Docket #W-98-30

PUBLIC COMMENTS

ON

HEALTH RISK REDUCTION AND COST ANALYSIS FOR RADON IN DRINKING WATER

Prepared on behalf of

U.S. Small Business Administration Office of Advocacy

by

Austin Ray Perez

April 27, 1999

TABLE OF CONTENTS

1. SUMMARY

Pursuant to Section 1412(b) of the Safe Drinking Water Act (SDWA) as amended by the 1996 SDWA amendments, the U.S. Environmental Protection Agency (EPA) is expected to publish a new radon proposal in August 1999. To support the rulemaking, the EPA published a health risk reduction and cost analysis (HRRCA) for radon in February 1999. These comments, written on behalf of the U.S. Small Business Administration Office of Advocacy, address issues raised in the HRRCA.

A central concern raised by the original proposal published in 1991 was that small public water systems would have had to spend too much on mitigating radon in drinking water for minimal health gains. By mitigating radon in indoor air instead, the EPA could have achieved the same gains at less cost. The same is true today. According to the HRRCA, it is still less costly to mitigate radon in the air at <u>every</u> potential drinking water standard under consideration. As a result, it does not make sense to establish a standard at <u>any</u> radon level below 4,000pCi/l.[1] This is true from a cost-effectiveness perspective as well as from a cost-benefit perspective.

Therefore, I recommend that the EPA establish the water standard—that is, the maximum containment level (MCL) at 4,000 pCi/l. The following analysis, based not only information provided in the HRRCA, supports this finding. It further supports the finding that the goal for radon—that is, the maximum containment level goal (MCLG) should <u>not</u> be set to zero; instead, it should be established at 1,000 pCi/l. I recommend that as well. And, while these constitute my central conclusions, the following comments also contain an array of recommendations, designed to improve the presentation and

[1]A curie (Ci) is a standard measure of radioactivity, and a picocurie (pCi) is one trillionth (1 X 10^{-12}) of a curie.

substance of the HRRCA. (I expect that the HRRCA will be used to develop the regulatory impact analysis (RIA) for the proposed radon rule.) Those recommendations include requests for additional information so that the public may better evaluate any radon proposal.

The organization of these comments is as follows. I shall begin in section 2 with the background of the new radon proposal. In section 3, I provide the analytical context, in which I would like the EPA to consider the recommendations to follow. This section is also intended to be a foundation, on which to build further analysis supporting those recommendations. Section 4 consists of the recommendations and further analysis. It is sub-divided into three parts: recommendations regarding EPA decisions to be made in a new radon proposal (e.g., where to set the standard); recommendations regarding changes to the HRRCA/RIA analysis; and recommendations regarding changes to the text of the HRRCA/RIA.

2. BACKGROUND

Pursuant to Section 1412(b) of the Safe Drinking Water Act (SDWA) as amended by the 1996 SDWA amendments, the U.S. Environmental Protection Agency (EPA) is expected to propose a new national primary drinking water regulation (NPDWR) for radon in August 1999. To support the upcoming rulemaking, the EPA contracted with the National Academy of Sciences (NAS) to complete an independent assessment of EPA's 1991 radon proposal and supporting analyses. That assessment was released in September 1998. The EPA also performed a health risk reduction and cost analysis (HRRCA) for radon, which was published in late February for public comment, in advance of the new radon proposal. These comments, prepared on behalf of the U.S. Small Business Administration Office of Advocacy, address issues raised in the HRRCA.

By amending the SDWA in 1996, the Congress addressed concerns involving the EPA's multi-media approach to radon. Among those concerns was the cost-effectiveness of mitigating radon in water (versus air). As a result, the Congress provided for an alternative maximum containment level (AMCL) if the EPA proposed an MCL less than the concentration in water "necessary to reduce the contribution of radon in indoor air from drinking water to a concentration that is equivalent to the national [outdoor] average concentration." That is, if the proposed standard (MCL) is less than 4,000 pCi/l (the concentration of radon in water equivalent to the national average outdoor radon concentration),[2] the EPA must also establish an alternative standard (AMCL) at 4,000 pCi/l, with which public water systems (PWSs) may comply if their state government implements a multi-media mitigation (MMM) program. The EPA must approve MMM programs before they can be implemented. If, however, a state government chooses not to implement a MMM program (or cannot get one approved), systems in that state need only comply with the AMCL if the systems themselves implement EPA-approved MMM programs. These programs are intended to educate and provide incentives to households (and other building owners) to test and mitigate radon in indoor air where it is most cost-effective to do so. As expected, MMM programs are estimated in the HRRCA to deliver health benefits at much lower costs than conventional water treatment, particularly for small systems.

[2]The EPA and NAS have estimated that 10,000 pCi/l of radon in water, on average, contributes to 1 pCi/l of radon in the air.

3. ANALYSIS

A central concern raised by EPA's original radon proposal published in 1991 was that small public water systems (PWSs) would have had to spend too much on mitigating radon in drinking water for minimal health gains. Instead, the EPA could have achieved the same gains at less cost by mitigating radon in indoor air. The same is true today. According to the HRRCA, the same level of risk reduction can be achieved at less cost by supporting programs (i.e., multi-media mitigation [MMM] programs), designed to encourage homeowners (and other building owners) to mitigate radon in indoor air. Table 3.1 (below) presents the incremental costs per death avoided if systems, anticipated to exceed a radon water level of 4,000 pCi/l, mitigate to that level and below using conventional water treatment. It also presents the equivalent costs if systems mitigate radon in water to 4,000 pCi/l but instead make up the difference (between 4,000 pCi/l and any standard below that) with MMM programs (assuming that 100 percent of states implement them).

Table 3.1: It Always Costs Less to Avoid Each Cancer Death by Mitigating Radon in Air than to do it in Water.

Radon Level (pCi/l)	Incremental Costs Per Death Avoided ($Millions/year)	
	Via MMM programs	Via H_20 Treatment
*2000	1.05	5.12
1000	0.77	5.47
700	0.56	5.56
500	0.73	6.36
300	0.73	7.05
100	0.70	7.40

Source: Compiled from EPA HRRCA tables 6-1, 6-7, 7-2.

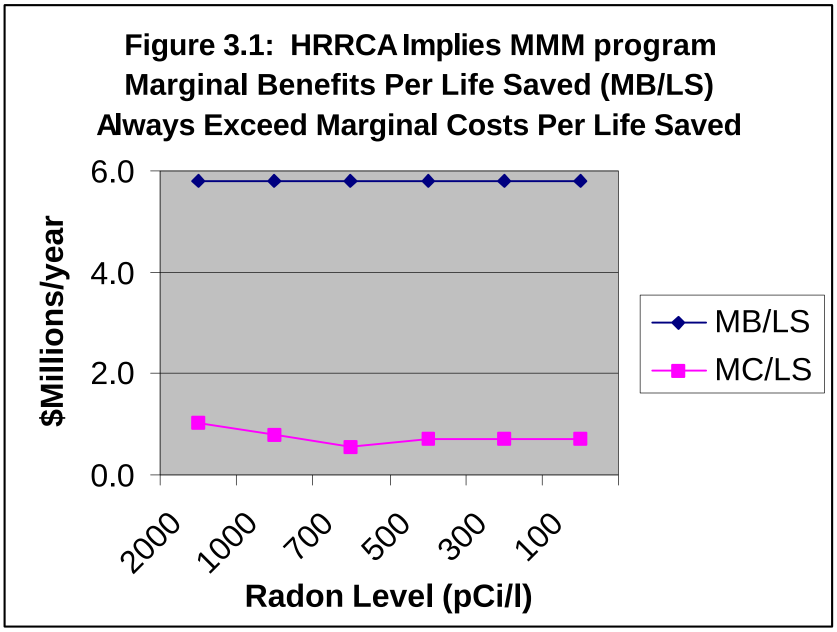
*4,000 pCi/l is the baseline.

Table 3.1 shows that it would be more cost-effective to avoid each fatal cancer case if systems mitigate via MMM programs. This is true at <u>every</u> radon level. For instance, while it is estimated to cost all affected systems $7.05 million annually to mitigate radon in water from 500 to 300 pCi/l, it would only cost them $730,000 to achieve the same amount of mitigation with MMM programs. However, while I arrived at these conclusions by using EPA estimates, there may be reason to question those estimates.

The EPA should explain why the incremental costs per death avoided for MMM programs tend to decline, as the standard (MCL) becomes more stringent. Consider that the costs presented in table 3.1 (above) are essentially the marginal costs of treating radon in air versus water, except that the costs of each MCL have been standardized—divided by incremental deaths avoided. The costs have been standardized so that we may directly compare the two approaches. They have also been standardized so that we may compare them with the marginal benefits (see figure 4.1 [below]). Further consider that an economist would expect these costs—the marginal costs per life saved—to increase, as the standard becomes more stringent.[3] Small reductions in a water contaminant are generally less expensive per unit than large reductions in that contaminant because they are easier to achieve. Then the optimal level at which to set the standard could be determined at the intersection between marginal costs per life saved, which should increase, and marginal benefits per life saved, which should in this case remain constant (each additional statistical life saved is valued at $5.8 million [1997$]). Yet, this is not the story being told with the numbers in Table 3.1.

[3]Even if these costs were decreasing over a range, economists would still expect them to eventually level off and to increase since managerial inefficiencies would begin to overtake factors driving the increasing returns to scale—greater division of labor and specialization of function (Nicholson, 1995, pp. 321-22).

Instead, the implication is that, with one exception (MCL=500 pCi/l), it is always becoming less costly to tighten the standard—a proposition that is difficult to believe. Figure 3.1 illustrates:



Source: Generated using Table 3.1 and $5.8 million per statistical life saved.

If this were truly the case—that its marginal costs per life saved are always declining, then why wouldn't the EPA set the water standard at zero—intending to achieve risk-reduction benefits in indoor air equivalent to eliminating all radon in water—and guarantee the resources for MMM programs. It would seem to always be less costly to do so. Net benefits (the distance between marginal benefits and costs) appear to always be increasing. From a pure efficiency standpoint, it would be the sensible action to take.[4]

[4] Of course, EPA decisionmaking cannot be based solely on efficiency. There are other criteria (e.g., political feasibility) as well. Even if the EPA could ensure each and every system had the resources to achieve a water standard of zero using MMM programs, the EPA would still have to force homeowners to remediate their homes, which is impractical even if the homeowners could be reimbursed for the expenses.

Yet, the EPA does not appear to be considering this option. Why?[5] Perhaps the EPA could shed some light on this matter.

Notwithstanding substantial changes to MMM-program assumptions, table 3.1 (above) demonstrates that it is always more costly to mitigate radon in water than in air. Further, the potential benefits from mitigating it in water are small in comparison with the potential benefits of saving statistical lives through other means, such as smoking cessation programs for instance. In the public summary of its 1998 report on radon, the National Academy of Sciences (NAS) presented a comparison of the lung and stomach cancer fatalities in the United States compiled from several sources. The American Cancer Society (1998) estimated that 160,000 lung cancer deaths occur each year, which could be attributed mainly to smoking. The society also estimated that there were 14,000 stomach cancer deaths per year from all sources. In its BEIR VI Report (1998), the National Research Council (NRC) estimated that 19,000 lung cancer deaths could be attributed to breathing radon in indoor air (most of whom were also smokers), and the NAS estimated that 720 lung cancer deaths annually could be attributable to breathing radon outdoors.

By comparison, the NAS (1998) estimates that, by mitigating radon in drinking water, the EPA could help the public avoid at most only 180 cancer deaths annually (assuming the EPA sets the water standard to zero—an option the Agency does not appear to be considering at this time). Of those, 160 lung cancer deaths would come from people no longer breathing radon emitted from in-home water while another 20

[5] I suspect the marginal-costs-per-death-avoided result has to do with assumptions driving the estimates—in particular, an ever (and geometrically) growing proportion of the population is anticipated to experience risk reductions as the standard increases in stringency, and the costs grow more slowly. If this is the case, perhaps the EPA should rethink its assumptions (see section 4.2.4 [below] for further explanation).

stomach cancer deaths would come from people no longer drinking water containing radon. Then, at most, the EPA could help us avoid only 0.14 percent (20/14,000*100%) of total annual stomach cancer deaths and only 0.10 percent (160/160,000*100%) of total annual lung cancer deaths. These percentages are presented in the following table.

Table 3.2: Potential Health Gains (if MCL=0) from Mitigating Radon in Water Would be Minimal

	Number of Deaths Per Year		Percent Of Total
	Radon in H_20	Total (all sources)	
Lung Cancer	160	160,000	0.10%
Stomach Cancer	20	14,000	0.14%

Source: NAS (1998), public summary figure.

