impact for populations. The underlying physical models in CAP–88 are essentially the same as those underlying AIRDOS and DARTAB (USEPA 1992c). In fact, the main differences between CAP–88–PC model and its predecessors is that CAP–88–PC is intended for wide-spread use in a personal computer environment (the CAP–88–PC model and its supporting documentation can be downloaded from the EPA homepage, http://www.epa.gov/rpdweb00/assessment/cap88.html). EPA has made comparisons between the AIRDOS-EPA dispersion model results and actual annual-average ground-level concentrations and found very good agreement. EPA has studied the validity of AIRDOS-EPA and concluded that its predictions are within a factor of two within actual average ground-level concentrations, the results of which are as good as any existing comparable model (USEPA 1992c).

Estimates of ground-level radon exposure were made for the following parameters: air dispersion of radioactive emissions, including radon and progeny isotopes of radon decay; concentrations in the air and on the ground; amounts of radionuclides taken into the body via inhalation of air and ingestion of meat, milk, and fresh vegetables, dose rates to organs and estimates of fatal cancers to exposed persons within a 50 kilometer radius of the water treatment facilities. Estimates of individual risk and numbers of annual cancer cases were completed for each of the 20 water systems, as well as a crude estimate of U.S. risks (total national risks) based on a projection of results obtained for the 20 water systems. These estimates were based on exposure analyses on a limited number of model plants, located in urban, suburban and rural settings, which were scaled to evaluate a number of facilities. (A similar approach has been used by the Agency in assessing risks associated with dispersion of coal and oil combustion products.) The risk assessment results for the 20 systems indicate the following: a highest maximum lifetime risk of 2×10^{-5} for individuals within 50 km of one of these systems, with a maximum incidence at the same location of 0.003 cancer cases per year; an estimate of annual cancer cases for all 20 systems of 0.0038 per year; and a crude U.S. estimate of 0.09 fatal cancer cases/year due to air emissions if all drinking water supplies are treated by aeration to meet an MCL of 300 pCi/L. Two other cases were evaluated: (1) Assuming that small drinking water systems are treated by aeration to meet the MCL/MMM option of 4000 pCi/L and large systems are treated to meet the MCL of 300 pCi/L, the best estimate of total national fatal cancer cases per year due to radon off-gas emissions is 0.04 cases/year, and (2) Assuming that all systems treat by aeration to meet the (A)MCL/MMM option of 4000 pCi/L , the best estimate is 0.01 cases/year. These results of the risk assessment for potential radon emissions from drinking water facilities are summarized in Table VIII.A.7. For all MCL options shown, the maximum lifetime individual risks from radon off-gas are much smaller (100 to 70,000 times smaller) than the average lifetime individual risks from the untreated water. Regarding national population risks (fatal cancer cases per year), the estimated population risk from radon off-gas is 850 to 17,000 times smaller than the estimated population risk from the untreated water.

TABLE VIII.A.7.—ESTIMATES OF RISKS AT 20 SITES DUE TO POTENTIAL RADON EMISSIONS FROM AERATION UNITS AND CRUDE PROJECTION OF TOTAL U.S. RISK [1]

