Final Report

History and Basis of NESHAPs and Subpart W

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Under

Contract Number EP-D-05-002
Work Assignment No. 4-11, Task 4

Prepared for

U.S. Environmental Protection Agency
Office of Radiation and Indoor Air
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Washington, DC 20460

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September 25, 2008

In accordance with the *Quality Assurance Project Plan: Technical and Regulatory Support to Develop a Rulemaking to Modify the NESHAP Subpart W Standard for Radon Emissions from Operating Uranium Mills (40 CFR 61.25)*, this document has been reviewed and approved by the following individuals:

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1.0 INTRODUCTION

On December 15, 1989, the Environmental Protection Agency's (EPA) Office of Radiation and Indoor Air (ORIA) promulgated a National Emission Standard for Hazardous Air Pollutant (NESHAP) for radon emissions from operating uranium mill tailings (Subpart W). Section 112(q) of the Clean Air Act (CAA), as amended, requires the EPA to review, and if appropriate, revise or update the Subpart W standard on a timely basis (10-year interval). To date, EPA has not revisited this standard since its promulgation and now desires to do so. The purpose of this work assignment is to provide essential technical and regulatory support necessary for EPA to review the technical basis on which the standard was based and the decision-making process that was used to determine the requirements of the standard. Furthermore, this effort will assist the EPA in determining the appropriateness of the standard for this type of pollutant, and to decide if modification of Subpart W is warranted.

The facilities covered by Subpart W are uranium mills licensed and regulated by the U.S. Nuclear Regulatory Commission (NRC) or its Agreement States. There are two separate standards outlined in Subpart W. The first states that existing sources must ensure emissions from tailings impoundments not exceed 20 pCi/m^2-sec of radon-222 (Rn-222). The second prescribes a work practice specifying one of two types of impoundment structures that new sources must construct to handle tailings during operations. The work practice also applies to operations at existing sources once their existing impoundments can no longer accept additional tailings. As part of these two standards, Subpart W also requires that existing sources file an annual report of the facility's emissions.

The standard as promulgated was a health-based standard. It is important to review how the initial standard was developed and to ascertain if it is still valid. Furthermore, it needs to be determined if the standard requires revision to satisfy the requirements in CAA Section 112(d), which requires a technology-based standard. It is also important to determine if this type of standard is appropriate for this type of pollutant.

The reports collected for this review include the original risk assessment material used by EPA to develop the Subpart W standard, including the final rulemaking package for Subpart W (FR 1989), the background information document (BID) for the Subpart W rulemaking (EPA 1989, Volumes 1 and 2), and the economic impact analysis for the Subpart W rulemaking (EPA 1989, Volume 3). This regulatory information was evaluated and compared and contrasted to current risk assessment modeling methodologies. The purpose of this report is to illuminate the differences, if any, and detail what impact this information would have on the original radon risk standard as provided in Subpart W.

2.0 BACKGROUND ON THE DEVELOPMENT OF RADIONUCLIDE NESHAPS

In the following subsections, we present a brief history of the development of environmental radiation protection standards by the EPA, with particular emphasis on the development of radionuclide NESHAPs.

2.1 The 1977 Amendments to the Clean Air Act

On January 13, 1977, the EPA established environmental protection standards for nuclear power operations pursuant to its authority under the Atomic Energy Act (AEA) (FR 1977). The standards, Title 40, Part 190, of the *Code of Federal Regulations* (40 CFR 190), which covered all licensed facilities that are part of the uranium fuel cycle, established an annual limit of exposure and the requirement that licensees keep all exposures "as low as reasonably achievable" (ALARA). Because of the uncertainties associated with the risk of inhaled radon, the standards exempted Rn-222 from the annual limit.

After the promulgation of 40 CFR 190, the 1977 amendments to the Clean Air Act (CAA) were passed. These amendments included the requirement that the Administrator of the EPA determine whether or not radionuclides should be regulated under the Act.

In December of 1979, the Agency published its determination in the *Federal Register* (FR 1979) that radionuclides constitute a hazardous air pollutant within the meaning of Section 112(a)(1). As was stated in the *Federal Register,* radionuclides are known to cause cancer and genetic defects, and contribute to air pollution that may be anticipated to result in an increase in mortality or an increase in serious irreversible or incapacitating reversible illness. The Agency further determined that the risks posed by emissions of radionuclides into the ambient air warranted regulation, and listed radionuclides as a hazardous air pollutant under Section 112.

