Remedial Actions

Environmental Remedial Action – Are We Doing More Harm than Good?

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Abstract

Background: The International Commission on Radiological Protection (ICRP) [1] has stated that interventions i.e., remedial actions should do more good than harm. Because remedial action is largely a construction activity one can examine the published statistics to understand the construction worker risk involved. Construction risks ranks third in occupational danger behind agriculture/mining and forestry/fishing, but has a much larger workforce. For the decade of the 1990s the fatality rate and causes have not changed significantly with an annual risk of about 1 in 10,000 to construction workers of being killed on the job. This risk is considerably higher than the environmental risk (typically expressed as cancer) to the public which remedial action criteria tend to specify.

Various researchers have published that toxins in the environment only cause a small percentage of cancers i.e., 1–3 percent [2,3]. Estimates of hypothetical fatal cancers are inflated because of highly inflated parameters driving dose estimates. Primarily it is assumed that people will change their living habits and move onto or near uncontrolled waste sites.

Methods: The experience from completed cleanup projects has been examined to answer the question posed in the title. These case studies highlight methods used to estimate the risk or cancers saved because of the remediation-taking place compared to the actual worker injury and fatality experience. Even though some analysis include the estimates of worker risk, there is little or no discussion which highlights the fact that *real risk* is being traded for hypothetical risk. This paper is an attempt to review this situation and through cited literature and the cases studied, come to a better understanding of what if any good is really being done.

Results & Discussion: High percentage occupancy factors, e.g., 100% are used which multiplied by large populations exposed to miniscule levels of radiation [4] (at or near background levels) unreal levels of fatal cancers are predicted. Observed are technically indefensible numbers of cancers being calculated for these hypothetical people. This and other maximizing assumptions inflate the risk. The inflated risk, along with very conservative criteria, drives the removal of large volumes of soil and debris. An unintended consequence of these costly well-intentioned [5] remedial actions is the real fatalities and injuries that occur to workers doing the construction and to members of the public through transportation activities.

Conclusion: It is important to consider the transfer of risk from hypothetical victims to the real victims in remedial action decision making.

Abbreviations: **CERCLA:** Comprehensive Environmental Response, Compensation, & Liability Act; **DOE:** United States Department of Energy; **EA:** Environmental Assessment; **EIS:** Environmental Impact Statement; **ICRP:** International Commission on Radiological Protection; **NOAA:** National Oceanic and Atmospheric Administration; **NRC:** Nuclear Regulatory Commission; **OSH:** Occupational Safety & Health; **RCRA:** Resource Conservation & Recovery Act; **SARA:** Superfund Amendments & Reauthorization Act; **UMTRA:** Uranium Mill Tailings Remedial Action

Keywords: Cancer; debris; Enewetak; environment; fatalities; harm; hypothetical; injuries; intervention; population; radiation; radon; remedial action; risk; soil

Introduction

The International Commission on Radiological Protection (ICRP) [1], has proposed for environmental remedial actions a philosophical view that "The proposed intervention should do more good than harm, i.e., the reduction in detriment resulting from the reduction in dose should be sufficient to justify the harm and the costs, including social costs, of the intervention."

Living each day is not without some risk. As we engage in activities, either personally or as a society, we incur risk to others and ourselves. Congress has passed various legislation that has mandated and driven environmental remedial action, e.g., CERCLA, RCRA, SARA and UMTRA, etc. When Congress passed this legislation, they probably believed that they were doing the right thing and were helping to reduce risk. The various US Government Agencies that implement these laws and others seem to be bent on reducing risk from *any* potential environmental toxin/carcinogen to the lowest achievable level. The various criteria, which have been implemented to direct environmental remedial action, have evolved to where today's standards are very low. The median cost for proposed Environmental Protection Agency's (EPA) environmental intervention ($7.8 million/life year saved) has greatly exceeded the median cost of intervention required by other federal regulators, such as the Federal Aviation Administration ($23 thousand/life-year saved) [6]. Performing the construction work dictated by these highly conservative criteria can transfer the risk from what is generally a hypothetical population with fatal cancers calculated as theoretical deaths, to workers and members of the public which are real, where deaths and injuries happen to people with names. The thesis of this paper is that in creating this situation where billions of dollars are spent annually saving hypothetical lives, the Federal laws as administered by the various Bureaucracies may, in fact, cause more harm than good. Questions emerge like a) Why are costs per life, or life year saved for toxins in the environment (e.g., air, water and soil) very large compared to other type of health and safety interventions? b) Why is the percentage of total cancers caused by air, water, and soil toxins small compared to cancers caused by other 'environmental' factors, e.g., diet, smoking etc.? c) If these total environmental cancers are such a small percentage of the total cancer experience why is the cleanup criteria so conservative? d) Why has regulatory agencies ratcheted down the national and internationally accepted radiation exposure standard for the public applying additional layers of conservatism? e) Why is the risk of fatalities to real workers acceptable at two orders of magnitude more than risk of theoretical cancer to hypothetical residents? The first sections of the paper lay the groundwork for discussing the case studies which give insight to these questions, the question of how risk is considered in decision making and a different look at the impact of soil remedial action. Using case studies, the paper will highlight the unacknowledged transfer of risk to the two segments of society mentioned above. These observations indicate that while pursuing very conservative risk reduction goals, the US regulatory agencies have traded computed theoretical cancer lives saved for actual observed fatalities and injuries from construction and transportation accidents while expending exorbitantly large quantities of public money.

While participating in the Enewetak Cleanup 1977 through 1980, the Author observed that the risk assessment published in the Enewetak EIS [7] projected less than one latent cancer fatality from the inhalation of plutonium for the NO cleanup case. The cleanup of Pu was the focus for the project and the risk assessment conservatively assumed a returning hypothetical population of a thousand people over the next 30 years. It was disturbing that 6 fatalities occurred among the military participants over the cleanup period at Enewetak Atoll [8]. When pre-operational risk assessments reveal that avoidance of harm as a beneficiary of the cleanup is small compared to NO action, or can't be distinguished from the natural occurrence rate, penetrating questions should be asked about the value of the risk criteria.

The current EPA risk criteria (1 in a million) [3,9,10,11] espoused to protect people from risk associated with air, soil and water borne toxicants compared to that of the risk taken by those who will perform the construction work is out of balance (about 1 in 100 for a injury and 1 in 10,000 for a fatality). This lack of balance should shout for us to ask the question, "will this pending activity accomplish more good than harm?"

According to Kelly [8] "there is apparently no sound scientific, social, economic, or other basis for the selection of 1: 1 million as a cleanup goal for hazardous waste sites."

Herr [10] writes that "while thousands of workers die on the job annually from injuries and tens of thousands of workers die each year from chronic occupational diseases, only one person has been jailed for violating the OSH Act since its inception, and the sentence was 6 months. In contrast, hundreds of people have been jailed for violating EPA standards. In fiscal year 1996, 221 defendants were charged, resulting in 1116 months of sentences. The contrast is very dramatically illustrated with the knowledge that seven people have received 1-year jail sentences for harassing a wild burro on federal land." With this illustration, it is no small wonder those subject to environmental regulation act so conservatively. At the very minimum; however, aggressive risk assessments should be performed that looks at the most probable risk, and not focus on the worst case situation.

It has been illuminating to examine other completed remedial actions to review what the standards and criteria were, how was the risk assessment accomplished and specifically what was the projected avoidance of harm that was estimated in the planning phase to justify the remedial work. From these retrospective studies, coupled with the examination of Super Fund experience, (which uses the same philosophy of protection, e.g., a risk factor of about 1 in a million as the driver for setting concentrations of the toxin of interest to be achieved in the removal process), we should hopefully gain some insight as to the effectiveness and efficiency of remedial soil work. Although the focus of UMTRA and Enewetak is on radionuclides, the problems and processes are very nearly the same at Superfund sites remediating chemicals.

1 Criteria and Standards

The USEPA has published the specific dose level permitted for radioactivity in soil at 0.15 mSv/y or 4.0 E-6 annual risk for cancer [11] apparently justified by extrapolation using the linear, no-threshold (LNT) model. These extremely low risk values nominally cause a great deal of soil to be removed from point A and transported to point B for disposal. EPA's Federal Guidance Report 13, 'Cancer Risk Coefficients for Environmental Exposure to Radionuclides' [12], calculates the probability of a single atom of radioactive material causing cancer. An EPA official has very recently stated [13], that EPA believes it is reasonable to continue to use the LNT model to project risk at these low levels, *until improvements in science* will bring them closer to knowing the true risk of radiation exposure at low levels.

