Academy Recommendations on the Proposed Yucca Mountain Waste Repository: Overview and Criticisms

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Erratum

Title listed as "Overview of the Academy's Yucca Mountain Recommendations" in the journal's table of contents. The title "Academy Recommendations on the Proposed Yucca Mountain Waste Repository: Overview and Criticisms" appears on the article itself and is listed that way in most commercial databases.

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Introduction

When risk assessors face a situation of probabilistic uncertainty in which they cannot minimize both false negatives and false positives, what should they do? In dealing with situations of ignorance or uncertainty, what default assumptions should they follow? Should they assume worst cases or reasonably probable ones? Should they propose risk standards to protect maximally exposed individuals or persons receiving average exposures? Should they assume that future generations have rights to protection equal to those of present generations? To what degree do scientific experts, asked for technical advice on protection from radiation risks, have the right to make policy recommendations about whether to be conservative or permissive in setting standards for public health and safety?

All of these issues have been at the forefront of debate over a recent report published by the U.S. National Academy of Sciences.[1] It recommends standards for protecting public health and safety from threats caused by radioactive waste disposal. This and another article by Thomas Pigford discuss the strengths and weaknesses of the report.

Background and Overview

In 1992, Congress directed the U.S. Environmental Protection Agency (EPA) to promulgate standards to protect public health from high-level radioactive waste in a permanent geological repository that it

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1 National Research Council, Technical Bases for Yucca Mountain Standards (1995); Robert Fri, *Guessing Is Not the Point,* 46 BioScience 490 (1996); Kristin S. Shrader-Frechette, *Science Versus Educated Guessing: Risk Assessment, Nuclear Waste, and Public Policy,* 46 BioScience 488 (1996).

is considering building at Yucca Mountain.[2] The Act requires the EPA to set standards to protect the health of individual members of the public and to ask the National Academy of Sciences for advice. In August 1995, a committee of the Board on Radioactive Waste Disposal of the National Research Council published the advice for which Congress asked.[3]

Since publication, the report has been the subject of great controversy. Indeed, within the Committee itself, there was disagreement about what advice the report ought to give to Congress.

2 The Energy Policy Act, P. L. 102-486.
SEC. 801. Nuclear Waste Disposal.
(a) Environmental Protection Agency Standards.–
(1) Promulgation.–Notwithstanding... any other authority of the Administrator of the Environmental Protection Agency to set generally applicable standards for the Yucca Mountain site, the Administrator shall, based upon and consistent with the findings and recommendations of the National Academy of Sciences, promulgate, by rule, public health and safety standards for protection of the public from releases from radioactive materials stored or disposed of in the repository at the Yucca Mountain site. Such standards shall prescribe the maximum annual effective dose equivalent to individual members of the public from releases to the accessible environment from radioactive materials stored or disposed of in the repository. The standards shall be promulgated not later than 1 year after the Administrator receives the findings and recommendations of the National Academy of Sciences under paragraph (2) and shall be the only such standards applicable to the Yucca Mountain site.
(2) Study by National Academy of Sciences.–Within 90 days after the date of the enactment of this Act, the Administrator shall contract with the National Academy of Sciences to conduct a study to provide, by not later than December 31, 1993, findings and recommendations on reasonable standards for protection of the public health and safety, including–
(A) whether a health-based standard based upon doses to individual members of the public from releases to the accessible environment (as that term is defined in the regulations contained in subpart B of part 191 of title 40, Code of Federal Regulations, as in effect on November 18, 1985) will provide a reasonable standard for protection of the health and safety of the general public;
(B) whether it is reasonable to assume that a system for post-closure oversight of the repository can be developed, based upon active institutional controls, that will prevent an unreasonable risk of breaching the repository's engineered or geologic barriers or increasing the exposure of individual members of the public to radiation beyond allowable limits; and
(C) whether it is possible to make scientifically supportable predictions of the probability that the repository's engineered or geologic barriers will be breached as a result of human intrusion over a period of 10,000 years.
(3) Applicability.–The provisions of this section shall apply to the Yucca Mountain site, rather than any other authority of the Administrator to set generally applicable standards for radiation protection.