Section 112(b)(1)(B) requires the Administrator to establish NESHAPs as a "level which (in the judgment of the Administrator) provides an ample margin of safety to protect the public health" or find that they are not hazardous and delist them.

2.2 Regulatory Activities between 1979 and 1987

To support the development of radionuclide NESHAPs, the Agency developed a BID to characterize "source categories" of facilities that emit radionuclides into ambient air (EPA 1979). For each source category, information needed to characterize the exposure of the public was developed. This included characterization of the facilities included in the source category (numbers, locations, proximity of nearby individuals); radionuclide source terms [curie/year (Ci/y)] release rates by radionuclide, solubility class, and particle size); release point data (stack height, volumetric flow, area size); and effluent controls (type, efficiency). Doses to nearby individuals and regional populations caused by releases from either actual of model facilities were estimated using the computer codes AIRDOSE-EPA and DARTAB.

In 1983, the EPA proposed radionuclide NESHAPs for four source categories based on the results reported in a new BID (EPA 1983). The four source categories for which NESHAPs were proposed were Department of Energy (DOE) and Non-NRC-Licensed Federal Facilities, NRC-Licensed Facilities, Elemental Phosphorus Plants, and Underground Uranium Mines. For all of the other source categories that it had considered in its BID (i.e., coal-fired boilers, the phosphate industry, other extraction industries, uranium fuel-cycle facilities, uranium mill tailings, high-level waste disposal, and low-energy accelerators), the Agency found that NESHAPs were not necessary. In reaching this conclusion, the EPA found that (1) the levels of radionuclide emissions did not cause a significant dose to nearby individuals or the regional populations,

(2) the costs of additional effluent controls were not cost effective, or (3) existing regulations under other authorities were sufficient to keep emissions at an acceptable level.

During the public comment period on the proposed NESHAPs, the Agency completed its rulemaking efforts under the Uranium Mill Tailings Remedial Control Act (UMTRCA) to establish standards (40 CFR 192) for the disposal of uranium mill tailings. With respect to the emission of Rn-222, the UMTRCA standards established a design standard calling for a Rn-222 flux rate of no more than 20 pCi/m^2-sec.

In February of 1984, the Sierra Club sued the EPA in the U.S. District Court for Northern California (Sierra Club v. Ruckelshaus, No. 84-0656) (EPA 1989), demanding that the Agency promulgate final NESHAPs or delist radionuclides as a hazardous air pollutant. The court sided with the Sierra Club and ordered the EPA to promulgate final regulations. In October of 1984, the EPA withdrew the proposed NESHAPs for Elemental Phosphorus Plants, DOE-Facilities, and NRC-Licensed Facilities, finding that existing control practices protected the public health with an ample margin of safety (FR 1984). The EPA also withdrew the NESHAP for Underground Uranium Mines, but stated its intention to promulgate a different standard, and published an Advance Notice of Proposed Rulemaking (ANPR) to solicit additional information on control methods. It also published an ANPR for licensed uranium mills. Finally, the *Federal Register* notice affirmed the decision not to regulate the other source categories identified in the proposed rule, with the exception that it was doing further studies of phosphogypsum stacks to see if a standard was needed.

In December of 1984, the District Court for Northern California found the EPA's action withdrawing the NESHAPs to be in contempt of its order. Given the ruling, the EPA issued the final BID (EPA 1984) and promulgated final standards for Elemental Phosphorus Plants, DOE-Facilities, and NRC-Licensed Facilities in February of 1985 (FR 1985a), and a work practice standard for Underground Uranium Mines in April (FR 1985b).

The Environmental Defense Fund (EDF), the Natural Resources Defense Council (NRDC), and the Sierra Club (SC) filed court petitions seeking review of the October 1984 final decision not to regulate the source categories identified above, the February 1985 NESHAPs, and the April 1985 NESHAP. The American Mining Congress (AMC) also filed a petition seeking judicial review of the NESHAP for underground uranium mines.