However, the Health Physics Society, in its Position Statement on Radiation Risk [14] states that "There is, however, substantial scientific evidence that this model is an oversimplification of the dose-response relationship and results in an overestimation of health risks in the low dose range. Biological mechanisms including cellular repair of radiation injury, which are not accounted for by the linear, no-threshold model, reduce the likelihood of cancers and genetic effects. In addition Michael Gough writes [3] that these type of "risk assessment predictions cannot be tested because the predicted rates of illness or death are so small that they cannot be detected. No one can measure an increase of a one-in-a-million lifetime cancer risk, which is equivalent to about three cancer cases or deaths per year in the United States. The increase is simply too small to be seen against the background of cancer present in our society. Likewise, no one will be able to see the results of a regulation or some other reduction in exposure that reduces risk by one in a million." It is highly noticeable that this criterion, which claims billions in the federal budget each year, *has* never received widespread debate or even had regulatory or scientific review [9].

Recently, in a report prepared for Senator Peter Domenici, the United States General Accounting Office (GAO) [15] examined: "What Standards should be used to protect the public from the risks of exposure to low-level radiation ......" Because federal agencies share regulating the various sites and have published disparate standards the GAO examined whether the current U.S. radiation protection standards have a well-verified scientific basis, whether federal agencies have come closer to agreeing on standards and how implementing these standards may affect the cost of cleanup and disposal activities. Very briefly the GAO concluded that: "U.S. standards to protect the public from the potential health risks of nuclear radiation lack a conclusively verified scientific basis, according to a consensus of recognized scientists." They continue in stating that the linear, no-threshold hypothesis or model is controversial in its assumption that even the smallest radiation exposure carries a risk. They also state that the research evidence is lacking at regulated public exposure level – levels of 1 mSv a year and below from human-generated sources. Lacking conclusive evidence of low-level radiation effects, U.S. regulators have set differing exposure limits. These more restrictive standards cost many millions of dollars more per site for compliance and generate much more soil to be excavated and transported.

On July 18, 2000 the President of the Health Physics Society testified before the House Science Subcommittee on Energy and Environment, [16] that "The implication that intakes of insignificant quantities of radioactivity may result in an actual risk of cancer, regardless of how small the calculated risk, is a mis-use of the Linear Non-Threshold model (LNT) since it does not accommodate the uncertainty in the model itself." He concluded in his testimony, that "The misuse of a LNT model can result in the mis-appropriation of pubic money with a net harm to public health."

In early December 1999 scientists, engineers, lawyers, social scientists, regulators, and policy makers from five continents and 20 countries met at the Arlie House Conference Center, in Warrenton, Virginia regarding low-level ionizing radiation exposures. The conference report [17] titled 'Bridging Radiation Policy and Science' contains various conclusions and recommendations. Significant among them is:

- The lowest dose at which a statistically significant radiation risk has been shown is ~100 mSv.
- The effects of low-level radiation below 1 mSv per year above background radiation cannot currently be distinguished from those of everyday natural health hazards.
- The concept of collective dose is often misapplied, e.g., to estimate health impacts of very low average radiation doses in large populations and/or doses delivered over long time periods.

Several years earlier, a similar conference [18] was held under the primary sponsorship of The Council of Scientific Society Presidents, with many technical societies and governmental agencies co-sponsoring. This conference was held at the Wingspread Conference Center, Racine, WI, August 1997 and had as its theme 'Creating a Strategy for Science-Based National Policy: Addressing Conflicting Views on the Health Risks of Low-Level Ionizing Radiation.' The participants reached general accord on the following points plus others:

- A substantial body of scientific evidence demonstrates statistically significant increases in cancer incidence for acute whole-body exposures of adults to ionizing radiation at doses of about 100 mSv and greater.
- Various factors such as the dose rate, at which the radiation dose is delivered, different kinds of radiation, gender, and the age at exposure influence the precise nature of the relationship between dose and cancer incidence.
- A major factor influencing the detection of an excess of cancer induced by radiation is the high incidence of cancer from all causes in populations in countries like the United States.
- Based on historical records, about one-third of the population will develop cancer and one-fifth to one-fourth of the population will die of cancer from all causes.

Science and the scientific method are the methodical collection of data to empirically test a formulated hypothesis. If the collection of data satisfies the hypothesis, the thesis is generally accepted. A risk assessment at the EPA risk level is a hypothesis without a test. The basis of a risk assessment is observations about health effects in animals or people under specified conditions, and its product is a hypothesis about expected health effects under the exposure conditions. Only rarely, if ever, can such hypotheses be tested [3]. Some cannot be tested because the person at risk does not exist, as in the case of the maximally exposed individual, or the fence line person. In the case of the EPA's risk level and in view of the fact that even with abundant scientific evidence that an increase in cancer incidence cannot be demonstrated below 100 mSv (10 rem), EPA continues to insist that [13] science needs to be improved. But, how can risk assessment predictions be tested, and science improved, if the predicted rates of illness or death are so small that they cannot be detected [3]?

In the meantime, remedial operations have to deal with the impact of very low conservative criteria. Unfortunately for those involved with soil cleanup is that while linearly decreasing the allowed dose/risk, the volumes required to be excavated increase exponentially [19]. This exponential rise in volume has a big impact on cost and increased worker and public exposure to construction related injury.

2 Cancer Risk from the Environment

The public has shown great concern over being exposed to carcinogens in the environment. This anxiety is understandable when in the US 1 of 4 deaths is from cancer [20]. It is presumed that government's motive in passing laws, which regulate carcinogens, is that they are attempting to avoid cancers, which are believed to be caused from potential exposure. Several decades ago it was common to hear that the 'environment' was the major cause of cancer, i.e., 80 to 90 percent [21]. This misunderstanding originated from a 1964 report by the World Health Organization (WHO) which stated "that 60–90% of all cancers might be the result of some environmental factor." The WHO report was misinterpreted to mean that 60–90% of cancers were the result of industrial pollution of air, water, and food. The writers, who referred to the environment in a much more general sense, did not intend this at all. For example, cigarette smoking was identified as the most important environmental factor, but personal hygiene and dietary customs were also stated to be important. Environmental pollution was properly included as a possible factor, but there was no intent to imply that it was the major cause of cancer [22]. Since then, many scientists, as a result of epidemiology, have concluded that only a small percentage of human cancers is caused by exposure from environmental pathways, i.e., contaminated air, water, and soil [3].

Doll and Peto completed a classic and definitive work examining the causes of cancer as a report to the Office of Technology Assessment, U.S. Congress in 1981 [2]. The intent of their report was to review the established evidence and research relating to ways or groups of ways of avoiding cancer. They concluded that much human cancer is avoidable. The authors looked at 12 different classes of causative factors and developed a best estimate of the percent of all cancer deaths attributable to these factors. **Table 1** lists the factors and their percentages used by the authors. Other workers [3] have added some comparable data to the original Doll and Peto original estimates but without any significant change to their proportion estimates of cancer deaths.

Gough [20] examined the question of 'How Much Cancer Can EPA Regulate Away' and after comparing the Doll and Peto estimates with EPA estimates of cancers resulting from the Agency's review of 17 major problem areas in the environment, found that the two sets of estimates agree closely. Gough concluded that between 2 and 3% of all cancers are associated with environmental pollution and between 3 and 6% with natural radiation included. However, as noted in Table 1, Doll and Peto do not consider natural radiation avoidable. Gough goes further and examines the number of cancers that EPA is likely to affect by regulation of emissions from manufacturing, agricultural, commercial, and other sources.

He concludes that "if EPA risk assessment techniques are accurate, and all identified carcinogens amenable to EPA regulation were completely controlled, about 1.3% of the annual total would be prevented." Considering the different method of the Food and Drug Administration, he further states "if the methods of the FDA are used the number of regulatable cancers is smaller, about 0.25% of the total."