3 Technical Bases, *supra* note 1.

Members agreed on most points, but on one issue they diverged. In recommending assumptions for calculating radiation exposures to people in the far future, there was conflict. The Committee presented two alternative exposure scenarios, one involving the "probabilistic critical group" and another involving the "subsistence-farmer critical group." Because the subsistence farmer is the individual at calculated maximum risk, that scenario is conservative and bounding with respect to public health and safety. The probabilistic critical group, however, is based on individual assessors' choices of reference populations and, as such, may be susceptible to manipulation by those performing the calculations. For this reason, the probabilistic critical group may not include the individual at calculated maximum risk and thus may be a more permissive scenario (than that of the subsistence-farmer critical group). Some would argue that it is also a more realistic scenario with respect to public health and safety. A majority of members writing the Academy report sanctioned the use of either the probabilistic critical group or the subsistence-farmer group, in calculating repository-related radiation exposures to people in the far future. One member, however, disagreed and said only the subsistence-farmer scenario was reasonable. This member is nuclear engineer Thomas Pigford, one of the most distinguished experts on the Committee.[4]

Who is correct, Pigford or the rest of the Committee? One way to answer this question is to consult his companion article. A second is to investigate the strengths and weaknesses of the report, independent of Pigford's criticisms. This essay follows the second course but recommends that people also read his analysis. It argues that, despite the strengths of the Academy recommendations on Yucca Mountain,[5] the document falls victim to at least three significant weaknesses: (1) its bibliographical resources are incomplete, and this incompleteness may have skewed its conclusions; (2) the Committee is underrepresented in the areas of public health, hydrology and geology, and overrepresented in physics and engineering, and this imbalance in membership may have skewed the Committee conclusions; (3) because

4 *See* Thomas Pigford, *Maximum Individual Dose and Vicinity-Average Dose for a Geological Repository Containing Radioactive Waste, infra;* Thomas Pigford, *Personal Supplementary Statement* in Technical Bases, *supra* note 1. at 161-185.

5 Technical Bases, *supra* note 1..

the Committee sanctioned moving from both dose and risk standards for radiation to merely a risk standard, its recommendations are less protective of public health and safety than those of the International Commission on Radiological Protection (ICRP), the world's most important standard-setting agency for radiation.

The Strengths of the National Academy Report

The report is a landmark that significantly advances our understanding of both the science and the policy relevant to high-level radioactive waste disposal. It has many assets, especially its recommendation that compliance with the risk standard for radioactive waste be measured at the time of peak risk, whenever it occurs;[6] its conclusion that there is no scientific basis for limiting health-and-safety concern merely to 10,000 years[7] and its important stance on protecting intergenerational equity.

The report also does an excellent job of emphasizing the fact that it is impossible to assess the frequency of intrusion into a permanent nuclear-waste repository for a million years into the future.[8] It explains effectively that there is no system (based on active institutional controls), for post-closure oversight of a repository, that can prevent an unreasonable risk of breaching the engineered barriers.[9]

It is clear and straightforward about many important uncertainties in its recommendations about radioactive waste disposal, site modelling and performance assessment generally.[10] It also does an excellent job of emphasizing that there is no sharp dividing line between science and policy,[11] that there is a limited scientific basis for choosing one policy option over another,[12] and that the Committee ought not recommend what levels of radiological risk (to the public) are acceptable because this is a policy decision.[13] The Committee does a superb job of charting a

6 *Id.* at 2, 55-56, 67.
7 *Id.* at 56.
8 *Id.* at 2, 73.
9 *Id.* at 11.
10 *Id.* at 19-20.
11 *Id.* at *viii.*
12 *Id.*
13 *Id.* at 20, 49.

thoughtful and even-handed course through the tangled morass of science and policy issues.

Perhaps most importantly, the National Academy report correctly calls for choosing Yucca Mountain exposure scenarios on the basis of rule making with full public participation.[14] Such conclusions and recommendations are especially balanced and credible. The breadth and accuracy of the document are remarkable. Despite these strengths, however, three aspects of the report raise concerns: (1) its bibliographical incompleteness; (2) its partially skewed committee membership; and (3) its recommendations' being less protective of public health than those of the International Commission on Radiological Protection (ICRP).

