Are we paying too much to reduce radiological risk?

BY HERBERT INHABER

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THE LINEAR NO-THRESHOLD (LNT) theory of radiation has generated strident debate ringing down the halls of ANS meetings for years. Detractors of the theory claim that it costs the public truckloads of cash due to excessive regulation of nuclear power and related industries. The debate would be considerably more polite if it were merely a matter of biology, not money.

Zbigniew Jaworowski, of Poland, has been a delegate to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) for decades. In a widely circulated article in *Physics Today* last year, he said that the theory has cost the world billions of dollars for little effect, and is one of the greatest scientific scandals of the 20th century.[1] The question then is, how can we determine if we are spending too much on reducing radiological risk?

Bernard Cohen (professor emeritus of physics and of environmental and occupational health at the University of Pittsburgh) and others have prepared lists of costs per death avoided for various situations. For example, a vaccine to save a child from perishing in Africa may cost tens of dollars. The cost of saving a radiation-induced death (assuming the LNT theory and collective dose) from certain Nuclear Regulatory Commission regulations may run to hundreds of millions of dollars. It would then seem logical, as well as highly humane, to transfer at least a little of the money that is spent on expensive regulations to some of the more effective death reduction methods, such as immunizations for the Third World.

However, there is no mechanism for doing so. Even if the NRC commissioners decided that perhaps some of their regulations were a tad too strict and encouraged utilities to send the money saved to pharmaceutical companies for medicines, there is no way of enforcing this. Thus the lists of costs per death avoided, while useful conceptually, provide no concrete way to produce rational action.

There is another way of solving the problem. The methodology used here is that of comparison of costs to save a life, within a specific organization, the Nevada Test Site (NTS) of the Department of Energy (DOE). As Thomas Fuller wrote, "Nothing is good or bad but by comparison" (*Gnomologia,* 1732). If we can show that spending to reduce radiological risks is substantially greater than that to decrease other risks, we have reinforced Jaworowski's points. Further, we can get more "bang" (reduced risk) for the buck.

Action may not flow from such a demonstration. All we can do, as Elie Wiesel, the 1986 Nobel Peace Prize winner, noted long ago, is to "speak truth to power."

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No comprehensive document

Although the DOE has prepared hundreds, or even thousands, of risk-related documents dealing with its sites over the decades, curiously enough, there is no comprehensive document for each site, intercomparing all of its risks. To check the truth of this statement, I quizzed some DOE "old-timers." They had worked for DOE or its contractors for decades, and had seen or heard of most documents. They confirmed that there has been no such all-encompassing study. This article, and the ANS meeting paper it is derived from, is apparently the first dealing with the issue of intercomparing risks at DOE sites.[2]

Accelerating Cleanup: Paths to Closure is the DOE's most comprehensive document describing the cleanup (sometimes called remediation) program by its Office of Environmental Management. In principle, the agenda is driven by risk. That is, presumably the largest risks to human health and safety are to be tackled first, the next largest are dealt with in turn, and so on, down to insignificant risks. Missing, however, from this extensive document of more than 300 pages are estimates of risks at the various DOE sites, and how those risks would drop after cleanup.

Without those estimates, it is difficult, if not impossible, for policymakers and members of the public to judge how much progress is made toward lowering risks, or whether large pots of money are chasing minuscule risks. In addition, there is no estimate of the new risks created by the cleanup process itself.

Total costs of the DOE remediation are estimated at about $147 billion, in constant 1998 dollars. This will be by far the largest cleanup in history, dwarfing the Superfund for abandoned industrial waste sites. A glance at the *Statistical Abstract of the United States* shows that perhaps only two dozen of the approximately 200 nations in the world have annual gross domestic products higher than this sum. (Granted, the expenditures will take place over decades, rather than in one year).

What are the sources of data for a risk comparison? The Environmental Impact Statement (EIS) is generally the most comprehensive source of data for any DOE site. In the case of the NTS, it was also the most expensive, costing about $10 million, according to a published report. EISs, however, are generally hermetically sealed, in the sense that Chapter 7 does not talk to Chapter 3, and Chapter 4 will have nothing to do with either of them. Thus, in order to intercompare risks comprehensively, the entire EIS must be evaluated. Other data, such as that from a risk project at the University of Nevada at Las Vegas (UNLV), and yet more risk-related papers, were used.