The data developed by Doll and Peto, with EPA's data in agreement, poses an important question. If so few cancers in society occur from toxins in air, water and soil, why then does the cleanup risk standard have to be so low?

The American Cancer Society (ACS) estimates that 552,200 cancer deaths [21] will occur during the year 2000. Using the percentages discussed above by Gough, EPA is attempting to currently regulate between 1380 and 7200 annual cancer deaths, resulting from the environment, i.e., air, water, and soil. These levels have to be impossible to distinguish from the 'natural' occurrence rate. Implying that environmental regulation at the current risk level is not consistent with reality.

Table 1: Percentages of cancer deaths attributed to various factors

	Source of Estimate			
Factor	**Doll & Peto [2]**	**EPA [3]**	**Willett [3]**	**Ames et al. [3]**
Diet	35 (10–70)[1]	–	32 (20–42)	20–40
Tobacco	30 (25–40)	–	–	35
Infection	10 (1–<10)[2]	–	–	–
Reproductive and sexual behavior	7 (1–13)	–	–	–
Occupation • Ionizing radiation – 0.3 %	4 (2–8)	1–4	–	5
Alcohol	3 (2–4)	–	–	–
Geophysical Factors • UV (sunlight on white skin) 1–2 % • Ionizing radiation[3] 1.4 % (cosmic, radon, + other radionuclides in air, our bodies & all natural materials, i.e., Natural Background)	3	3–6	–	–
Pollution	2 (<1–5)	1–3	–	–
Food Additives	1 (–5–2)	–	–	–
Medicines & medical procedures	1 (0.5–3)	–	–	–
Industrial (consumer) products	<1 (<1–2)	<1	–	–
Unknown	?	–	–	–

[1] The best estimate is presented followed by the 'range of acceptable estimates.'
[2] Doll & Peto considered these numbers very uncertain.
[3] Doll & Peto do not consider these cancers derived from 'natural background' avoidable.

3 Cost of Intervention

Tengs et al. [6] has published long tabulations comparing various risks, loss of life expectancy, and the cost of life saving interventions for activities ranging from using automobile seat belts to radon control in homes. Tengs et al., in summary, states that the median intervention costs $42,000 per life-year saved, the median medical intervention costs $19,000 per life-year; the median injury reduction intervention costs $48,000 per life-year, the median toxin control intervention costs $2,800,000 per life-year, and the median EPA intervention costs $7.6 million per life-year (1993 dollars).

Hamilton and Viscusi [4] and their students recently published a book, which made an in-depth and comprehensive analysis of 150 Superfund sites. The authors claim the subsample of 150 sites is representative of the full nonfederal National Priority List (NPL) in terms of regional distribution, past site use, and the nature of contamination. They found that taking the EPA site risk estimates at face value, the maximum individual cancer risks calculated by EPA were high relative to other risks regulated by the government.

They go on to state, "However, risks are only consequential if people are exposed to them. Most assessed Superfund 'risks' do not now pose a threat to human health. Many of these risks will be present only if there are hypothetical changes in land use in the future. Conservative assumptions regarding exposure and risk parameter values also inflate the risks." Through Monte Carlo analysis, the authors conclude that there is less than 1% chance that the risks are as great as the EPA estimates, even assuming that people are exposed to the hazards.

Hamilton and Viscusi ask the question concerning the desirability to judge a cleanup based on benefit-cost analysis. One measure of cost-effectiveness is cost per cancer case avoided. They find that the number of expected cancer cases avoided by site remediation is low at the majority of the sites in their sample and that the costs per cancer case averted are extremely high relative to estimates for other risk-regulatory programs.

The authors expose an extremely important point when it comes to performing risk analysis or benefit-cost analysis, which involve people being actually exposed to the various chemical pathways. They found that 72% of pathways that involved changes in current land use or changes in current exposure pathways dealt with future risk. Nearly half of the pathways presented in the documents examined, involved exposure by future residents living on-site in contaminated areas that generally do not have current on-site residential developments. Future risks played an even larger role in the maximum risk pathways calculated at the sample sites, accounting for 88% of the maximum cancer pathway risks and 89% of the maximum noncancer risk pathways estimated.

The authors continue by stating "What is surprising about the dominant role of future risks is that it stems largely from EPA's assumptions that in the future individuals will gravitate to live directly on hazardous waste sites." An interesting point is that "people will be making this decision after knowing that these sites have been designated to be on the National Priority List (NPL). Because most residents view these sites with alarm and tend to flee these areas which are publicized that to assume people will be drawn to them is contrary to observed behavior."

Another important fact observed by the authors is that EPA's risk methodology doesn't incorporate a probability that a future land use will occur.

The authors, using EPA's conservative parameter assumptions and ignoring disease latency periods, estimate that there will be 731 cases over thirty years arising from contamination at the 150 sites. Interestingly, 652 of these cases come from one California site. This site dominance underscores the conservative exposure assumptions and the overstatement of the occurrence of estimated cancers using EPA risk data. Most of the hazardous waste area at this site is on land that has been paved over and is now an industrial parking lot, so the estimated individual cancer risks are unlikely to occur. This dominance suggests that the median risk is probably a better indicator than the average risk. Using the mean, the cost per cancer case averted is $3.0 million at the 150 sites. However, the median cost per cancer case averted is $388 million. The costs per cancer case averted ranges widely from less than $20,000 to over $1billion. Estimates using more realistic risk assumptions are even higher. Overall, 101 out of the 145 sites with costs per cancer case had costs per cancer case averted above $100 million. An amount the authors suggest is well in excess of a sensible risk-cost trade-off. Additionally, the Authors in reviewing suggested risk reforms state: "We find that currently 95% of the expenditures at Superfund sites are devoted to eliminating only 0.5% of the cancer risks."

Justice Breyer [23] further illustrates this point as he discusses the costs of removal of the last 10%. In his book, he reports "that a former EPA administrator noted that about 95% of the toxic material could be removed from waste sites in a few months, but years are spent trying to remove the last little bit."

Breyer exemplifies this with a case from his own court (US vs Ottati and Goss). In this case, which was a 10-year effort to force the cleanup of a toxic waste dump in southern New Hampshire, the site was mostly cleaned up, all but one of the private parties had settled. The remaining party litigated the cost of cleaning up the last little bit, a cost of about $9.3 million to remove a small amount of highly diluted polychlorinated biphenyl (PCBs) and volatile organic compounds (VOCs) by incinerating the dirt. How much extra safety did this $9.3 million buy? The 43,000 page record of this 10 year effort indicated, with all parties agreeing, that, without the extra expenditure, the waste dump was clean enough for children playing on the site to eat small amounts of dirt daily for 70 days each year without significant harm. Incinerating the soil would have made it clean enough for the children to eat small amounts daily for 245 days per year without significant harm. But there were no dirt-eating children playing in the area, for it was a swamp. Nor were dirt-eating children likely to appear there, for future building seemed unlikely. The parties also agreed that at least half of the VOCs would likely evaporate by the year 2000.

To spend \$9.3 million to protect non-existent dirt-eating children further illustrates the cost of remediating the last few percent, the conservatism of criteria and how volumes of dirt to be removed balloon.

This author believes this example also illustrates the cause and effect of extremely conservative standards and the point made by Hamilton and Viscusi that the risk analysis performed is using assumptions that place hypothetical people where they will most likely never be.

4 Case Studies

UMTRA was the result of legislation in 1972, which authorized the removal of tailings from various sites, and structures. The UMTRA Project was established with the enactment of the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978 (Public Law 95-604, November 8, 1978) [24]. The law specified that the U.S. Environmental Protection Agency would establish the standards to be used during remedial action. The Nuclear Regulatory Commission (NRC) was directed to provide consultation and concurrence in the type of remedial action that would be performed. Department of Energy (DOE) was directed to comply with the National Environmental Policy Act and perform detailed studies of the environmental impacts that remedial action would have at each site before remedial action began. DOE was responsible for cleanup of the 24 designated former uranium sites, referred to as Title I sites (Title II sites were cleaned up by their private owners). DOE was also responsible for properties in the vicinity (the vicinity properties are not addressed in this paper) of the sites where wind and water erosion deposited tailings or where people removed them from the site for use in construction or landscaping. [Two sites, Belfield and Bowman, ND were removed as designated sites. This action was taken at the request of the State of ND because of the lack of public support, limited state funding, and the very small risk to the public and environment. Its owner, Tennessee Valley Authority cleaned up Edgemont, SD, before the UMTRCA was enacted; however, there were a few vicinity properties remediated under UMTRA. This explains why data for 21 of the 24 sites are discussed.] Cleanup was to be undertaken in cooperation and participation with state governments and Indian Tribes within whose boundaries the sites were located.