Bibliographical Incompleteness

One bibliographical concern is that the massive 1992 document of the Department of Energy (DOE) peer reviewers, on the Early Site Suitability Evaluation (ESSE) for Yucca Mountain, neither is in the report's bibliography nor appears to have been part of the Committee's deliberations. This document is significant because it is the product of fourteen of the most distinguished geologists and earth scientists in the nation and because the peer reviewers' consensus statement appears to challenge some of the Committee's conclusions. In particular, the peer reviewers' consensus statement challenges the feasibility of many long-term geological estimates at Yucca Mountain, the very estimates that the Academy report said were possible.

Because the Committee's confidence in long-term geological estimation, adequate for performance assessment and compliance, seems at odds with the consensus conclusions of the fourteen DOE peer reviewers for Yucca Mountain, it is important to examine what each group says. After discussing difficulties with the "subjective judgments" in the ESSE,[15] the DOE reviewers (primarily geologists) unanimously concluded, in a "Consensus Position":[16]

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14 *Id.* at 99, 127.

15 *See* Kristin S. Shrader-Frechette, Burying Uncertainty: Risk and the Case Against Geological Disposal of Nuclear Waste, 123-124, 152-153, 164-168, 175 (1993).

16 J. L. Younker, et al., Report of the Peer Review Panel on the Early Site Suitability Evaluation of the Potential Repository Site at Yucca Mountain, Nevada, B2 (DOE

> It is the opinion of the panel that many aspects of site suitability are not well suited for quantitative risk assessment. In particular are predictions involving future geological activity, future value of mineral deposits, and mineral occurrence models. Any projections of the rates of tectonic activity and volcanism, as well as natural resource occurrence and value, will be fraught with substantial uncertainties that cannot be quantified using standard statistical methods.

Although the DOE peer reviewers' "Consensus Position" may be consistent with the geological conclusions of the Academy report, their apparent incompatibility bears examination. Yet, the Academy report did not examine this apparent inconsistency. Despite the peer reviewers' misgivings about long-term risk assessments and future estimates of volcanic and seismic activities at Yucca Mountain, instead the Academy report claims, for example:[17]

> We conclude that the probabilities and consequences of modifications generated by climate change, seismic activity, and volcanic eruptions at Yucca Mountain are sufficiently boundable so that these factors can be included in performance assessments that extend over periods on the order of about 106 years.
>
> Established procedures of risk analysis should enable the combination of the results of all repository system simulations into a single estimated risk to be compared with the standard. (Human intrusion is excluded from such a combination.)
>
> Processes are sufficiently boundable that they can be included in performance assessments that extend over time frames... on the order of about 106 years.
>
> It is possible through careful examination of the geologic record to establish a chronological history of the activity over millions of years. Estimates of activity over similar periods into the future can be made by extrapolation from the past activity.

Whether or not the report agrees with peer reviewers is not the main issue, however. The real concern is that the peer reviewers appear to have raised significant questions that it would have been good to address explicitly in the report. Such questions include:

- If the Committee believes that future societal events cannot be

1992).

17 Technical Bases, *supra* note 1. at 91, 69, 85 and 93, respectively.

predicted,[18] but if future societal events could influence "geological engineering factors," then how are geological engineering factors susceptible to realistic estimation?

• Given massive uncertainties and problems with verification and validation of computer models of future geological events,[19] should million-year performance assessments or million-year estimates of geological events be reliable?

• Are claims about repository compliance and million-year geological estimates matters of expert opinion or science?

• If the Committee finds serious uncertainties about $^{14}CO_2$ exposures;[20] nonuniform radionuclide distributions;[21] fracture flow, especially in the unsaturated zone[22] and "several glacial periods" during the million years of the repository,[23] then how can it place confidence in the million-year geological estimates already mentioned?

While the previous questions, suggested by the "Consensus Position" of the fourteen DOE peer reviewers, may have reasonable answers, the inclusion and discussion of the thick peer reviewers' document — absent from the report bibliography — might have clarified some of these issues. Although no single Committee can do everything, nevertheless inclusion and discussion of the DOE peer reviewers' document might have enabled the Committee to address some important and precisely focused geological questions.[24] The Academy's prestige often gives it "the last word." It cannot have the last word, however, if it relies on repository proponents to give it only the documents that the DOE proponents think the Academy needs.

