SIX

Uranium Mine Workers, Atomic Downwinders, and the Radiation Exposure Compensation Act (RECA)

The Nuclear Legacy

Susan E. Dawson and Gary E. Madsen

Since September 11, 2001, government officials have attempted to tighten national security in the United States. In addition to creating a new administrative agency, Homeland Security, and passing the Patriot Act, the federal government has renewed its emphasis on nuclear weapons development. At the same time, recent threats of terrorism and breaches in information security at the nuclear research facility in Los Alamos, New Mexico, have heightened concern about maintaining the security of the entire nuclear research and development program (Associated Press 2004; Emery 2004; Holmes 2004). Security violations also led the Nuclear Regulatory Commission (NRC) to announce in 2004 that security problems at nuclear plants would no longer be made public, so that such information would not be available to terrorists (Rulon 2004). The failure of the United States to persuade North Korea and Iran to abandon their emerging nuclear weapons programs presents another threat (Dickey et al. 2006; Bernstein 2005; Sanger 2004). Indeed, North Korea announced in February 2005 that it actually possesses nuclear weapons (T. Johnson 2005), not just the capacity to make them, and substantiated this claim with a nuclear test in October 2006.

Citing national security concerns, the Bush administration in 2003 requested and received from Congress $42.8 million for research and development for a new generation of nuclear weapons. Funding requests in 2004 included $36.5 million to develop more low-yield nuclear weapons, such as the Robust Nuclear Earth Penetrator (RNEP) bomb, or bunker-buster bomb; $29.8 million for a new nuclear bomb factory; and $30 million to upgrade the Nevada Test Site (HEAL Utah 2004). Because of strong opposition among downwinders (people exposed to atomic fallout from previous nuclear testing) and congressional leaders such as Representative Jim Matheson (D-UT), Congress did not fund these requests (Gehrke 2004; Lofholm 2005). The 2006 federal budget initially included research funding for the bunker-buster bomb; however, this bomb was eliminated in favor of conventional weapons (Burr 2005).

The uranium mining industry in the United States is experiencing a resurgence, thanks to efforts to revive the development of nuclear power plants and nuclear weapons and to meet global production demands worldwide. The industry has largely been on hold since the 1990s, when the price of uranium plummeted. Uranium was selling for approximately $43 a pound in May 2006 (Fahys 2005; Kosich 2006; Oberbeck 2006a, 2006b), up from about $7 a pound in 2001. By December 2006, the price had risen to $60 a pound. The Cotter Company of Colorado reopened one of its uranium mines in 2004 and plans to open additional mines in the future. If the price of uranium continues to escalate, more mines may resume operations (Lofholm 2005). Unfortunately, this combination of the possible resumption of nuclear testing, renewed uranium mining, and increased security may create a climate similar to that of the Cold War period (the 1940s through the 1980s), in which the United States and the Soviet Union produced and tested nuclear weapons in an atmosphere of utmost secrecy.

The US uranium mining and atomic testing that began in the post–World War II era, the subsequent scientific studies of radiation-induced health effects, and the struggle to win compensation for the victims offer some lessons that contemporary policy makers would do well to heed. During this period of nuclear weapons production and testing, a lack of safety precautions and risk notification by the government and industry resulted in large-scale health problems and deaths of citizens and workers, culminating in a large-scale technological, human-made, disaster that we can ill afford to repeat. The implications of this disaster may best be understood by examining the historical context of US uranium mining and nuclear testing.

Uranium Mining in the United States

Extensive uranium mining began in the western United States in the late 1940s. Thousands of mines had operated by the early 1980s, chiefly on the Colorado Plateau. Ninety-two percent of western mines were clustered there, including 325 in Arizona, 1,276 in Colorado, 215 in New Mexico, 1,197 in Utah, and 280 in Wyoming, for a total of 3,293. In the 1950s and 1960s, Colorado and Utah produced most of the nation's uranium ore, but in the 1970s and 1980s production shifted to New Mexico and Wyoming (Yih et al. 1995).