Table 2 compares the occupational fatality and injury experience from the Enewetak and UMTRA projects with national construction experience compiled from the National Bureau of Labor Statistics and reported by the National Safety Council [25]. The worker fatalities are noted; however, there were also 2 fatalities to members of the public, which are not listed in the tabulation [26]. These fatalities were a result of traffic accidents involving trucks transporting tailings, UMTRA drivers; however, were not faulted.

These data are basically the same as that experienced by the construction industry nation-wide. The data suggest that if sufficient man-years are expended, one can expect that the injury and fatality rate will mirror the national experience. When more soil is moved than is really needed for health, then extra risk is being created and transferred to the worker and the public.

To investigate what decision makers knew prior to implementing UMTRA cleanup operations and if this information impacted decisions on worker risk, the EPA 'Remedial Action Standards' EIS and individual UMTRA project site EISs and EAs were examined. The intent is to compare projected hypothetical cancers calculated for the NO action alternative for each of the tailing piles and compare the theoretical cancer deaths avoided by the cleanup with actual worker fatality and injury experience described.

The EPA published the final Remedial Action Standards EIS [27] for the UMTRA in October 1982. This document contains the initial risk assessment and projection of hypothetical fatal cancers projected to be avoided by the tailings cleanup, i.e., saved by the standards. Following that is the review of the results of the individual pile risk assessment

Table 2: Observed worker risk

Observed Worker Risk [25]							
Case Study	**Total Workers**	**Total Injuries and Illnesses**	**Total Fatal Injuries**	**Rate**		**Risk**	
				Injuries per 10^5 Workers	**Fatal injuries per 10^5 Workers**	**Worker Injury**	**Worker Death**
Enewetak	8,033[a]	63 LWC[b]	6	784 LWC	75	7.8 10^{-3}	7.5 10^{-4}
UMTRA	13,880[a]	378 TRC[c] 144 LWC	2	2,723 TRC 1,037 LWC	14.4	2.7 10^{-2} TRC 1.0 10^{-2} LWC	1.4 10^{-4}
NSC/BLS All Industry (97)	1.3081 10^{8}	3.8 10^{6}	5,100	2,905	3.9	2.9 10^{-2}	3.9 10^{-5}
NSC/BLS Construction (97)	7.844 10^{6}	3.9 10^{5}	1,060	4,970	13.5	4.9 10^{-2}	1.35 10^{-4}
DOE wide (84–98)	2.36 10^{6}	74,363 TRC 36,026 LWC	66	3,150 TRC 1,526 LWC	2.8	3.1 10^{-2}TRC 1.5 10^{-2}LWC	2.8 10^{-5}

[a] Total Workers is also equivalent to man-years.

[b] LWC – Lost Workday Cases

[c] TRC – Total Recordable Cases

made the assumptions used and the estimates of the hypothetical fatal cancers to be avoided through implementation of the cleanup standards. These data were gleaned from the individual site's EIS, Environmental Assessment, Characterization and/or Engineering Assessment report(s). These estimates of hypothetical cancers to occur in the future (i.e., 100 years) for the NO cleanup case including no other type of intervention are then comparable (see Table 6 and 8) to the actual and estimated occupational injuries and fatalities experienced. Similar comparisons have been published by Miller et al., [28] and are listed in Table 6.

Listed below are the assumptions used by the EPA in examining the major pathways that can reach man, the risks to man and the estimate of potential effects on health.

- Risk estimates based on studies of persons exposed at doses higher than those usually resulting from tailings and the assumption that at lower doses the effects will be proportionally less, i.e., LNT model.
- The major threat comes from breathing air containing radon decay products with short half-life, e.g. Po-218. Additionally, there is exposure to gamma rays from radioactive material in the tailings pile, e.g., Ra-226.
- Because of a lack of detailed knowledge of the deposition pattern of the radioactive particles in the lung, the distances from the particles to the susceptible cells the exact doses delivered to cells that can become cancerous cannot be characterized adequately. Therefore estimates of lung cancer risk are based on the amount of inhaled radon decay products people are exposed to rather than the dose absorbed by the lung.
- Estimates for 6 'urban' sites (see Table 6) were calculated using the following methodology. "The remaining piles are in remote areas and collectively have only about one tenth of the local and regional population exposures that these six piles collectively have."

For the purpose of estimating impacts a theoretical pile with uniform Ra concentration of 500 pCi/g, completely dry, and unstabilized is assumed. For these conditions an emission rate of 1.0 pCi/m^{2}s radon per pCi/g of radium was assumed. It was further assumed that the pile covers an area of 31 acres and is infinitely deep. The resulting radon release rate for this theoretical pile is 2000 Ci/y.

- Results are scaled to specific piles using the theoretical pile according to the annual radon release of the pile. The estimated/assumed radon release rate ranges from 200 to 11,500 Ci/y. Corrections were not made for pile area sizes different from the theoretical pile.
- The atmospheric dispersion of radon from the theoretical pile at distances up to 7.5 miles was calculated using a sector-averaged gaussian plume model and wind frequency data for the Fort St. Vrain reactor site in Colorado. Dispersion factors were averaged over all directions to estimate a single value for each distance, i.e., dispersion was assumed to be the same in all directions. The average windspeed for the site was 6 mph. The generic approach was used because adequate data for site-specific dispersion estimates are not available. EPA states "that site-specific data would show differences with distance and direction. However, the generic approach should provide reasonable estimates of the average exposure of individuals living near a pile. We do not expect a high degree of accuracy for any specific individual's location, since wind direction patterns can be highly asymmetric."
- Dispersion estimates for radon for the regional (7.5–50 miles from the pile) scale were based on a National Oceanic and Atmospheric Administration (NOAA) model. Local meteorology was not considered for these estimates, and dispersion was averaged over all directions.
- A NOAA model was developed for the NRC to calculate the concentration in air across the continent due to radon emitted from four sites in the West. EPA used an average of 0.56 person-WL per 1000 Ci released per year to make the national collective exposure for the United States population.
- EPA developed a model to calculate the Rn concentration versus distance from the tailings pile center. They assumed 20 pCi/m^{2}s for 3 different pile sizes, used generic wind data from the NRC Generic EIS and their own AIRDOS dispersion model for their calculations a family of curves were derived. From this they concluded that the average concentration near the center of the pile and at the edge of the pile are relatively insensitive to the size of the pile. However, they did not perform any site-specific calculations.
- To account for the in growth of Rn decay products they used a concept called the equilibrium fraction, which is the fraction of the potential alpha energy from decay products at complete equilibrium to that actually present. EPA claims that since the radon and its decay products are transported by the wind, the equilibrium fraction increases with distance from the pile as the decay products grow in. They also state however, that the equilibrium is slightly underestimated close to the source, and that depletion processes, e.g., dry deposition or precipitation scavenging, will remove some decay products, so complete equilibrium with the radon will seldom, if ever, be reached.
- EPA assumed that on the average, Americans spend approximately 75% of their time indoors and have used a weighting factor for indoor and outdoor equilibrium fractions of 0.75 & 0.25 respectively, to estimate an average value for calculating exposure to radon decay products from a specific pile. They state that since indoor exposure is dominant, this average equilibrium fraction does not depend strongly on the distance from the tailings pile.
- EPA used the 1970 census data to estimate the population distribution near each of the piles. Where the census data was not adequate, supplementary data was used. They did not attempt to project local population changes between 1970 & 1980 because the data available were inadequate.
- In discussing the exposure to gamma radiation from the tailings piles, EPA noted that field measurements indicated that on top of a pile the levels range up to 0.45 to 0.9 mrem per hour, and if a person stood on top of such a pile for a whole year they could exceed the annual standard of the day of 500 mrem/y for an individual. They go on to state that the gamma radiation decreases rapidly with distance and cannot be differentiated from

the normal background at more than a few tenths of a mile from most of the tailings piles.
- Exposure pathways for water and food for both radioactive material and other toxic chemicals are discussed, but because of the lack of site specific data on the behavior of the contaminants and the low expectation that any effect on man or beast could be observed, little attempt was made to estimate any potential effects for these two pathways. Leaving the airborne pathway as the dominant pathway specific to Rn and its progeny for consideration of any significant effects.

