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DRINKING WATER

Revisions to EPA's Cost Analysis for the Radon Rule Would Improve Its Credibility and Usefulness

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Chairman
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Subcommittee on VA, HUD, and Independent Agencies
Committee on Appropriations
House of Representatives

The Honorable Barbara A. Mikulski
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The National Academy of Sciences has estimated that about 20,000 lung cancer deaths occur in the United States each year from exposures to radon, a naturally occurring radioactive gas found in soil, rock formations, and water. The vast majority of these deaths result from the inhalation of radon that has been released to indoor air from soil beneath homes. However, about 160 of these deaths are estimated to stem from inhalation of radon that has evaporated from drinking water. The Safe Drinking Water Act, as amended, mandates that the Environmental Protection Agency (EPA) issue a regulation setting a drinking water standard for radon. In setting the standard, EPA must, among other things, consider the costs and benefits of control programs for radon from other sources, such as air. While EPA does not directly regulate radon in indoor air,[1] the Safe Drinking Water Act authorizes EPA to set a drinking water standard that allows states and water systems to offset high radon levels in drinking water with reductions of radon levels in indoor air.

In a proposed rule issued in November 1999, EPA presented a unique and complex drinking water regulation that used the framework for regulating radon specified in the Safe Drinking Water Act. Under the proposed radon

[1]According to EPA, the agency does not have the statutory authority to directly regulate radon in indoor air.

rule, states and water systems could, for the first time, choose one of two different standards, or limits, for a drinking water contaminant. The first standard reflects the typical regulatory approach under the Safe Drinking Water Act—that is, it imposes a health-based limit on the level of radon in drinking water and requires water systems to provide drinking water that does not exceed the limit. The second standard, called the alternative standard, allows considerably higher levels of radon in drinking water, but may be used only when an EPA-approved program to reduce radon in indoor air is also implemented. The alternative standard allows higher levels of radon in drinking water because the associated health risks are offset by reduced exposure to radon in indoor air. EPA believes that the most cost-effective approach to reducing the health risks associated with radon in water is to use the alternative standard, along with a program to reduce radon levels in indoor air.

EPA estimated that the benefits of its proposed rule—consisting almost entirely of reduced cancer deaths—would be worth $362 million annually. EPA estimated that the annual cost of implementing the rule would range from $60 million to $408 million, with $121 million as EPA's best estimate.[2] EPA's cost estimates are designed to reflect the typical costs that water systems would incur to monitor water and install treatment technologies, when needed, to comply with the regulation. The estimates also reflect the administrative costs that states and water systems would incur to implement programs encouraging homeowners to reduce radon in indoor air and homeowners' costs to do so. As of February 2002, EPA has not yet developed a schedule for issuing the final rule.

Citing the significant financial implications of the 1999 proposed rule, the conference report accompanying EPA's fiscal year 2001 appropriations act directed us to report on the financial impacts of the proposed radon rule and encouraged EPA to consider our findings prior to finalizing the rule. As agreed with your offices, this report identifies the (1) strengths and (2) limitations of EPA's cost analysis for the proposed rule. Because the scope of our review was limited to EPA's cost analysis, we did not evaluate EPA's analysis supporting the benefits the agency expects the proposed rule to provide. EPA officials said the agency plans to revise its estimate of the benefits in the final rule.

[2]EPA reported its estimates of the costs and benefits of the radon rule in 1997 dollars.

Results in Brief

EPA's analysis of the costs to implement the proposed radon rule has a number of strengths. First, EPA's estimates of the typical costs for water systems to purchase and install radon removal technologies—a key determinant of total national costs—are reasonable for estimating national compliance costs. Most of the radon removal technologies that EPA's cost analysis assumes will be used most frequently are already being used by a number of water systems across the country to remove radon and other contaminants, and EPA's cost estimates are generally within the ranges of costs reported in case studies on these technologies. Other strengths of the analysis include EPA's (1) use of recommendations from an expert panel in estimating water systems' costs for construction, engineering, and labor needed to install and maintain radon removal equipment and (2) development of a range of annual cost estimates, rather than a single estimate, to account for uncertainty about the extent to which the less costly alternative standard will be adopted by states.

EPA's analysis of the national annual costs of complying with its proposed radon drinking water rule has several limitations that, if corrected, would likely increase EPA's best estimate of these costs. Specifically, EPA

- made two errors in estimating the various costs associated with programs to reduce radon levels in indoor air under the alternative standard—one that understated radon testing and mitigation costs by about $37 million and another that overstated administrative costs by about $31 million—resulting in a combined understatement of costs by about $6 million; and
- excluded from its analysis "mixed" water systems, which use a mix of groundwater and surface water sources, effectively understating compliance costs by approximately $17 million.

Correcting these errors and including the mixed water systems alone would increase EPA's estimate by about 20 percent, from about $121 million to about $145 million (see app. I). Other aspects of EPA's analysis may have further understated total compliance costs, although by an unknown amount. For example, EPA assumed that more water systems than suggested by some evidence would choose the less-costly alternative standard. In addition, EPA may have insufficiently considered potential costs faced by water systems to alleviate concerns about the use of water treatment technologies that would vent radon near homes, schools, or other population centers. Further, EPA's cost analysis reflects inadequate quality assurance, does not consistently comply with EPA's guidelines calling for clarity and transparency in presenting economic analyses, and includes a number of inaccuracies. For example, the economic analysis contains inconsistent and inaccurate information about an important cost

factor as well as unclear or conflicting information about the responsibility for certain costs, and it omits assumptions underlying a key cost determinant. EPA has taken steps to improve the agency's quality assurance process, but it is not clear that these steps will be sufficient to identify and correct deficiencies like those we found.

Because of the limitations we identified, we are making several recommendations aimed at improving EPA's cost analysis for the radon rule and its economic analyses in general. In commenting on a draft of this report, EPA officials from the Offices of Water; Air and Radiation; and Policy, Economics, and Innovation generally agreed with our findings and recommendations, providing some technical and editorial suggestions that we have incorporated into the report, as appropriate. However, while agreeing that the proposed rule contained the errors and other inaccuracies we identified, the Office of Water did not agree that an effect of these errors was reduced credibility of EPA's cost analysis. While our report identifies a number of strengths of the cost analysis, these strengths do not offset or negate the effects of the errors and inaccuracies we found. We continue to believe that, collectively, the limitations we identified reduced both the credibility and usefulness of the cost analysis for the radon rule.

Background

The majority of the estimated cancer deaths in the United States associated with radon are related to the inhalation of radon in outdoor or indoor air. Specifically, the National Academy of Sciences has estimated that about 700 deaths occur from inhaling radon in outdoor air and more than 19,000 deaths occur each year from inhaling radon in indoor air.[3] Some radon in indoor air is derived from the evaporation of drinking water, and the academy estimated that about 160 of these 19,000 deaths are associated with such releases. In addition, the academy estimated that consumption of drinking water containing radon causes about 23 deaths from stomach cancer each year. EPA relied on the academy's estimates of radon health risks in developing the proposed rule on radon in drinking water.