Modeling scenario	Concentration in water (pCi/L)	Emissions from facility (Ci Rn/Yr)	Maximum lifetime individual risk [2]	Population risk [2] (fatal cancer cases per year)
20 Facilities Modeled:				
1	1,839	2.79	3×10^{-7}	7×10^{-5}
2	5,003	6.22	6×10^{-7}	2×10^{-4}
3	2,175	2.85	3×10^{-7}	9×10^{-5}
4	1,890	20.89	6×10^{-6}	1×10^{-4}
5	1,310	1.81	5×10^{-7}	9×10^{-7}
6	1,329	91.80	9×10^{-6}	1×10^{-3}
7	4,085	2.26	2×10^{-7}	3×10^{-5}
8	10,640	1.18	1×10^{-7}	1×10^{-5}
9	3,083	0.55	5×10^{-8}	7×10^{-6}
10	3,270	9.04	2×10^{-5}	1×10^{-3}
11	2,565	3.54	7×10^{-6}	6×10^{-4}
12	4,092	13.75	2×10^{-7}	3×10^{-5}
13	16,135	2.23	2×10^{-7}	3×10^{-5}
14	3,882	0.27	8×10^{-8}	5×10^{-6}
15	1,244	1.03	3×10^{-7}	2×10^{-5}
16	2,437	1.35	4×10^{-7}	5×10^{-7}
17	996	8.94	9×10^{-7}	2×10^{-4}
18	7,890	0.87	3×10^{-7}	6×10^{-6}
19	9,195	1.02	3×10^{-7}	1×10^{-5}
20	7,500	1.04	3×10^{-7}	6×10^{-6}
Totals for All 20 Facilities		161		0.004
Totals Assuming All U.S. Community Water Systems Treat to 300 pCi/L [3], i.e., All Systems Meet MCL of 300 pCi/L.		3700		0.09
Totals Assuming All Small U.S. Drinking Water Facilities Treat to 4000 pCi/L [3] and All Large U.S. Drinking Water Treat to 300 pCi/L, i.e., All Small Systems Meet MCL of 4000 pCi/L and All Large Systems: meet MCL of 300 pCi/L.		1600		0.04
Totals Assuming All U.S. Drinking Water Facilities Treat to 4000 pCi/L [3], i.e., All Systems meet MCL of 4000 pCi/L.		240		0.01

Notes:

[1] Estimates of Risk Assessment Using AIRDOS–EPA to estimate radon exposure. The total U.S. risk is based on the very conservative projection that all CWSs will treat to 200 pCi/L, USEPA 1993b.

[2] Risks are based on the National Academy of Science's lifetime fatal cancer unit risk or radon in drinking water of 6.7 x 10^{-7}.

[3] USEPA 1999j.

A second ''worst case'' evaluation was performed using four scenarios with high radon influent levels (ranging from 1,323 pCi/L to 110,000 pCi/L) and/or high flows to further determine whether individuals living near water treatment plants would experience significant increases in cancer risks due to radon off-gas emissions. For this analysis, the MINEDOSE model was used in conjunction with radon emissions estimates to estimate lifetime fatal cancer risks for individuals living near the modeled facility. Emissions were estimated using MINDOSE 1.0 (1989), a predecessor to COMPLY–R (1.2), which can be downloaded from the EPA homepage (http://www.epa.gov/rpdweb00/assessment/comply.html). Comply–R (1.2, radon-specific) is intended for demonstrating compliance with the National Emissions Standards for Hazardous Air Pollutants (NESHAPS) in 40 CFR 61, Subpart B, which are the Federal standards for radon emissions from underground uranium mines. While these standards do not apply to drinking water facilities, the model can be used to estimate radon exposures from aeration vents at drinking water facilities. To check for consistency between MINEDOSE and COMPLY–R, several modeling scenarios done in the original analysis with MINEDOSE were repeated using COMPLY–R and the results from MINEDOSE were found to be conservative with respect to the COMPLY-R results, *i.e.*, COMPLY–R predicts lower exposures for the scenarios modeled. The MINEDOSE code was originally used instead of the AIRDOS code because of its relative ease of use. When modeling the same scenarios with MINEDOSE and AIRDOS, the predicted exposures were determined to be similar enough to warrant the use of MINEDOSE for this work. The results from the MINEDOSE modeling work and subsequent work (USEPA 1994a) concluded that even these ''worst case maximum individual risks'' from radon off-gas were much smaller (300 to 1,000 times smaller) than the average individual risks posed by the untreated water.