Categories of hazards

In order to make sense from the mass of DOE risk-related documents, the hazards they describe have to be arranged in some type of conceptual order. Figure 1 shows a reasonable system. The three dimensions (directions are arbitrary) are category (or source) of risk, location (on or off site), and time (present or future).

The eight categories include:

- Contaminated soils from aboveground weapons tests, which ended in the 1960s.
- Radioactive waste management—The NTS accepts much low-level radwaste from other DOE sites. This category refers to the possibility of eventual settlement on these locations.
- Underground test areas—Here is calculated the chance that radionuclides from belowground weapons tests (which ended in 1992) may someday flow off site. The main nuclide of concern is tritium.
- Transportation of the radwaste mentioned above—By far, the largest proportion of this risk is nonradiological, i.e., ordinary vehicle accidents.
- Worker risk from radiological and chemical sources.
- Worker risk from ordinary occupational accidents—This is shown below to be the biggest source of risks.
- Large accidents, from aircraft hitting waste sites and workers.

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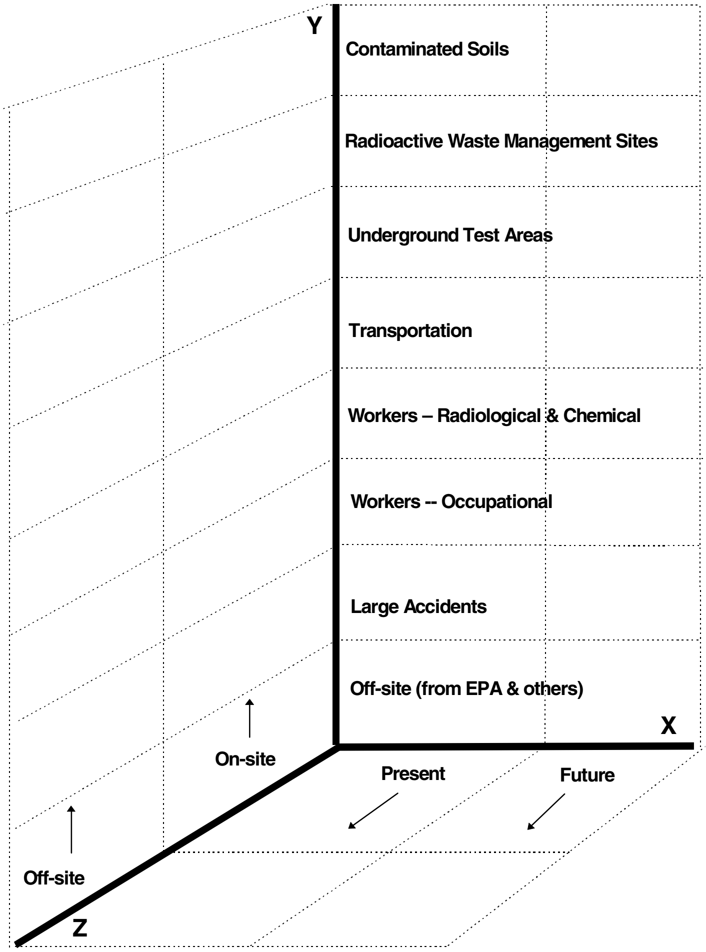

Fig. 1. Arrangement of Nevada Test Site risks in three dimensions. The dimensions are time (X), category, or source (Y), and location (Z).

■ Present offsite emissions from routine activities.

Many of the 32 (8×2×2) conceptual boxes in Fig. 1 have a zero risk. For example, since no below-ground tritiated water has been detected beyond the NTS boundaries to date, the present offsite risk from underground test areas is zero. Similarly, all worker risks are, by definition, on site. Their risk off site is assumed to be zero.