EPA's proposed radon rule applies to water systems that include only groundwater and those that include both ground and surface water (rivers

[3]National Academy of Sciences, *Risk Assessment of Radon in Drinking Water*, Washington, D.C.: 1999.

and lakes), referred to as mixed systems.[4] Radon is usually present in only negligible amounts in surface water because this water is exposed to the air and the radon in it will tend to be released to the air. Groundwater originating in underground aquifers is not similarly exposed to air. As a result, high levels of radon are sometimes found in groundwater that collects and flows under the earth's surface. Radon levels in groundwater vary across the country, with the highest levels in New England and the Appalachian uplands of the Middle Atlantic and Southeastern states. There are also isolated areas in the Rocky Mountains, California, Texas, and the upper midwest where radon levels tend to be higher than the U.S. average. According to EPA, at the state level, high levels of radon in drinking water can occur in areas with low levels of radon in the soil (thus low levels in indoor air) and vice versa.

1996 Safe Drinking Water Amendments Require EPA to Establish a Radon Standard

Under the Safe Drinking Water Act, EPA sets health-based, legally enforceable standards limiting the level of drinking water contaminants that can adversely affect public health. In developing a standard, EPA establishes a health-based goal at a level that causes no known or anticipated adverse health effects and that allows an "adequate margin of safety." If a contaminant, such as radon, is likely to cause cancer, EPA generally sets the goal at zero. After setting the goal, EPA typically issues a regulation establishing an enforceable standard, called a maximum contaminant level, that is as close to the health-based goal as is feasible, considering the available technology, treatment techniques, and costs. Under the 1996 amendments, when proposing a standard, EPA is also required to perform an economic analysis to determine whether the benefits of the standard justify the costs. If the benefits do not appear to be justified, EPA may adjust the standard to a level that "maximizes health risk reduction benefits at a cost that is justified by the benefits."

The 1996 amendments also included a number of provisions specific to a radon standard. First, the amendments required EPA to withdraw its 1991 proposed rule on radon. Before issuing a new proposed rule on radon, EPA was required to obtain from the National Academy of Sciences an

[4]The proposed rule excludes certain groundwater systems: (1) nontransient noncommunity water systems are excluded on the basis that the more limited exposure to radon from drinking water in the schools, hospitals, and factories in this category results in lower health risks compared with life-time exposures in homes and (2) transient noncommunity water systems are excluded because most people who use such facilities (service stations, campgrounds) do so only occasionally.

assessment of the health risks from radon in drinking water and arrange for the academy to assess the health risk reduction benefits from various measures to reduce radon levels in indoor air. In addition, EPA was also required to (1) publish and seek public comment on its analyses of the costs and health risk reduction benefits for standards being considered for radon in drinking water and (2) respond to all significant public comments received on the analyses in the preamble for the proposed rule. In setting a radon standard for drinking water, EPA was also required, under the amendments, to consider the costs and benefits of programs to reduce radon exposures from other sources, such as indoor air.

The amendments specified that if the drinking water standard is more stringent than necessary to reduce the concentration of radon in indoor air from drinking water to a level equivalent to the national average concentration of radon found in outdoor air, then EPA must also promulgate an alternative standard (alternative maximum contaminant level). The alternative standard must be set at a level that would result in a concentration of radon in indoor air from drinking water equivalent to the national average concentration of radon in outdoor air. The alternative standard would allow more radon in drinking water than the more stringent standard. To offset the higher level, the water systems that use the alternative standard must be covered by an EPA-approved program to reduce radon in indoor air. Such a program could be managed by either states or water systems. To be approved, a program's expected health risk reduction benefits must be equal to or greater than the health risk reduction benefits that would result from compliance with the more stringent standard for radon in drinking water. Finally, the 1996 amendments required EPA to propose a new radon rule in 1999 and to promulgate it within 12 months. EPA issued the proposed rule in 1999. As of February 2002, EPA has not yet developed a schedule for issuing a final rule.

EPA Developed a Proposed Radon Rule and a Supporting Economic Analysis

In developing the proposed rule, EPA obtained and relied on assessments conducted by the National Academy of Sciences and issued its economic analysis for public comment in February 1999.[5] When EPA issued the proposed radon rule in November 1999, it set the health goal at zero, proposed a standard of 300 picocuries per liter of water, and proposed an

[5]U.S. Environmental Protection Agency, *Radon in Drinking Water Health Risk Reduction and Cost Analysis* (Washington, D.C.: Feb. 26, 1999).

alternative standard of 4,000 picocuries per liter to be used in conjunction with state or water system programs that reduce radon in indoor air.[6]

In the economic analysis supporting the proposed radon rule, EPA indicated that 46 percent of the 40,863 groundwater systems that would be subject to the rule would, in the absence of any additional treatment, exceed the standard of 300 picocuries. (The majority of these water systems serve 500 or fewer customers.[7]) Further, EPA estimated that if these systems had to comply with the more stringent standard, the systems would incur costs of about $2.5 billion to purchase and install radon treatment technologies, or about $233 million each year for 20 years. EPA estimated that the total annual cost of the rule would be about $408 million,[8] as follows

- $233 million to purchase and install radon treatment technologies,
- $152 million to operate and maintain the treatment technologies,
- $14 million to monitor water for radon,
- $6 million to administer these activities, and
- $2.5 million for states to oversee the water systems.

However, EPA estimated that the vast majority of water systems would not incur any water treatment costs because they would be subject to the alternative standard of 4,000 picocuries. EPA estimated that only about 4 percent of water systems subject to the rule have radon levels in excess of the alternative standard. EPA provided lower-bound, best, and upper-bound cost estimates that reflect varying assumptions about the proportion of states and local water systems that would choose the alternative standard and thus implement programs to reduce radon levels in indoor air, as follows:

- EPA's upper-bound estimate of $408 million annually assumed that all water systems would be subject to the more stringent water standard.
- EPA's best estimate of $121 million annually assumed that about two-thirds of water systems would be subject to the less stringent alternative standard.

[6]A picocurie is one trillionth of a curie, a unit of radioactivity.

[7]Most (96 percent) groundwater systems serve 10,000 or fewer customers; 67 percent of the systems serve 500 or fewer customers.

[8]Most of the estimated cost—$405 million—would be borne by water systems.

- EPA's lower-bound estimate of $60 million annually assumed that about 97 percent of water systems would be subject to the less stringent alternative standard.

The benefits that EPA estimates would be provided by the proposed rule—$362 million annually—are the same under all the scenarios, differing only in the extent to which the lives are saved because of water treatment versus reductions of radon in indoor air. Considering these costs and benefits, along with more subjective benefits and costs that EPA did not quantify,[9] EPA determined that the costs of the proposed rule were justified by the benefits. EPA stated that in making this determination, the agency also considered that costs would be substantially less than $408 million annually if most states implement indoor air programs, allowing water systems to comply with the less stringent water standard. Regarding the benefits, we note that EPA's estimates of future benefits in the proposed rule were not discounted (reduced) to present value, although the cost of purchasing and installing radon equipment was appropriately discounted. According to EPA officials, EPA will discount the benefits in the final rule in response to recommendations from the Science Advisory Board.

EPA's *Guidelines for Preparing Economic Analyses* highlight the importance of economic analyses in making informed policy choices and specify criteria for effective presentation of economic analyses, such as the cost analysis supporting EPA's proposed radon rule.[10] Primary criteria include clarity and transparency of all aspects of the analyses and descriptions of all important data sources, key assumptions, and their justifications. In addition, EPA's Office of Water has a quality management plan to guide its quality assurance and control activities, specifying which types of such activities are necessary and the various procedures for conducting quality reviews. The quality assurance elements include internal peer review, external peer review, external agency review, and stakeholder meetings, among other measures.

[9]These nonquantified benefits and costs include, among other items, customer comfort from knowing that radon is being removed from their water and customer anxiety about living near treatment plants that emit radon gas.