On September 24, 1986, the Agency issued a final NESHAP for Operating Uranium Mill Tailings, establishing an emission standard of 20 pCi/m^2-sec for Rn-222 and a work practice standard requiring that new tailings be disposed of in small impoundments or by continuous disposal. The justifications for the work practices included the fact that while large impoundments did not pose an unacceptable risk during active operations, the cyclical nature of the uranium milling industry could lead to prolonged periods of plant stand-by and the risk that the tailing impoundments could experience significant drying with the resulting increase in Rn-222 emissions. Furthermore, the two acceptable work practices were believed to actually save the industry the significant costs of constructing and closing large impoundments before they were completely filled. With the promulgation of the NESHAP for Operating Uranium Mill

Tailings, releases of radionuclides to air during operations and tailings disposal at uranium mills were covered by three EPA regulations, 40 CFR 190, 40 CFR 192, and 40 CFR 61, Subpart W.

In November of 1986, the AMC and the EDF filed petitions challenging the NESHAP for operating uranium mill tailings.

2.3 Regulatory Activities between 1987 and 1989

While the petitions filed by the EDF, NRDC, SC, and AMC were still before the courts, a decision by the U.S. District Court for the District of Columbia in NRDC v. EPA (FR 1989), found that the Administrator had impermissibly considered costs and technological feasibility in promulgating the NESHAP for Vinyl Chloride. The court outlined a two-step decision process that it would find acceptable, first establishing a standard based solely on an acceptable level of risk, and then considering additional factors, such as costs to establish the "ample margin of safety." Given the Court's decision, the Agency reviewed how it had conducted all its NESHAP rulemakings and requested that the Court grant it a voluntary remand for its radionuclide NESHAPs. As part of an agreement with the Court and the NRDC, the Agency agreed to reconsider all issues that were currently being litigated, and it agreed that it would explicitly consider the need for a NESHAP for two additional source categories; radon from phosphogypsum stacks and radon from DOE facilities. The subsequent reconsideration became know as the radionuclide NESHAPs reconsideration rulemaking.

2.4 1989 Radionuclide NESHAPs Reconsideration Rulemaking

In the radionuclide NESHAPs reconsideration rulemaking, the Administrator relied on a "bright line" approach for determining whether or not a source category required a NESHAP. Namely, no NESHAP was required if all individuals exposed to the radionuclide emissions from the facilities in the source category were at a life-time cancer risk of less than 1 in 1,000,000, and less than 1 fatal cancer per year was estimated to be incurred in the population. For source categories that did not meet this "bright line" exclusion, a two-step multi-factor approach to setting the emission standards was adopted.

The first step established a presumptively acceptable emissions level corresponding to a maximum individual risk (MIR) of about 1 in 10,000 life-time cancer risk, with the vast majority of exposed individuals at a lifetime risk lower than 1 in 1,000,000, and with the total fatal cancers per year in the exposed population of less than 1. If the baseline emissions from a source category met these criteria, they were presumptively adequately safe. If they did not meet these criteria, then the Administrator was compelled by his non-discretionary duty to provide adequate safety to determine an emission limit that would correspond to risks that were adequately safe.

After baseline emissions were determined to be adequately safe, or an adequately safe alternative limit defined, the analysis moved to the second step, where reduced risks for alternative emission limits were evaluated, along with the technological feasibility and costs estimated to be associated with reaching lower levels. In the two-step approach, the Administrator retained the discretion to decide whether or not the NESHAP should be set at these lower limits.

As with previous radionuclide NESHAPs, exposures were estimated using a combination of actual site data and model or representative facilities and computer models. For all radionuclides other than Rn-222, the CAP88 computer code, which included updates to AIRDOSE-EPA and DARTAB, and the addition of RADRISK, was used to calculate total effective dose equivalent and lifetime fatal cancer risk, and the distribution of risks in the exposed populations. For Rn-222, the CAP88 computer codes were used to established ambient concentrations (pCi/m^3) in each of the sectors in a 0-80 km radius of the source. The concentration within each sector was then converted to working level months (WLMs), based on a 0.70 equilibrium fraction between Rn-222 and its decay products, and a respiration rate appropriate to members of the general public. Using risk factors derived from human epidemiological studies, the WLM exposure data were converted to risks.