(ii) Permitting of Radon Off-Gas from Drinking Water Facilities. Radon emissions to ambient air are only Federally regulated under 40 CFR 61,

National Emission Standards for Hazardous Air Pollutants (NESHAPs). These regulations apply to radon emissions under very specific circumstances, including emissions of radon to ambient air from uranium mine tailings, phosphogypsum stacks (40 CFR 61, Subpart R), Department of Energy storage and disposal facilities for radium-containing materials (40 CFR 61, Subpart Q), and underground uranium mines (40 CFR 61, Subpart B). At present, there are no State or Federal regulations that directly apply to radon air emissions from water treatment facilities.

To assess potential procedures (*e.g.,* permit applications, off-gas risk modeling) and costs that could be associated with radon off-gas from aeration facilities, EPA gathered information from agencies responsible for air permitting (USEPA 1999h), using California as a case study. California air permitting requirements are expected to be more restrictive than most States, and for this reason, it is considered a conservative case study. The information gathered is not expected to be nationally representative, but is illustrative as a ''worst case scenario''.

EPA contacted representatives from nine air districts in California via telephone to determine the likely response of their district to promulgation of a radon rule with an associated radon MCL requirement (USEPA 1999h). The air boards were chosen to represent large, metropolitan areas, medium-sized cities, and smaller, more rural areas. The representatives responded to the following questions:

- What is the likely response of your permitting board to water systems installing aeration treatment to comply with the radon rule?
- What are the likely permitting procedures and costs for water systems installing aeration for radon? Who would be responsible, the permitting board or the water system, for carrying out each procedure and paying the costs?
- Will large water systems and small water systems follow different procedures, or are procedures uniform regardless of water system size (*e.g.,* off-gas volume)? How do permitting costs change with the applicant's system size?
- Will water systems be required to perform off-gas risk modeling as part of the permitting procedure or will they be required to do other environmental impact analyses?
- Would there be annual renewal procedures (*e.g.,* reapplication, compliance monitoring) and costs? Who would be responsible for carrying our the procedures and bearing the costs?
- Is ongoing monitoring likely to be required?

Where possible, representatives provided estimates of time and cost that could be incurred by water systems and the districts as a result of the potential district response to the radon rule.

Responses to these questions indicated that the likely response to a radon rule is similar across the California air districts contacted. Most districts indicated they are likely to follow the lead of the State. ''Following the State's lead'' means that, if the State includes radon on its Toxic Air Contaminants List and establishes potency factors (unit risk factors and expected exposure levels for radon), air districts will probably regulate drinking water system aeration facilities through permits. Permitting procedures are similar across air districts and generally do not vary for facilities of different sizes. However, permitting costs and who bears those costs can vary significantly from air district to air district. Some portion of the costs are likely to vary based on facility size or emissions level.

Currently, ''radionuclides'' (which includes radon) are on the Toxic Air Contaminant Identification List developed by the California Air Resources Board. Listed contaminants are categorized by priority, and depending on what category a substance is in, the substance may or may not have ''potency factors'' developed by California's Office of Environmental Hazard Health Assessment (OEHHA). At the present time, radon is ''Category 4A'', which means that OEHHA is *not* currently planning on publishing values for the radon unit risk factor and reference exposure level, indicating that air boards are not likely to require permitting for radon off-gas at the present time. However, radon has been proposed for elevation in priority to ''Category 3'', which means that it could be a candidate for the development potency numbers in the future. Since California air quality districts generally follow the lead of OEHHA, if OEHHA publishes a unit risk factor and reference exposure level for radon in the future, air districts are then likely to evaluate whether radon should be considered in their air permitting programs. If OEHHA decides not to establish potency factors for radon, California air districts are not likely to require permitting for radon off-gas from drinking water treatment plants.