[10]EPA replaced its 1983 *Guidelines for Performing Regulatory Impact Analyses* with *Guidelines for Preparing Economic Analyses* in September 2000. EPA was using draft revised guidelines for economic analyses when the proposed radon rule was issued. The criteria for effective presentation of economic analyses were substantially the same in the 1999 draft guidelines and the issued guidelines.

EPA's Cost Analysis Has a Number of Strengths

EPA's cost analysis has a number of strengths. First, and most importantly, the estimates of the typical costs for a water system to remove radon are reasonable for the purpose of estimating the rule's national costs. The estimates of typical costs are for currently used technologies whose effectiveness is generally known and for which published cost data are available. Moreover, these estimates have been improved by input from a blue ribbon panel of drinking water and cost experts and other stakeholders. Further, while some concerned parties questioned several of EPA's assumptions on water treatment issues—such as the extent to which water systems would have to address certain water quality issues and how they would be addressed—our review indicated that EPA generally had a reasonable basis for its assumptions. Another strength of the analysis is that EPA estimated a range of costs to account for uncertainty about the approach that states will use to comply with the rule.

EPA's Estimates of Typical Costs for Water Treatment Are Reasonable for Estimating National Costs

EPA's estimates of the typical costs for water systems to purchase, install, and operate radon removal technologies—a key determinant of total national costs to implement the proposed rule—are reasonable for use in estimating national compliance costs. To estimate the typical costs for a system to remove radon from drinking water, EPA generally assumed the use of aeration technologies that have been commonly used by water systems to remove radon and other contaminants, such as volatile organic compounds.[11] EPA estimated radon removal costs for eight size categories of water systems, ranging from those that serve between 25 to 100 people to those serving between 100,000 and 1 million people. EPA's cost estimates for systems to purchase and install treatment technologies ranged from about $45,000 for the smallest systems to more than $6 million for the largest—or about $4,200 to $580,000 per year for 20 years. In addition, EPA estimated operations and maintenance costs ranging from about $3,600 per year for the smallest systems to about $440,000 for the largest.

Information on the cost of installing aeration technologies is available in published case studies, which EPA used to cross-check its estimates. For example, in 1998, the American Water Works Association published a guide for water utilities to use for evaluating and selecting radon treatment

[11]Aeration technologies force air through drinking water and strip away contaminants, which are then vented into outdoor air.

technologies that includes construction cost information for 33 water treatment sites, including 12 very small facilities, and performance information for most of the sites. EPA's technology cost estimates are generally within the ranges of costs identified in this and in other case studies. Such data are not always available to inform regulatory cost estimates. For example, in estimating costs for its arsenic rule, EPA had to rely on more limited data because some of the technologies for removing arsenic from drinking water are not commonly used.

Moreover, EPA's estimates of the typical costs for a water system to remove radon have benefited from the recommendations of an expert panel of water design and cost engineers from utilities, state and federal agencies, consulting firms, and public utility regulatory commissions. Following the reauthorization of the Safe Drinking Water Act, EPA convened the panel to help improve the accuracy of the agency's cost estimates for all drinking water regulations. EPA's cost analysis for the radon rule relies on the panel's recommendations in estimating a water system's cost for construction, engineering, and labor needed to install and maintain radon removal equipment. For example, based on the panel's recommendations, EPA increased its estimates of the labor costs to operate and maintain such equipment to include not only base salaries but also fringe and other benefits.[12]

In addition, EPA incorporated advice from other stakeholders in developing its estimates. For example, in response to comments that its initial estimates were not adequate, EPA increased its radon technology costs for pumps and blowers needed to operate aeration equipment.

Although some stakeholders said that EPA did not increase its technology cost estimates sufficiently, our analysis of the key issues they raised indicates that EPA generally used reasonable assumptions in developing its estimates, as the following examples show.

- Some parties commented that EPA did not include adequate costs for water systems to remove iron and manganese from water. These parties said that water systems would, in many cases, need to remove iron and manganese from their water before it is aerated so as not to damage the

[12]EPA analysts had previously assumed labor rates for water treatment professionals to be about $15 per hour. For the proposed rule, EPA adjusted labor rates to add fringe and other benefits, resulting in hourly labor costs ranging from $28 to $52, depending on the size of the water system.

aeration equipment. However, EPA assumed that water systems that need to treat for iron and manganese would generally be able to add chemicals to neutralize these elements, which is less expensive than removing them. Based on estimates of the number of water systems with elevated levels of iron and manganese, EPA included costs for 25 percent of small systems (systems serving fewer than 10,000 people) and 15 percent of large systems (systems serving more than 10,000 people). In addition, EPA assumed that systems with levels of iron and manganese too high for chemical neutralization would already be removing these elements because high levels of these elements result in unacceptable discoloration of water. Because these removal costs would not be incurred as a result of the radon rule, EPA's cost estimates do not include them. We believe that EPA's assumptions are reasonable for the purpose of estimating national costs.

- Some parties commented that EPA did not include adequate costs for water systems to disinfect water that might be contaminated by microbes during aeration. For example, a stakeholder said that the cost estimates may be understated for clearwells—wells or tanks that are needed to hold water so that it can be disinfected. This comment stemmed from two conflicting sets of cost estimates for clearwells, one much higher than the other, which EPA included in a supporting report on technology costs. EPA used the lower estimates in its cost analysis. EPA officials told us that the higher estimates were incorrect and were inadvertently included in the supporting report and that the lower estimates—generated by EPA's cost model for aeration technologies—were correct. The lower estimates are consistent with EPA's guidance manual for disinfecting drinking water and incorporate best engineering judgment.[13] We note that national costs for clearwells may be overstated because EPA included these costs for all systems that add radon treatment. However, as case studies show, a number of systems (particularly those that already disinfect their water) will be able to use existing clearwells.
- A stakeholder commented that EPA did not include adequate costs to address the increased corrosiveness of water resulting from aeration. We believe, however, that EPA's addition of such costs for a small portion of water systems is appropriate based on information from the National Academy of Sciences and case studies indicating that aeration does not generally increase the corrosiveness of water.

[13]U.S. Environmental Protection Agency, *Guidance Manual for Compliance With the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources* (Washington, D.C.: March 1991).

- A stakeholder commented that EPA might have understated treatment costs for large water systems because it underestimated the number of treatment sites at these systems. Underestimating the number of treatment sites that potentially need to have radon treatment technologies would understate costs because costs increase as the number of sites needing radon treatment increases. In its cost analysis, EPA estimated that there were an average of 13.1 treatment sites for groundwater systems serving between 100,000 and 1,000,000 customers.[14] In contrast, the stakeholder commented that its survey of water systems serving over 100,000 customers indicated the correct number of average treatment sites would be 23.8. We believe, however, that EPA's estimate was adequately supported, based on our review of EPA's assumptions and data as well as the information provided by the stakeholder. For example, the stakeholder's estimate of 23.8 sites included systems serving more than 1,000,000 customers and therefore was not directly comparable to EPA's estimate. When, as part of our review, the stakeholder provided us with an estimate that was consistent with EPA's size categories, the estimate was 14.7—a number reasonably close to EPA's estimate of 13.1. Further, our limited review of the stakeholder's data indicates that such data would need to be evaluated for accuracy and representativeness. Specifically, in reviewing information about 4 of the 102 survey respondents, we found that an entity identified as having 650 sites—an atypically high number[15]—was incorrectly classified as a single system. This entity represents a number of affiliated water districts of varying sizes in different locations, each with its own rate structure. The stakeholder acknowledged that these water districts should have been analyzed as individual water systems, not aggregated into one system.[16]

In finding that EPA's technology cost estimates are appropriate for estimating national costs, we recognize that some systems would incur higher costs than EPA estimates and others would incur lower costs. Costs for individual water systems—even those of similar size—would vary

[14]This is the largest category of groundwater systems for which EPA included costs. According to EPA, its review of the two groundwater systems that serve more than 1 million customers indicated that these systems would not have to treat for radon.