Review of individual site documents, e.g., EAs, EISs, Engineering Assessment and Characterization reports all confirm that the gamma dose and the food and water pathway are as EPA reports and are negligible enough that they are not discussed any further in this paper.

The assumptions of the individual DOE site Environmental Assessments and Environmental Impact Statements plus other DOE characterization and assessment documents were reviewed to compare to the EPA Standards EIS. This data is also compared to other UMTRA published data on the cancers avoided and costs after the completion of the project.

Typical UMTRA dose/risk assessment statements and assumptions:

- Radiation and its associated health effects have been studied more thoroughly than health effects from other carcinogenic agents. The evaluation of health effects caused by low-level radiation is, however, a difficult task, and many uncertainties are associated with the estimation of risks from radiation. The traditional approach for estimating risk from low-level radiation exposures is to extrapolate from effects observed at high radiation exposures using linear-dose response and no threshold assumptions.
- Radon flux calculated using NRC's (84) RAECOM model.
- Assume no cover exists on the tailings pile.
- Site Geometry assumed to be circular.
- Crosswind dispersion ignored. (e.g., for Grand Junction assumed the entire population within 0.6 miles (1 km) was exposed to the met. conditions of the NW quadrant to which the winds blow the majority (44%) of time.
- Stability Classes used from distant cities (e.g., Grand Junction, CO used for Green River, UT) because no meteorological data available at local sites.
- Radon concentration as a function of distance modeled not measured (See Green River, Table 7 for example).
- No specific annual Radon measurements made in nearby residences and/or used in health effects calculations. (e.g., for Grand Junction the radon at 0.5 km (0.31 mi.) from the pile edge in the NW quadrant was assumed to represent the average radon for the entire 1 km distance interval.)
- Residential occupancy sometimes assumed to be 100%, other times 75% (Occupancy time was then split 75% of time spent indoors & 25% spent outdoors).
- For general populations health effects calculations assumptions were made which resulted in a conservative estimate of working levels as a function of distance from the edge of the site (e.g., Green River worst case wind sector was assumed to contain the entire population).
- In-growth of radon daughter's products assumes no daughter products are removed from the air by plateout.
- To account for plateout in health effect calculation for outdoor conditions working levels assumed to be 0.5 of that used in in-growth formula. For indoor working level, the outdoor concentration as a function of distance was multiplied by a 50% equilibrium factor for Rn daughters.

The following tables review specifics of the data used by EPA & DOE to calculate the hypothetical cancers avoided. **Table 3** and **Table 4** review the history of ownership of the sites, showing the entity administering control of the individual tailings piles, and disposal cells (past, present and future). Demonstrating, in the UMTRA case, the impossibility of people moving onto a waste site. The radiological profile of the various tailing piles is shown in **Table 5**. Specifically it shows the wide variability that exists and with only one exception the model pile is much more a worst case than the data presented in DOE documents indicate.

This data allows comparison to the model pile that EPA used in developing their dose and risk projections. **Table 6** tabulates the hypothetical cancers calculated using the EPA model and assumptions stated above. Table 6 also compares the hypothetical cancers presented in DOE's End of Project Report [24] and published by Miller et al. [28] in the Journal Health Physics.

Table 7 tabulates the radon measurements made at or on the pile and offsite locations where people may live. Some of the data, particularly on or near the pile were measured, while those further out were modeled. Also listed is the background or baseline measured away from the influence of the pile. The background values all appear to be actual measurements taken outdoors and the number noted is most generally an average of many measurements. As can be noted, some of the published background values are of the same magnitude as those very near the pile, and some modeled values are considerably less than background values.

The data are extracted from DOE reports, whose source is listed. It appears that in nearly every case, background Rn values were observed at distances of 0.4 km (0.25 miles) to 1.61 km (1.0 miles) from the tailings pile. However, even though only background values were observed, hypothetical cancer deaths were still calculated for populations typically out to a radius of 10–80 km (6 to 50 miles). EPA calculated hypothetical cancer deaths and tabulated them out to 80 km, and then from 80 km out for the whole of the United States.

Very illustrative of the point that background Rn was generally observed at distances at 1.5 km (~1 mi.) is a set of data collected before and after remedial action at Mexican Hat, Utah. **Table 8** summarizes the results from the final report [31] of this activity. For the background area encircling the community of Mexican Hat, using track etch detectors located between 1.5 and 2.5 km from the center of the tailings pile (**Fig. 1**), the authors concluded: "Essentially, the background concentrations did not change significantly before and after completing remedial action activities."

Table 3: Site ownership

Site Name	Contam. Area (ha)	Precleanup Owner	Post Cleanup Owner (Tailings Pile)	Disposal Cell Owner	Site Information	Notes
Ambrosia Lake, NM	272	Acquired by NM (1991)	U.S Gov't (1998)	U.S. Gov't	Stabilized on Site	
Belfield, ND	12.8	Burlington Northern Railroad Co.	*	*	Site Removed fm Program	* Removed by the Sec. Of Energy as designated sites at the request of ND because of minimal public support, limited state funding, and very small risks
Bowman, ND	28.8	Roger Stearns & Stanley Soderstrom	*	*	Site Removed fm Program	
Canonsburg, PA	12.1	Purchased by the State of PA in 1983	Transferred to US Gov't in 1996	U.S. Gov't	Stabilized on Site	
Burrell, PA	3.6	Purchased by the State of PA in 1983	Transferred to US Gov't in 1994	U.S. Gov't	Stabilized on Site	
Durango, CO	13.3	State of CO granted ownership in 1990	? State of CO Assumed	Transferred to US Gov't in 1996	Tailings Pile Relocated	Acquired by CO in 1987 transferred to U.S. Gov't in 1996
Edgemont, SD	86	Purchased by the TVA in 1974	TVA	TVA	Vicinity Property Site	
Falls City, TX	246	Acquired by TX in 1990 & 91	State of TX	Deeded to the US Gov't in 1997	Stabilized on Site	Parcel B remains in private ownership following remedial action
Grand Junction, CO	46.2	Deeded to State of CO in 1970	State of CO	Site transferred fm BLM to DOE in 1990	Tailings Pile Relocated	7 acres of the original site is privately owned. The Disposal Site is to remain open until 2023 to receive vicinity property material
Green River, UT	3.6	Acquired by UT in 1988	U.S. Gov't (1996)	Conveyed title to U.S. Gov't in 1996	Stabilized on Site	Site adjacent to the U.S. Army's White Sands Missile Range Utah Launch Complex
Gunnison, CO	15.8	State of CO claimed ownership in 1990	State of CO	Transferred from BLM to DOE in 1992	Tailings Pile Relocated	Former mill & tailings site was located adjacent to the Gunnison airport. The disposal cell is 7 miles east of Gunnison
Lakeview, OR	38	County & various private land owners	same	State of Oregon	Tailings Pile Relocated	Disposal site acquired by OR in 1986 through a civil action suit
Lowman, ID	15	ID acquired site fm private & Fed. sources	DOE	DOE	Stabilized on Site	
Maybell, CO	118	Private & BLM	DOE	DOE	Stabilized on Site	State of CO acquired the private land and transferred it to the DOE in 1997
Mexican Hat, UT	124.6	Navajo Nation	Navajo Nation	Navajo Nation	Stabilized on Site	A 1996 custodial access agreement conveyed to U.S. Gov't title to the Rad. Mat.
Monument Valley, AZ	40.9	Navajo Nation	Navajo Nation	Navajo Nation	Tailings Pile Relocated	? No information on agreement with Fed. Gov't
Naturita, CO	55.9	Hecla Mining Co. & Cyprus/Foot Mineral Co.	same	Acquired by DOE in 1997	Tailings Pile Relocated	
Rifle, CO (new + old)	18.7	State of CO	State of CO	U.S. Gov't	Tailings Pile Relocated	
Riverton, WY	29.1	Acquired fm private owners by State of WY in 1987	State of WY	Uemtco Mineral Corp.	Tailings Pile Relocated	The Rad. Mat. was located with existing Title II tailings at the Umetco mill site. A separate disposal site not required, but DOE to retain control over both sites
Salt Lake City, UT	48.6	Central Valley Water Treatment Facility Board	same	U.S. Gov't	Tailings Pile Relocated	Utah transferred ownership of the disposal site to the U.S. Government in 1997
Shiprock, NM	29.1	Navajo Nation	Navajo Nation	Navajo Nation	Stabilized on Site	Custodial care agreement with DOE to restrict entry and provide federal access
Slick Rock, CO	24.7	Umetco Mineral Corp.	Umetco Mineral Corp.	BLM transferred site to DOE in 1995	Tailings Pile Relocated	
Spook, WY	2	WY & Hornbuckle Ranch	WY	DOE	Stabilized on Site	WY in 1989 acquired land fm the Hornbuckle Ranch ; Subsurface rights transferred to DOE by BLM in 1990
Tuba City, AZ	42.5	Navajo Nation	Navajo Nation	Navajo Nation	Stabilized on Site	Custodial access agreement in 1996 conveys title of the rad mat to U.S. Gov't.