We know what "present" means, but what is denoted by "future"? While some DOE documents assume guarding of the NTS and other sites for thousands of years, others contend that this is unreasonable hubris. As Ausonius (AD 310–395) wrote in *Epitaphs,* "death comes even to monuments and to the names engraved on them." The UNLV study and some parts of the EIS assume that the NTS will be available for public land use in about 100 years and that all barriers will be open. Thus, worker risk at that time is also zero.

It would take considerable space to list all the assumptions in the NTS EIS and other documents. Some are buried in the computer codes that DOE uses to estimate radiological risk. Others can be spelled out more clearly. For example, given the site's availability in about a century, people settle there (at a density estimated recently for Nye County, the location of the NTS, in 2020, by Comstock, a Las Vegas bank). About 3000 take up residence, probably a gross overestimate, given the desert conditions and long distance from any town. They are further assumed to lack knowledge of radiation or its hazards. They farm and drill wells randomly on the site. It is assumed that all security barriers to the site have disappeared over time. Given the large gusts for which southern Nevada is known, the gates, fences, and locks may be, as the song has it, "blowin' in the wind." In spite of these perhaps extreme assumptions, the main risks are still not radiological.

A group not considered here is the "downwinders," those (mostly in Utah) affected by the aboveground weapons tests of the 1950s and '60s. While important, those radioactive releases took place long ago. The horizontal axis of Fig. 1 is divided into "present" and "future," not "past." It is true that there are potential future risks in Utah from the long-ago fallout. There are no estimates of the size of these risks. A cleanup might, as in the case of the NTS, increase total risk, rather than decrease it.

A major assumption is that all deaths, from radiological or nonradiological sources, are equivalent. This probably overestimates the effects of radiologically induced deaths, since latent cancer fatalities from this source ordinarily affect older persons. Accidental deaths generally fell much younger people. Thus, the years of life lost from a radiologically caused death are usually considerably less than that from accidents.

Some uncertainties

There are, of course, uncertainties in a study of this type. Pliny the Elder (AD 23–79) foretold risk analysis when he wrote two millennia ago, "The only certainty is that nothing is certain."

Some NTS data are classified, and unavailable for public scrutiny. For example, the so-called underground source term—that is, the amount and location of radionuclides from underground tests—is secret. Given little knowledge of this source term, there are considerable uncertainties about its risks.

Even if the source term were known and published, the geology and hydrology of the NTS still contain many unknowns. Exactly how fast and in which direction(s) the water flows may not be known with certainty for years, if ever. The risk to offsite populations will then remain uncertain. It is shown below, however, that the upper bound of this uncertainty is still much less than other sources of risk.

Other aspects have considerably less uncertainty. For example, fatalities from low-level waste transportation to the NTS have a variation of about 5 percent from the average value. This is based on the annual variation in traffic fatalities per truck mile driven.

The data, then, are a combination of highly uncertain values, spanning orders of magnitude, and much more precise numbers. Fortunately for the conclusions, the largest risk sources are relatively well-known.

The NTS EIS implicitly uses the LNT model relating radiation dose to risk. For example, if a dose of X rem (a measure of the absorbed radiation dose, taking into account the differing biological effectiveness of each type of radiation) produces a given risk, then a dose of half that amount would produce half the calculated risk. The LNT dose response assumption is used in many DOE and other federal agency regulations.

The Health Physics Society (HPS) has stated, however, that below a lifetime dose of 10 rem (0.1 Sv), "risks of health effects are either too small to be observed or are non-existent."[3] Almost all radiation doses (and associated risks) evaluated here are less than 10 rem over a lifetime. The only exceptions are (a) large accidents, when an aircraft crashes into a radwaste site, and (b) drilling by future site residents into so-called Greater Confinement Disposal narrow-diameter boreholes, which house high-specific-activity wastes such as tritium. The probabilities of these two events is so small that the estimated risk is microscopic. To avoid inadvertently underestimating radiological risk, the LNT model is used here.

Results are shown in Fig. 2. Only the top four (out of 14) risks are shown, to conserve space. The other 10 are much smaller than those shown here. The scale is logarithmic, compressing large differences. The endpoints are accidental deaths or latent cancer fatalities annually. Other endpoints, such as genetic effects and nonfatal accidents, can also be used.