[15]According to the stakeholder's survey data, most large systems have an average of 11 sites.

[16]Because this system serves more than 1,000,000 customers, its inclusion distorted the stakeholder's estimate of 23.8 sites per system but did not distort its subsequent estimate of 14.7 sites.

depending on factors such as the technologies selected and the site-specific conditions, including water quality and management skills. EPA's estimates should not be interpreted as being representative of the individual decisions that thousands of water systems will make on the basis of their unique circumstances.

EPA Supported Its Assumption about States' Compliance with the Rule

In developing its best estimate of total national costs for the rule, EPA assumed that 50 percent of states would implement EPA-approved indoor air programs that have expected health risk reduction benefits equal to or greater than the benefits that would result from compliance with the more stringent drinking water standard. As a result, the vast majority of local water systems in those states would not have to mitigate radon levels in drinking water because only those with radon levels in excess of 4,000 picocuries (the alternative standard) would have to reduce the radon in the water.[17] EPA's assumption was supported by the results of a survey of state indoor air and drinking water officials conducted by the American Water Works Association.[18] Fifty percent of the survey respondents indicated that they probably would adopt the indoor air option, and 9 percent indicated that they definitely would.

EPA's assumption about the decisions states would make is also supported by extensive discussions between EPA and state representatives and recognizes the potential difficulties that may dissuade some states from implementing the option. Most states already conduct indoor air programs for radon. To comply with the proposed rule, states would have to upgrade their existing programs by setting quantitative risk reduction goals, reporting on progress toward those goals, and allowing for extensive public participation in developing the indoor air programs. According to EPA, program officials from many states believe they would be able to comply with these requirements without too much difficulty. Furthermore, officials from many states believe that it makes good public health sense to mitigate radon levels through indoor air, rather than water, because indoor air risks are much higher than drinking water risks and indoor air mitigation is more cost-effective. However, other states are not inclined to use the indoor air option to comply with the rule because of concerns about potential public relations problems that could arise

[17]EPA estimates that 1,776 systems nationwide have radon levels above 4,000 picocuries.

[18]American Water Works Association, *State Response to the Proposed Multimedia Mitigation Program Option*, Washington, D.C.: 2000.

because of different protections people will receive, depending upon where they live. Specifically, the executive director of the Association of State Drinking Water Administrators told us that states are greatly concerned about explaining to the public that the same level of radon in drinking water is safe in some states but unsafe in others, depending on whether the state adopted the indoor air option. She stated that trading the drinking water risks of the community for the indoor air risks of relatively few residents would cause substantial public confusion. Similarly, the National Academy of Sciences stated that concerns regarding the equity of risk trading "might ultimately constitute the deciding factor" in whether the air mitigation option is undertaken. A program official from one state told us that her state would likely not adopt the air mitigation option partially because the unequal treatment of radon risks could lead to court cases.

Nonetheless, according to EPA officials, their estimate that 50 percent of the states would upgrade their indoor air programs to comply with the radon drinking water rule may be conservative. These officials told us that after several workshops EPA held with the states in late 2000, nearly two-thirds of the state program managers indicated that they would likely adopt the indoor air option. However, an EPA official acknowledged that some state program managers that favor the program may not be the ones making this decision, and therefore some of these "likely" states may not adopt the program. This recognition corroborates a potential impediment that program officials from some states had discussed with us—that is, adopting the indoor air option could be subject to the approval of the legislature or the governor. As a result, the decisions of the state program managers may be subject to political processes, the outcomes of which cannot be certain. Overall, we believe that EPA had a reasonable and supported basis for its assumption, reflected in its best estimate of costs, that 50 percent of states would choose the indoor air option, as the assumption reflects the potential disincentives that could prevent some states from participating.

EPA's Estimates Include a Range of Costs to Account for Uncertainty about How States Would Choose to Comply with the Rule

Another strength of EPA's cost analysis for the proposed radon rule is that it provided a range of national annual compliance costs to address the uncertainty about how states would choose to comply with the rule. EPA's designation of a range helps decisionmakers and the public understand how costs could vary depending on how the rule is implemented, and it is consistent with EPA's guidelines for preparing economic analyses, as well as with guidance issued by the Office of Management and Budget in 2000. Because it is generally less costly to reduce radon risks in indoor air than

in drinking water, the estimated costs of compliance with the radon rule are lower when more states are assumed to implement indoor air programs. Reflecting a range of potential responses, EPA's cost estimates range from $60 million to $408 million per year.[19] EPA designated $121 million as its best, or most likely, estimate of annual costs.

Limitations of EPA's Cost Analysis Reduce Its Credibility and Usefulness

EPA's analysis of the national annual cost of complying with its proposed radon drinking water rule has several limitations that, if corrected, would likely increase EPA's best estimate of national costs. Specifically, EPA made two errors in estimating the annual costs associated with programs to reduce radon levels in indoor air under the alternative standard—one that understated radon testing and treatment costs by about $37 million and another that overstated administrative costs by about $31 million. Correcting the two errors would increase EPA's best estimate of national annual costs for the proposed rule by about $6 million. In addition, EPA excluded from its analysis mixed water systems—those that get their water from a mix of both groundwater and surface water sources—which effectively understates compliance costs by approximately $17 million. Correcting these errors and including the mixed water systems alone would increase EPA's estimate by about 20 percent, from about $121 million to about $145 million. Other aspects of EPA's analysis may have underestimated total compliance costs, although by an unknown amount. Specifically, EPA

- assumed that more water systems than suggested by some evidence would choose the less-costly alternative standard and
- insufficiently considered potential costs faced by water systems that remove radon from water using aeration facilities—which vent the radon to the outside air—located near homes, schools, or other population centers.

Further, EPA's cost analysis reflects a lack of quality assurance in certain important respects. For example, the analysis contains inconsistent and inaccurate information about an important cost factor and unclear or conflicting information about the responsibility for certain costs, and omits the assumptions underlying a key cost determinant. EPA has taken steps to improve its quality assurance process, but it is not clear that they

[19]EPA's estimates are in 1997 dollars.

will be sufficient to identify and correct deficiencies like those we identified.

EPA Miscalculated Costs for the Rule's Indoor Air Option

In estimating costs for reducing radon levels in indoor air under the alternative water standard, EPA made two errors—one that understated the costs of testing and treating indoor air for radon by about $37 million and another that overstated administrative costs to implement and oversee the programs by about $31 million. Correcting the two errors would increase EPA's best estimate of national annual costs for the proposed rule by about $6 million. (See app. I.)

EPA's first error resulted in an underestimate of the annual costs for reducing radon levels in indoor air that the agency expects will be borne by individual households. EPA multiplied its assumed cost of testing and treating for radon in indoor air per life saved ($700,000)[20] by the expected number of lives saved per year,[21] and then amortized the result over 20 years at a discount rate of 7 percent. However, EPA should not have amortized the result because it represents costs that would be incurred every year. For example, in its best estimate, EPA assumed that 59 lives[22] would be saved every year at a total cost of $41 million (59 lives times $700,000 per life). EPA then amortized the $41 million over 20 years, resulting in an estimated annual cost of $3.9 million, even though the $41 million cost would be incurred each year. EPA officials acknowledged that they should not have amortized the $41 million cost and told us that they intend to correct this error in EPA's economic analysis for the final rule.

