

Radiation Protection with Recommendations for Change*

confusion, with significant consequences for a majority of the U.S. population.

While the NRC uses Reference Man in its overall regulations specified in 10 CFR 20, it uses a different framework in evaluating the effect of the emissions from power plants. These emissions are supposed to be kept “as low as reasonably achievable” (ALARA). The design criteria for this are specified in federal regulations 10 CFR 50, Appendix I. The 1977 guidance for use by the NRC staff in evaluating nuclear power plant applications includes dose conversion factors for infants, four-year-olds, teenagers, and adults. In its guidance, the NRC specifies the evaluation of internal doses to the public in each of these age groups to ensure that the dose to the most exposed does not exceed ALARA guidelines. In evaluating the design of reactors to meet the ALARA criteria, the NRC’s guidance, in effect since the mid-1970s, specifies parameters that enable the calculation of internal radiation doses for exposed individuals of various ages, including infants. However, external radiation doses were not estimated according to age in this guidance.

Department of Energy

Reference Man is also used in the DOE guidance, “Radiation Protection of the Public and the Environment,” because it uses the dose conversion factors from FGR 11. The DOE guidance allows for exceptions to the use of Reference Man, but the use of other models requires special permission and must be approved by DOE. Further, the guidance allows parametric variation, such as location of the individual in relation to the radiation source, but not variation for gender or age.

For external doses, the DOE guidance specifies using dose conversion factors for submersion from EPA’s FGR 12, but also refers to a 1988 DOE document that considers a hermaphrodite model that is an improvement over the Reference Man model. The use of a lower weight (58 kilograms) and the locations of the ovaries and breasts are more appropriate than that in FGR 12, but there is still no routine consideration of children in the DOE guidance.

“RESRAD”

Reference Man is also built into the main computer program used by government and industry to assess risks from radioactivity remaining after remediation of radioactively-contaminated sites and for projections of radiation doses from low-level waste disposal facilities. This model, called RESRAD, was developed and is maintained by DOE’s Argonne National Laboratory.

In the 2007 version of RESRAD, dose conversion factors for children are included, but these new libraries are not required to be used for compliance calculations. In fact, its default dose conversion factor library remains that from FGR 11, which is based on Reference Man. This version of RESRAD is an improvement over prior ones, since one can now calculate doses to children using RESRAD which was not possible with previous versions of the program without modification by the user. However, insofar as the decommissioning regulations of the NRC are based on Reference Man — and they generally are, as discussed above — the nuclear industry is still free to argue that children are not relevant to the regulations and guidance.

Obama-Waxman-EPA correspondence

We applaud EPA’s declaration that it “does not believe in continued use of Reference Man.”

On May 30, 2008, then-Senator Barack Obama and Congressman Henry Waxman, then-Chairman of the House Oversight and Government Reform Committee, sent a letter to then-Administrator Stephen L. Johnson of the EPA, inquiring about the use of Reference Man in EPA guidelines and standards and plans to phase out the use of the Reference Man model.

In EPA’s July 24, 2008 response, Robert J. Meyers, then Principal Deputy Assistant Administrator of the EPA’s Office of Air and Radiation, described the current situation as regards Reference Man as follows:

EPA regulations, guidance documents, and procedures issued prior to 1990 (prior to ICRP Publication 60) were based on Reference [Standard] Man....For some regulatory applications, numerical values to radionuclide-specific doses — as distinct from risks — are still taken from the adult worker dose conversion factors provided in Federal Guidance Reports 11 and 12. However, for many years, our calculations of risk and our regulatory actions and guidance for environmental exposures have factored in the varying age-sensitivity of the population.

The EPA also made this statement in the same letter:

EPA does not believe in continued use of Reference Man, and generally stopped using it in 1990. EPA continues to update and improve its age- and gender- specific models in light of continuing research. EPA’s radionuclide-specific cancer risk coefficients are used for calculating the excess cancer risk to the general population from chronic low level exposure to radionuclides in the environment. Our

risk coefficients and regulatory actions are “conservative” in that they sum the risks from an entire lifetime exposure, taking into account age dependent differences in intake, biokinetics, and sensitivity to radiation. Thus, our regulations are fully protective of the entire population, including infants and children.

We applaud EPA’s declaration that it “does not believe in continued use of Reference Man.” An explicit statement along these lines is long overdue and it is a sign of great progress that it has been made. However, the latter part of the same sentence — that the EPA “generally stopped using it [Reference Man] in 1990” is not fully consistent with the first quote from the letter in which EPA admits that it continues to rely on FGR 11 and FGR 12 for “some regulatory applications.” Not only are these guidance documents based on Reference Man, they are applied widely, in the EPA as well as in the NRC and DOE. EPA’s Clean Air Act compliance is also based on Reference Man.

Further, while the EPA letter states that “the varying age-sensitivity of the population” is factored in to its guidance, there is in fact no specific guidance that even enables a calculation of external doses to children. Children’s external organ doses are estimated as if their bodies were as developed as those of Reference Man, which underestimates doses in many situations. The EPA also has not published guidance for calculating radionuclide-specific internal doses to women of any age for a given intake.

EPA does use updated lifetime risks in its calculations, but such calculations are not at issue. EPA, NRC and DOE regulations are not based on risk but on radiation dose. If the guidance for calculating doses is based on Reference Man, then doses to women and children will be systematically underestimated in many situations.

Hence, it is clear that the EPA did not “generally stop” using Reference Man in 1990. Rather, the use of Reference Man continues to be pervasive. And even in the cases where FGR 13 is properly applied to estimating dose that includes age-dependence, the dose conversion factors for males and females continue to be averaged, as are the risk factors.