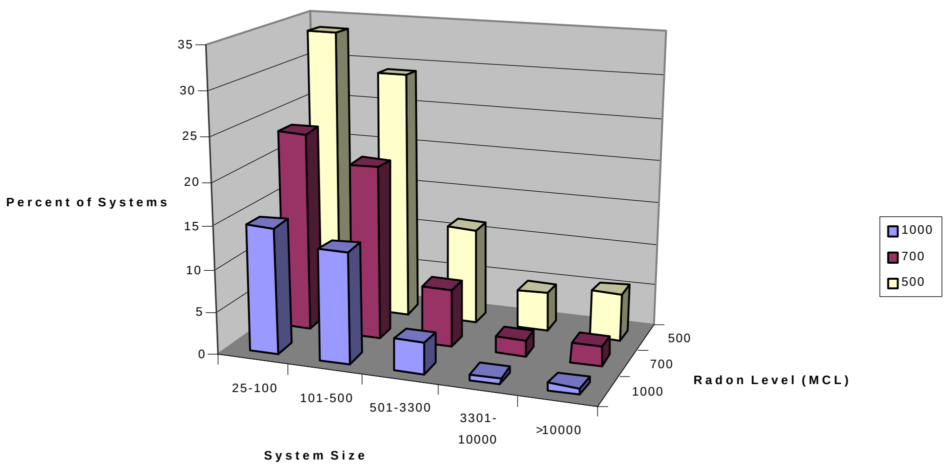
In total then, the EPA could help the public to avoid at most 0.11 percent ([160+23]/[14,000+160,000]*100<0.11 percent), a mere fraction of a percent, of all lung and stomach cancer deaths expected to occur annually. (Even if I used the upper-bound estimate of deaths avoided from a standard of zero, the gains would still constitute only a fraction of a percent of the total.) Of course, all benefits presented above would be the maximum achievable, if the EPA were to set the MCL at zero. However, the Agency is not now considering such a standard. Instead, the EPA is considering standards at levels greater than zero and so the benefits actually achieved would be less (potentially much less) than the percentages presented.

Not only are the benefits of treating radon in water relatively small, but the estimates also suggest that there are better ways to achieve those benefits. First, there appears to be a fatal synergy between smoking and breathing radon. The NRC (1998) estimates that most of the 19,000 lung cancer deaths per year occurred among smokers. The EPA estimates that 120 of the 142 lung cancer deaths (84.5 percent) attributed to breathing radon decay by-products occurred among past or present smokers (HRRCA table 3-9). Second, the costs per statistical life saved of smoking-cessation interventions appear to be much less than those for mitigating radon in water—from $2,000 to $3,000 per statistical life (depending on the nature of the intervention), according to the Agency for Health Care Policy Research. Perhaps resources committed to waterborne radon could be more efficiently allocated if redirected toward helping people to quit smoking. The EPA should research this option. More funding for smoking cessation programs might even help us to reduce a substantial number of the total 160,000 lung cancer deaths each year, most of which have also been attributed to smoking.

Nevertheless, the EPA has been charged with promulgating a goal (MCLG) and a standard (MCL) for radon in drinking water, which is required under section 1412(b) to be as close to the goal as feasible. Fortunately, the level at which to set the standard has yet to be determined. And, in light of the forgoing discussion, I respectfully submit that the EPA should, when determining where to set the standard, consider the cost-ineffectiveness of establishing a water standard more stringent than 4,000 pCi/l (the level mandated by Congress). Only when 100 percent of states (or systems instead of states) implement MMM programs, allowing systems to achieve the water standard through air programs, does such a standard potentially make economic sense. Moreover, the EPA should consider the minimal benefits achievable by such standards, compared with the potential benefits that could be achieved by saving statistical lives through other means (e.g., smoking cessation and voluntary indoor air remediation programs). I would further submit the disproportionate share of the cost burden borne by small systems and their customers, who will realize only a small fraction of the already minimal potential health gains, as an additional—though equally important—consideration when setting the MCL.

A disproportionate share of the cost burden will be borne by small public water systems—systems serving between 25 and 10,000 customers. Based on HRRCA estimates, if the MCL were 300 pCi/l (the standard proposed in 1991), 51.4 percent of the smallest systems (25-100 customers) would be affected while only 16.2 percent of large systems (more than 10,000 customers) would. Figure 3.1 (below) presents the percentages for three MCLs—at 500, 700, and 1,000 pCi/l.

Figure 3.2: Small Public Water Systems (less than 10,000 customers) Will Shoulder A Disproportionate Share of the Regulatory Cost Burden



Source: EPA HRRCA table 3-2.

Not only will small systems be disproportionately affected (relative to large systems) but that percentage will also increase, as the standard becomes more stringent. At an MCL of 1,000 pCi/l, almost 15 percent of systems in the smallest size category (25-100 customers) will be affected. At an MCL of 500 pCi/l, nearly 35 percent of the smallest systems will be affected.

Since small systems serve fewer customers than large systems, each small-system customer will have to pay relatively more per household per year than large-system customers will. By EPA's own estimates (HRRCA table 6-10), customers of the smallest systems (25-100 customers) could pay from $292 per household per year (if the proposed MCL were 4,000 pCi/l) to $398 per household per year (if the MCL were 100 pCi/l). Compare this with the range of costs borne by large-system customers (systems with more than 10,000 customers). Each could pay as little as $6 per household per year (MCL=4,000 pCi/l) or as much as $7 per household per year (MCL=100 pCi/l). Hence, small-system customers will pay a lot more per household per year than their counterparts served by larger systems, and that difference will become larger as the standard increases in stringency.

Yet, the customers of smaller systems will receive less of the risk-reduction benefits from radon mitigation in water. Consider that, by setting the standard to 300 pCi/l, the EPA estimates that 144 (of 174,000 [total]) stomach and lung cancer deaths could be avoided each year (HRRCA table 6-13). These are deaths that would no longer occur among all of the customers of water systems affected by the standard (although they do not refer to any particular, identifiable death). However, if we only consider a subset of these customers—customers served by the smallest systems (25-100 customers), only one death could be avoided among the subset. Only one (1) death out of 144 (0.7 percent) would be avoided among customers served by the smallest systems (if the proposed MCL were 300 pCi/l), even though these customers would be expected to shoulder most of the cost burden. By EPA estimates, these customers would pay in total $178 million annually (summing the incremental costs for only the smallest systems from 4,000 pCi/l to 300 pCi/l) for that single statistical life.

Such a finding is also reflected in the benefit-cost results from mitigating radon in water, if we separate the results by system size. Table 3.3 (below) provides the net benefits (benefits minus costs) for systems, by size, of mitigating to each radon level at and below 4,000 pCi/l. The shading denotes net losses to systems.

Table 3.3: Smaller Systems (<3,300) Generally Pay More Annually in Water Treatment Costs ($millions) for Minimal Health Gains.

Radon	System Size (Persons Served)				
Level (pCi/l)	25-100	101-500	501-3,300	3,300-10,000	>10,000
4000	-5.8	-10.6	-2.5	0.6	6.2
2000	-10.8	-19.8	-2.4	4.0	20.6
1000	-21.4	-33.1	-5.2	9.7	47.7
700	-30.0	-43.0	-10.4	12.2	66.4
500	-40.5	-53.5	-16.6	14.3	89.0
300	-61.8	-75.0	-28.8	10.8	121.1
100	-116.6	-132.3	-55.4	-5.1	181.5

Source: Generated using HRRCA table 6-13 & $5.8 million per statistical life saved.

By separating the results, we find that the net benefits are negative for smaller systems (strictly less than 3,301 customers) at <u>every</u> radon level being considered. The costs to these systems of mitigating (to each and every level) exceed the benefits by the shaded amount. We also find that the net benefits among the smallest systems (25-100 customers) are more negative than they are for almost any other size category. (Only systems in next to smallest size category [101-500 customers] achieve net benefits that are more negative.) If for instance the EPA moved the standard from 300 pCi/l to 100 pCi/l, it would cost the smallest systems $123 million per year for only one (1) additional cancer death avoided, realized among approximately 375,000 customers served by those 14,651 systems. Hence, the net benefits there would be –$116.6 million (1.1*5.8–123).

Therefore, small systems (3,300 customers or less) always lose at standards under consideration. The net benefits to these small systems are never positive, which means that the costs to these systems always exceed the benefits (at every radon standard at and below 4,000 pCi/l). It also means that the customers of these smallest systems (25-100 customers) could pay as much as $400 per household per year for at most two statistical lives saved (MCL=100) (HRRCA, table 6-10). Even at the least stringent standard (4,000 pCi/l), these same households would still pay $300 each year and they would not even save a single statistical life. These small-system customers (HRRCA table 3-2) would realize very small risk-reduction benefits indeed, for which they pay substantially. This is unfair. The EPA should consider these households too, when determining where to set the standard.

4. RECOMMENDATIONS AND FURTHER ANALYSIS

In the following recommendations, I intend to address three issues: (1) Has the EPA provided enough information to support the upcoming rulemaking and, if not, what other information should the Agency provide; (2) Does the HRRCA include reasonable estimates of the costs and benefits; and (3) what preliminary decisions can and should the Agency make based on the HRRCA and information contained therein. I shall begin with issue three—my preliminary recommendations based on information provided in the HRRCA. These recommendations are preliminary because the information may change in response to public comments.

4.1 Preliminary Recommendations based on the HRRCA

4.1.1 Set MCL equal to the AMCL (4,000pCi/l). There are three options: the EPA can set the maximum containment level (MCL) above, below, or equal to the alternative maximum containment level (AMCL). However, the argument for setting the MCL equal to the AMCL appears to be the most persuasive.

The argument for setting the MCL greater than the AMCL has to do with increasing the consistency of EPA's multi-media approach to mitigating radon. To mitigate radon in water, in 1991 the EPA proposed an MCL of 300 pCi/l_{water}. Yet, to mitigate radon in indoor air, the EPA had already established a voluntary action level for radon at 4 pCi/l_{air} (in 1986), the level at which the Agency has since publicly represented indoor concentrations of radon as relatively safe (1992b and 1992c). An air standard of 4 pCi/l_{air} is equivalent to a water standard of 40,000 $pCi/l_{air\text{-}to\text{-}water}$ (every 10,000 pCi/l of radon in water is estimated to on average contribute only 1 pCi/l to indoor air). As a result, the EPA was proposing a water standard (300 pCi/l_{water}), presented as the safe concentration of radon in water, which was substantially more stringent than the air standard (equivalent to 40,000 $pCi/l_{air\text{-}to\text{-}water}$) also being presented as safe. Consumers who performed these calculations would probably have been confused. (And even if they had not, it is likely that they would have still been confused, by the difference between an air standard of 4 pCi/l and a water standard of 300 pCi/l.) The EPA should not perpetuate such confusion by establishing a water standard that is unnecessarily different than the air standard.

The regulated community and the public have a right to know what to expect from the EPA in terms of regulations and policies with respect to radon. Yet, setting multimedia standards that are inconsistent is contrary to such a notion. Moreover, the greater the distance between the water standard and the air standard, the greater the potential for public confusion over what exactly constitutes a safe concentration of radon. Hence, the EPA should set radon standards as consistently as possible.

Setting inconsistent standards would also be contrary to the message of the EPA Citizen's Guide to Radon (1992c), which advises citizens to only concern themselves with radon in water when high levels of it have already been detected in indoor air (p. 8)—a common sense approach. Further, the EPA (1992b, p 7-6) states that it set the action level at 4 pCi/l_{air} because a lower action level would have resulted in too many measurement mistakes (a three-fold increase in false negatives and a two-fold increase in false positives).[6] Also, the incremental costs would have been too high. Yet, by rejecting an action level of 3 pCi/l, the EPA missed (and continues to miss) the opportunity to gain an additional 400 statistical lives saved per year at an incremental cost of only $1.7 million per life (1992b, Appendix H). (By contrast, the EPA is now considering a total gain [all systems] of 2 statistical lives per year at a cost of $24 million by setting the water standard at 4,000 pCi/l, which is incremental to the baseline of no mitigation of waterborne radon at all [HRRCA table 6-13].) Should the EPA depart from a common sense

[6]A false positive refers to instances where in-home radon concentrations are found (via testing) to exceed the action level when those concentrations actually do not exceed the level. The house tests positive (exceeds the action level) when it is falsely so. A false negative is where those concentrations are found not to exceed the action level when actually they do.

approach, already formulated with great deliberation, where it has a choice under the law? Also, should the EPA depart from such an approach when there are further (and substantial) gains to be made by encouraging homeowners to mitigate radon in in-home air? Perhaps the EPA should avoid public confusion and carefully act to reconcile the two approaches.

The argument for setting the MCL below the AMCL is that greater incremental risk-reduction benefits can be achieved by doing so.[7] Unfortunately, the risk-reduction benefits would be small compared to total stomach and lung cancer deaths each year, if the MCL were established at zero (section 3 above). At standards being considered the benefits would be even smaller in comparison to the total. Table 4.1 (below) demonstrates this:

Table 4.1: Potential Health Gains (if MCL>0) from Mitigating Radon in Water Would Be Minimal

Radon Level (pCi/l)	Annual Lung & Stomach Cancer Deaths		Percent of Total
	Deaths Avoided by MCL	Total Deaths	
2,000	8.7	174,000	0.01%
1,000	16.0	174,000	0.01%
500	61.0	174,000	0.04%
300	58.0	174,000	0.03%
100	115.0	174,000	0.07%

Source: HRRCA table 6-7, and NAS (1998) public summary figure.

Even if the EPA were to set the water standard at its most stringent level (100 pCi/l), the relative number of cancer cases avoided annually would still constitute only 7 hundredths of one percent of the total (115/[160,000+14,000]=0.07).

[7]To accurately assess the net benefits to society of instituting any particular water standard for radon, the appropriate unit of comparison is between social incremental benefits and social incremental costs since the task is to compare one possible standard to another. If instead the task were to compare a particular standard to the status quo (no standard), then total benefits (the sum of incremental benefits up to the

Further, the net benefits (benefits minus costs) to society of such a standard would be negative, even when considering nonquantified benefits.