[20]This assumption is based directly on an estimate described in EPA's *Technical Support Document for the 1992 Citizen's Guide to Radon* (May 1992). EPA did not adjust the estimate, which was reported in 1991 dollars, for inflation because it believed that testing and treatment costs had not increased since 1991.

[21]EPA's estimate of the number of lives saved per year assumes that the indoor air programs adopted in conjunction with the less stringent drinking water standard would save the same number of lives as compliance with the more stringent standard. This assumption is based on the requirements of the 1996 amendments to the Safe Drinking Water Act.

[22]EPA estimated that if all systems were required to comply with the alternative standard of 300 picocuries, 62 lives would be saved each year. However, in the case of EPA's best estimate, about 95 percent of systems either would be in states with indoor air programs or would implement their own indoor air programs, so indoor air programs would be expected to save 59 lives (95 percent of the 62 lives that would be saved assuming that all systems were required to comply with the more stringent standard of 300 picocuries).

The second error occurred because EPA inadvertently included costs to administer and oversee indoor air programs of water systems that will not implement such programs. EPA's estimate did not reflect the fact that regardless of whether the states choose to implement indoor air programs, water systems with radon levels below 300 picocuries would be required only to monitor the radon level in their water. They would not be required to treat their water, nor would they be required to implement their own indoor air programs. The estimate also did not reflect that water systems with radon levels above 4,000 picocuries are unlikely to implement indoor air programs because they would be required to treat their water regardless of whether they implement these programs. As a result, EPA's best estimate of national annual costs included $53 million in costs associated with oversight and administration of about 18,400 water systems' indoor air programs, inadvertently including costs for about 10,800 water systems. We estimate that correcting this error would reduce costs associated with oversight and administration of water systems' indoor air programs to about $22 million. EPA plans to correct both errors in its economic analysis for the final rule.

EPA Excluded Certain Systems That Would Be Subject to the Rule

EPA's cost analysis excluded mixed water systems, which get their water from a combination of groundwater and surface water sources, even though these systems would be subject to the radon rule. EPA officials told us that they did not include costs for mixed systems in the economic analysis because of data limitations and because their preliminary analysis indicated that including the mixed water systems in its analysis would not have a significant effect on the total annual cost of complying with the rule. However, EPA did include mixed systems in its economic analysis for the January 2001 arsenic rule. An EPA official told us that there does not seem to be a strong technical basis for handling mixed systems differently in the two rules. In January 2002, EPA officials told us that the agency would consider including costs for these systems in the economic analysis for the final rule. We estimate that including mixed systems in EPA's best estimate would further increase total annual costs by about $17 million

(see app. I).[23] Including these systems would also increase the estimated benefits of the proposed rule.[24]

EPA May Have Underestimated Compliance Costs for Some Water Systems

A key factor in EPA's cost estimate is the extent to which programs to mitigate radon levels in indoor air would supplant the more costly approach of mitigating radon levels through water treatment. While EPA's assumption about the number of states that would adopt indoor air programs is well supported, we found that its assumption about the number of local water systems that would do so is not and appears to be overly optimistic. A decrease in the estimated number of systems choosing the less expensive approach would increase the total annual cost of compliance.

In the 50 percent of states where EPA did not assume selection of the indoor air option, EPA assumed that 90 percent of local water systems would elect the alternative standard and establish their own indoor air programs. According to EPA officials, the assumption was based solely on the premise that water systems would choose the least costly approach to mitigating radon risks. EPA officials acknowledged that they did not collect any data on the extent to which water systems would establish air programs.

This data limitation reduces the credibility of EPA's optimistic assumption in light of questions that have been raised about the likelihood of small water systems adopting air programs. For example, EPA's assumption conflicts with the opinions of the National Academy of Sciences and state and industry associations. Specifically, the National Academy of Sciences reported in 1999 that "non-economic considerations" could play a large role in a local water system's decision about whether to use an indoor air program to meet the rule's requirements. According to the academy's report, experience with certain provisions of the Clean Water Act indicates

[23]Our estimate of the costs for mixed systems is based on an estimate that EPA developed and we reviewed. The estimate includes 1,074 mixed water systems receiving more than 50 percent of their water from groundwater sources. It does not include the costs for three systems serving more than 1,000,000 customers that receive some of their water from groundwater sources and that EPA believes would incur costs to comply with the radon rule. We did not develop an estimate for these systems, which should also be included in EPA's cost estimate for the final radon rule.

[24]Of the limitations we found, the exclusion of mixed systems is the only one that has an effect on EPA's estimates of the benefits of the rule.

that small entities have had difficulties dealing with complex federal program requirements. While EPA may be correct in its assertion that the requirements for indoor air programs are not as complex as the requirements cited by the academy, small water systems may have limitations or concerns that could lead them to choose compliance with the more stringent standard. For example, the executive director of the Association of State Drinking Water Administrators told us that local water companies, especially the small ones, will not want to be involved in public meetings, goal setting, and program monitoring and reporting—activities required under the proposed rule's indoor air option. The National Association of Water Companies, a trade association representing the nation's privately owned drinking water utilities, expressed similar doubts in its comments on the proposed rule: "We believe that the prospect of water systems implementing local (indoor air) programs in the absence of state programs is unrealistic… Tracking new home construction and remedial venting of existing homes is far removed from the chartered objectives of community water systems, not to mention the expectations of water ratepayers." In our view, these are reasonable concerns.

The academy also raised concerns that the indoor air option may not be practical for some local water systems that have elevated radon in their water but not in their customers' indoor air. EPA acknowledges that elevated radon in drinking water and in indoor air may not occur in the same geographic area. Program officials from several states concurred that the indoor air option may be problematic for some local water systems for this reason. One of these officials also said that using the indoor air option would not work nearly as well at the local level as it would at the state level. The official explained that because states have a larger geographic area than local water systems, states would have a much better chance to offset one area's elevated radon in drinking water by mitigating another area's indoor air radon.

Considering the evidence indicating a fair amount of uncertainty about the extent to which local water systems, in the absence of a state program, would choose the indoor air option to comply with the rule, EPA's assumption that 90 percent of systems would do so appears overly optimistic. As discussed previously, the uncertainty about adopting the indoor air option is particularly strong for small water systems—the majority of systems subject to the rule. Adjusting EPA's assumptions to reflect less optimistic scenarios would increase the total national cost estimate for the proposed rule. For example, assuming that 75 percent, instead of 90 percent, of local water systems would choose the indoor air

option would increase national annual costs by $23 million; assuming 50 percent of systems would choose the option increases the estimated national annual cost by $61 million (see app. I). In January 2002, EPA officials told us that in finalizing the economic analysis for the rule, they plan to include a range of costs based on different assumptions about how many water systems will adopt indoor air programs. EPA's planned use of varying assumptions about the choices of water systems would appropriately reflect the uncertainty associated with the responses of water systems. (As discussed previously, EPA's proposed rule already included a range of costs to reflect uncertainty about how many states would adopt indoor air programs.)