Table 4: Ownership summary tabulation

Category of Ownership	Pre Cleanup	Post Cleanup
Private	2	1
Private + State and/or Federal	3	0
State	12	1
Federal	1	16
Indian Tribes	4	4
Removed from Program and remaining as private property	2	2
Totals	24	24

Table 5: Radiological profile of the UMTRA tailings piles

Radiological Profile of the UMTRA Tailings Piles-Compiled from End-of-Project Report [24]						
Site Name	**Area of Site (ha)**	**Rad. Mat. Handled (m^3)**	**Rad. Mat. in Cell (m^3)**	**Clean Material Handled (m^3)**	**Average Tailings Concentration (Ra-226 pCi/g)**	**Total Curies of Ra-226 in Cell**
Ambrosia Lake, NM	272	2.73 E6	4.63 E6	6.65 E5	571	1,850
Belfield, ND	12.8	1.2 E6 *	N/A	N/A	61	
Bowman, ND	28.8		N/A	N/A	32	
Canonsburg, PA	12.1	2.0 E5	2.0 E5	1.52 E5	2,315	100
Burrell, PA	3.6	3.1 E4	4.1 E4		7	4
Durango, CO	13.3	1.9 E6	1.9 E6	8.9 E5	671	1400
Edgemont, SD	86					
Falls City, TX	246	4.6 E6	parcel B put in cell with parcel A		189	1277
Grand Junction, CO	46.2	1.9 E6				
Green River, UT	3.6	2.9 E5	2.9 E5	4.4 E4	76	30
Gunnison, CO	15.8	5.7 E5	5.7 E5	5.2 E5	314	175
Lakeview, OR	38	7.2 E5	7.2 E5	6.0 E4	112	42
Lowman, ID	15	1.2 E5	1.2 E5		157	12
Maybell, CO	118	7.7 E4	3.1 E6	7.0 E5	200	455
Mexican Hat, UT	124.6	1.6 E6	2.6 E6		667	1800
Monument Valley, AZ	40.9	7.1 E5	Placed in Mex. Hat Disposal Cell		54	
Naturita, CO	55.9	6.1 E5	6.1 E5		46	79
Rifle, CO (new + old)	18.7	2.9 E6	2.9 E5		700	2738
Riverton, WY	29.1	1.4 E6			292	
Salt Lake City, UT	48.6	2.1 E6	2.1 E6		481	1550
Shiprock, NM	29.1	8.3 E5	1.4 E6		422	748
Slick Rock, CO	24.7	6.0 E5	6.0 E5		113	149
Spook, WY	2	2.4 E5	2.4 E5		320	125
Tuba City, AZ	42.5	7.5 E5	1.3 E6		441	940

* Includes both sites

Table 6: Estimates of hypothetical fatal cancers avoided from remediating the UMTRA tailings piles

UMTRA Hypothetical Cancer Deaths Avoided per 100 years					
Site Name	**EPA FEIS–1982 [27]**			**DOE End of Project [b] Report [24] & Miller [28] 10 mi.**	**DOE EISs & EAs (see Table 9 for reported distance)**
	Local [a] Population 7.5 mi.	**Regional [a] Population 7.5 to 50 mi.**	**U.S. [a] Population >50 mi.**		
Ambrosia Lake, NM			5	0.086	0.048
Belfield, ND			<0.1		
Bowman, ND			<0.1		
Canonsburg, PA	17 [c]	[c]		15	1.2
Burrell, PA					0.1
Durango, CO			1	22	1.3
Edgemont, SD	site cleaned up by owner (TVA) prior to UMTRA				
Falls City, TX			5	2.3	2.8
Grand Junction, CO	18	0.2	3	588	37
Green River, UT			0.5	0.007	0.01
Gunnison, CO	2	0.01	1	6.5	4.7
Lakeview, OR			1	0.027	0.08
Lowman, ID			0.2	0.013	0.01
Maybell, CO			2	0.003	0.01
Mexican Hat, UT	0	0.05	3	1.3	1
Monument Valley, AZ			0.3	0.016	0.02
Naturita, CO			2	0.91	0.01
Rifle, CO (new + old)	1	0.02	3	40	10
Riverton, WY			3	5.6	2.3
Salt Lake City, UT	79	5	7	313	22
Shiprock, NM	3	0.1	2	2	0.6
Slick Rock, CO			1	0.003	0.005
Spook, WY			0.1	0.002	0.0006
Tuba City, AZ			0.2	1.9	1.7
Totals	120	5.4	40.3	999	85

[a] EPA calculated hypothetical cancers using both the Absolute Risk Model & Relative Risk Model, only the Absolute Risk Model results are shown. The Absolute Risk Model calculates a lower number of fatal cancers, except at SLC, UT where because of the low lung cancer rates in Utah, the Relative Risk values are lower than the Absolute Risk values.

[b] Based on annual collective radiation doses to the general public, typically within a 10 mile radius, published in the project EIS or EA.

[c] Canonsburg's effects were estimated separately because workers at the site receive most of the Rn exposure. The value includes workers and the local population.

Note: EPA only calculated the hypothetical cancers avoided for these 6 sites apparently because of availability of data. They state: "The remaining piles are in remote areas and collectively have only about 1/10 of the local and regional population exposures that these six piles collectively have." However, EPA went further and calculated the hypothetical cancer deaths at more than 50 miles for each of the specific tailing sites. They apparently used their model pile and scaled the results for the 1970 population of 200 million persons.