President Clinton's Executive Order 12866 directs Federal departments and agencies to perform an analysis of regulations estimated to impose a significant cost burden (greater than $100 million annually) on society as a whole or on any industry in particular. Such an analysis allows the promulgating agency to demonstrate that the benefits of those regulations justify the costs, considering quantifiable and nonquantifiable benefits, which is required by executive order unless applicable law requires otherwise. If benefits exceed costs, the agency would have demonstrated that promulgating the regulation would maximize potential net benefits to society. That is, the beneficiaries of the regulation would achieve benefits in an amount sufficient for them in principle to compensate those bearing the cost burden of the regulation, if they so choose. If not, it would have demonstrated that the potential for such compensation is not there. This is known as the Kaldor-Hicks criterion.[8]

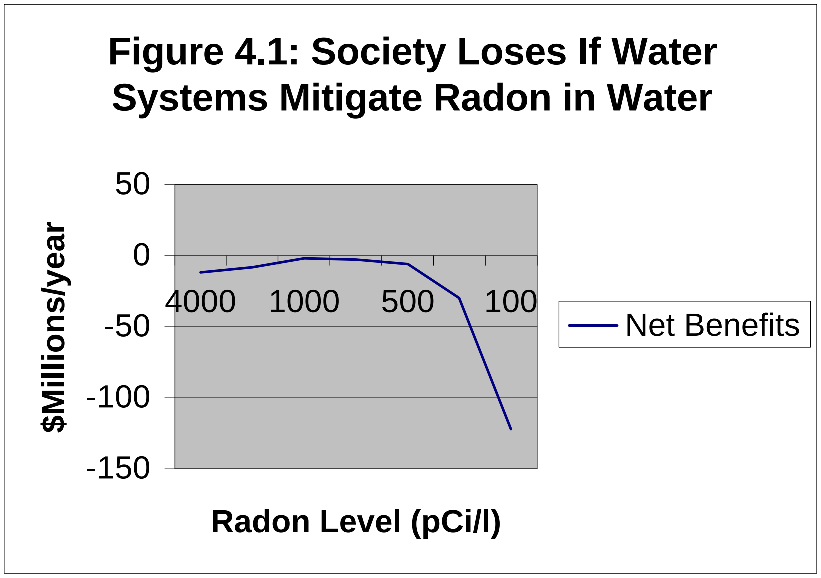
In this instance, the HRRCA demonstrates that the quantified benefits of the radon regulation would <u>not</u> exceed the costs at <u>any</u> MCL under consideration (except when the EPA accounts for the uncertainty inherent in those estimates). If we consider the central tendency of quantified costs and benefits at each possible MCL (as opposed to the upper-bound estimate of the benefits and lower-bound

---

particular standard) minus total costs (the sum of incremental costs to that standard) would be the appropriate comparison.

[8]Kaldor-Hicks is not the only criterion available. Departments and agencies could have been required to demonstrate that the net benefits of a regulation would still be positive, <u>after the winners had actually compensated the losers</u>; however, the informational, distributional and political constraints of such a requirement would often if not always make it untenable.

estimate of the costs), the net benefits are <u>never</u> positive and so society would <u>always</u> experience net losses as a result. The winners could never compensate the losers, even if they wished to. Figure 4.1 (below) illustrates this point.



Source: EPA HRRCA, table 6-12.

If we accept EPA's estimates of the benefits and the costs (and there is reason not to—see subsections 4.2.1-4.2.3 [below] for explanation), it would never make economic sense to establish a water standard at any radon level being considered. The net benefits to society would never be maximized in doing so.

However, we must also consider any potential nonquantifiable benefits of a radon proposal. If nonquantified benefits in addition to quantified benefits were sufficiently large so that benefits exceeded costs, then in principle the winners could compensate the losers and society would experience a net gain as a result. Benefits would justify costs. Unfortunately, in my estimation, the potential benefits submitted by the EPA as nonquantifiable would never make up the difference between quantified benefits and costs, at any MCL considered. Fortunately, the SDWA specifically allows the EPA to raise the MCL if costs exceed the benefits under SDWA section 1412(b)(4).

In the HRRCA, the EPA estimates that quantified costs would come within 10 percent of quantified benefits for MCLs between 1,000 and 300 pCi/l. Presumably, if in August the EPA proposes a standard in that range, the Agency would likely justify such a standard by arguing that the nonquantified benefits could easily make up the difference (between quantified costs and benefits) at the proposed standard. Let us suppose for the moment that the quantified benefits have not been overstated and the costs, not understated (again, see subsections 4.2.1-3). Even so, the nonquantified benefit would still have to be at least $2 million (in 1997$), the difference between costs and benefits where quantified benefits are closest to exceeding costs (1,000 pCi/l), in order for the net benefits to ever be positive. I do not believe that will be the case. Each of the nonquantified benefits submitted would be small if positive at all. Together, they certainly would not be sufficiently large to bridge the gap. Moreover, if nonquantified benefits are insufficient in the case where quantified benefits and costs are nearest each other, then they would also be insufficient at every other radon level, where quantified costs and benefits are further apart. Therefore, the benefits of any MCL considered (<=4,000 pCi/l) would never justify the costs.

In the HRRCA, the EPA identifies several possible nonquantifiable benefits that may result from promulgating the radon rule (which together with the quantified benefits presumably close the gap between benefits and costs at the proposed standard). First, the EPA believes that there would be a "peace of mind" benefit—that is, each consumer would be willing to pay a dollar amount in order to feel better about the ground water they use, as a result of mitigating radon in their water to the proposed MCL. Were we to add up all those dollar amounts, we could arrive at society's willingness to pay to avoid the discomfort (i.e., dis-peace of mind) associated with having quantities of radon in ground water in excess of the MCL. That total dollar amount would thus represent how much better off society would be as a result of the proposed MCL. Second, the EPA believes that the mitigation equipment that would be installed as a result of the regulation could make it easier for water systems to comply with the arsenic regulation. The various aeration technologies considered in the HRRCA are expected to transform any arsenic present in the groundwater of systems installing such technologies into a more soluble form and thus render it easier to remove under the arsenic regulation. Third, the EPA also considers any additional information that systems provide as a result of the radon rule, which contributes to greater consumer awareness regarding safe drinking water, to be another nonquantified benefit of the rule. However, I do not believe that any of these three nonquantified benefits will provide large benefits if any at all. Instead, each of them will likely be offset largely by a disbenefit of the radon rule.

(1) Peace-of-Mind Benefit. It is unlikely that water consumers will experience peace of mind because of the radon rule. First, the EPA provides insufficient justification in the HRRCA (nor is there any reason to believe) that their estimates of the social benefits of mitigating

waterborne radon (i.e., willingness to pay to avoid all the costs of fatal and non-fatal cancers) would not already account for any such peace-of-mind benefits. Second, any such benefits would likely be offset by the confusion the EPA may cause by promulgating too stringent a drinking water standard (below 4,000 pCi/l).

There is insufficient justification given for why the EPA believes that its willingness-to-pay (WTP) measures would not account for "peace of mind" benefits. The EPA explained in the HRRCA that it derived its estimate of society's WTP to avoid fatal cancer cases from 26 studies of the value of a statistical life (VSL); that estimate is the average of a distribution of VSL estimates, borrowed from those studies on the subject. The EPA also explains that its societal WTP estimate to avoid non-fatal cancer cases is borrowed from recent efforts (for the 1998 regulatory impact analysis (RIA) of the Stage I Disinfection By-Products Rule) to estimate WTP to avoid chronic bronchitis.

Because little else is said about those studies (on which social benefits are based), I have to assume that, when deriving their estimates, authors intended to estimate all of the costs that study subjects wished to avoid in estimating their WTP to avoid them. These should include the costs of any dis-peace of mind that people felt from knowing that they must live with chronic bronchitis or even face death, as a consequence of the decisions they make. I have to further assume that the portion of WTP estimates in those studies, which can be attributed only to dis-peace, would be comparable with that of water customers facing cancer risks from radon, since the EPA chose to use those estimates in the first place. By using the average of those estimates in the HRRCA, the EPA has implicitly acknowledged that the WTP to avoid risks in those underlying studies is sufficiently comparable, in every respect, to the WTP to avoid the costs of waterborne radon. If they are not, perhaps the EPA should use different estimates of the social benefits of radon standards. At the very least, the Agency should elaborate upon the studies on which their estimates are based.

Further, any peace of mind benefits would also be offset by confusion over EPA's (so far) divergent approaches to radon. If consumers discover that the EPA has promulgated a water standard that is more stringent than the air standard (4 pCi/l), they are at the very least going to be confused. Imagine a homeowner who has read the EPA Citizen's Guide to Radon (1992c) and has spent years taking the appropriate steps to mitigate radon to 4 pCi/l in indoor air, who then learns that is not enough. In addition, he or she must spend more (potentially much more) for a safe level of radon in drinking water because otherwise it would contribute to their in-home air that he or she has already been assured is relatively safe.

Or, imagine the homeowner, who after reading the citizen's guide, has tested and found relatively safe concentrations of radon in in-home air (below 4 pCi/l) and is at peace that he or she is safe from radon. He or she would be hearing a different message now as well. The guide advised citizens to test the water if radon had been detected in high levels in in-home air. Now the message will be you must pay more for water, regardless of indoor concentrations of radon, because there may be an opportunity to reduce total lung and stomach cancer deaths annually by less than a tenth of a percent.

Leaving aside the possibility that homeowners dismiss outright the tenth of a percent health gain for a moment, it is unlikely that homeowners will believe that they could benefit from that minimal gain. It has been well established in the technical support document to the guide (1992b) that for whatever reason homeowners are unconcerned about radon. It has also been suggested therefrom that one possible source for the lack of concern might be that consumers do not believe they will ever get cancer from radon. (Another plausible explanation might be that, after reading the guide, consumers make a rational choice not to mitigate [or even test] because they consider the risk to be negligible.) Yet, by promulgating a water standard more stringent than 4,000 pCi/l (by congressional mandate the EPA must at least set it there), the EPA would be sending a message to consumers to pay attention to radon because the Agency knows what is best for them. (Since the Congress did not mandate that EPA set the standard below 4,000 pCi/l, the EPA would probably be held accountable for such an action, if the benefits do not justify the costs.) Does the EPA truly believe that the consumers described above will experience a peace of mind as a result of this rule?

(2) Arsenic Regulatory Benefit. The EPA has argued that there is a significant arsenic treatment benefit from radon treatment because aeration facilitates greater arsenic reductions. However, the size of the overlap between radon and arsenic exceedances of the MCL is likely to be quite small. According to the American Water Works Association (AWWA), only several thousand of 56,000 systems are expected to need arsenic treatment for an MCL of 10 ppb. There is no expected correlation between radon hotspots and high arsenic levels. Therefore, the risk-reduction benefits of this rule from reducing arsenic are likely to be small. In addition, any such arsenic benefit may be offset by the costs of risk increases from chlorine disinfection by-products, the consequence of systems having to disinfect because they must install aeration to mitigate radon.

(3) Informational Benefit. There are two reasons why this nonquantified radon benefit is unlikely to be large if positive at all. First, water systems will soon have to produce an annual consumer confidence report, which educates the public with data about drinking water contaminants, including radon. To account for the information benefit in this rule, if it has already been accounted for under the consumer confidence reports rule, is double counting. Second, any small benefit that this rule could affect (incremental to other sources of information) would probably be

> offset by confusion over EPA's inconsistent approaches to radon. It would also be offset by the non-complementary message that the Agency would be sending about radon in air and water, if standards continue to be set so inconsistently.

Therefore, the nonquantified benefits as submitted by the EPA are likely to be small, if positive at all. Certainly the aggregate of those benefits will likely not exceed $2 million (1997$), necessary for the EPA to justify the costs of a standard at 1,000 pCi/l. And, if the EPA cannot even justify a standard there (in the case where benefits are nearest costs), the Agency would not be able to justify any other standard being considered either. Therefore, the benefits would never justify the costs and so the EPA should <u>not</u> propose a water standard below the congressional mandate of 4,000 pCi/l, which brings me to the argument for setting the standard (MCL) at the alternative MCL (AMCL) of 4,000 pCi/l.

The argument for setting the MCL equal to the AMCL is that the net benefits would be most favorable there. By providing for an AMCL, the Congress appears to have established an upper bound, above which it considers radon water concentrations to be unacceptably risky. Hence, the EPA must establish a standard at least at that level (4,000 pCi/l). If, however, the benefits of more stringent standards do not justify the costs, then it would be the EPA (and not the Congress) taking the initiative in setting a more stringent standard. The EPA alone would be held accountable for such an action.