EPA May Have Underestimated the Costs to Address the Risks from Radon Emitted during Aeration

EPA's cost estimates may not adequately account for the additional costs to address the health risks from radon that would be emitted into outdoor air as it is removed from drinking water through aeration. These risks may be of particular concern where water treatment facilities that remove radon in water and vent it into the air would be located close to homes and schools and other population centers. In these cases, water systems may face public relations problems due to residents' concerns. Credible information on the estimated risks from such emissions could help water systems address such concerns.

However, we found that EPA's analysis of these health risks has some limitations that tend to underestimate the risks and reduce its credibility. The limitations stem from the use of outdated health risk data and the outdated air quality model EPA used to develop its estimate of risk from emissions for the proposed radon rule. Specifically, EPA's estimates of the risks from radon emitted during aeration inadvertently did not incorporate updated information from the National Academy of Sciences. EPA officials said that updated information from the academy indicated that the health risk from exposure to radon was about 2.5 times higher than its previous estimate. While EPA incorporated this revision in its estimates of the risks from radon in drinking water, it erred by not doing so for its estimates of the risks associated with radon emissions from aeration. Furthermore, EPA used the deficient health risk data in an outdated 1988 model that the agency acknowledged has substantial limitations, even though the agency had newer models available. Specifically, EPA's documentation of the 1988 air quality model states that the resulting estimates of human health risks associated with radon emitted during aeration are (1) "preliminary in nature and should be used with caution," and (2) "do not account for the additive impact of emissions from plants located close to one another."

A 1999 study commissioned by a water district in California suggests that EPA's 1988 model may understate these health risks. Specifically, the study includes a comparison of the estimated health risks associated with using aeration technologies to remove radon from the district's water first using the 1988 model, and then using an updated EPA model. In this site-specific analysis, the risk estimate developed from the updated model was five times higher than the estimate developed using EPA's 1988 model.

In discussing this issue, EPA officials told us that they may update the final rule's estimates of the health risks from radon emissions by incorporating the academy's updated risk information and using updated air quality models. However, the officials said that taking these steps would not substantially change the overall risk estimates for exposures to radon emissions from water treatment shown in the proposed rule. They also said that the health risks associated with emissions of radon from treatment plants would still be negligible compared to the risks of radon in water. While the officials agreed that higher risk estimates could lead to higher national costs to implement the rule, they believe the cost increases would be insignificant. However, without an updated risk estimate using current data and models, water systems may have difficulty addressing concerns their customers may raise about the risks—actual or perceived—of radon treatment. These concerns could increase costs if, for example, customers demand more expensive technologies to reduce risks associated with treating water for radon.[25] Along these lines, we note that in commenting on the proposed rule, the American Water Works Association pointed out that "the perception of risk is often as important as the actual risks when siting any industrial process, including water treatment systems. The mitigation of such concerns of the citizenry can result in substantially increased costs…."

EPA's Cost Analysis Indicates Inadequate Quality Assurance

EPA's cost analysis for the proposed radon rule does not consistently comply with EPA guidance calling for clarity and transparency of all aspects of the analyses and inclusion of all important data sources, key assumptions, and their justifications. These presentation deficiencies, as well as analytical errors, occurred despite the agency's quality assurance

[25]One alternative technology, granular activated carbon (GAC), is much more costly than aeration for all but the very smallest water systems. This technology does not vent radon into the air during treatment but collects the radon in filters.

process. As a result, the credibility of the analysis was reduced and the ability of affected parties to provide informed comments was hampered.

Documents Were Not Uniformly Clear, Accurate, and Consistent

EPA's guidelines for preparing economic analyses state that EPA should strive for maximum clarity and transparency of all aspects of the assessments and clearly describe all important data sources, key assumptions, and their justifications. The guidelines also say that the presentation should highlight the key elements that dominate modeling frameworks and its results and address uncertainties by identifying ranges for inputs and results. We found a number of instances in which EPA did not comply with its guidance. For example

- EPA's proposed rule and the accompanying regulatory impact analysis contain inconsistent and inaccurate information about an important cost factor—the number of sites at which each water system would have to monitor radon concentrations and potentially install treatment technologies. In both documents, EPA states that it assumed treatment would occur at each well with a radon level higher than the applicable drinking water standard. Tables presenting numbers of wells accompany these statements. However, EPA actually assumed that testing and treatment would occur at sites known as "entry points" where water from multiple wells is often combined. Because there are many fewer entry points than wells, assuming treatment at each entry point instead of each well leads to a much lower national cost estimate. Comments on the proposed rule show that affected parties were confused about how EPA could have arrived at its national cost estimate by assuming treatment at each well, as EPA incorrectly indicated it had done.
- EPA's documents are not clear about whether implementing an indoor air program in lieu of treating radon in drinking water is a choice or a requirement for small local water systems—because the documents contain conflicting statements. Both the proposed rule and the economic analysis state that small water systems "must" implement an indoor air program if there is no state indoor air program that meets the rule's requirements. However, both documents also state that small water systems may "choose" to either implement an indoor air program or comply with the more stringent water standard. In fact, under the proposed rule, implementing an indoor air program would be a choice—not a requirement—for small local water systems, just as it is for large water systems. These conflicting statements confused some affected parties about the proposed rule's requirements and the associated costs.
- Both the proposed rule and the economic analysis lack transparency and clarity about who would incur the costs to test and, if necessary, treat

indoor air for radon. The documents incorrectly indicate that state and community water systems would pay to test indoor air and reduce radon levels in homes under the proposed rule's alternative standard. However, EPA officials told us that, in fact, households would be expected to bear most of these costs and that EPA intends to clarify this in the final rule. By misstating who would bear a substantial portion of the costs of the proposed rule, EPA did not disclose that the success of this rule depends on the ability of states and water systems to persuade thousands of households to spend a total of about $41 million each year to reduce their health risks from exposure to radon in indoor air. As discussed previously, EPA also erred in estimating these annual costs in the proposed rule, reporting them as $3.9 million.

- EPA's documents do not disclose the agency's assumptions regarding how many systems would need to remove 50 percent, 80 percent, or 99 percent of the radon in their water under the proposed rule. Because costs increase with the level of radon removed, the number of systems assumed to fall into each of the removal categories is a key determinant of the total national cost of the proposed rule. EPA's omission of these assumptions prevented stakeholders from readily assessing the reasonableness of EPA's cost estimate.
- EPA's proposed rule is unclear about whether EPA accounted for the additional costs to reduce the risks from radon that would be emitted into outdoor air as it is removed from drinking water through aeration. For example, in the proposed rule, EPA first states that its cost estimates do not include the additional costs associated with reducing the risks from such radon emissions. Yet later in the proposed rule, EPA states that its cost estimates do include these additional costs. EPA's confusing presentation contributed to affected parties' concerns that EPA's estimates had not accounted for any of these additional costs. In fact, EPA did include some costs for reducing the risks from radon that would be emitted through aeration,[26] as shown by documentation that EPA provided to us. However, as noted previously, EPA may have understated these costs because it underestimated the health risks associated with radon emissions generated by aeration equipment.

[26]Specifically, EPA's analysis assumed that (1) no systems serving populations smaller than 3,301 would face additional costs to address emissions from water treatment because EPA believes that these small systems are generally located in rural areas where emissions would not be a concern and (2) 15 percent of systems that serve populations larger than 3,300 and that install aeration treatment would incur additional costs to address emissions, at an average annual cost of $39,000 per system. This cost represents a 35-percent increase to these systems' average costs for treating and monitoring their water for radon.