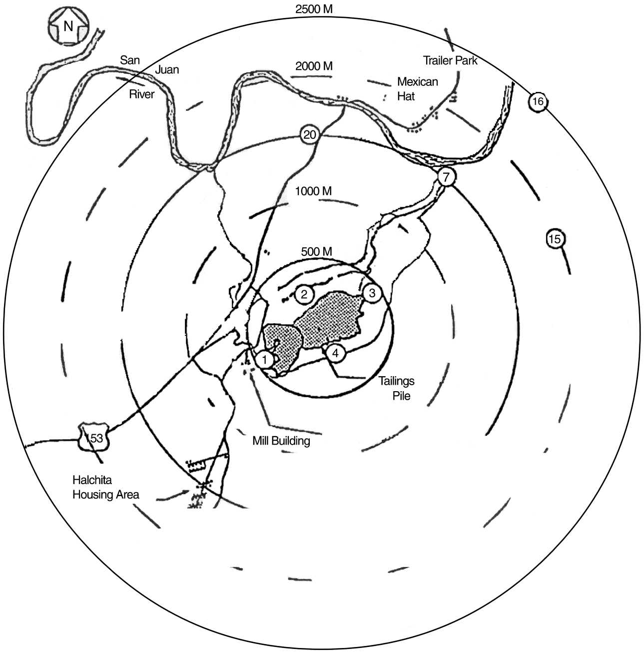

Fig. 1: Radon measurement locations

Table 7: Radon emission data

Site Name	Radon Measurements Versus Distance From The Pile pCi/l @ miles						Rn Bkg pCi/l	Source
Ambrosia Lake, NM	16.7 pile edge	9.4 @ 0.1	5.5 @ 0.5	2.9 @ 0.7			2.9*	See remarks in the footnotes
Canonsburg, PA	8.6@ 0.05	2.1 pile edge	0.75@ 0.3				0.3	EIS
Burrell, PA	bkg on pile						0.3	EIS
Durango, CO	16 on pile	12.5 @ 0.2*	1.1 @ 0.44*	1.3 @ 0.98*	0.8 @ 2.1	1.6 @ 2.8	0.51* & 1.2*	EIS
Falls City, TX	1.6 @ near pile	1.9 @ 0.3	1.0 @ 0.6	1.0 @ 1.0	1.0 @ 1.6		1.0*	FBDU-130-19 GJT-16 (77)
Grand Junction, CO	26.0 @ on pile	6.7 @ 0.08	2.6 @ 0.33	0.8 @ 1.7			0.8	FEIS
Green River, UT	**13.5 @ pile cntr**	0.02 @ 0.5 **0.9 @ 0.08**	0.005 @ 1.0 **1.2 @ 0.4**	0.003 @ 1.5 **1.7 @ 3.1**	0.002 @ 2.0 **2.3 @ 3.4**		**2.0***	DOE/EA-0343 **FBDU-360-14 (81) (Meas.)**
Gunnison, CO	4.5* @ pile edge						0.5*	EA
Lakeview, OR	2.1 @ pile center	0.2 @ 0.25	0.07 @ 0.5	0.03 @ 1.0			0.7*	EA
Lowman, ID	1.8 @ former area						1.2*	EA
Maybell, CO	3.4* @ on site						0.7*	EA
Mexican Hat, UT	8.0* @ onsite	1.1 @ offsite					1.1*	EA
Monument Valley, AZ	6.8 @ onsite			0.6 @ 2.2			0.4*	EA
Naturita, CO	10.5* @ on pile				2.0 @ 3		2.0*	EA
Rifle, CO (new + old)	6.5 o @ pile; 7.2 n @ pile						0.4	EIS
Riverton, WY	6.2 @ on pile						1.1	EA
Salt Lake City, UT	3.0 @ pile edge	0.4 @ 0.5	0.3 @ 1.0	0.25 @ 1–2			0.25	EIS
Shiprock, NM	6.2 @ on pile	3.2 @ 0.1					0.8*	EA
Slick Rock, CO							0.5	EA
Spook, WY	**17.1 @ on pile**	**2.8 @ 0.4**	0.007 @ 1.2–1.9	**1.1 @ 2**			1.1	EA **FBDU-15 (77)**
Tuba City, AZ	8.6 @ pile center	0.7–2.1 @ off pile					0.7	EA

Note: Source for these data is the same as indicated in Table 9 unless otherwise stated.

*average of multiple measurements

Remarks: Ambrosia Lake is a radon anomaly. Considerable radon was continuously released from underground mine vents. Additionally there was a Title II tailings pile upwind from the DOE Title I site.

Table 8: Rn-222 Concentrations (pCi/l) before and after remedial action at Mexican Hat, Utah

Detector Location (Fig. 1)	Before Remedial Action		After Remedial Action	
	Averaged Time Weighted Concentrations	Range of Average Concentrations	Averaged Time Weighted Concentrations	Range of Average Concentrations
Site Perimeter (1,2,3,4)	8.0	3.6 – 12.2	0.8	0.7 – 1.0
Background (7,15,16,20)	0.7	0.6 – 1.0	0.5	0.3 – 0.8

Table 9: Projected hypothetical fatal cancers, injury and illness data

Projected Hypothetical Fatal Cancers, Injury and Illness Data as estimated in Site EIS or EAs

Site Name	Nearest Population	Distance from Tailings Pile (miles)	Fatal Cancers for next 100 years No Action Alt.	*Worker Fatalities (Miller et al. [26])	*Worker Injuries	*Transportation Fatalities	*Transportation Injuries	Source
Ambrosia Lake, NM	5 60**	2.5 2.5–6.0	0.048	0.6 (0.2)	6	0.3	0.9	DOE/EA-0322 (87)
Canonsburg, PA	7938 63942	0–1 6.2 radius	1.2	nem	nem	0.005	nem	DOE/EIS-0096-F (83)
Burrell, PA	2312 4546	0–1 1.24	0.1	nem	nem	nem	0	DOE/EIS-0096-F (83)
Durango, CO	>10,000	50	1.3	0.03 (0.03)	4.23			DOE/EIS-0111F (85)
Falls City, TX	1,350** (442-1970 census)	0–5**	0.6** (2.8 in EA)	0.05 (0.04)	4.8	negligible	negligible	FBDU **DOE/EA-0468 (91)
Grand Junction, CO	843 nef	0.62 1 to 50	21 16	0.1 (0.35)	9	0.3	9	DOE/EIS-0126 (86)
Green River, UT	6 39	0–0.5 0–1.0	0.01	0.045 (0.02)	4.2 calc	–		DOE/UMT-0114 & FBDU-360–14 (81)
Gunnison, CO	6783	6	4.7	nef (0.05)				DOE/EA-0376 (92)
Lakeview, OR	10 182 2820**	0.25 1 6**	0.08**	0.3 (0.02)	30	0.2	1.1	DOE/EA-0271 (85)
Lowman, ID	90	3	0.01	0.02 (0.01)	0.6			DOE/EA-0353 (91)
Maybell, CO	125	6	0.01	nef (0.06)				DOE/EA-0347 (95)
Mexican Hat, UT	516	1.5	1	0.03 (0.03)	21			DOE/EA-0332 (87)
Monument Valley, AZ	37	1.5	0.02	0.1 (0.01)	9.3	0.1	16	DOE/EA-0368 (89)
Naturita, CO	23	1.5	0.01	nef (0.07)				DOE/EA-0464,rev5 (94)
Rifle, CO (new + old)	4524	10	10	0.5 (0.36)	24			DOE/EIS-0132F (90)
Riverton, WY	13,000	6	2.3	nef (0.55)	26	0.5	9	DOE/EA-0254 (87)
Salt Lake City, UT	500 nef nef	0.5 1.2 10.0	1.2 2.4 18.0	0.7 (0.14)	52			DOE/EIS-0099F (84)
Shiprock, NM	1237	1	0.6	nef (0)				DOE/EA-0232 (84)
Slick Rock, CO	0 10**	1.0 10**	0.005**	nef (0.09)				DOE/EA-0339 rev1 (94)
Spook, WY	0 18**	1.2 3.1**	0.0006	nef (0.02)				DOE/EA-0345 (89)
Tuba City, AZ	20	0.75	1.7	nef (0.07)				DOE/EA-0317 (86)

* Data taken from Alternative chosen
** Values used in Fatal Cancer Calculations and their source
nef = no estimate found
nem = no estimate made
Note: North Dakota sites with drawn from program by request of the State. The South Dakota tailings site was cleaned up by its owner (TVA), vicinity properties were cleaned up by the UMTRA project.

Table 9 is an extension of the data tabulated from the DOE reports used to extract the radon emission data. This table lists the nearest population to the pile, and the population (when identified) used in the estimate of hypothetical fatal cancers predicted for the NO action alternative. This, then, was the theoretical number of cancers to be avoided when the pile was removed or capped, preventing exposure of the public from the emanating radon. These values are then projected for 100 years. Also included when available are the predicted worker accidents and fatalities, transportation injuries and fatalities for the preferred alternative.