I have already established (above) that the benefits would never exceed the costs, even when considering EPA's nonquantified benefits (above). Ergo, the benefits of water standards below 4,000 pCi/l would never justify the costs. Ergo, such a standard would never maximize net benefits to society. Instead, society would always experience a net loss because the winners from such standards could not compensate the losers at those MCLs. Therefore, the EPA should establish the standard, the MCL, equal to the alternative standard, the AMCL, as the net benefits are most favorable there (even if they are still negative). Establishing it there would be consistent with the congressional mandate (the Congress specifically provided this option) and it would be most cost-beneficial at that level.[9]

4.1.2 Set the MCLG equal to 1,000 pCi/l_{water}. Because radon has been classified as a known human carcinogen, the maximum containment level goal (MCLG) for it has been set to zero. However, the goal—eliminating all cancer risk from radon in groundwater—is unrealistic. It is my understanding that humanity has always been forced to endure exposure to naturally occurring background concentrations of radon outdoors (and perhaps always will). Do such concentrations pose an unacceptable degree of risk? Then why should water utilities have to achieve

[9] The EPA may be concerned that setting the MCL at the AMCL would be contrary to congressional intent (in providing for an AMCL). Had the Congress intended for this (MCL=AMCL), the Congress could have also tied the MCL to the average outdoor concentration of radon. However, the EPA should consider that, at the time, the NAS report had not been released and so the Congress had to rely on information, about which many had voiced concerns (industry groups, OMB, and the EPA Science Advisory Board). As a result, the Congress had to prepare for the possibility that the NAS would find that the risks from radon in water were substantially higher than EPA estimated. Had the Congress blindly tied the MCL to the average outdoor radon concentration, and the NAS did find something unexpectedly disturbing, the Congress would have constrained the EPA from making a decision in the best interests of the American public. The Congress acted appropriately cautious in this instance. And, since NAS findings did generally confirm previous estimates (the risk-reduction benefits of any water standard considered would be minimal), it is reasonable to set the MCL at the AMCL. Indeed, it would be consistent with congressional intent.

lower levels in air than those natural background levels? The EPA should consider background levels when determining the MCLG.

Radiation scientists have always considered background levels when determining acceptable levels of risk. The EPA Science Advisory Board (SAB) noted this when commenting that EPA's approach to mitigating chemical public-health threats is at odds with its approach to mitigating radiation threats. While risk-reduction strategies toward chemical threats (initially developed in the early 1900s for food additives) proceeded from the premise that any risk from man-made chemicals would be unacceptable, such strategies toward radiation did not.

> Underlying all th[e] development [of the notion of practical thresholds—levels of radiation exposure below which lifetime cancer risk is considered negligible] was the knowledge that background exposures to radiation in the range of about 70 to 250 millirem per year (mrem/yr) and averaging perhaps 100 mrem/year dose equivalent (NCPR, 1987) were inescapable. At least initially, these background exposures were generally assumed not to confer significant risks. Thus, as recommended radiation standards became more stringent with the discovery of adverse effects at ever lower levels of protracted exposure, the radiation scientists kept in mind the difficulty of separating excess exposures from natural exposures when the former did not substantially exceed the later. <u>Consequently, cancer risk-reduction strategies for excess radiation exposures have very probably included comparison to background</u>

> radiation in addition to the comparison of risks and benefits resulting from radiation-producing technologies, even though the background exposure issue has usually not been explicitly presented in such decisions (emphasis added) (EPA, 1992a, p. 3).

Some radiation scientists would even question the legitimacy of radiation-source standards that failed to account for natural background radiation levels. The SAB commentary continues:

> The application of standard chemical risk-reduction criteria to radionuclides in these situations leads to limitations on excess radiation dose that are small in comparison to natural background radiation. Knowing the history of the radiation paradigm, it should come as no surprise that some radiation scientists see such limitations on radiation exposures as unworkable or even misguided (Ibid., p. 1).

Radiation scientists have acknowledged the need to account for background concentrations. So has the SAB, by noting it in their commentary. Even the Congress has acknowledged such a need, by providing for an alternative MCL that is tied to the average ambient (outdoor) level of radon (0.4 pCi/l_{air}, according to NAS). Why doesn't the EPA account for background levels?

The EPA has approached radon as if it were a chemical public-health threat—i.e., any risk greater than 10^{-6} (three excess cancer cases per year) should be regulated until it no longer poses a threat (MCLG=0). That may not be appropriate since chemicals do not present the same problem in terms of natural background levels. (Most chemicals do not have them.) Yet, even if the EPA believed that a chemical approach was warranted here, the Agency must recognize that the criterion used (regulate any threat greater than 10^{-6}) is merely one of convenience, as the EPA SAB has noted (Ibid., p. 6). Such recognition would at least be consistent with Agency decisionmaking in the past, when for instance the EPA accepted MCLs above 10^{-4} for chloroform from water disinfection. Indeed, the Agency has accepted MCLs at or above 10^{-4} for carcinogens in drinking water "when limiting them further is not technically or economically feasible" (Ibid., p. 7). The EPA has also "often chosen not require reductions in exposure [to certain chemical threats] when the calculated risks were as high as 10^{-4} or even 10^{-3} when the population exposed was small [according to studies by Travis et al. (1987) and Rodricks et al. (1987)]" (EPA, 1992a, p. 6). Therefore, it would be consistent with SAB commentary and with Agency decisionmaking to accept an MCLG greater than zero. The Agency has made exceptions to the rule for chemical threats (regulate risks above 10^{-6}) before, when it made sense to. It makes sense to make an exception in this case, based on the history of the chemical versus radiation approach (above) and based on the science of radon (below). The EPA should set radon's MCLG greater than zero.

The EPA must also recognize that there is not any direct epidemiological evidence that radon is carcinogenic when ingested—the kind of evidence required to classify a substance as a known (Category I, Class A) human carcinogen (AWWA petition to EPA, 1993).[10] (The EPA has already acknowledged in the

[10]EPA notes that in classifying a substance, "each chemical is analyzed for evidence of carcinogenicity via ingestion" (emphasis added) (56 Fed. Reg. at 33070).

HRRCA [p. 7] that ingesting radon is only “suspected” of being associated with increased risk mostly of stomach cancer.) Instead, the Agency has provided estimates of the cancer risk from ingesting radon based on indirect evidence: mathematical models by the EPA and NAS and a single, unpublished, non-peer reviewed study of xenon’s behavior in the body, xenon presumably being analogous to radon. The EPA has also relied on the understanding that since it has been fairly well established epidemiologically that radon is carcinogenic at high levels of prolonged airborne radon exposure, it is reasonable to infer its carcinogenicity when ingested. However, radon in water poses a slightly different risk than radon in air. Exposure to radon in water is suspected of being associated mainly with increased risk of stomach cancer, whereas exposure to it in air is associated with increased risk of lung cancer. Moreover, the modeled ingestion risk, if correct, would be only 15.4 percent ($[0.2 \times 10^{-8}]/[1.3 \times 10^{-8}]$) of the lung cancer risk from inhalation.

Not to suggest that we should not have a goal; I am only suggesting that it should be set at an achievable level that at the same time provides an adequate margin of safety. The lower-bound estimate of ambient (outdoor) background radon concentrations would constitute such a goal. While the most recent, best estimate for this lower bound would be 0.37 pCi/l (according to the NAS [1998]), setting the MCLG equal to 0.10 pCi/l (EPA’s original estimate of the lower bound) would suffice since it would also provide an adequate margin of safety.[11]

[11] In 1991, the EPA estimated that outdoor radon concentrations averaged 0.30 pCi/l and ranged between 0.10 and 0.50 pCi/l_{air} (EPA, 1994). The NAS [1998] has since updated those figures, estimating that the average outdoor radon concentration is 0.4 pCi/l and is bounded within a credible range of approximately 0.37 to 0.43 pCi/l.

That is, an MCLG of 0.10 pCi/l would be less than half the NAS lower bound (1/2*0.37=0.15), providing a safety buffer of factor 2. Therefore, EPA should establish an MCLG for radon in water equivalent to 0.10 pCi/l_{air}. Since each pCi/l of radon in water contributes on average only 1/10,000 pCi/l to air, radon's MCLG should be established at 1,000 pCi/l_{water}. Establishing such a goal would not only appropriately account for natural background concentrations of radon but would also provide an adequate margin of safety.

4.1.3 Reconsider Best Available Technology (BAT) Determination.[12] The EPA indicated in its 1991 proposal that the Packed Tower Aeration (PTA) technology is the best available technology. However, assuming systems can afford the technology (some may not), many public water systems (mostly small systems) may be unable to install it. Local governments may refuse to issue the appropriate permits because the resulting radon air emissions, the waste by-product of the technology, may pose an unacceptable degree of risk to surrounding populations. Or, systems may choose not to install aeration because the costs are so high, if regulations require permitting and off-gassing treatment. Permitting alone could be cost prohibitive—as much as $10,000 according to an AWWA report (1991, p. 3-34) based on system experiences in California with aeration for volatized organic chemicals (VOCs). As a result, a number of systems may need to install the Granular Activated Carbon (GAC) technology

[12] I have recommended reconsideration of the BAT instead of a small systems variance because there is not an obvious technology on which to base such a variance. Even though it is EPA's position that BAT determinations be based on large systems (since variances have been made available for small systems), I would like the EPA to consider small businesses in determining feasibility in the instance of radon. In this

instead, which is less effective at mitigating radon and more expensive especially when all of the costs of GAC are taken into account. These should include the costs of waste disposal and any associated increases in risk as a result of the spent carbon (which I believe to be radioactive). The annual operating cost of carbon replacement (once every two years) and waste disposal as a low level waste has been estimated to be $5,500 per year, in the AWWA report (Ibid.). The EPA has not indicated whether spent carbon would pose significant risks to society.

Based on figures provided by EPA, GAC technology would be cost competitive with aeration only for the smallest systems (where systems would have to treat only for a few customers) and only then under special circumstances (i.e., when permitting and off-gassing treatment are required for aeration). Yet, the EPA does not seem to have prepared for the possibility that small systems in larger size categories can neither install aeration (because permitting and off-gassing treatment are required) nor GAC (because it is so expensive). The EPA does not expect any significant off-gassing risk from any PTA treatment facilities. I suggest that the EPA reconsider BAT, in light of the above considerations.

4.1.4 Facilitate MMMM programs and establish a default MMM program. Small systems will bear a disproportionate share of the cost burden of a radon proposal and yet these systems will be the least likely to have their own resources available to establish MMM programs (if states do not establish programs for them). Each system will require time, staff, and funds not only to research and develop an

---

instance, the circumstances appear to be unique: (a) a variance technology may be unavailable and (b) any systems unable to install aeration or afford GAC will likely be small.

adequate program but also to coordinate their efforts with their state environmental agency, the EPA, and customers. In other words, the transaction costs of developing MMM programs will be high.

Additionally, the EPA has demonstrated that MMM programs face increasing returns to scale (the standardized marginal costs of these programs are declining [section 3 above]). Since small systems have fewer staff and resources, they will be less able than larger systems and state governments to spread research and other expenses across staff and revenue sources. Hence, the solution to the small-system dilemma will be to somehow reduce the transaction costs of MMM programs and to take advantage of their large economies of scale.

Perhaps one way to do this would be for the EPA to facilitate associations of systems. The EPA could provide a forum and resources for small systems to come together and combine to establish MMM programs. Instead of having one MMM program per system, perhaps we could also have Multi-system MMM programs—MMMM programs. That way, small systems could better spread the costs over a combined, larger staff and resource pool.

The EPA might also provide default "packages" making implementation simple for small systems. Perhaps, the default plan could work as follows. Each system would provide each customer with an information pamphlet about the availability of kits to test radon in in-home air and offer to pay for them. Any customer requesting a kit would receive one and systems would report annually to the EPA with the number of kits provided, number of homes remediating, et cetera. By establishing such a simple default program, the EPA might significantly reduce the transaction costs of developing MMM programs and enable many small systems to use these programs that could not have done so otherwise. Solutions such these—facilitating MMMM programs and establishing default MMM programs—could solve the small-system dilemma. They might even produce benefits that exceed the costs, when considering EPA concerns.

I am aware of several EPA concerns that a "one size fits all" MMM program might be contrary to fulfilling the requirements of the law. First, the EPA seems to be concerned that a default program could allow systems to implement a program without having to fully consider the maximum level of risk-reduction benefits achievable by each system. As long as a default program provided enough benefits for EPA approval, systems would look no further. Second, the Agency seems to be concerned about the perceived fairness of such an approach. By providing a default program, systems with higher radon concentrations in water (and in greater need of mitigation) could use the same program as systems with lower concentrations, which might be perceived as unfair by the systems with low concentrations. Third, the EPA seems also be concerned that such a program might unnecessarily constrain state flexibility in developing MMM programs.

I am unsure these concerns warrant not having default programs, however. As for the first concern, I cannot imagine that systems would ever mitigate to a radon level below what is required for compliance with the standard, not unless doing so made good financial sense. And default programs would make good financial sense, for a lot of systems. At the same time, some systems might still use them, even though they require fewer benefits to achieve the standard. The reductions in transaction costs—savings from not having to coordinate efforts for a more tailored program—might make it financially worthwhile. Hence, default programs might deliver greater risk-reduction benefits than would have resulted in the absence of such programs, if the transaction costs were high enough and enough systems wished to avoid them.

As for the second concern, it is not clear that the problem described would be significant. The default program can be designed to ensure that systems with higher radon levels do more. For example, the EPA could require systems with high levels of radon to provide a minimum of 10 tests per 100 homes, while systems with lower levels could be required to provide only 5 tests per 100. It would be up to systems to determine how best to advertise those kits. The EPA could also design the kits so that the information provided would be adequate to inform the public about the risks associated with radon and the costs and benefits of mitigating it in indoor air.

As for the third, it is not immediately apparent how a default program would affect state flexibility. States could either choose to adopt it (as one possible option) or not, for its own systems. Further, the EPA is not required by statute to allow systems to adopt options that the state would not allow, although this should be considered to allow systems added flexibility.