We also found that stakeholders questioned certain cost estimates, in part, because of the lack of clarity and transparency about cost elements in the documents supporting the rule. For example, as discussed previously, EPA cited two sets of cost estimates for clearwells. In addition, regarding the costs for treating iron and manganese, EPA said in its proposed rule that it included some costs for this task, but said in its regulatory impact analysis that it excluded them.

Some of the flaws we identified in the cost analysis for the radon rule are similar to those that we previously identified in EPA's economic analyses for other rules. For example, in 1997 we reported that in several of the analyses we reviewed, EPA did not describe certain key assumptions used to estimate costs and benefits.[27]

EPA's Quality Assurance Process Did Not Identify Analytical Errors and Documentation Flaws in the Cost Analysis

The analytical errors and documentation flaws that we identified in EPA's proposed rule and cost analysis were not detected or corrected by the agency's quality assurance process. EPA officials said that the Office of Water has a quality management plan that guides its quality assurance and control activities, specifying which types of such activities are necessary and the various procedures for conducting quality reviews. The quality assurance elements include internal peer review, external peer review, external agency review, and stakeholder meetings, among other measures. According to EPA officials, the primary quality assurance elements that EPA relied on for the proposed radon rule were

- the National Academy of Sciences' assessments of the health risks from radon;
- recommendations from an expert panel on the costs water systems would incur for construction, engineering, and labor related to installing radon water treatment equipment;
- recommendations from EPA's National Drinking Water Advisory Council on issues related to the analysis of costs and benefits of drinking water regulations in general;
- recommendations from EPA's Science Advisory Board valuing the benefits of cancer cases avoided in environmental regulations in general;
- comments received at three national meetings with stakeholders; and

[27]U.S. General Accounting Office, *Air Pollution: Information Contained in EPA's Regulatory Impact Analyses Can be Made Clearer*, GAO/RCED-97-38 (Washington, D.C.: Apr. 14, 1997).

- meetings with the American Water Works Association to examine technical components of the rulemaking.

In addition, EPA published its health risk reduction and cost analysis for public comment more than 6 months prior to issuing a proposed rule on radon. The expert groups and the public comments provided EPA with valuable information that it used to improve key components of the proposed rule during its development. However, these reviews did not provide a detailed, comprehensive review of the completed cost analysis supporting the proposed radon rule.

EPA's economic analyses do not undergo external peer review nor have they typically undergone formal internal peer review by experts outside of the program offices that prepared them. We have previously stated that important economic analyses supporting regulations should receive peer review—the critical evaluation of scientific and technical work products by independent experts—to enhance the quality, credibility, and acceptability of both the analyses and the associated agency decisions.[28] Experts in economic analysis have also noted the importance of peer review. For example, a diverse panel of renowned economists recommended in a 1996 paper[29] that peer review of economic analyses be used for regulations with potentially large economic impacts. In addition, the Presidential/Congressional Commission on Risk Assessment and Risk Management reported that agencies did not give enough attention to the quality and interpretation of economic analyses and recommended that these analyses receive adequate peer review.

EPA has recognized the need to improve the quality of its economic analyses, and in August 2001, the EPA Administrator approved the implementation of the recommendations of an agency work group to, among other things, require internal review of EPA's major rules and the economic analyses supporting them. As part of this effort, EPA's National Center for Environmental Economics has begun to develop a process to systematically review economic analyses for the agency's major rules. The

[28]U.S. General Accounting Office, *Regulatory Reform: Comments on S. 981—The Regulatory Improvement Act of 1997*, GAO/T-GGD/RCED-97-250 (Washington, D.C.: Sept. 12, 1997).

[29]Arrow, Kenneth J. et al., *Benefit-Cost Analysis in Environmental, Health, and Safety Regulation: A Statement of Principles* (the American Enterprise Institute, the Annapolis Center, and Resources for the Future, 1996).

center has developed a draft "Economic Regulatory Review Summary and Critique," dated December 12, 2001, that includes a lengthy checklist the center may use to review key data, assumptions, and modeling techniques used in the analyses and the transparency and clarity of the economic analyses. The center's reviews of the economic analyses prepared by EPA's program offices could provide the agency with meaningful internal peer review of its economic analyses.

Implementation of the regulatory work group's recommendation that the economic analyses supporting major rules undergo internal peer review has the potential to improve the quality of EPA's rules and eliminate some of the errors and other limitations we identified in the proposed radon rule. EPA's National Center for Environmental Economics has already conducted several internal peer reviews of economic analyses supporting major rules as case studies, and EPA has found that such reviews can produce meaningful results. For example, the center's director told us that one of the peer reviews served as a forum for airing differences of opinion among program office and legal staff on whether and how to account for pre-existing subsidies. As a result of discussions of this issue during the internal peer review, the proper accounting method was selected. If the subsidies had not been properly recognized and accounted for, the costs of the rule would have been understated by about $700 million.

The draft checklist that the center is developing to peer review economic analyses contains many questions divided into nine sections: regulation description, baseline, benefits, costs, economic impact analysis, equity assessment, discounting, sensitivity analysis, and summary and critique of the entire economic analysis. The sections on costs and the summary and critique of the economic analysis include the following:

- Was the proper modeling approach used to assess the economic costs?
- Were relevant and high quality data sources used?
- Did the analysis address all significant economic costs?
- Are all of the data sources and assumptions clearly described?
- Is the analysis generally clear and transparent?

The questions in the draft are reasonable and specifically address some of the problems we identified with the proposed radon rule, such as the lack of clarity and transparency. However, the questions do not incorporate basic quality assurance checks for accuracy and consistency that could better ensure that the agency's economic analyses do not contain errors such as inappropriately amortized costs. The errors that EPA made in conducting and presenting its economic analysis supporting the radon rule

could, in most cases, have been easily avoided with basic quality assurance checks for accuracy and consistency.

While EPA's proposed radon rule was issued before the agency started to implement its new regulatory review process, the director of EPA's National Center for Environmental Economics told us that the drinking water rule on radon will be subject to the review process before the rule is finalized.

Conclusions

In developing its proposed rule on radon in drinking water, EPA sought and was generally responsive to advice from experts and stakeholders, which strengthened important aspects of the cost analysis supporting the proposed rule. However, because of the limitations we identified in EPA's cost analysis, the agency did not provide policymakers and stakeholders with complete and reliable estimates of the expected compliance costs of the proposed rule and who would bear them. Identifying the regulatory costs that water systems are expected to incur is particularly important in light of the anticipated financial demands on water systems to enhance security and comply with other pending drinking water regulations. It is also important to accurately estimate the costs that households would have to incur—on a voluntary basis—to remove radon from the indoor air in their homes to reduce radon health risks as anticipated by the rule. The limitations in EPA's cost analysis and presentation also hampered the ability of interested parties and the public to provide informed comments to EPA. Whether addressing these limitations would change EPA's conclusion that the rule is economically justified is not known given that EPA will also be revising its estimate of the benefits in the final rule, for example, to respond to recommendations from the Science Advisory Board that estimates of benefits be discounted to present value.

EPA appears to be moving in the right direction by requiring internal peer reviews of the economic analyses supporting its major rules and starting to develop standard procedures for these reviews. The internal peer reviews—if properly and routinely conducted—should improve the credibility and usefulness of the agency's economic analyses and improve its regulatory actions overall. While we continue to believe that some economic analyses may also warrant external peer review, there are signs that an internal peer review process could produce meaningful results at EPA. In our view, the agency's efforts to establish standard procedures for the reviews of economic analyses could help the agency ensure that its reviews are thorough and consistent. Yet it is not clear whether EPA's review procedures, as presently drafted, would be sufficiently rigorous

and detailed to identify some of the errors we identified, such as the accounting error that incorrectly amortized an annual cost over a 20-year period. However, EPA still has the opportunity to build in such procedures.