Of the NESHAPs promulgated in 1989, those for Phosphogypsum Stacks (Subpart R), Radon from DOE Facilities (Subpart Q), and Operating Uranium Mills Tailings Disposal (Subpart T) are the most relevant for comparison with Subpart W, in that they all address the emission of Rn-222 from relatively large area sources. Furthermore, the basic post-disposal Rn-222 emission limit is consistent at 20 pCi/m^2-s. Regarding the operational phase, no standard was deemed to be necessary for phosphogypsum stacks, since the large ponds that cover most to the top of the stacks and are part of the plants normal operation to control Rn-222 emissions to an acceptable level. For DOE facilities, there is no operational phase, as all these site are simply storage sites for radon-emitting wastes that were generated in the past (most as part of the Manhattan Project). The NESHAP for disposal of uranium mill tailings (Subpart T) was determined to be necessary by the Administrator to assure that the tailings did not remain unreclaimed for long periods of time, as was possible under the UMTRCA standard (40 CFR 192). Additionally, the design standard of the UMTRCA regulations were enhanced by the requirement that the 20 pCi/m^2-sec Rn-222 design standard be demonstrated to have been achieved by post-disposal radon monitoring.

3.0 BASIS FOR THE SUBPART W RISK ASSESSMENT

3.1 Existing Impoundments

As noted previously, the NESHAP for operating uranium mill tailings addressed both existing and future tailings impoundments. For the existing impoundments, the radon emissions and estimated risks were developed using site-specific data for each of the 12 mills that were operating or operable at the time the assessment was made. These data included the average radium-226 (Ra-226) content of the tailings; the overall dimensions and areas of the impoundments (developed from licensing data and areal photographs); areas of dry (unsaturated) tailings; the existing populations within 5 km of the centers of the impoundments (identified by field enumeration); 5–80 km populations derived from U.S. Census tract data; meteorological data (joint frequency distributions) from nearby weather stations; mixing heights; and annual precipitation rates.

The CAP88 codes were used to estimate airborne concentrations based on the calculated Rn-222 source term for each facility. Radon-222 source terms were estimated on the assumption that a Rn-222 flux of 1 pCi/m^2 -sec results for each 1 pCi/g Ra-226 in the tailings and the areas of dried tailings at each site. The radon flux rate of 1 pCi/m^2-sec per pCi/g Ra-226 was derived based on both theoretical radon diffusion equations and the available radon emissions measurements.

For each sector in the 0–80 km grid around each facility, the estimated Rn-222 airborne concentration was converted to cumulative WLMs assuming a 0.70 equilibrium fraction between radon and its decay products, an average respiration rate appropriate for members of the general public, and the assumption of continuous exposure over a 70-year lifetime. Using a risk coefficient of 760 fatalities/10^6 WLM, lifetime risk, fatal cancers per year, and the risk distribution were calculated for the exposed population.

The baseline risk assessment for existing uranium tailings showed MIR of 3×10^{-5}, with 0.0043 committed cancers in the 2 million persons living within 80 km of the mills. The distribution of the cancer risk showed that 240 persons were at risks between 1×10^{-5} and 1×10^{-4}, and 60,000 were at risks between 1×10^{-6} and 1×10^{-5}. The remainder of the population of about 2 million were at a risk of less than 1×10^{-6}. Based on these findings, the EPA concluded that baseline risks were acceptable.

The decision on an ample margin of safety considered all of the risk data presented above plus costs, scientific uncertainty, and the technical feasibility of control technology necessary to lower emissions from operating uranium mill tailings piles. As the risks from existing emissions were very low, the EPA determined that an emission standard of 20 pCi/m^2-sec, which represented current emissions, was all that was necessary to provide the ample margin of safety. The necessity for the standard was explained by the need to assure that mills continued the current control practice of keeping tailings wet and/or covered. Finally, in order to assure that groundwater was not adversely affected by continued operation of existing piles that were not synthetically lined or clay lined, the NESHAP ended the exemption to the requirements of 40 CFR 192.32(a), which protects water supplies from contamination.

3.2 New Impoundments

The risk assessment for new mill tailings impoundments was based on a set of model mills, defined so that the impact of alternative disposal strategies could be evaluated. For the purpose of estimating the risks, the model mills were characterized to reflect operating mills, and the dispersion modeling and population exposures were based on the arid conditions and sparse population density that characterize existing impoundments in the southwestern states.

The results of the modeling exercise indicated an MIR of 1.6×10^{-4}, a fatal cancer incidence of 0.014 per year, and only 200 persons at a risk greater than 1×10^{-4}. Given the numerous uncertainties in establishing the parameters for the risk assessment and in modeling actual emissions and exposures, the Administrator found that the baseline emissions for new tailings impoundments met the criteria for presumptively safe.