Respondents indicated that typical permitting procedures were: a system applies for a permit to construct; the board evaluates the application and decides whether or not to issue a permit; a permit may then be issued, after which the system may construct the aerator; the District conducts an inspection and the system may or may not have to perform testing; a public notice is issued if required by risk level and proximity of schools; the District issues a permit to operate; system must annually renew the permit (no monitoring or inspection likely). It is likely that water systems in the more densely populated, Metropolitan areas are more likely to need to do a risk assessment and perform modeling as part of their permit application. Permitting costs ranged from < $500 for simple permitting up to $50,000 for more complicated situations, with typical permitting costs reported in the $1,000 to $5,000 range. These costs do not include any radon dispersion controls or other engineering controls that might be required for the permit.

(b) Centralized Liquid Phase Granular Activated Carbon (GAC) and Point-of-Entry GAC. GAC removes radon from water via sorption. ''Downflow'' designs are used, in which the raw water is introduced at the top of the carbon bed and flows under pressure downwards through the bed. The treated water may then be disinfected or otherwise post-treated and piped to the distribution system. Advantages to the use of GAC relative to aeration include the lack of a need to break pressure (and hence re-pump), the lack of radon off-gas emissions, and, in very small systems applications with good water quality, GAC typically has no moving parts and requires little maintenance. Details regarding the process of radon removal via GAC are provided elsewhere (USEPA 1999h, AWWARF 1998a,b). This discussion will focus on potential issues that small water systems may face if they choose GAC for radon removal. Of these, raw water quality is of paramount concern since it affects radon removal efficiency, unit lifetime, and the potential for secondary radiation hazards. Radon, iron, uranium, and radium levels are most important.

(i) Radon Influent Levels for POE GAC: Gamma Radiation Hazards. An upper limit of 5,000 pCi/L of radon in influent water being treated by POE GAC is suggested by Rydell et al. (1989) and Kinner et al. (1990b) to protect persons in frequent proximity to the carbon bed (*i.e.,* residents) from gamma ray exposures. This influent level is based on a residential exposure limit of 170 mRem/year, or 0.058 mR/hour based on 8 hours/day of maximum exposure, 365 days per year. The 170 mRem/year limit was established by the National Council on Radiation

Protection Bulletin (cited by Rydell et al. 1989). Note that this residential exposure limit is less conservative than the EPA recommended limit of 100 mRem/year for water treatment plant personnel. However, the assumption of 8 hours/day of maximum proximity is extremely conservative. The 100 mRem/year limit is achieved if a person gets maximum exposure for approximately 5 hours per day or less, 365 days per year, which is still a conservative assumption.

Rydell *et al.* determined this influent limit based on an empirical and theoretical relationship between radon influent level and gamma ray emissions from the carbon bed. As will be discussed next, based on recent work using improved gamma ray detection methodology, Hess *et al.* (1998) report that this limit may be too low by a factor of 2, *i.e.*, the suggested radon influent limit may be closer to 10,000 pCi/L. Note that these limits are based on assumptions about GAC contact basin configurations, type and extent of shielding, length of time and proximity of persons to the unit, *etc.* While the ''rules-of-thumb'' described previously are useful, appropriate radon influent limits may be higher or lower depending upon site-specific considerations and should be determined on a case-by-case basis.

The University of Maine reported results on the removal of radon from drinking water using GAC (Hess *et al.* 1998). Nine carbon beds (all in Maine), which had been in use for more than 10 years by public water systems and private homes for radon removal, were studied. Radon influent levels ranged from 330 to 107,000 pCi/L, with a mean of 24,500 pCi/L and a standard deviation of 11,800 pCi/L. Gamma ray emissions from the GAC units and accumulated radon progeny, uranium, and radium were analyzed. Gamma ray emissions from the GAC surface ranged from 11.5 uR/h to 301 uR/h, with a mean of 78 uR/h and a standard deviation of 82 uR/h, and were 2 to 4 times lower than predicted by theory. The authors concluded that the limit of 5,000 pCi/L suggested by Rydell *et al.* (1989) may be too low by a factor of 2 or more.