Recommendations for Executive Action

To improve the credibility and usefulness of its economic analysis for the final drinking water rule on radon, we recommend that the administrator, EPA, require the Office of Water to

- correct its cost estimates for testing for and treating radon in indoor air and disclose that homeowners are expected to bear these costs,
- correct its estimates of states' and water systems' costs for administration of indoor air programs,
- include mixed water systems in its economic analysis,
- revise its economic analysis to include less optimistic assumptions about how many water systems will use indoor air programs to comply with the rule, and
- revise its estimate of the risks from radon emitted during water treatment by incorporating the National Academy of Sciences' increased estimate of these risks, and by using the agency's current air quality models, and assess the extent to which the revised risk estimate would change costs.

To better ensure the quality of economic analyses for the radon rule and other major rules prepared by EPA, we also recommend that the administrator, EPA, require the agency to expeditiously implement standard procedures for conducting internal peer reviews of its economic analyses. These procedures should include quality assurance measures to identify errors in calculations; check the reasonableness of assumptions and methodologies; and ensure that the documentation of the analyses is clear, transparent, accurate, and complete.

Agency Comments

We provided EPA with a draft of this report for its review and comment. In response, officials from the Offices of Water; Air and Radiation; and Policy, Economics, and Innovation generally agreed with our findings and recommendations. The officials provided some technical and editorial suggestions that we have incorporated into the report, as appropriate. However, while agreeing that the proposed rule contained the errors and other inaccuracies we identified, the Office of Water did not agree that an effect of these errors was reduced credibility of EPA's cost analysis. While our report identifies a number of strengths of EPA's cost analysis, these strengths do not offset or negate the effects of the errors and

misstatements we found. We continue to believe that, collectively, the limitations we identified reduced both the credibility and usefulness of the cost analysis for the radon rule. For example, we believe that the credibility of EPA's estimates was reduced by an analytic error and a presentation error that EPA made related to an important cost component—the cost of testing and treating indoor air for radon. The analytic error involved EPA estimating annual costs of $4 million, when the correct estimate is about $41 million. The presentation error involved EPA indicating that states and local water systems would bear these costs, when such costs would actually be borne largely by individual households. We believe that correcting these and other errors would, in fact, improve the credibility and usefulness of the analysis to policymakers and stakeholders.

Scope and Methodology

To assess the strengths and limitations of EPA's cost estimate for the November 1999 proposed radon rule, we reviewed the two primary EPA documents describing the agency's cost analysis; namely, the proposed rule and the agency's economic analysis supporting the rule (the regulatory impact analysis). In addition, we reviewed key EPA documents that the agency used to support its economic analysis, including *Technologies and Costs for the Removal of Radon from Drinking Water*; *Methods*, *Occurrence*, *and Monitoring Document for Radon in Drinking Water*; *Technical Support Document for the 1992 Citizen's Guide to Radon;* and the October 1999 supporting statement for information collection request for radon. We reviewed case studies identifying the costs associated with installing and maintaining aeration equipment, including *Critical Assessment of Radon Removal Systems for Drinking Water Supplies* published by the American Water Works Association Research Foundation and the American Water Works Association in 1998. In addition, we met with EPA officials responsible for the proposed rule and the economic analysis to obtain information about key assumptions and methodologies. These officials provided us with internal documents, such as costing models and spreadsheets that supported the analysis, which we also reviewed. We reviewed stakeholder comments made on the proposed rule, including those by the American Water Works Association, the National Rural Water Association, and the Association of State Drinking Water Administrators. We met with representatives of the American Water Works Association and interviewed water treatment professionals who have experience with radon removal.

Because the scope of our review was limited to assessing EPA's cost estimate, we reported on, but did not evaluate, EPA's estimates of the

expected benefits of the proposed rule. As also agreed with your offices, we reviewed the assumptions EPA used in its cost models to generate its water treatment estimates, but we did not validate the costing models or the data EPA used in developing its cost estimates. For several of the analytical limitations we identified, we developed estimates of the change in EPA's estimated costs if EPA were to correct its analysis (see app. I). We developed these estimates based on information from EPA's primary documents and additional internal documents that we obtained from EPA officials. We did not have a basis to estimate increased costs that water systems might incur if EPA updated its estimate of the health risks from radon that would be emitted into outdoor air as it is removed from drinking water through aeration. We conducted our work from May 2001 through January 2002 in accordance with generally accepted government auditing standards.

We will send copies of this report to the administrator, EPA, and make copies available to others who request them. If you or your staff have questions about this report, please call me on (202) 512-3841.

John B. Stephenson
Director, Natural Resources
and Environment

Appendix I: Adjustments to EPA's Best Estimates of Total National Costs to Address Limitations in EPA's Economic Analysis

Dollars in millions

Cost components	EPA's best estimate	EPA's best estimate corrected for two accounting errors	EPA's best estimate corrected for two accounting errors and including mixed systems[a]	EPA's best estimate corrected for two accounting errors; including mixed systems; and adjusting overly optimistic assumption from 90% of systems to 75% of systems	EPA's best estimate corrected for two accounting errors; including mixed systems; and adjusting overly optimistic assumption from 90% of systems to 50% of systems
Water					
Capital	$23.1	$23.1	$26.0	$44.6	$75.6
Operations and maintenance	15.5	15.5	17.4	29.6	49.8
Monitoring	14.1	14.1	15.9	15.9	15.9
System administration	6.1	6.1	6.3	6.3	6.3
State administration	2.5	2.5	2.5	2.5	2.5
Subtotal	**$61.3**	**$61.3**	**$68.1**	**$98.8**	**$150.1**
Indoor air					
Testing and treatment[b]	3.9	41.2	51.3	47.2	40.5
System administration of systems' indoor air programs	45.1	18.6	19.1	15.9	10.6
State oversight of systems' indoor air programs	7.8	3.3	3.4	2.9	2.0
State administration of states' indoor air programs[c]	2.9	2.9	2.9	2.9	2.9
Subtotal	**$59.8**	**$66.1**	**$76.7**	**$68.9**	**$56.0**
Total costs	**$121.1**	**$127.4**	**$144.8**	**$167.8**	**$206.1**

Note: Line items may not sum to totals due to rounding.

[a]Our estimate of the costs for mixed systems is based on an estimate that EPA developed and we reviewed. The estimate includes 1,074 mixed water systems receiving more than 50 percent of their water from groundwater sources. However, it does not include the costs for three systems serving more than 1,000,000 customers that receive some of their water from groundwater sources and that EPA believes would incur costs to comply with the radon rule. We did not develop an estimate for these costs, which should also be included in EPA's cost estimate for the final radon rule.

[b]EPA assumes that most of these costs will be borne by individual homeowners.

[c]EPA's best estimate assumes 25 states will have indoor air programs, but its estimate of state administration costs is based on costs for 23 states. According to EPA, the estimate in the final rule will include costs for 25 states.

Source: GAO's analysis of EPA data.

Appendix II: GAO Contact and Staff Acknowledgments

GAO Contact

Christine Fishkin (202) 512-6895

Staff Acknowledgments

Other key contributors to this report include David Goldstein, Timothy Guinane, Patricia Manthe, Cynthia Norris, and Amy Webbink.

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