The risks

The largest risk is commonplace: accidental occupational deaths. Second and third are transportation (mostly of low-level wastes to the NTS), both off- and on-site. But these are nonradiological—that is, truck crashes and the like. Radiological risk due to transportation is far too small to show here.

The fourth category, Workers—Radiological and Chemical, for the first time, in this graph, includes radiological risk. But it is over two orders of magnitude smaller than the first item in the graph. As well, it includes chemical risk, clearly nonradiological.

The DOE remediation program does not specify a "bright line," where remediation efforts will be abandoned at a level, say, of 1 millionth of a death per year or a collective dose of so many microsieverts (ten-thousandths of a rem) annually. The ratio of cost to risk may reach extreme heights—that is, diminishing returns on remediation programs. While apparently not with reference to the DOE program, the question of diminishing re-

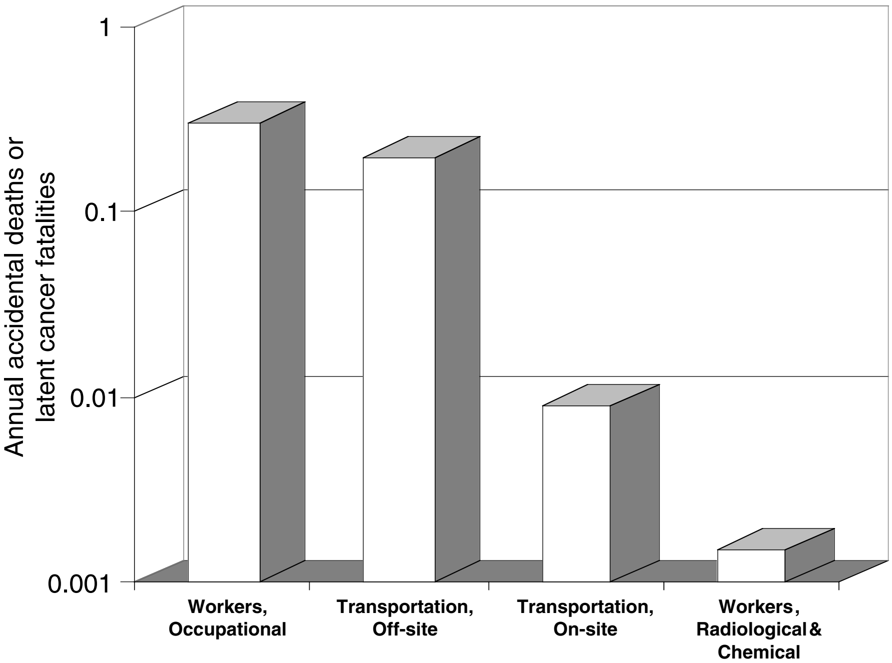

Fig. 2. Four largest NTS risk sources. All four are to workers, not the public. As well, they are all in the present, not the future. Of the four, only the second highest (Transportation, Off-site) occurs off site.

turns has been debated in other areas of public policy. In a court case dealing with water quality, "The nub of the finding turned on Judge Stearns's conclusion that 'the expenditure of $180 million to achieve less than a 1 percent improvement in the capacity . . . to inactivate cryptosporidium is not an efficient or productive use of limited public resources.'"[4]

Figure 2 illustrates risk transfer, where hazards are conveyed—either deliberately or inadvertently—from one group to another. The subject is important enough to have been one of the main subjects of a book by a Supreme Court justice (Stephen Breyer), the first time that the question of risk has reached such an exalted level. In the case of the NTS, an apparently small public risk of low-level radwaste at other DOE sites is shifted to truck drivers and workers at NTS, because of transport of LLW for storage there. The results suggest that in the process it may also be magnified, i.e, increased. The ethics of inadvertent risk transfer bothered Justice Breyer, and we should feel uneasy as well.