(ii) Radon Influent Levels for Centralized GAC: Gamma Radiation Hazards. Using the very conservative assumption that a water treatment operator will be in close proximity for 40 hours per week, the 100 mRem/year translates to around 0.05 mR/hour, which also corresponds to a maximum of 5,000–10,000 pCi/L of radon for small flows. However, since GAC is likely to be used only by very small water systems and does not involve intensive O&M, much shorter work weeks are likely. Using 10 hours/week, the maximum radon influent level would be higher. Again, these are ''rule-of-thumb'' suggestions only. The best means to ensure that 100 mRem/year maximum exposure limits are maintained is to implement appropriate monitoring of gamma levels in the treatment facility and to ensure that proper shielding and worker proximity restraints are engineered to minimize exposures.

(iii) Other Water Quality Considerations: Naturally-Occurring Iron and Dissolved Organic Materials. The adsorption of iron precipitates can reduce a unit's radon removal efficiency, so that the raw water may need to be pre-treated to stabilize and/or remove the dissolved iron. The American Water Works Association Research Foundation (AWWARF 1998a,b) reports that waters with low iron and low levels of naturally occurring organic matter (''total organic carbon'', TOC) can achieve good radon steady-state removals (*i.e.*, radon sorption equals radon decay), but that the negative effects of iron and TOC on removal efficiencies may necessitate pilot testing to ensure proper contactor design. For raw water with high iron and/or TOC, pre-filtration or pre-oxidation/filtration may be required to achieve good steady-state removals.

(iv) Other Water Quality Considerations: Naturally-Occurring Uranium and Radium: Uranium and radium raw water levels are also of concern since sorption may occur onto the GAC surface, which results in uranium and radium occurrence in the GAC filter backwash residuals and ultimately may create a final GAC bed disposal problem. Water quality (pH, iron levels, natural organic matter levels, alkalinity, *etc.*) determine the extent to which uranium and radium sorb to the GAC surface. AWWARF (1998b) reported results from case studies conducted over a two year period in New Hampshire, New Jersey, and Colorado, including findings regarding loadings of uranium and radium on the GAC surface and respective levels in backwash residuals. Radon influent levels were 15,000–17,000 pCi/L, 2,220 pCi/L, and <7,500 pCi/L at the New Hampshire, New Jersey, and Colorado sites, respectively. In the New Hampshire pilot study, backwash residuals contained ~200 pCi/g uranium and ~50 to 60 pCi/g radium. For water treatment residuals with uranium levels between 75 and 750 pCi/g, EPA suggests that disposal measures be determined on a case-by-case basis (USEPA 1994b). In general, disposal in a controlled landfill environment may be necessary. The GAC bed itself accumulated less than the limit of 75 pCi/g for all but one of the five GAC columns in New Hampshire. For the New Jersey and Colorado pilot plants, uranium, radium, and radon progeny levels were low enough in the backwash residuals and the GAC bed that special disposal considerations were not an issue. It should be noted that State disposal restrictions may be more stringent than EPA's suggestions, which may make GAC a less attractive alternative in these States.

(v) GAC Disposal Issues. Radon progeny (*e.g.*, Pb–210, a beta emitter) accumulation is also related to radon influent level. If radon influent levels are high, the GAC unit lifetime may decrease significantly, where this lifetime is defined as the length of time between start-up and when an unacceptable accumulation of radioactive Pb–210 occurs. While no Federal agency currently has the legislative authority to regulate the disposal of wastes generated by water treatment facilities on the basis of naturally occurring radioactive materials (NORM), EPA (USEPA 1994b) suggests that NORM solid wastes with radioactivity above 2,000 pCi/g be disposed of in appropriate low-level radioactive waste facilities. Furthermore, given the prohibitive expense and burden of disposing of low-level radioactive waste, EPA would suggest that water treatment facilities avoid situations where such high waste levels would expected to potentially occur. In the case of wastes containing Pb–210, EPA suggests that case-by-case determinations be made for determining appropriate disposal. In summary, for higher radon influent levels, shorter bed lifetimes may be appropriate to reduce Pb–210 build-up.