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18 *Id.* at 96.

19 Naomi Oreskes, Kristin S. Shrader-Frechette & Kenneth Belitz, *Verification, Validation, and Confirmation of Numerical Models in the Earth Sciences,* 263 Science 64 (1994).

20 Technical Bases, *supra* note 1. at 87-88.

21 *Id.* at 88-89.

22 *Id.* at 88-90.

23 *Id.* at 97.

24 *See* Kristin S. Shrader-Frechette, *Nuclear Waste: The Academy and Million-Year Estimates,* 71 Q. Rev. Biology 1 (1996).

Committee Membership: Imbalance and Underrepresentation

A second concern is the composition of the Committee, given the geological and public-health-related conclusions of the Academy report. There appears to have been only one person on the Committee with an advanced degree in geology or hydrogeology (Jean Bahr), only one with an advanced degree in hydrology (Fred Phillips), only one in public health (Melvin Carter), and only one medical doctor (Arthur Upton) out of fifteen members. Instead, most of the members have degrees in physics or engineering. More geologists — particularly specialists in long-term seismic and volcanic prediction and in long-term prediction of rock distress under natural circumstances — might have been useful. Especially in the light of the report of the prestigious peer reviewers, adding volcanologists and seismologists might have forced the Committee to consider and address each of the serious scientific misgivings expressed by the peer reviewers of the DOE report.

Also, because the Academy Committee's charge was "to conduct a study to provide findings and recommendations on reasonable standards for protection of the public health and safety," it seems important to have more than one medical doctor and more than one public-health expert on a Committee of fifteen members. While it is true that such a group can seek expertise from outside, its day-to-day deliberations and decisions need to be accomplished by people who adequately represent the most relevant areas of the Committee charge. To have one public-health expert, on a committee of fifteen charged with making public-health recommendations, is questionable. Also, as well as a "balance of expertise," committees need a "balance of approach." Public-health experts often approach health and safety issues differently than physicists or engineers. Given an Academy Committee dominated by physicists and engineers and with only one public-health expert, it is easy to see that the conclusions may not be as balanced and well considered as they could be.

The concern about sufficient representation in medicine and public health is especially relevant because one member, Thomas Pigford, criticized the recommended exposure scenario as "more permissive than current national and international practice" and said that "its adoption would undermine confidence in the adequacy of public health protection." Whether Pigford is correct or not, more representation in the areas of medicine and public health might have alleviated such concerns and given the Academy report more credibility.

ICRP Recommendations Appear More Protective of Public Health

A third concern about the report is that it rejects the radiological protections recommended by the ICRP, the most influential body recommending radiation standards today.[25] Specifically, the report rejects the ICRP risk-based *and* dose-based (in favor merely of a risk-based) radiation standard. The document also rejects the ICRP ALARA (keep exposures as low as reasonably achievable) rule,[26] and it appears to reject the ICRP principle of optimizing radiation protection and limiting inequity in exposures.[27]

Although there are theoretical reasons for the Committee to reject the double ICRP dose and risk standards, and instead to recommend standards based only on radiation risk (that is, based on the expected value of the probabilistic distribution of health effects), the Committee's decision is questionable. Its choice of *risk,* rather than *dose and risk* standards, appears least practical in the very situation (million-year repository protection) in which the Committee proposes it. The Committee seems correct that, in situations in which the relevant probabilities and consequences can be known precisely, risk may be as desirable a standard as both dose and risk. For situations covering estimates over the next million years, however, it is less clear that a risk standard is preferable to the double ICRP standards of both dose and risk. One reason is that long-term estimates of risk are much less reliable than short-term estimates. Also, actual doses usually can be measured, whereas risks always must be calculated, often on the basis of subjective judgments. The longer the time period of calculation, the more subjective are the judgments used.

The Committee argued that a benefit of their risk (as compared to the ICRP risk and dose) standard was that it would not need to be changed, as knowledge of the dose-response relationship changed.

25 Technical Bases, *supra* note 1. at 4.

26 *See* International Commission on Radiation Protection, Recommendations of the International Commission on Radiation Protection, 28, 71 (Pub. 60 1991).