The national media generally miss the story about the total risks of a DOE site, centering attention mainly on small radiological risks. For example, in the only story about Nevada Test Site risks in a national newspaper in the last year and a half, the entire report was about the hazards of the underground radioactive wastes from nuclear tests.[5] Using highly conservative assumptions, however, the risks from this source are of the order of a thousandth that of the major risk source, workers' occupational risks. A reporter who, while writing about construction accidents, concentrated only on hammers smashing thumbs would not have his job for long.

In the past year, the DOE has stated that compensation should be paid to DOE contract workers who may have developed radiation- and chemical-induced disease due to their service. By June 2000, the Senate had agreed to financial terms.[6] It is unclear, however, how these decisions would affect the results shown here, since the policy is financial and political in nature, rather than solely scientific. Many, although possibly not all, of the diseases discussed in Congress are part of the risk titled here Workers—Radiological and Chemical.

Risks versus expenditures

How do we relate risks to expenditures? For the NTS, budget requests for Defense Environmental Restoration and Waste Management for fiscal year 2000 were $90.2 million; for Environmental, Safety and Health, $2.4 million. The two organizations deal primarily with radiological and nonradiological risk, respectively, although there is some overlap in missions.

For simplicity, only fatalities are considered in Fig. 3. Nonfatal cases can also be evaluated using this methodology. The four combinations of risks—present on- and off-site, and future on- and off-site—are combined here. Results are shown in Fig. 3. At the NTS, at least, expenditures per fatality are about 5000 times greater for radiological as opposed to nonradiological deaths. The latter amount, as graphed, is barely visible. If a more realistic estimate of radiologic risk were used, instead of the likely overestimates noted above, the ratio could be in the tens of thousands. The upper bar would extend off the page. But the point is made.

While DOE data are used here, the DOE should not be the sole object of attention. There are undoubtedly other agencies throughout the world that focus most of their money and regulatory efforts on smaller, rather than larger, risks. Studies of this type may prompt second thoughts.

Although DOE concentrates most of its risk-reduction funding on radiological sources, by far the largest proportion of risk derives from nonradiological sources. Whether or not this is a misallocation of resources is ultimately for the public and its elected representatives to determine. Figure 3, however, suggests that there is more than a grain of truth in Jaworowski's assertion that huge amounts of money are being wasted in a search to lower already infinitesimal risks.

An old Italian saying states that at the end of the game, the pawns and kings go into the same box. For the two sources of fatalities we are considering, one box is 5000 times the size of the other.

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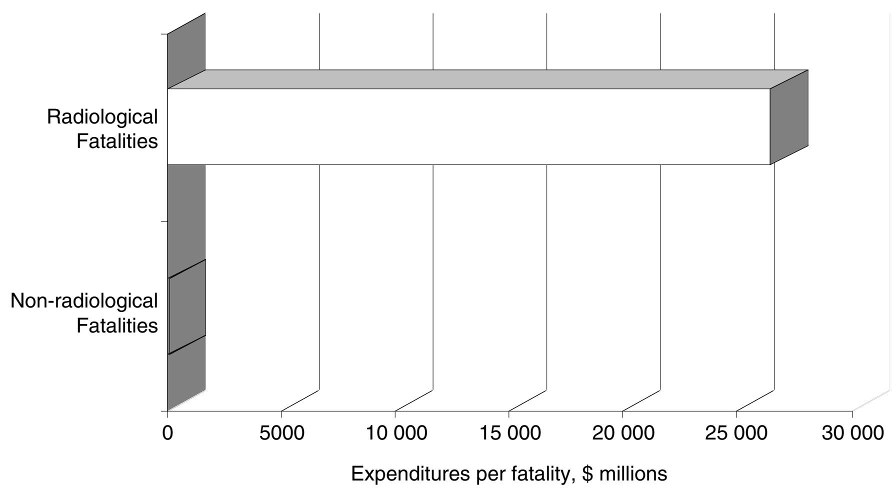

Fig. 3. Nevada Test Site expenditures, per estimated fatality, for radiological and nonradiological risks. Spending on radiological risks is about 5000 times that for nonradiological risks. Similar calculations can be made for nonfatal risks.