5 Findings and Observations

- Prior to commencement of cleanup, governmental authority acquired the land occupied by the tailings piles and \$11.5 million was expended on site acquisition [24].
- With one exception, governmental authority, including those with piles removed to distant burial cells has retained the control of all sites. The States and Tribes either had or obtained title to the land holding the tailings, and have subsequently given title or access to the U.S. Government via DOE for long-term observation and monitoring. This illustrates the point made by Hamilton and Vicusi that it is unlikely that people will move onto waste areas.
- A majority of the tailings piles are in isolated regions with very few people in the adjacent areas. Only five of the 20 tailings sites are either in or very near communities that had a population over 100 people, 7 over 50 people.
- Source terms, i.e., content, distribution and total radioactivity of the individual piles are highly variable and with only one exception the EPA model pile is more of a worst case than the data presented in DOE documents.
- EPA's risk methodology doesn't incorporate a probability that a future land use will occur.
- Key atmospheric dispersion parameter data e.g., wind rose and frequency were not collected for many individual sites. Wind input data was assumed and/or used data from distant sites.
- The dosimetry uses worst case assumptions as input to EPA's MILDOS model.
- No actual radon measurements are made in nearby resident's homes.
- No estimate of the uncertainty of the dose calculations and the subsequent cancer deaths was systematically established.
- Populations were assumed to be at avoidable risk even at distances beyond where background had been established. See Table 8 and Fig. 1.
- Background was systematically measured, but when more than one method or more than one contractor was used, the data varied by factors as high as two.
- Radon, measured or more often modeled, fell to background levels generally about 1 mile or less from the pile.
- When measured radon data was available as a function of distance, there was considerable difference observed in modeled versus measured Rn values. See Table 7, Green River as an example.
- No apparent accounting in the dose estimates for diurnal or seasonal variation in Rn emission. A nominal factor of two or more is observable in measurements taken. Engineering Assessment documents illustrated these distinctive phenomena in their measured data.
- The method of calculating collective dose for low levels of exposure is contrary to the recommendations advanced by the 1999 conference 'Bridging Radiation Policy and Science.'
- Considerably more effort was expended to characterize the gamma measurements and concentration of Ra-226 on the tailings pile versus making actual radon measurements downwind from the piles. A large amount of data, of the type indicated is available in the documents reviewed versus minimal radon data.
- Considerable variation exists in the cancer risk factor from radon exposure. Generally a range over nearly an order of magnitude (1.0–8.5 10^{-4} lung cancers per person-WLM) was discussed in the DOE documents. Most commonly the value (3.0 10^{-4}) was used. Since 1988 the risk factor generally used, e.g., Miller et al. [28] has been that published in BEIR IV (3.5 10^{-4}) [29]
- Occupational injury & fatalities experienced at Enewetak and UMTRA show that the national risk data is a good predictor of expected harm from doing remediation work employing conventional construction technology.
- Arguments that the LNT is not scientifically based and that only a few cancers can be caused by exposure to toxins in air, water and soil, gives little support for a risk protection standard of one in one million.
- Environmental toxin interventions are extremely high in monetary cost when compared to the vast majority of life saving interventions as already illustrated [4,6]. Data from Miller et al. [28] indicate that the cost of theoretical cancers averted from the UMTRA project averages about \$42.0 million per cancer death avoided with a median of about the same magnitude.

6 Discussion and Conclusions

Construction work is hazardous and efforts to reduce the fatality rate apparently have reached a plateau. Schriver, et al., have recently reported [32] that in examining the overall rank patterns of the causes of fatal events in the construction industry during the 1991–1999 period, that there has not been a significant change. And that the ranking of the causes of fatalities in the construction industry have been as stable as can be over the past 10 years. With risk this stable and high (3rd most dangerous occupation) estimating the risk to the remedial worker is dependable and should be considered in very significant way in the planning phase of a project.

It is obvious when comparing sites that it is the population multiplier that generates the larger observed hypothetical cancer values. Illustrative of how population numbers influence the numbers of hypothetical cancer deaths is the discussion from the Grand Junction EIS [DOE/EIS-0126 (86)] of the maximally exposed resident (MER) and the hypothetical maximally exposed individual (MEI). The MER lives 200 feet from the NW corner of the site full-time, receives 9.3 rem/y for 2.7 years, equating to 0.05 hypothetical cancer deaths over 100 years for the remedial action, for this single individual. However, for 800 individuals at this spot this would equate to 40 hypothetical lung cancer deaths. The MEI sometime in the future, builds a home on the unremediated tailings pile, only eats food grown on the pile, drinks water from a well in the shallow alluvium, and spends 24 hours a day on the pile (8 hours indoors and 16 outdoors). This risk equates to 0.2 hypothetical cancer deaths in 100 years to an individual, but if you assumed 800 people lived on the pile there would be 160 hypothetical cancer deaths in the population of 800 who live 100 years on the pile. This is somewhat exaggerated but aptly explains how the hypothetical cancer deaths are derived as reported in Tables VI and IX. Even considering that the dosimetry was probably greatly exaggerated (using very conservative risk estimates, e.g., worst case factors and lack of annual radon measurements under actual living conditions), more than half the sites (Table 9), had 1 or less projected fatal cancers for the next 100 years; 16 sites had 2 hypothetical fatalities or less, and 9 sites had estimates of hypothetical fatal cancers less than the estimated worker fatalities.

The inflation of the hypothetical cancer values becomes less than fact when exposures equal background. According to Doll and Peto [2] these theoretical cancer deaths, if they exist, are not avoidable. This author would then argue that a remedial action cannot take credit for saving these theoretical deaths if they can't be avoided. Further, as long as risk assessments are performed at the dose level required by the specified criteria, their results will apparently not be testable. If you can't avoid the background cancers and you can't test for any incremental increase at low dose levels specified in the standards and criteria, the only fatalities and injuries empirically observed will be the fatalities and injuries employing high risk work such as construction.

The parallels displayed at Superfund sites discussed by Hamilton and Viscusi are amazingly similar to the findings observed for UMTRA (e.g., future risk to hypothetical people, worst case risk assessment) and one can probably come to the same conclusion about doing more harm than good. In fact, Justice Breyer expressed this very concern in his book [23].

Considering the 4 real fatalities that occurred, directly or indirectly from UMTRA activities, it would be difficult not to conclude that overall UMTRA possibly did more harm than good.

Some additional conclusions follow:

- Risk analysis had little impact on the decision to remediate a tailings pile. The program appears to have been mostly driven by NRC and EPA criteria to remove soil. There were major remediation activities associated with each tailings pile, as evidenced by the $ multi-millions spent on each. Even though risk assessment estimates for fatalities to workers exceeded in numbers the estimate of hypothetical cancer deaths for 9 sites (in the DOE planning documents) integrated out to 100 years, remediation still occurred. There was 1.0 or less hypothetical cancer death for 100 years for 12 sites, over half of the total piles remediated.
- For the small cost of bringing the tailings piles under Federal control, risk probably could have been very adequately controlled under the NO action alternative until land use and subsequent risk assessment dictated further action. The exception might be Salt Lake City, UT and Grand Junction, CO because of large populations in the near-pile vicinity; the most probable risk assessment may have still suggested additional remedial work above NO action.
- Absent sound scientific justification for extrapolation to very low doses using the LNT model, there is no justification for using the very low risk standards based on that extrapolation.
- EPA risk assessment methodology exaggerates the risk. According to Hamilton and Vicusi [4] by as much as 2 orders of magnitude.
- Environmental regulation at the current risk level is not consistent with reality.
- There appears to be a significant deficiency in the collection of radon data given that all UMTRA EIS, EA and other documents are unanimous in concluding that radon is the only significant pathway of concern. As a result most radon values are modeled with the exception of those on the pile, very near and/or at sufficient distance to establish the background or baseline level. I could not find a statement explaining this discrepancy, but suspect that is because the majority of houses existed at or near the established background. Modeling allowed extrapolation out to these distances, e.g., 10 to 80 km (6–50 miles).
- Based on the UMTRA experience ($1.1 Billion / 4 fatalities) one might predict that for each expenditure of about $250–$300 million spent on soil-moving type of construction, one fatality may occur.
- The methods used to model the exposure of hypothetical subjects depended on modeled radon projections versus measured values. This appears to make the output (hypothetical fatal cancers avoided) more of a screening type number one would use to decide on the need for further characterization work, rather than the actual decision to proceed to expend tens of millions of dollars moving soil and accruing real risk. The NCRP [30] states for estimating radon daughter inhalation, "It must be stressed repeatedly that the only relevant measurement for radon daughter exposure is the annual average exposure under actual living conditions."

7 Recommendations

Improvements could include: criteria which considers all the risk involved equally weighted such that risk is not increased by the generation of unnecessary volumes of soil and material to be moved; improvement of risk assessments by using real data versus modeled data; use of the most probable pathway parameters resulting in the most probable estimate of risk, not the worst case; and then use the risk assessment to make decisions. For those remedial actions where projections of occupational injuries and fatalities exceed the hypothetical cancers to be avoided, the status quo should be maintained.

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