In summary, EPA concerns appear to be minor. By contrast, the benefits of even a simple MMM program could be substantial (relative to conventional water treatment). Even if one home in 100 mitigates (reduces radon in indoor air from 6 pCi/l to 2), it would be equivalent to reducing radon levels of one home by 40,000 pCi/l of water or a reduction of 400 pCi/l for 100 homes. Treating one home in the air would be the equivalent of treating the entire water system serving 100 homes, at a fraction of the cost.

Default programs would also have a number of advantages. Assuming a default program provides each system with risk reductions sufficient for EPA approval, such an approach would:

(1) Eliminate resource barriers for systems and states,

(2) Provide a ready-made simple program for small systems, and

(3) Ensure a cost-effective mechanism for delivering health benefits.

Not only could such an approach produce more health risk-reduction benefits (than if systems met the standard through conventional water treatment) but it would also produce several others (above) as well.

On balance then, the potential benefits of a default program appear to outweigh the costs. EPA concerns regarding the requirements of the statute appear to be small in comparison with the potential benefits and advantages of default MMM programs. Therefore, I recommend that EPA develop one.

4.2 Recommended Changes to the HRRCA/RIA Analysis

So far, I have accepted the EPA's estimates of costs and benefits, presented in the HRRCA. My analysis and conclusions have been based upon them. However, in the following recommendations, I shall present concerns with respect to the magnitude of those estimates. A central theme of those concerns will be that the HRRCA/RIA will overestimate the benefits and underestimate the costs of the radon proposal, unless key assumptions used to derive the estimates are changed.

4.2.1 Use a lower value of a statistical life for cancer deaths avoided. To estimate the risk-reduction benefits of mitigating radon in water to particular levels, the EPA must quantify the reductions in risk (of premature death from waterborne radon) to be achieved by mitigating to each one of those levels. The EPA must also estimate society's willingness to pay for relatively small changes in that risk. In the HRRCA, that value is $5.8 million per statistical life saved (1997$).[13]

However, EPA's estimate of the value of a statistical life (VSL) may be too high. The EPA concedes in the HRRCA (p. 14) that the cost-benefit results are highly sensitive to its VSL estimate. Yet, judging from the range of VSL estimates used by various agencies in the federal government, EPA's estimate appears to be high (Morrall, 1986). Consequently, the net benefits of a radon proposal may be overestimated. That could mean that the net benefits at every MCL being considered (already negative) would be even more negative. It could also mean that, once corrected, benefits and costs would no longer overlap when the EPA accounts for the uncertainty involved in those estimates.

There is insufficient information in the HRRCA to decide. While the EPA acknowledges the general limitations of using the VSL approach to approximating

[13]The value of a statistical life refers to the willingness to pay for small reductions in the risk of premature death and not to the value of an identifiable individual's life. It is calculated by summing individual willingness to pay to avoid the costs of premature death across a population. The term statistical life refers to the sum of risk reductions expected in a population. It is calculated by multiplying the risk reduction by the size of the affected population. For example, if the proposed MCL for radon reduces the annual risk of death by 1 in 10 for each of 20 people, that would represent 2 "statistical lives" saved per year (20*1/10). If it reduces the risk by 1 in 100 for each of 200 people, that would also represent 2 statistical lives saved.

social benefits, the Agency does not provide any information specific to mitigating waterborne radon. As a result, the validity of the EPA VSL estimate ($5.8 million) remains in question. Without further information, the public will be unable to make an informed decision about EPA's VSL point estimate. They could not even make an informed decision about the range ($0.7-16.3 million, 1997$) and whether it is credible or not.

The public requires more information about the 26 studies, from which the EPA derived the VSL estimate. Specifically, the public needs information about the representativeness of populations studied relative to the population of public ground-water users (for example, the typical public ground-water user may have lower income than the typical member of populations sampled in those studies). At minimum, the EPA should provide descriptive statistics (mean, standard deviation) on the age and income level of studied populations versus those of the public ground-water user population (since age and income are the demographic characteristics most likely to confound the representativeness of the VSL estimate). The public should also have information on the nature of risks encountered by studied populations. If for instance the labor market studies tended to involve unusually risky jobs—e.g., nuclear waste disposal, EPA's VSL estimate may overestimate the true VSL of public ground-water users because less risk adverse people may be more likely to take such jobs. Finally, the EPA should explain what any differences (between studied and ground-water user populations) mean for the representativeness of the VSL estimate. If, for instance, the populations sampled in the 26 studies were on average younger than the typical member of the population of public ground-water users, the VSL estimate may be biased too high because younger people tend to be less risk adverse than older people. The public should be informed of any potential biases in the EPA VSL estimate.

The public not only requires information about the studies themselves but also about how those studies were chosen. My understanding is that the EPA VSL is based on an effort by the EPA to value the benefits of the Clean Air Act (EPA, 1997). In that effort, the EPA decided to base its VSL estimate on a 1992 survey of VSL studies by Viscusi, as opposed to one by Miller (1990) or one by Fisher et al. (1989). Then, the EPA decided to use only certain selected studies from within Viscusi. (The EPA selected 21 wage-risk studies and 5 contingent-valuation studies.) The Agency's willingness-to-pay estimate (to avoid the costs of premature death from unclean air) was based on those selected studies. Apparently, the EPA now intends to use the same results (of the clean air analysis) in the radon analysis.

Consequently, there are two pieces of information missing from the HRRCA, which may be important in evaluating the VSL estimate: the criteria for selecting Viscusi (1992) over Miller (1990) and Fisher et al. (1989), and the criteria for selecting only certain studies from among those contained within Viscusi. With respect to the former, there is document prepared by a contractor (Unsworth, Neumann, and Browne, 1992), which may prove useful to the public. It should be included in the public record with the radon proposal. As for the latter, I cannot identify a comparable document, which could provide the public with information on how the VSL studies were selected from within Viscusi (1992). The EPA should identify one, which could be included in public record with the radon proposal as well.

In Unsworth, Neumann, and Browne (1992), the argument for selecting the Viscusi survey over others is as follows. Because Miller (1990) included certain kinds of studies in his data set (consumer behavioral studies) and also because his results were sensitive to adjustments made to the data (which were controversial among economists), the authors argued that the choice should be between Viscusi (1992) and Fisher et al. (1989). However, so the argument continued, the Viscusi survey should be preferred to Fisher et al.'s because the Fisher survey was older and the Viscusi survey included studies contained within Fisher. The EPA appears to have been persuaded.

Based on the analysis, however, I would have to respectfully disagree with the conclusions of the Unsworth study. I believe the authors should have chosen Miller's survey over Viscusi's and Fisher et al.'s because Miller made adjustments to minimize key, reoccurring sources of bias in VSL studies (e.g., accuracy of risk perception, age, and income). These adjustments were not performed in the other surveys. (Unsworth, Neumann, and Browne, p. 10.) And even if indeed Miller were wrong (because he made the wrong kinds of adjustments), his would have been conservative estimates of the VSL—biased against government intervention, which is the right thing to do since the costs of doing otherwise are so high. If the EPA determines that the benefits justify the costs when really they do not (because their VSL is truly too high), many small systems could go out of business, and so the costs would be too high.

I would have preferred Miller's conservative VSL estimates because of the possible improvements in information. I would urge the EPA to do the same. By contrast, the authors seemed to believe that the adjustments were too controversial to justify any such improvements. But unless the EPA provides the suggested additional information, members of the public will be unable to decide for themselves, about this or any other matter pertaining to EPA's VSL estimate. Until this information is revealed, the credibility of the VSL point and range estimates will remain in question.

4.2.2 Discount Risk-Reduction Benefits (at a real discount rate of 7 percent and over a 20-year period). In estimating the benefits of the radon regulation, the EPA has assumed that risk-reduction benefits will occur immediately (in year zero) and that they will continue to occur in the same amount each year, presumably into perpetuity. However, a statistical life saved tomorrow is simply not as valuable as a statistical life saved today. By committing resources to an investment to save statistical lives, society must forgo all those other things that it could have consumed today instead, with those same resources. The same principle underlies the concept of an interest rate. If banks did not offer an interest rate, consumers, given the choice between consuming today and saving for tomorrow, would never save. This is a basic principle underlying cost-benefit analysis. The Agency should recognize this. It should recognize this because it did so when discounting future cost streams of radon MCLs to the present. It should also recognize this because the US Office of Management and Budget (OMB) instructs them to. In its guidance on Executive Order 12866, the OMB [1996] urges that federal agencies discount future constant-dollar costs <u>and</u> benefits using a real discount rate (i.e., a discount rate adjusted for inflation) of 7 percent. Therefore, the EPA should discount these constant-dollar risk-reduction benefits at every MCL being considered, using the appropriate real discount rate (7-percent) and the appropriate time period (20-years, analogous to EPA's treatment of the costs).

4.2.3 <u>Adopt cost estimates closer to AWWA's</u>. To accurately estimate the net benefits of a radon regulation, the EPA requires good approximations of both the social benefits and costs of the regulation. In the HRRCA, the EPA is using willingness-to-pay (WTP) measures in order to approximate the social benefits. That way, the Agency believes it can more accurately capture societal WTP to avoid <u>all</u> of the costs of waterborne radon. For example, the EPA is using a WTP measure (Value/Life*Lives-Saved) for cancer deaths avoided instead of summing the associated medical expenses and forgone earnings because such a measure is expected to account for those in addition to other related costs (e.g., pain and suffering). Therefore, I believe the EPA has sufficiently justified that, in general, WTP measures better approximate social benefits (although I do not agree with the Agency's particular Value/Life estimate [section 4.2.1 above]). On the cost side of the ledger, however, the EPA has not justified that agency cost estimates better approximate social or opportunity cost (than some other measure). As a result, I believe the proposal's net benefits have been overstated, which are negative already.

The EPA has not justified that its accounting-cost estimates—the cost of purchasing, installing, operating, and maintaining radon mitigation equipment, which any accountant would include on his or her balance sheet—accurately reflect actual system practices. Those estimates certainly do not appear to be based on system experiences. In an AWWA report (1991, pp. 3-31 through 3-33), a contractor verified that the EPA had underestimated the actual costs incurred by 7 of the 9 systems surveyed (8 of the 9 installed PTA).[14] In one instance, the contractor found that the EPA had underestimated costs by 1,136 percent.

The EPA has also not justified that the accounting costs of a radon proposal accurately reflect the opportunity (social) cost of the proposal—the value of the resources committed to mitigating waterborne radon in their next best use. Accounting costs only equal opportunity cost when the market under consideration is competitive (price is perfectly elastic) and any price shifts in that market do not result in significant price shifts in other markets. However, in markets that are imperfectly competitive, accounting costs will underestimate (overestimate) the opportunity cost by the amount of the social loss (gain), resulting from a government intervention (Boardman, Greenberg, Vining, and Weimer, 1996, pp. 68-76). The market for water is obviously not competitive.

[14]However, the EPA believes that industry estimates are more typical of additional costs likely to be incurred by large systems while agency estimates better reflect likely practices among small systems (1993, p. 4-18). I am not sure this is true. Although the representativeness of systems surveyed is unclear from the AWWA report, at least 1 of the 9 systems was small. In that instance, EPA underestimated the system's actual costs, when the costs were adjusted to meet the requirements of the 1991 proposal.

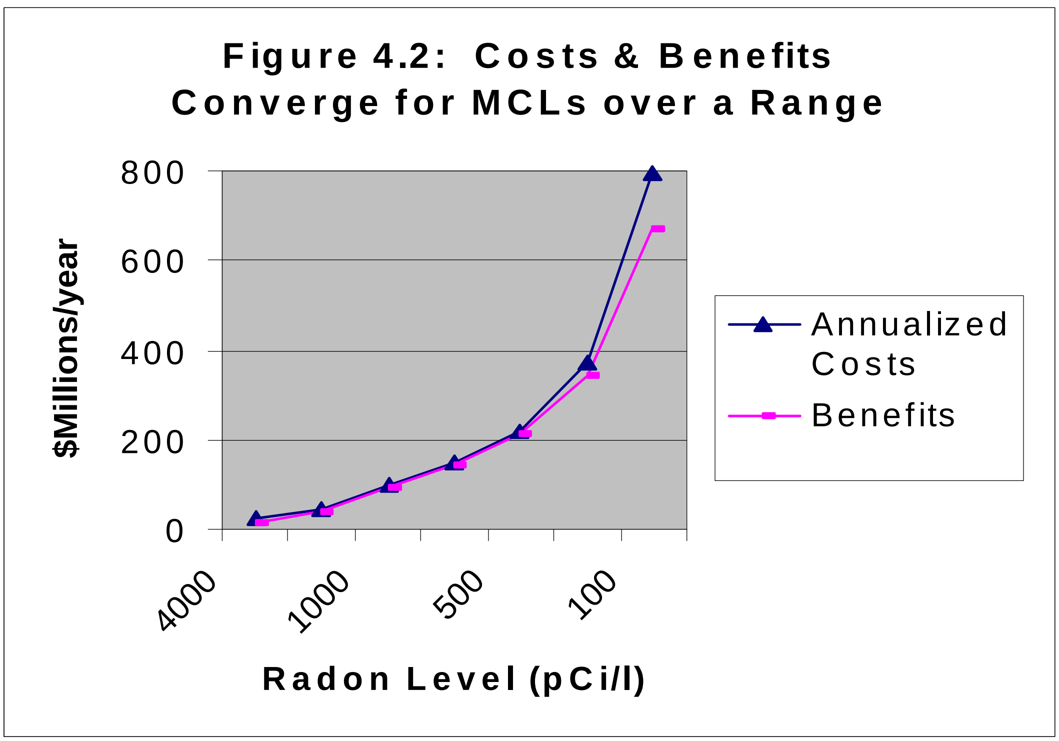
The market for water consists of a collection of regional natural monopolies. Because it is less costly for one system (as opposed to many) to install the water pipes and other equipment necessary to provide water service, one system serves each region. Stated differently, there are large economies of scale in the provision of water. The problem from an efficiency perspective, however, is that a natural monopoly by virtue of being the only supplier of a good can over-charge for it, which could result in too little of the good being provided.