The decision on an ample margin of safety for new tailings considered two alternatives to the baseline of one large impoundment; phased disposal using a series of small impoundments and continuous disposal. The evaluation of these alternatives showed a modest reduction in the MIR and the number of fatal cancers per year, but a significant increase in the number of individuals at a lifetime risk of less than 1×10^{-6}. The costs estimated for the two alternatives showed that phased disposal would lead to an incremental cost of $6.3 million, while continuous disposal was believed to actually result in a modest cost saving of $1 million.

Given the large uncertainties associated with the risk and economic assessments performed for the new tailing impoundments, and considering the boom and bust cycles that the uranium industry has experienced, the Administrator determined that a work practice standard was necessary to prevent the risks from increasing if an impoundment were allowed to become dry. Finally, although continuous disposal showed slightly lower over-all risks and costs than phased disposal, the Administrator recognized that it was not a proven technology for disposal of uranium mills tailings. Therefore, he determined that the work practice standard should allow for either phased disposal (limited to 40-acre impoundments, with a maximum of 2 impoundments open at any one time) or continuous disposal.

4.0 COMPARISON OF THE NESHAPS RISK ASSESSMENT WITH CURRENT RISK ASSESSMENT APPROACHES

Since it is neither feasible nor practical to directly measure the exposure of individuals in the 0–80-km area surrounding an emission source, risk assessments rely on modeling exposures. The essential elements in assessing the risk from a source emitting Rn-222 to the ambient air are as follows:

- The source term (Ci/y)
- The dispersion of the Rn-222 from the source to the receptor
- The ingrowth and depletion of the short-lived Rn-222 decay products from the source to the receptor
- The location of the receptors within the assessment area
- The duration of the receptors' exposures
- The fatal cancer risk/unit of exposure (risk/cumulative WLM)

The following paragraphs discuss how each of these elements were derived for the risk assessments performed in support of the Subpart W rulemaking and suggest where different values might be used if the assessments were performed now.

The source terms for existing impoundments were based on radon flux rates (pCi/m^2), Ra-226 concentrations in the tailings, and the areas of unsaturated tailings exposed at each site. The radon flux rate that was used, 1 pCi/m^2 Rn-222/pCi/g Ra-226, was selected based on theoretical diffusion rates from thick sources. As diffusion rates depend on the porosity of the matrix and its moisture content, the specific rate that was selected was chosen to reflect site conditions that pertain in the southwestern part of the country where the industry is concentrated. The concentrations of Ra-226 in the tailings reflect measurement data, while the areas of unsaturated tailings were estimated based on both photographs of the impoundments and information supplied by the industry during the public comment period. Given that the NESHAP imposed an annual requirement for the facilities to measure and report their Rn-222 emissions, it should now be possible to develop the source term for each mill based on measurement data. If this approach were to be taken, it would be necessary to know the configuration of the impoundment during each measurement period.

The dispersion of the Rn-222 from the tailings impoundments to the receptors in the assessment area were estimated using the AIRDOSE-EPA model in the CAP88 assessment code. AIRDOSE-EPA uses a Gaussian plume dispersion model to calculate air concentrations at the locations of the receptors. The model uses meteorological data (in the form of joint frequency distributions of wind speed and direction by stability class), annual precipitation rate, and lid height supplied by the user, and it accounts for removal from the plume by dry deposition and scavenging. The model allows for the source to be characterized as either a point source or an area source, and allows the user to input the effective release height. For the risk assessments, impoundments were characterized as area sources with an effective release height of 1 meter. As on-site meteorological data were not available, joint frequency data representing long-term averages were obtained from the nearest weather station. Annual precipitation rates and lid heights were site-specific.

While the EPA has developed a number of dispersion models, including some that are more sophisticated than the AIRDOSE-EPA model, the AIRDOSE-EPA model is preferred for assessments involving radionuclides. When its predicted concentrations have been benchmarked against measured values, it has demonstrated good agreement; in fact, it has often surpassed the performance of more “sophisticated” models.