Hess *et al.* (1998), cited previously, also studied several methods of cleaning the GAC bed by removing Pb–210 and radium from the spent GAC with various chemical cleaning solutions (*e.g.*, solutions of hydrochloric acid, nitric acid, sodium hydroxide, *etc.*). Disposal of the cleaned GAC and the much smaller volume of concentrated radon progeny and radium is expected to be cheaper in some cases than disposal of the contaminated GAC bed to a controlled disposal-facility. The authors concluded that several of the cleaning solutions (hydrochloric acid at 1 mole/liter, nitric acid at 0.5 mole/liter, and acetic acid 0.5 mole/liter in quantities of 150 mL solution per 100 grams of carbon) show promise. Precipitates on the GAC surface (including iron oxides, sorbed radium and radon progeny, including Pb–210) were effectively removed. Removal efficiencies for Pb–210 ranged from 30 percent to 70 percent and radium removals from 70 to 90 percent. This work indicates that a viable system of collecting and cleaning spent GAC material may be feasible, potentially making GAC a more attractive small systems alternative. Work supporting programs of this type deserves further consideration.

(vi) The American Water Works Association Research Foundation Report on Radon Removal Using GAC. The American Water Works Association Research Foundation (AWWARF 1998a,b) has recently reported on radon removal by GAC. AWWARF suggests that water systems with design flows below 70 gallons per minute may want to evaluate GAC and POE GAC as potential radon removal technologies (AWWARF 1999a), but warns that they appear to be attractive technologies only for very small systems with radon influent levels below 5,000 pCi/L, iron and manganese levels low enough not to warrant pre-treatment, and uranium and radium levels low enough not to accumulate to levels of concern on the GAC bed (USEPA 1994b). These findings are generally consistent with EPA's findings.

B. Analytical Methods

1. Background

The SDWA directs EPA to set a contaminant's MCL as close to its MCLG as is ''feasible'', the definition of which includes an evaluation of the feasibility of performing chemical analysis of the contaminant at standard drinking water laboratories. Specifically, SDWA directs EPA to determine that it is economically and technologically feasible to ascertain the level of the contaminant being regulated in water in public water systems (Section 1401(1)(C)(i)). NPDWRs are also to contain ''criteria and procedures to assure a supply of drinking water which dependably complies with such [MCLs]; including accepted methods for quality control and testing procedures to insure compliance with such levels. * * *'' (Section 1401(1)(D)).

To comply with these requirements, EPA considers method performance under relevant laboratory conditions, their likely prevalence in certified drinking water laboratories, and the associated analytical costs. A critical part of the method performance evaluation involves an analysis of inter-laboratory collaborative study data. This analysis allows EPA to confirm that the method provides reliable and repeatable results when used within a given laboratory and when used ''identically'' in other standard laboratories. Other technical limitations, e.g., sampling and sample preservation requirements, requirements for non-standard apparatus, and hazards from wastestreams, are also considered.

In particular, the reliability of analytical methods at the maximum contaminant level is critical to the implementation and enforcement of the NPDWR. Therefore, each analytical method considered was evaluated for accuracy, recovery (lack of bias), and precision (good reproducibility over the range of MCLs considered). The primary purpose of this evaluation is to determine:

• Whether currently available analytical methods measure radon in drinking water with adequate accuracy, bias, and precision;

• If any newly developed analytical methods can measure radon in drinking water with acceptable performance;

• Reasonable expectations of technical performance for these methods by analytical laboratories conducting routine analysis at or near the MCL levels (interlaboratory studies); and

• Analytical costs. The selection of analytical methods for compliance with the proposed regulation includes consideration of the following factors:

(a) Reliability (*i.e.*, Precision/accuracy of the analytical results over a range of concentrations, including the MCL);

(b) Specificity in the presence of interferences;

(c) Availability of adequate equipment and trained personnel to implement a national compliance monitoring program (*i.e.*, laboratory availability);

(d) Rapidity of analysis to permit routine use; and

(e) Cost of analysis to water supply systems.