We appreciate that the EPA has committed to review the gender-specific dose and risk situation in light of the publication of the BEIR VII report, as noted in its letter:

At issue now is whether separate male and female risk coefficients should be published for the general population, given the approximate two-fold difference in risk per unit dose estimated in BEIR VII. EPA is now examining how best to account for this difference in future guidance and regulations. Any proposed changes in EPA’s radiation risk assessment approach will be subjected to interagency review and public comment through the usual rulemaking and guidance development procedures.

Despite this acknowledged “two-fold” difference in risk between males and females, the EPA’s letter also claims “that the BEIR VII risk estimates do not differ dramatically from those currently in use by the EPA and that “current standards and guidance are protective.” This is misleading.

Current standards are in terms of dose limits, which were largely set in the era of Reference Man. The fatal cancer risk implied by current standards is all over the map, ranging from about 1 in 240 for the overall NRC dose limit of 100 millirem per year to the pathway specific limit of about 1 in 6,000 (rounded) for the 4 millirem per year drinking water limit for most beta and gamma emitting radionuclides that give a whole body dose. However, the fatal cancer risk to females is about 1 in 200 and that to males is considerably lower — about 1 in 300.

The situation is even more problematic when cancer incidence risk is taken into account. The best estimate for cancer incidence risk for women in BEIR VII is more than 60 percent higher than the EPA’s estimate in FGR 13 which averages the risks for males and females. The lifetime cancer incidence risk for females, using the BEIR VII risk coefficients, is about 1 in 100, if the annual dose limit of 100 millirem is maintained. This is very high; a significant tightening of radiation protection standards for the public is in order.

Conclusions

While there has been a modest amount of progress in incorporating some recent guidance that concerns women into radiation protection, the use of Reference Man in radiation protection regulations remains pervasive. Children have often been ignored, even though the science to determine when they may get higher doses has long been available. Women are either partially included or not included at all.

Current radiation protection standards were mostly set before publication, in the last decade, of conclusions that women

and children are generally at much greater risk of developing cancer than men from the same exposure. Hence, radiation protection standards are outdated in two ways that reinforce a lower level of protection for women and children:

- Radiation dose calculations done for proving compliance with regulations use dose conversion factors for Reference Man, with relatively minor adjustments in some cases. This underestimates radiation doses to children in most cases and to women in some cases for the same environmental conditions. Female children are the most adversely affected in many situations.

- Cancer risks from the same radiation dose are generally higher for children and women, though, for some specific cancers, men have a higher risk.

The failure to estimate doses to children and cancer risks to children when they are in excess of doses and risks received by adults would appear to be in violation of President Clinton’s 1997 Executive Order on children, which was reaffirmed by President Bush, with some changes, in 2003:

A growing body of scientific knowledge demonstrates that children may suffer disproportionately from environmental health risks and safety risks. These risks arise because: children’s neurological, immunological, digestive, and other bodily systems are still developing; children eat more food, drink more fluids, and breathe more air in proportion to their body weight than adults; children’s size and weight may diminish their protection from standard safety features; and children’s behavior patterns may make them more susceptible to accidents because they are less able to protect themselves. Therefore, to the extent permitted by law and appropriate, and consistent with the agency’s mission, each Federal agency:

(a) shall make it a high priority to identify and assess environmental health risks and safety risks that may disproportionately affect children; and

(b) shall ensure that its policies, programs, activities and standards address disproportionate risks to children that result from environmental health risks or safety risks.

IEER’s recommendations abbrev’d:

1. **End the use of Reference Man** for estimating both dose conversion factors and cancer risk in radiation protection regulations and guidance.

2. **Calculate compliance to the part of the population receiving the highest dose.** Compliance with annual maximum exposure limits should be calculated using dose conversion factors for the portion of the population that would receive the highest radiation dose for a given set of environmental conditions.

3. **Develop and publish dose conversion factors for females.** EPA’s FGR 11 should be retired and replaced

with an updated version of FGR 13 with dose conversion factors and cancer risks for males and females separately (not averaged) at various ages.

4. **Develop and publish age and gender specific external dose conversion factors.** EPA’s FGR 12 should be revised to include dose conversion factors at various ages for males and females.

5. **Develop and publish fetal dose conversion factors** for use in compliance calculations for cases of declared pregnancy.

6. **Fill critical gaps in early fetal dose estimation methods and put protective standards into place until then.** The assumption that the dose to the embryo/fetus in the first eight weeks of pregnancy is the same as that to the uterine wall is not valid for all radionuclides. Consideration should be given to tightening the maximum contaminant limits for tritium and alpha-emitters until a satisfactory scientific framework can be put into place.

7. **Calculate risks for those most at risk.** Lifetime risk calculations should be based on those most at risk. In general, this means that lifetime risks would be calculated for females, unless risks for specific cancers to which men are more vulnerable are being evaluated.

8. **Revise the default parameters in RESRAD.** DOE Argonne should modify the RESRAD program so that the default calculations always refer to those who would get the highest dose and are at highest risk from a given set of environmental conditions.

9. **Reduce maximum allowable fetal exposure in the workplace.** The maximum allowable fetal exposure in radiation-related workplaces (including DOE facilities and those regulated by the NRC) in cases where a radiation worker declares her pregnancy should be reduced from 500 millirem to 100 millirem using dose conversion factors for fetal exposure. This limit should be reduced when dose limits to members of the public are reduced.

10. **Publish reference characteristics for populations not adequately covered.** The EPA should examine and publish reference biological characteristics for sections of the U.S.

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