Local governments in California have addressed such a concern about the water market by establishing water boards, from which water systems must seek approval in order to raise water prices. Unfortunately, those boards do not seem to have accomplished what they set out to do. Instead of establishing the price where it should be (i.e., at the marginal social cost of water, where the price would be if the water market were competitive), an economist might argue that the price of water has been set too low. He or she might also say that taxpayers have since been making up the difference (between water's marginal social cost and price) elsewhere, in the form of higher taxes and user fees. Even though the outcome is still inefficient, water consumers do not seem be encountering the type of problem we would expect from a natural monopoly. On the contrary, water prices may now be too low and water consumers may now be experiencing a social gain as a result (even though taxpayers will eventually have to pay for the gain and more, elsewhere).

When estimating the opportunity cost of the radon proposal, the EPA must not only consider the resulting changes in price but also the associated changes in social surplus. If the EPA promulgates a standard that results in systems charging a new water price that exceeds marginal social cost, then the accounting costs of that standard would underestimate the social cost by the amount of the net loss to society. I believe this to be likely, considering the magnitude of the costs of the standard proposed in 1991 (300 pCi/l_{water}). By EPA estimates (1993), such a standard would have cost $286 million per year nationally, which is somewhat lower than other estimates of the costs. In 1991, the AWWA estimated that the proposed standard would cost $2.5 billion per year nationally, while the Association of California Water Agencies (ACWA) estimated that it would cost $520 to $710 million each year in California alone.

Therefore, I recommend that the EPA increase the magnitude of its cost estimates. Since the AWWA has larger cost estimates and those estimates seem to be consistent with actual system practices and experiences with regulations, I suggest that EPA adopt estimates closer to AWWA's. I would even suggest that EPA average its estimates with AWWA's to approximate the social cost of the new proposal. For example, if the EPA proposes a standard of 300 pCi/l in August, the national annual cost of the rule should be $1.4 billion ($[286+2,500]/2 \times 10^9$), assuming all else is equal to the 1991 proposal. If indeed the EPA has underestimated the social or opportunity cost of a radon proposal (and I believe the EPA has), such an approach—i.e., averaging EPA's cost estimates with AWWA's—would be reasonable for solving the problem. Such an approach would also provide EPA with a justifiable and timely fix. I recommend that the EPA use this approach.

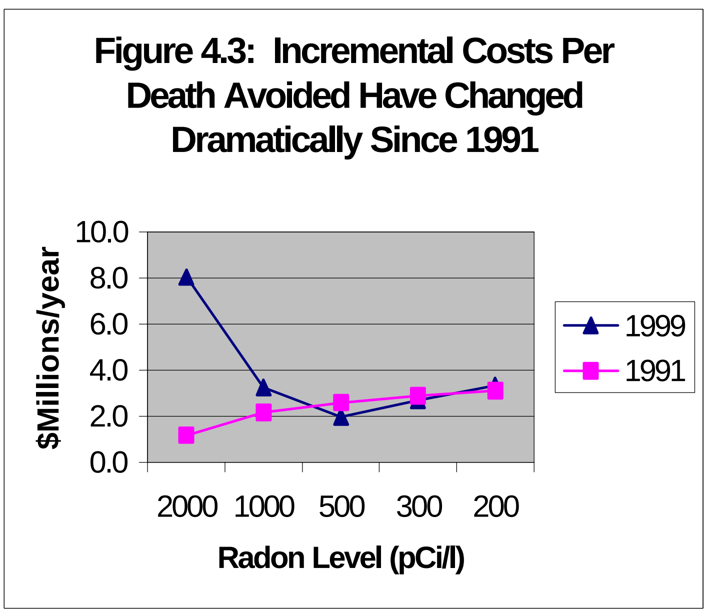
4.2.4 Account for changes to the regulatory analysis since the 1991 proposal. Pursuant to Section 1412(b)(4) of the Safe Drinking Water Act (SDWA) as amended by the 1986 SDWA amendments, the EPA is required to evaluate whether the benefits of a proposed standard would justify the costs. This can only occur if the Agency can demonstrate that the quantified benefits of more stringent standards come closer to exceeding quantified costs than less stringent standards. If the EPA could establish that such a trend exists, the Agency would have a strong cost-benefit argument for setting the standard at more stringent levels, when nonquantified benefits are considered. Rather conveniently, it seems the Agency has found such a trend. Figure 4.2 (below) presents the quantified costs and benefits of a radon proposal, as the standard becomes more stringent.



Source: HRRCA table 6-11.

At radon levels ranging roughly between 2,000 and 500 pCi/l, the quantified benefits and cost curves converge (whereas above 2,000 pCi/l and below 500 pCi/l, they begin to diverge). Assuming that nonquantified benefits could bridge the gap between quantified costs and benefits in that range, standards there would appear to be justifiable from a cost-benefit perspective. Convenient, indeed.

The EPA has indicated in the HRRCA that quantified benefits are within 10 percent of costs over a particular range of standards (from 1,000 to 300 pCi/l). Apparently, this finding is a recent development, as such a trend was not present in the cost-effectiveness analysis—marginal costs divided by non-monetized benefits—supporting the 1991 radon proposal. Figure 4.3 (below) compares the curve of incremental costs per cancer death avoided presented in the 1991 proposal with its equivalent being presented in the HRRCA:



Source: HRRCA tables 6-1,6-7 and 1991 RIA exhibit 6-1.

The shape of the curve, which indicates the rate at which costs are changing relative to benefits, has changed dramatically. In 1999, the non-monetized benefits are increasing at a much faster rate (relative to costs) than they were in 1991. As a result, costs/death avoided were increasing from 2,000 pCi/l to 500 in 1991 but are now declining in 1999 over that range. I am not sure why that is. The number of noncomplying systems has generally declined since 1991 (see table 4.4 below). So has the size of the population that would be affected, at all but one standard considered (200 pCi/l, see table 4.5 below). The NAS report (1998) does not appear to be the source of any of these changes: estimates of the average outdoor concentration of radon, the risks of cancer from ingested and inhaled radon, and the water-to-air transfer factor—these data are all virtually unchanged. Yet, without any apparent cause, the incremental costs have increased only slightly while the non-monetized benefits (incremental deaths avoided) have increased dramatically. Table 4.2 (below) provides a comparison of the incremental costs and deaths avoided presented in the 1991 proposal versus those being presented in the HRRCA. This will allow us to estimate percentage changes in those figures.

Table 4.2: Annual Incremental Costs and Deaths Avoided (over no regulation) Have Changed since 1991.

Radon Level (pCi/l)	Annual Incremental Costs ($Millions)		Annual Incremental Deaths Avoided		Annual Incremental Costs Per Death Avoided	
	1991	1999	1991	1999	1991	1999
2000	23.0	70.0	19.4	8.7	1.2	8.0
1000	31.4	52.0	14.4	16.0	2.2	3.3
500	59.1	120.0	22.8	61.0	2.6	2.0
300	66.4	156.0	22.9	58.0	2.9	2.7
200	64.1	289.0*	20.6	86.5*	3.1	3.3

Source: Compiled from EPA HRRCA tables 6-1, 6-7 and 1991 RIA for Radionuclides exhibit 6-1.

*Note: 1999 figures at 200 pCi/l were calculated by averaging values provided at 300 and 100 pCi/l.

For instance, from the table, we learn that in 1991 the annual incremental cost of changing the standard from 1,000 pCi/l to 500 would be $59.1 million. If the standard were changed again, from 500 pCi/l to 300, the annual incremental cost would be higher, at $66.4 million. This would represent a unit increase of $7.3 million (66.4–59.1) or a 12-percent increase in annual incremental costs ([66.4 – 59.1]/59.1*100%). In 1999, however, the same change in the standard would result in annual incremental costs rising from $120 million to $156 million, a $36 million unit increase or a 30-percent increase ([156–70]/70*100%). Hence, the annual incremental costs for standards between 1,000 pCi/l and 300 increased in 1999 at a faster rate than in 1991. Indeed, it was higher by a factor of 2.5 (30%/12%). If we carry out these same calculations—expressing all of the unit changes in table 4.2 as percentages, a striking pattern emerges. Table 4.3 (below) unveils that pattern. It presents the same incremental annual costs and deaths avoided found in table 4.2 (above), except that changes (from one standard to another) are expressed as percentages.

Table 4.3: Annual Incremental Benefits (deaths avoided) Have Increased Dramatically while Annual Incremental Costs Have Not.

Radon Level (pCi/l)	Annual Incremental Costs ($Millions)		Annual Incremental Deaths Avoided	
	1991	1999	1991	1999
2000	0%	0%	0%	0%
1000	37%	-26%	-26%	84%
500	88%	131%	58%	281%
300	12%	30%	0%	-5%
200	-3%	85%	-10%	49%
Average Δ	33%	55%	6%	102%
Factor Δ (1999/1991)	1	2	1	18

Source: table 4.2.

*Note: 2,000 pCi/l is the baseline.

We find that in 1991 costs increased on average by 33 percent while in 1999 they increased on average by 55 percent. The average change almost doubled

(55%/33%) from 1991 to 1999. Said differently, it increased approximately by a factor of two. By comparison, the non-monetized benefits changed much more dramatically. In 1991, the average increase in benefits was only 6 percent while in 1999 that average was an incredible 102 percent, an 18-fold increase over 1991. A new trend has been revealed. The non-monetized benefits or number of deaths avoided have dramatically increased while costs have remained relatively unchanged.

Therefore, the best explanation for the change in the shape of the cost/death-avoided curve in figure 4.3 (and of the benefit and cost curves in figure 4.2) seems to be that the number of deaths avoided is growing much faster (relative to costs) today than they were yesterday. This is particularly true for MCLs ranging from 2,000 to 500 pCi/l. Since costs have remained relatively unchanged since 1991 (the average change has not even doubled), the dramatic differences must be due to changes in the estimated number of deaths avoided per standard, which brings me to the question of why. (Incidentally, this also brings me back to the question posed in section 3 [analysis] about the shape of the marginal costs/death-avoided curve of MMM-programs. It was always declining, which I speculated in footnote 5 might be due to assumptions that the population affected grows at a geometric rate, as the standard becomes more stringent, and costs grow much slower. The forgoing analysis confirms this.)

In its 1991 radon proposal, the EPA explained how the Agency derived the non-monetized benefits (i.e., the number of deaths avoided) for each MCL. The Agency calculated the product of the annual individual cancer risk per pCi/l of waterborne radon, the size of the population exposed, and the difference between the average level of exposure (among only the exposed population) and the MCL. The annual risk is simply the lifetime risk per pCi/l divided by 70 (the estimated average yearly life span).

Deaths Avoided = Lifetime Cancer Risk/pCil^{-1}/year/individual x Individuals x (Avg. pCil^{-1} - MCL)

For instance, if the proposed MCL were 1,000 pCi/l, 10 people were exposed above that (at an average of 1,010 pCi/l), and the annual cancer risk were 1 in 100, the EPA would expect to avoid one cancer death, by establishing such a standard (10*1/100*[1,010–1,000]). (EPA, 1991, pp. 5-1 through 5-2.)

Therefore, to understand why the number of deaths avoided changed so dramatically, we should examine factors used to estimate them and then determine if and by how much each changed since 1991. These factors include the annual cancer risk per pCi/l (of waterborne radon), number of systems affected per standard, number of individuals per affected system, and average level of exposure per affected individual (relative to the standard). One or more of these factors must have changed in order for deaths avoided to have changed so dramatically. If we could determine which one(s) and by how much, we should be able to answer the question of why.

Unfortunately, I still cannot answer that question. (Nor can I answer the question regarding shape of the MMM standardized marginal-cost curve.)

However, I have narrowed the possibilities. First, revisions in the occurrence data since 1991 do not appear to have contributed to the increase in the deaths avoided. Indeed, the number of systems affected by each standard has generally declined, which is reflected in table 4.4 (below). Any increases have been shaded.

Table 4.4: The Number of Affected Systems in Each Size Category Has Generally Declined since 1991.

Radon Level (pCi/l)	Number of Public Water Systems Affected (by customers served) at each Radon Level (1991 versus 1999)														
	25-100			101-501			501-3300			3301-10000			10000+		
	1991	1999	Δ*	1991	1999	Δ	1991	1999	Δ	1991	1999	Δ	1991	1999	Δ
2000	2,518	689	-73%	1,572	655	-58%	177	82	-54%	4	0	-100%	1	2	100%
1000	5,400	2,154	-60%	3,371	1922	-43%	605	370	-39%	36	15	-58%	17	12	-29%
500	9,799	4,923	-50%	6,117	4335	-29%	1,610	1,173	-27%	185	117	-37%	95	84	-12%
300	13,769	7,531	-45%	8,595	6718	-22%	2,844	2,273	-20%	454	363	-20%	239	249	4%
200**	17,078	9,970	-42%	10,661	9221	-14%	4,102	4,063	-1%	784	948	21%	418	607	45%

Source: Derived from HRRCA table 3-2 and 1991 RIA for Radionuclides, p. A-4.