2. Analytical Methods for Radon in Drinking Water

(a) Proposed Analytical Methods for Radon. The analytical methods described here are the testing procedures EPA identified and evaluated to insure compliance with the MCL and AMCL. Two analytical methods for radon in water that fit EPA's criteria for acceptability as compliance monitoring methods were identified: Liquid Scintillation Counting (LSC) and the de-emanation method. The LSC method is here defined as Standard Method 7500-Rn, SM 1995; the de-emanation method is described in the report, ''Two Test Procedures for Radon in Drinking Water, Interlaboratory Study'' (USEPA 1987). EPA believes these methods are technically sound, economical, and generally available for radon monitoring, and is proposing their use for monitoring to determine compliance with the MCL or AMCL. The reliability of these methods has been demonstrated by a history of many years of use by State, Federal, and private laboratories. Both methods have undergone interlaboratory collaborative studies (multi-laboratory testing), demonstrating acceptable accuracy and precision. Thirty-six laboratories participated in the interlaboratory study for Standard Method 7500-Rn and sixteen labs in the de-emanation study. The American Society for Testing and Materials (ASTM) has also published an LSC method (ASTM 1992). Although its collaborative study (15 participating laboratories) was conducted at radon sample concentrations greater than 1,500 pCi/L, it is substantially equivalent to Standard Method (SM) 7500-Rn. EPA is proposing that ASTM D–5072–92 serve as an alternate method for radon for both the MCL and AMCL, under the restriction that the quality controls from SM 7500-Rn are met; namely, that the relative percent differences between duplicate analyses are less than the 95 percent confidence level counting uncertainty, as defined in SM 7500-Rn. Table VIII.B.1 summarizes the proposed analytical methods for radon in drinking water.

TABLE VIII.B.1.—PROPOSED ANALYTICAL METHODS FOR RADON IN DRINKING WATER

Method	References (method or page number)		
	SM	ASTM	EPA
Liquid Scintillation Counting	7500–Rn[1]	D 5072–92[2]	
De-emanation			EPA 1987[3]

Notes:
[1] *Standard Methods for the Examination of Water and Wastewater.* 19th Edition Supplement. Clesceri, L., A. Eaton, A. Greenberg, and M. Franson, eds. American Public Health Association, American Water Works Association, and Water Environment Federation. Washington, DC. 1996.
[2] American Society for Testing and Materials (ASTM). Standard Test Method for Radon in Drinking Water. Designation: D 5072–92. *Annual Book of ASTM Standards.* Vol. 11.02. 1996.
[3] Appendix D, Analytical Test Procedure, ''The Determination of Radon in Drinking Water''. In ''Two Test Procedures for Radon in Drinking Water, Interlaboratory Collaborative Study''. EPA/600/2–87/082. March 1987. p. 22.

Other analytical methods were evaluated, but they failed at least one of the criteria described previously. These methods included an ''activated charcoal passive radon collector'', a ''de-gassing Lucas Cell'' technique (a variant of the de-emanation method), the ''electret ionization chamber system'', and a ''delay-coincidence liquid scintillation counting system''. All of these methods are described and evaluated elsewhere (USEPA 1999g). As described next, if EPA implements the ''Performance Based Measurement System'' (PBMS) program, then any method that performs according to specified criteria may be used for compliance monitoring.

(b) Summary of Methods. Analysis of radon in drinking water by the LSC method involves preparation of the water sample (ca. 20 mL), which includes the selective partitioning of radon from the water sample into a water-immiscible mineral-oil scintillation cocktail and allowance for equilibration of radon-222 with its progeny. The prepared sample is then analyzed with an alpha-particle counting system that is optimized for detecting radon alpha particles. Scintillation counting methods are discussed later. One of the advantages of transferring the radon from the water sample into the water-immiscible cocktail is that potential interferents (other alpha emitters) are left behind in the water phase.