27 *Id.*

However, as technology improves, inexpensive ways of avoiding needless risks are likely to force some risk standards to change, perhaps to become more protective. Hence both dose and risk standards seem likely to change. Facing possible future changes in standards, the ICRP came to a conclusion opposite to that of the Academy Committee. Providing for additional protection (likely possible because of future technology) is one reason that the ICRP argues that "the choice of [radiation exposure] limits cannot be based on health considerations [risk] alone." A technology-based dose standard is also required. As the ICRP puts it, "ideally" *both* a dose and a risk standard are required, even for potential exposures.[28] For all the preceding reasons, it is questionable for the Committee to recommend only a risk standard. Indeed, as the ICRP notes, a risk-based radiation-protection standard — although often reasonable as a supplement to a dose-based standard — appears to be most needed in the very cases in which it is the least useful: cases where time periods (therefore uncertainties) are great.

As the ICRP dose standards recognize,[29] when the relevant million-year probabilities and consequences are not known precisely — as they are not at permanent repositories like Yucca Mountain — using a risk-based standard, alone, can cause serious scientific and health-related problems. Using a risk standard, alone, may (1) require using arbitrary risk models and assumptions about unknowable future situations, (2) be vulnerable to manipulation by those doing the calculations and choosing the distributions, (3) remove the public's guarantee that exposures will be below a given dose and, most importantly, (4) may generate public controversy because of its complexity and susceptibility to manipulation. Although the proposed risk-based standard is desirable in including potential health effects of radionuclides,[30] members of the public can nevertheless "count on" particular dose standards. They know there will be a definite limit to their exposures, regardless of what experts say. Members of the public are less able to count on something subject to potentially arbitrary assumptions and models. Citizens may believe that they are being asked to "sign a blank check" if they are asked to give up the protection

28 *Id.* at 31.

29 *Id.* at 32.

30 Technical Bases, *supra* note 1. at 30, 63.

of current dose limits and instead to rely on a standard based on yet-to-be-specified models and assumptions about what will happen in a million years.

This "blank check" may become all the more onerous to the degree that radiation protection relies on expert judgment about exposure models, rather than firm guidelines about dose. The "blank check" also may not work if the public is susceptible to "lack of trust in DOE." Besides, practically speaking, a risk imposer cannot adhere to a (risk) standard if he has to perform calculations to determine exactly what the standard requires. Such a standard also would seem to lend itself to "after-the-fact" justifications of exposures, based on whatever was necessary to exonerate the risk imposer. If the current climate of controversy and distrust continues,[31] and if the U.S. adopts the risk-based standard, then citizens might easily imagine something like the following scenario. (1) Citizens receive a future exposure to high levels of radiation. (2) Public outcry results from this exposure. (3) Regulators and industry officials (the risk imposers) try to protect themselves from public criticism by doing an after-the-fact assessment of whether the high radiation releases violated risk standards. (4) Officials, surprisingly, reach the "conclusion" that the high radiation exposure really was associated with a very low risk.

Although a dose standard, alone, appears to have limitations (such as its needing to be changed), employing a risk standard, alone, has the same flaw. However, using the dose standard has the merit of being clear and dependable — no small one in a health standard. As a recent Committee of the National Research Council put it: "Give the public clear-cut, noncontroversial statements of regulatory philosophy."[32]

To understand why the 1995 report appears questionable in recommending risk standards and in rejecting dual risk and dose standards, knowledge of ICRP principles is essential. The ICRP argues that there are at least two cases to which radiation-protection standards are relevant, "exposures" — which we have some reason to expect — and "potential exposures" — for which we have "no certainty that they

[31] Public Reactions to Nuclear Waste (Riley Dunlap, Michael Kraft & Eugene Rosa, eds. 1993).

[32] National Research Council, Improving Risk Communication, 284 (1989).

will occur" or which "may not occur." The ICRP also argues that "dose constraints" are appropriate for "exposures," whereas "risk constraints" are also appropriate for "potential exposures." Because some radioactive waste is certain to lead to exposures over the million-year lifetime of the proposed repository, and because virtually all experts forecast that some exposure will eventually occur, it is arguable that Yucca Mountain will eventually lead to "exposures," and hence that the Committee report ought not have rejected dose constraints in favor merely of risk constraints. It would have been better for the report, instead, to follow ICRP guidelines and to propose dose constraints, or combined dose and risk constraints, which the ICRP says is the "ideal" way of restricting potential exposures,[33] rather than for the Committee to propose merely "risk constraints," as it has done.