The ingrowth and decay of the Rn-222 decay products is very important to estimating the risks from Rn-222 exposure. When the Rn-222 emanates from the tailings, the fraction of its short-lived decay products is zero, as they are retained in the tailings matrix. However, their ingrowth begins immediately, and theoretically could reach 100% (total equilibrium) at some distance. As a practical matter, 100% ingrowth is unlikely to ever be attained, due to dry deposition and scavenging during plume transport. For the Subpart W assessments, the equilibrium fraction of decay products was set at 0.70. The equilibrium fraction of 0.70 is appropriate for distances beyond approximately 15,000 meters from the impoundments (where the majority of the exposed populations are located) and assumes that an individual spends 75% of their time indoors. For individuals nearer to the impoundments than 15,000 meters, the assumption of a 0.70 equilibrium fractions will over-state their exposure and resulting risk.

Since the NESHAP Subpart W was promulgated, there has been a great deal of work done to better characterize the appropriate equilibrium fraction for assessing exposure to Rn-222. In general, these studies suggest a somewhat lower fraction than was used in the Subpart W assessments, which would have the effect of lowering the estimated risks (UNSCEAR 2000).

The locations of the receptors in the 80-km assessment area around each site were determined in one of two ways. For the 0–5 km radius, actual site visits were conducted, and the populations in each of 16 directions were determined for distances of 0.5, 1.0, 1.5, 2.0, 2.5, and 5.0 km. For distances between 5 and 80 km, increments of 5 km and 10 km were used, and U.S. Census tract data were used to estimate the population in each sector.

Locating the nearby receptors by actual enumeration is seldom possible when conducting risk assessments. Generally, the best that can be done is to identify nearby sectors where persons are presumed to reside. Using the U.S. Census tract data to populate the 5–80 km assessment grid, while not perfect, as it places all of the tract's population at the centroid of the tract, is as accurate a means of calculating collective exposure as we have.

For the NESHAPs risk assessment, individuals in the population are presumed to experience a constant level of exposure over a 70-year period (i.e., lifetime). While the Agency has often been criticized for making this assumption, it has repeatedly found that it is appropriate for evaluating radiation risks where age at exposure is an important factor in the over-all risk.

The final step in the assessment of the risks from Rn-222 released from operating uranium mill tailings impoundments is to correlate the exposures with risk. For almost all radionuclide risk assessments, the risk is based on dosimetry models. However, for Rn-222, it is based on epidemiology. Specifically, based largely on work presented by the Nation Council on Radiation Protection (NCRP 1984) and the International Commission on Radiological Protection (ICRP 1977), the NESHAP used a risk of 760 fatal cancers/10^6 cumulative WLM (reflecting a risk coefficient of 7.6×10^{-4}/WLM).

As with the equilibrium fraction, considerable additional studies have been conducted to determine the appropriate risk coefficient for Rn-222. EPA's current recommended risk coefficient is 5.38×10^{-4} per WLM. This value is based primarily on the National Academy of Sciences Report BEIR VI (NAS 1999). The EPA recommended risk coefficient is reported in Section VI of "EPA Assessment of Risks from Radon in Homes," EPA 402-R-03-003, June 2003. Table 10 of that report, reproduced below, provides a more detailed breakdown of the risks.

Table 10: Estimates of risk per WLM by smoking category and gender for a stationary population in which 53% of males and 41% of females are ES (Authors note: In this table, ES refers to ever smoked and NS refers to never smoked).

Gender	Smoking Category	Risk per WLM[a] (10-4)	Expected Life Span (years)
Male	ES	10.6	71.5
	NS	1.74	72.8
	ES and NS	6.40	72.1
Female	ES	8.81	78.0
	NS	1.61	79.4
	ES and NS	4.39	78.8
Male & Female	ES	9.68	74.2
	NS	1.67	76.4
	ES and NS	5.38	75.4

[a] Based on 1990 adult (ages greater than or equal to 19 y) ever smoked prevalence data (58.7 males and 42.3 females are ES) and assumption that 37% males and 36% females or children (ages < 18y) will become ES).

If the risk assessments for Subpart W were done today, the over-all risks that would be estimated would likely be somewhat lower than those estimated in 1989.

5.0 CONCLUSIONS

The risk assessments that were performed for the NESHAP for Operating Uranium Mill Tailings were based on the best data and science that were available at the time. While it is unlikely that the over-all risk profile would change significantly if the assessments were redone today, additional data and new scientific findings have become available. Most significantly, measured emissions data should be available, and the current scientific consensus on both equilibrium fractions and the radon risk coefficient could be used in the assessment.

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