*Note: Δ = (1999-1991)/1991, in percent.

**Note: Calculated 1999 figures at 200 pCi/l by averaging values provided at 300 and 100 pCi/l.

With few exceptions (e.g., systems serving 3,301-10,000 customers when the MCL goes from 300 to 200 pCi/l), the number of non-complying systems affected has declined since 1991. Thus, the dramatic changes in deaths avoided must be due to other factors. Perhaps the total population affected (more population per affected system), the annual risk and exposure, or both have increased.

First, the lifetime risk of an individual contracting cancer from waterborne radon (from which the annual risk is derived) remains relatively unchanged. By EPA estimates, that risk went from 6.75 chances in 10 million in 1991 down to 6.25 in 10 million in 1999. Second, in general, the affected population has also declined since 1991. Table 4.5 (below) presents the total population affected at each radon level in 1991 compared with that in 1999.

Table 4.5: The Size of the Affected Population Has Generally Declined too.

Radon Level (pCi/l)	Population Affected by MCL (in Millions)		
	1991	1999	Δ
2000	0.8	0.4	-55%
1000	2.7	1.7	-38%
500	8.4	6.9	-18%
300	17.1	16.6	-3%
200**	27.1	36.3	34%

Source: HRRCA table 3-3 and 1991 RIA for Radionuclides, p. A-4.

*Note: Δ = (1999-1991)/1991, in percent.

**Calculated 1999 figures at 200 pCi/l by averaging values at 300 &100 pCi/l.

The number of people affected increases only when the MCL moves from 300 pCi/l to 200. It increases by 34 percent. Nevertheless, notice that the affected population does not increase over the range that we would expect. From 2,000 pCi/l to 500, the cost per death avoided declined by a factor of 4 (table 4.2). If changes in population were truly driving changes in the curve, we would expect the population to increase over the same range. Yet, from 2,000 pCi/l to 500, the affected population is declining. Indeed, it has declined on average by 37 percent ([55+38+18]/3). So, the number of affected people has declined (where it should not). Hence, the population per affected system should be declining too. Table 4.6 confirms this:

Table 4.6: The Population/Affected System Declines.

Radon Level (pCi/l)	Population/Affected System		
	1991	1999	Δ
2000	145	198	37%
1000	307	289	-6%
500	634	470	-26%
300	1001	659	-34%
200	1558	820	-47%

Source: tables 4.4 and 4.5

With one exception, the number of people per affected system has declined. Only when the MCL is set at 2,000 pCi/l (from no standard at all) does the number of people per affected system increase. It increases by 37 percent. However, that does not even explain the difference between the cost/death-avoided curves (approximately 11 deaths, table 4-2) at that point (MCL= 2,000 pCi/l) on those curves. On average, there were 53 more people per affected system (MCL= 2,000 pCi/l) in 1999 than in 1991. Yet, at that MCL, there were 1,643 less affected systems (4,272–2,629, table 4-4). Hence, there were 87,079 less people affected in 1999 than in 1991 (–1643*53). That means that deaths avoided should have decreased, if population (which is declining) were truly the driving factor. In the one instance where population might have explained the change in deaths avoided, it does not.

In summary, the number of affected systems has declined, as have people per affected system (and the affected population). The annual risk has remained virtually unchanged. Every factor considered so far has either stayed the same or generally moved in the opposite direction of what we would expect. Then how have the incremental deaths avoided increased so dramatically since 1991? I would like the EPA to explain this.

The one remaining unexplained factor is whether the average exposure per individual per noncomplying system has changed much. However, I would find it difficult to believe, if the large relative change in deaths avoided were due to increases in average exposure per affected individual over the appropriate range (2,000 pCi/l to 500 pCi/l). Although I suppose it is possible, the change would have to be fairly large in order to offset decreases in the affected population since

1991. At this time at least, it does not appear that any of the factors used to calculate deaths avoided in 1991 are driving changes in deaths avoided.

There is yet another possibility, which could explain changes in non-monetized benefits. It is possible that the EPA used a sufficiently different method for calculating statistical lives saved in 1999. In 1991, the benefits were the product of risk, population size, and the difference between the MCL and the average exposure of the population exceeding the MCL. However, in 1999, the EPA appears to have calculated each difference instead, by assuming that systems with large concentrations of radon (relative to the MCL being considered) would mitigate 99 percent of their groundwater's concentration. Systems with medium exceedances would mitigate 80 percent of their radon concentrations and systems with low exceedances would mitigate 50 percent. If, as a result, the average system is estimated to achieve levels below the MCL, the difference between the MCL and that level could indicate that benefits have been overestimated. Since systems may not mitigate below a proposed MCL, the benefits would be overestimated, on average, by the amount of the difference. The EPA should perform this calculation and decide which is the better approach (estimating differences between exposure and MCL as it did in 1991 or as it did in 1999) by considering whether water systems are expected to regularly achieve levels below the MCL. The agency should also provide this calculation along with an explanation of its rationale in the revised HRRCA/RIA. The revised methodology could help to explain the dramatic changes in deaths avoided since 1991. It could also explain changes in the shape of the costs/death-avoided curve and of the costs and monetized benefits curves. At the very least, it would help to clarify how the EPA calculated non-monetized benefits in 1999 versus 1991.

This new trend—non-monetized benefits increasing at a faster rate than costs—cannot be explained by the information available. It cannot be explained by at least 3 of the 4 factors used to calculate those benefits (assuming the revised methodology did not dramatically change calculations). It also cannot be because the EPA included an estimate of the value of a statistical life in the HRRCA, since I compare changes in non-monetized benefits. Thus, I do not understand what has changed to so dramatically increase the number of deaths avoided since 1991. Therefore, the EPA should provide an accounting of the changes to the analysis since the 1991 proposal. Such an accounting would clear up this confusion and also lend credibility to the findings of the EPA analysis.

4.2.5 Reconsider assumption of Linear No-threshold Relationship. The EPA has estimated a relationship between risk of lung cancer and exposure to radon based on a questionable assumption—that is, the assumption of a linear no-threshold relationship between high-linear energy transfer (high-LET) and cancer risk. The EPA borrowed estimates of the relationship between miners exposed to high levels of radon and lung-cancer incidence among miners from epidemiological studies and has used them in order to estimate the incidence among the general (non-miner) population, who are exposed to much lower radon levels.

In the HRRCA, the EPA provides estimates of the risk-reduction benefits from mitigating radon to levels below 4,000 pCi/l. However, in order to do this, the Agency has assumed that the relationship between exposure to radon and cancer risk is the same at any level of exposure. If an individual is constantly exposed to one unit of radon (pCi/L), the EPA anticipates that there is a chance of approximately 6 in 10 million that person would get cancer during his or her lifetime. If that person is exposed instead to 1,000 units of radon, he or she would be expected to face an individual lifetime risk of roughly 6 in 10 thousand (1,000*6/10,000,000). And, if that person is exposed to one thousandth of a unit of radon, he or she would face a lifetime risk of about 6 in 10 billion (1/1,000*6/10,000,000). Regardless of which level of exposure to radon, the individual would always face a level of risk proportional to the level of exposure. This is the assumption that enables the EPA to draw on experiences of miners exposed at high levels of radon and to use them in order to project cancer deaths among the general population, exposed to low levels.

Unfortunately, the evidence supporting this assumption is weak. Studies of the incidence of cancer at lower level exposures to radon have produced mixed results. Of four case-control studies described by EPA (1992b, p. 2-9), only one (1) found a statistically significant relationship between radon exposure and cancer incidence.[15] One produced borderline results and two revealed nothing at all. Each study involved at least 200 lung cancer cases and 350 controls (n>550)—a sample size (n) large enough to detect fairly small changes in cancer risk due to residential-level radon exposures. Indeed, one study (not considered by the EPA) by Neuberger, Frost, and Gerald (1992) even found an inverse

[15]A statistically significant relationship is one that is unlikely to have been detected by chance alone.

relationship between radon and cancer, based on information from 26 Washington State counties. (The result was statistically significant.) Lung cancer deaths (as a proportion of the total population) were found to be highest in counties with the lowest radon concentrations and to decline toward counties with the highest concentrations.

Therefore, the EPA should reconsider its assumption of a linear no-threshold relationship between radon and lung cancer death. There is little evidence to support such an assumption in residential settings. There is also not any reason to believe that radon would be as effective in causing cancer at low levels of exposure as at high levels.

4.3 Recommended Changes to the HRRCA/RIA Text

I recommend the following changes to the text of the HRRCA/RIA. Many of these changes follow from suggested changes to the analysis (section 4.2 above). However, in instances where the EPA chooses not to adopt analytical recommendations, I would urge the EPA to justify their determinations in the text of the HRRCA/RIA. The following recommendations identify which determinations require justification.

4.3.1 <u>Provide more information on the value of a statistical life</u>. In section 4.2.1 (above), I stated that EPA's VSL estimate might be too high but that there is insufficient information at this time to decide. Therefore, I suggested that the EPA provide descriptive statistics of populations studied (from which the EPA derived its VSL estimate) and the public ground-water user population. I suggested that EPA provide an explanation of what any differences between them mean for the applicability of the EPA VSL in the context of radon. I also suggested that the public should have information regarding the nature of risks explored in those studies (e.g., type of occupations). Finally, I suggested that EPA provide a discussion of the criteria used to select the 26 studies on which the VSL is based. I recommend that the EPA implement those suggestions so that the public may more fully evaluate the EPA VSL.

4.3.2 Clarify derivation of annualized costs and the relationship between incremental and annualized costs. In cost-benefit analysis, one requires the present value of a future stream of costs to determine annualized cost—that is, the constant dollar amount investors must pay each year, for a specified number of years, in order to fully cover the present value of costs. For instance, in its 1991 RIA for Radionuclides, the EPA presented annualized costs based on their present value. Table 4.6 (left) confirms this.

Table 4.7: EPA's Annualized-Cost Finding in 1991 Radon Proposal Can Be Confirmed.

Year	Capital Costs ($M)	O&M Costs ($M/Yr.)*
0	1579	0
1	0	74
2	0	72
3	0	70
4	0	68
5	0	66
6	0	64
7	0	62
8	0	60
9	0	58
10	0	57
11	0	55
12	0	53
13	0	52
14	0	50
15	0	49
16	0	47
17	0	46
18	0	45
19	0	43
20	0	42
Total	1,579	1,131
Real Discount Rate (r)		3%
Present Value of Costs ($M)		2,710
Annualized Cost ($M/Yr)		182

Source: RIA for Radionuclides Exhibit 4-1
*O&M cost ($74m/yr) divided by (1+r)^(yr-1).

Based on EPA estimates in the 1991 proposal, table 4.6 demonstrates that the annualized cost of the proposed radon MCL (300 pCi/l) would have been $182 million per year (excluding monitoring cost). By comparison, the EPA estimated that cost would be $180 million per year. Except perhaps for rounding error, these are virtually the same estimates. Hence, the EPA presented annualized costs based on the present value of costs. Otherwise, I could not have reproduced the results.

However, it is not clear that the EPA has done the same in the HRRCA. Instead of providing the total capital cost, the EPA provides the annual capital cost per standard in HRRCA table 6-6 (along with annual operation and maintenance [O&M] and monitoring costs at each MCL). As a result, I have not been able to reproduce EPA's results. Therefore, I would suggest that the EPA go back to the way it presented annualized costs in 1991—i.e., providing total (not annual) capital costs per standard (except that EPA would now be using a real discount rate of 7 percent, as in the HRRCA). That way, it would be easier to confirm EPA findings.

Also, the EPA should clarify the relationship between the annualized and incremental costs. Specifically, I do not understand why the incremental costs are not the differences between annualized costs at MCLs being considered, as they increase incrementally in stringency. In HRRCA table 6-5, the EPA presents the annualized costs at each possible MCL. I reproduce the results of that table in table 4.7 (below) and add my own estimates of the incremental costs at each MCL, which are based on EPA figures:

Table 4.8: Incremental Costs Should Be Derived From Annualized Costs.

Radon Level (pCi/l)	Annualized Costs ($M/Yr.)	Incremental Costs ($M/Yr.)*
4,000	24	24
2,000	46	22
1,000	98	52
700	148	50
500	218	70
300	373	155
100	795	422

Source: HRRCA table 6-5.

*Incremental cost is the annualized cost at each MCL minus Annualized cost at the previous MCL.

The annual incremental cost of moving the MCL from 4,000 pCi/l to 2,000 is $22 million—that is, the annualized cost at 2,000 pCi/l ($46 million) minus the annualized cost at 4,000 pCi/l ($24 million). In HRRCA table 6-7, however, the EPA estimates that cost to be $46 million instead. I believe this difference is due to a simple mistake. Notice that the annualized cost at 2,000 pCi/l is $46 million. Also notice that, except for that single discrepancy, all other estimates in HRRCA table 6-7 correspond exactly with my estimates in table 4.7 above.