Even in cases of "potential exposure," the ICRP recommends using both dose and risk constraints,[34] for at least three reasons. *First,* "a potential exposure may become a real exposure." *Second,* the ICRP warns that assessing risk is more difficult than assessing dose because in the former case "it is necessary to depend on an examination of the procedures for estimating the probability of the exposures. The probabilities cannot be directly determined." In other words, the ICRP warns against the very arbitrariness in future risk calculations already described as a potential problem with the risk-based recommendations of the report. *Third,* according to the ICRP, the dose standard is needed not only "as a limiting restriction on the design and operation of an installation," but also for "its original function of applying controls on each individual's accumulation of dose." Obviously it is much easier to apply controls to an individual's radiation exposure if one has a dose standard than if one has a risk standard subject to potentially arbitrary assumptions about population and distribution. The dose standard clearly specifies that, independent of any assumptions about population or its distribution, no individual ought to be exposed above a certain limit. Moreover, individuals can "count on" this control in exactly the way the ICRP noted.[35]

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33 ICRP at 31.

34 *Id.*

35 *Id.*

For reasons discussed, using a risk standard, alone, as the report proposes, appears less clear and more controversial than using a combined dose and risk standard, as the ICRP recommends. For risks a million years in the future, the devil you know (measurable dose) may be better than only the devil you do not know (calculable risk). Ideally, of course, the acceptability of dose ought to be a function of the risk it entails, but risk is often less measurable than actual dose. Risk, alone, also may not be an adequate standard, given the variety of (and likely changes in) waste-related technologies.

The Committee also leaves itself open to question because it fails to follow ICRP standards that require radiation exposure to be "as low as reasonably achievable" (ALARA).[36] Its grounds for rejecting ALARA are that such a technology-based standard is not useful in discussing nuclear waste disposal because "technological alternatives for repository design are quite limited." Repository decision makers, however, have many technological options — such as whether to use double-walled versus single-walled, or copper versus stainless-steel, canisters. At least some of these options appear to pose choices that ALARA might require. Moreover, the ICRP adopted ALARA in large part to promote a "culture of safety," to tell people to optimize safety, and to pursue maximum vigilance. It adopted ALARA to keep people from blindly following dose or risk limits. Indeed, the optimization principle (optimizing safety) and ALARA constitute one of the three main foundations of ICRP radiation-protection norms.[37] In rejecting ALARA, the Committee appears to sanction something less.

Although the Committee is correct to point out that demonstrating compliance with ALARA is sometimes difficult,[38] courts in the U.K. have found that British Nuclear Fuels violated ALARA in disposing of radioactive waste, and courts in France have held that industries violated regulations by failing to keep exposures ALARA. Given this legal and regulatory background, the report's rejecting ALARA (and its goal of optimizing protection and equity) places the Committee in the questionable position of recommending a policy change which is less protective of public health and safety. The report appears to sanction

36 *Id.* at 28, 71.

37 *Id.*

38 Technical Bases, *supra* note 1. at 13.

radiation standards that are less protective than those of the ICRP, even though the ICRP explicitly warns against blindly following a dose or risk limit "when the optimization of protection [ALARA] is the more appropriate course of action."[39]

To be consistent with ICRP recommendations, the Committee could have retained the dose limit on the releases from the repository. For example, it could have allowed a dose standard of 0.25 mSv/yr, as the French do,[40] and it could have added a proposed risk standard to this dose limit. If the risk standard is as protective as the dose standard, then adopting it gives the public no cause for alarm and actually provides benefits, as the Committee recognizes.[41] If the risk standard is not as protective, then adopting it alone is problematic anyway. There are at least three reasons that it is questionable for the Committee to have rejected making such a dual recommendation on grounds of avoiding policy. *First,* the recommendation to use only a risk-based standard is itself already a policy decision. *Second,* this policy decision deviates from current ICRP policy. *Third,* if the decision is truly a matter of policy, then public rule making may be the better way to make it.

39 ICRP at 31.

40 Technical Bases, *supra* note 1. at 126.

41 *Id.* at 30, 63.