The de-emanation method involves bubbling radon-free helium or aged air (low background radon) through the water sample into an evacuated scintillation chamber. After equilibrium is reached (3 to 4 hours), this chamber is placed in a counter and the resulting scintillations are counted. This method generally allows measurement of lower level of radon than does low volume direct liquid scintillation. However, this method is more difficult to use, requiring specialized glassware and skilled technicians. Regions of the country with high radon levels in water (e.g., New Hampshire and Maine) may experience problems with this method, since the high radon levels in the samples can cause high backgrounds in the Lucas cell, forcing retirement of the cell for extended periods.

(c) Alpha Particle Counting Methods for Radon-222. One of the distinct characteristics of alpha particles is that they exhibit an intense loss of energy as they pass through matter, due to strong interactions between the alpha particles and the surrounding atoms. This intense loss of energy is used in differentiating alpha radioactivity from other types. Some of the alpha particle's energy loss is due to its ionization of atoms with which it comes in contact. Alpha particle detection is based on this phenomenon: when alpha particles ionize the phosphor coating of a detector, the energized phosphor ''scintillates'' (or emits light). The resulting light (or scintillations) are then detected and quantified with an appropriate detector that is calibrated to determine the concentration of the alpha emitter of interest. There are variants of detectors that measure these interactions, but this discussion will focus on the type relevant to the LSC and Lucas Cell methods.

In scintillation counting, the alpha particle transfers energy to a scintillator medium, e.g., a phosphor dissolved in a solvent ''cocktail'', which is enclosed within a ''light-tight'' container to reduce background light. The scintillation cocktail serves two roles: it contains the phosphor which is involved in quantifying the radon activity (concentration) and it selectively extracts the radon from the water sample, leaving behind other alpha emitters that may interfere with the analysis. The transfer of energy from the radon-derived alpha particles to the phosphor dissolved in the scintillator medium results in the production of light (scintillation) of energies characteristic of the phosphor and with an intensity proportional to the energy transmitted from the alpha particles, which are the ''signature'' of radon-222. A ''counter'' records the individual amplified pulses which are proportional to the number of alpha particles striking the scintillation detector, which is ultimately proportional to the radon activity in the original sample. The scintillation cell system used for the liquid scintillation method is as described previously. The system used for the de-emanation method is similar, with the exception that a scintillation flask (''Lucas Cell'', a 100–125 ml metal cup coated on the inside with a zinc sulfide phosphor and having a transparent window) replaces the liquid scintillation medium described. A counting system compatible with the scintillation flask is incorporated to quantify the radon concentration in the sample. Since radon has a short decay period (half-life of 3.8 days), correction methods are employed to account for the radon that decayed between the time of sample collection and the end of the analysis.

(d) Sampling Collection, Handling, and Preservation. In order to ensure that samples arriving at laboratories for analysis are in good condition, EPA is proposing requirements for sample collection, handling and preservation.

When sampling for dissolved gases like radon, special attention to sample collection is required. Either the sample collection method described in SM 7500-Rn, the VOC sample collection method, or one of the methods described in ''Two Test Procedures for Radon in Drinking Water, Interlaboratory Collaborative Study'' (USEPA 1987) should be used. In addition, because dissolved radon tends to accumulate at the interface between a water sample and some types of plastic containers, glass bottles with teflon lined caps must be used. Finally, EPA's assessment of laboratory performance is premised on the assumption that sample analysis occurs no later than 4 days after collection. Laboratories unable to comply with this holding time limit may have difficulty performing within the estimated precision and accuracy bounds. EPA solicits public comment on the proposed sample collection procedures for radon in drinking water.