The EPA should confirm that the calculations in HRRCA table 6-7 are accurate. The EPA should also clarify the relationship between incremental and annualized costs. In addition, the EPA should clarify that the annualized costs are based on the present values of costs. The EPA could do this by presenting costs in a manner similar to their presentation in the 1991 RIA for radionuclides. These clarifications would clear up this confusion and help to improve the credibility of the HRRCA/RIA analysis.

Such clarifications would also help to explain cost inconsistencies across HRRCA tables. For example, the annualized costs of a proposed MCL at 4,000 pCi/l is $24 million, yet in HRRCA table 7-2 the incremental cost of that standard (if 100 percent of states implement MMM programs) is $25 million. Should the incremental cost and the annualized cost not be the same at 4,000 pCi/l, since the annualized cost at that level is incremental to having no radon water standard at all? The suggested clarifications would help to answer this question as well.

4.3.3 Reconsider the classification of radon as a known (Category I, Group A) human carcinogen. EPA acknowledges in the HRRCA (p. 7) that radon is only "suspected" of inducing cancer illnesses as a result of ingestion. Yet, the EPA has classified radon as a known human carcinogen. If the Agency does not wish to lend credibility to AWWA's argument in its 1993 petition to EPA, the EPA should discuss the basis for such a classification. In the petition, the AWWA argued that the classification of radon as a known carcinogen must be based on sufficient epidemiological evidence of radon's carcinogenicity when ingested. The EPA has yet to produce such evidence. If there have been improvements in information since the petition, which support radon's carcinogenicity when ingested, then the EPA should provide that information in the HRRCA/RIA where it discusses radon's classification (e.g., p.7). If not, then the EPA should justify why it can classify radon as a known carcinogen without sufficient evidence, contrary to agency policy (56 Fed. Reg. at 33070).

4.3.4 Justify assumptions of lowest-cost technology selection and of accounting costs equaling social cost (p. 10). The EPA has made clear the Agency is assuming that each system will select the technology that could reduce radon to the target MCL at the lowest cost. It also seems clear that the EPA is using accounting costs to approximate social cost. It is not clear, however, that the Agency's lowest-cost assumption is the right assumption. Agency estimates of the unit treatment costs do not seem to be based on actual system practices (section 4.2.3 [above]). Instead, it appears that many systems, anticipated to select the lowest-cost technology, will be unable to because it will not be technically feasible to do so. For instance, small systems in the larger size categories may be unable to install PTA because permitting and off-gassing treatment are required. They may also be unable to install GAC because it would be too expensive to treat for every customer. The EPA should, therefore, justify why its lowest-cost assumption is the right assumption, considering that it may not be technically feasible for many systems to install the lowest-cost technology as assumed.

It is also not clear that accounting costs of a radon regulation are adequate surrogates for the opportunity cost of the regulation. In section 4.2.3 (above), I argued that the accounting cost of the radon regulation would not equal social cost, if the regulated market were imperfectly competitive. It would differ by the amount of the net loss or gain to society, depending on the government intervention. The market for water is imperfectly competitive. And even though water customers may not be experiencing the kind of problems we would expect from natural monopolies, there is nevertheless reason to believe that the water price may now be too low and taxpayers may now be paying for it elsewhere. If, however, the radon proposal results in a new water price, which does not equal marginal social cost; if instead that new price is higher, then the EPA's accounting costs would underestimate the proposal's social cost by the amount of the social loss. The EPA should address this in the HRRCA/RIA, in the appropriate sections.

Accounting costs would also not equal opportunity costs, if the radon regulation caused significant price shifts in other markets. I believe this is likely since capital markets, from which systems must purchase laboratory analyses (of the radon content of ground-water samples) and mitigation equipment, may be imperfectly competitive too. Because there are only a limited number of laboratories available, for example, the market for lab analyses is probably not competitive and so the price for those analyses would not be perfectly elastic. Depending on the relative shapes of the demand and supply curves, a small shift in demand for lab samples could result in significant changes in price and thus social surplus. I do not believe that the accounting costs of a radon proposal would reflect any such changes in social surplus. As a result, accounting costs might over- or underestimate social cost. In either case, accounting costs would not approximate social cost. The EPA should address whether the Agency believes that capital markets for lab analyses and mitigation equipment (the same argument [above] might be true for the equipment markets too) are sufficiently competitive. If they are not, the EPA should justify why the Agency believes that its accounting-cost estimates will adequately approximate social cost. The Agency has already sufficiently justified its willingness-to-pay measures as more adequately proxies of social benefits than other measures. The EPA should do the same with respect to the social costs.

4.3.5 Justify surrogate for non-fatal cancers (HRRCA, p. 11). The EPA has indicated its intention to use willingness to pay (WTP) to avoid small changes in risk from chronic bronchitis, as a proxy for WTP to avoid small changes in non-fatal cancer risk due to exposure of radon in groundwater. However, the appropriateness of such a substitution is not immediately obvious. The only justification given in the HRRCA is EPA discretion. However, discretion is not unlimited. A court may still have to decide if EPA's determination in this matter is arbitrary and capricious. Therefore, the EPA should avoid any confusion by providing some justification for the surrogate. If the justification is simply that the symptoms of chronic bronchitis are sufficiently comparable to the symptoms of radon exposure (and so their WTPs are substitutable), then the EPA should state this. Whatever the justification, the EPA should provide it in the HRRCA in the appropriate sections on non-fatal risks.

4.3.6 Address potential disbenefits of treatment (HRRCA, p. 12). It seems rather disingenuous for the Agency to suggest that this rule includes potential nonquantifiable benefits (i.e., rendering arsenic into a form more easily removed), without at the same time addressing the potential disbenefits, or costs, of such treatment. Specifically, it is possible that the aforementioned benefit may be more than offset by the cost of increases in risk due to chlorine disinfection by-products—a disbenefit of this rule. Hence, the net nonquantifiable benefits could be zero or negative. The EPA should mention this on page 12, in the summary section on the benefits of reducing co-occurring contaminants, and discuss it further in the equivalent section in the body of the report.

Also, another potential disbenefit might be due to the increased cancer risk resulting from systems that opt for the GAC technology. These systems will have to dispose of the spent carbon, the waste by-product of the technology, which might pose significant risks to surrounding communities. The EPA should address this in the same sections as well.

4.3.7 Re-check calculations in HRRCA Table 3-4 (p. 29). The total cancer risk (ingestion and inhalation) estimated in the HRRCA appears to include double counting. If the EPA risk estimates are based on the ES-1 table in the NAS report (1998), it is unclear how the Agency correctly estimated the total cancer unit risk per pCi/l of radon in water. In EPA table 3-4, the EPA presents its estimate of the total lifetime cancer risk per pCi/l in water as approximately 6.25×10^{-7}. That is, during one's lifetime, each person is estimated to face a little over 6 chances in 10 million of contracting cancer as a result of inhaling or ingesting radon from groundwater. In NAS table ES-1, however, the NAS estimates that risk to be only 5.55×10^{-7} (converted to pCi/l).

In ES-1, NAS estimates that the total lifetime risk posed by constant exposure to radon in drinking water at 1 becquerel per cubic meter (1 bq/m^3) is 1.5×10^{-8}(1.5 in 100 million). This figure includes exposure via both ingestion and inhalation pathways. However, we prefer the total lifetime cancer risk from constant exposure at 1 picocurie per liter (1 pCi/l) so we must convert the risk from constant exposure at 1 bq/m^3 to its pCi/l equivalent. Since 1 bq/m^3 is approximately equivalent to 0.027 pCi/l, a risk of 1.5 X 10^{-8} from constant exposure at 1 Bq/m^3 is roughly equivalent to a risk of 4.5 X 10^{-10} from constant exposure at 0.027 pCi/l. To determine the risk from constant exposure at 1 pCi/l (and not 0.027 pCi/l), we would multiply the risk at 0.027 pCi/l constant exposure by a conversion factor (δ), which is approximately 37 (1 pCi/l= δ * 0.027 pCi/l). As a result, the total lifetime risk posed by exposure (via inhalation and ingestion) to radon in drinking water at 1 pCi/l is 5.55 X 10^{-7} (1.5 X 10^{-8} * 37). Yet, in table 3-4, the EPA has estimated that risk from inhalation alone is 5.55 X 10^{-7}. The EPA then adds an additional 7.00 X 10^{-8} (from ingestion) for a total risk (inhalation and ingestion) of 6.25 X 10^{-7}. The risk of ingestion appears to have been double counted.

In general, it would be useful if, when citing or deriving figures from the NAS report, the EPA would refer to the particular table(s) in that report. If the NAS has since revised its estimates, then the EPA should include them in a new table in the HRRCA/RIA. (However, such a revision may not explain why my calculation of NAS's total lifetime risk, which is based on the 1998 NAS report, corresponds exactly to EPA's calculation of total lifetime risk only from inhalation.) In the particular case of risk, it would be useful if the EPA explained how it converted risk estimates from becquerel- to picocurie-unit exposures. It would also be useful if the EPA included NAS risk estimates in becquerel units (in addition to picocurie units). Such clarifications would clear up this confusion over differences between NAS and EPA figures. It would also help to build confidence in agency estimates.

5. REFERENCES

American Water Works Association. 1991. "The Cost of Compliance with the Proposed Federal Drinking Water Standards for Radionuclides," prepared by RCG/Hagler, Bailly, Inc. for American Water Works Association (October 10).

___. 1993. Petition to US EPA regarding National Drinking Water Regulations; Radionuclides (Radon) [WH-FRL 3956-4] (January 26).

Boardman, Anthony E., David H. Greenberg, Aidan R. Vining, and David L. Weimer. 1996. Cost-Benefit Analysis: Concepts and Practice. Upper Saddle River, New Jersey: Prentice Hall, Inc.

Fisher, Ann, Lauraine G. Chestnut, and Daniel M. Violette. "The Value of Reducing Risks of Death: A Note on Evidence." In the Journal of Policy Analysis and Management 8, no. 1: pp. 88-100.

Miller, Ted R. 1990. "The Plausible Range for the Value of Life—Red Herrings Among the Mackerel." In the Journal of Forensic Economics 3, no. 3: pp. 17-39.

Morrall, John F. III. 1986. "A Review of the Record." In Regulation 10, no. 2 (November/December): pp. 25-34.

National Academy of Sciences (NAS). 1998. "Risk Assessment of Radon in Drinking Water (Pre-publication Copy)," a report of the National Research Council. Washington, DC: National Academy Press.

National Council on Radiation Protection (NCRP). 1987. "Exposure of the Population of the United States and Canada from Natural Background Radiation," NCRP Report 94.

National Research Council (NRC). 1998. Health Effects of Exposures to Radon: BEIR VI. Washington, DC: National Academy Press.

Neuberger, John S., Floyd J. Frost, and Kenneth B. Gerald. 1992. "Residential Radon Exposure and Lung Cancer: Evidence of an Inverse Association in Washington State." In the Journal of Environmental Health 55, no. 23 (November): pp. 23-25.

Nicholson, Walter. 1995. Microeconomic Theory: Basic Principles and Extentions. 6th ed. New York: Dryden Press.

Policy Planning and Evaluation, Inc. 1998. "Regulatory Analysis of EPA's proposed Radon in Drinking Water Rule," prepared on behalf of Small Business Administration by Policy Planning and Evaluation, Inc. (October 30), (unpublished at this time).

Unsworth, Bob, Jim Neumann, and W. Eric Browne. 1992. Memorandum to Jim DeMocker, Office of Policy Analysis and Review, Office of Air and Radiation, US EPA regarding a review of existing value of life estimates, November 6. Prepared by Industrial Economics, Inc.

US Environmental Protection Agency (EPA). 1999. "Health Risk Reduction and Cost Analysis for Radon in Drinking Water: Notice, Request for Comments, and Announcement of Stakeholder Meeting (Pre-Publication Copy)," report EPA-815-2-99-002 (February).

____. 1997. "The Benefits and Costs of the Clean Air Act: 1970 to 1990." Appendix I of a report by EPA Office of Air and Radiation (October).

____. 1994. "Multimedia Risk and Cost Assessment of Radon," report EPA-811-R-94-001 to the US Congress on Radon in Drinking Water (March).

____. 1993. "Working Draft Regulatory Impact Analysis National Primary Drinking Water Regulations: Radionuclides." Prepared by Wade Miller Associates, Inc., for US EPA (September 30).

____. 1992a. "Harmonizing Chemical and Radiation Risk-Reduction Strategies," a Science Advisory Board commentary EPA-SAB-RAC-COM-92-003 (May 8).

____. 1992b. "Technical Support Document for the 1992 Citizen's Guide to Radon," report #EPA-400-R-92-011 (May).

____. 1992c. "A Citizen's Guide to Radon: The Guide to Protecting Yourself and Your Family from Radon." 3rd ed. (September).

____. 1991. "Regulatory Impact Analysis of Proposed National Primary Drinking Water Regulations for Radionuclides," prepared by Wade Miller Associates, Inc. under EPA Contract No. 68-CO-0069, WA #0-1 for the Office of Drinking Water, Washington, DC, July 17.

US Office of Management and Budget (OMB). 1996. "Economic Analysis of Federal Regulations," prepared by OIRA/OMB as a best-practices guidance on Executive Order 12866 (January 11).

Viscusi, W. Kip. 1992. "The Value of Risks to Life and Health." In the Journal of Economic Literature 31 (December): pp. 1912-46.

____. 1992. "Chapter 4: A Survey of Values of Risks to Life and Health." In Fatal Tradeoffs: Public and Private Responses to Risk. New York: Oxford University Press.