Between 1950 and 1989, US mines—both surface and underground—produced more than 225 million tons of uranium ore (DOE 1991). This activity heavily affected a number of American Indian nations. For example, the Navajo Nation, which encompasses portions of Arizona, New Mexico, and Utah, had more than a thousand mines (Dawson et al. 1997), whereas Laguna Pueblo, 40 miles west of Albuquerque, New Mexico, hosted the Jackpile Mine, the largest open-pit uranium mine in the United States.

The Atomic Energy Commission (AEC), established in 1946, was the only purchaser of uranium for nuclear weapons from 1948 until 1970 (DOE 1991). To put it another way, private US uranium mining companies had only one buyer: the federal government. This situation changed in 1964, when Congress enacted the Private Ownership of Special Nuclear Materials Act to provide for the production of nuclear power plants and arrangements between the AEC and private energy companies (DOE 1991).

We do not know how many workers in all have worked in uranium mining. Archer and colleagues estimate that in 1945 there were approximately 350 uranium miners in the United States, increasing to 550 in 1950. By 1955 more than twenty-one hundred miners held jobs in uranium mines, and by 1960 that figure had climbed to fifty-seven hundred (Archer et al. 1962). After 1960, thousands still worked in the mines, until their numbers fell significantly when the industry essentially ceased operations at the end of the 1980s (DOE 1991).

To understand the US uranium mining experience, it is important to present a history of uranium mining and health issues in Europe.

The Impact of Uranium Mining on Miners' Health

Uranium mining was not new when it began in the United States in the 1940s; Europeans had mined uranium in the late nineteenth century, and the adverse consequences for miners' health rapidly became evident. During the latter part of the 1800s, an active uranium mining industry existed in the Erzgebirge Mountains, a region between eastern Germany and the present Czech Republic. The Schneeberg mines in Germany (Saxony) began in the fifteen century. The Joachimsthal mines in Jáchymov in what is now the Czech Republic (Czechoslovakia and Bohemia) opened in the sixteenth century. At that time, these mines produced arsenic, bismuth, cobalt, copper, iron, nickel, and silver. By the late nineteenth century, they had turned to pitchblende for uranium dyes, especially in the Jáchymov region. By the twentieth century, the prize was radium. (For a history of the European experience, see ACHRE 1996; Holaday and Doyle 1952; Hueper 1942; Lorenz 1944; Ringholz 2002.)

A substantial number of the Erzgebirge region miners died of a lung disease known as *Bergkrankheit*, or "mountain disease." Härting and Hesse (1879) first diagnosed it as lung cancer. They found that 75 percent of all deaths among mine employees had resulted from lung cancer but that the incidence was lower for mine carpenters and masons than for miners. The study showed that miners developed lung cancer over a lengthy latency period of approximately twenty years. Research during the 1920s and 1930s generally supported the link between uranium mine work and lung cancer (see Hueper 1942; Lorenz 1944). To reduce risks associated with radiation exposures, mining companies built mechanical ventilation systems beginning in the 1930s (Bhounek 1970).

In the early 1940s, two prominent US medical researchers, Wilhelm Hueper and Egon Lorenz, summarized the Erzgebirge uranium miner studies. Hueper, an Austrian émigré, became the first director of the environmental cancer section of the National Cancer Institute (NCI). After reviewing the literature, he concluded that radiation caused the European miners' lung cancer, ruling out genetic, work, and nonwork factors (ACHRE 1996; Hueper 1942). Medical researchers in the United States did not unanimously accept Hueper's conclusions. Lorenz, a senior biophysicist at the NCI, published his own review of the literature on European miners, noting, "Whereas in former years pneumoconiosis in combination with arsenic and cobalt was assumed to be the cause of this cancer, today the radioactivity of the ore and the radon content of the air in the mines are generally considered to be the primary cause" (Lorenz 1944:5).

Lorenz emphasized other factors that might have caused the miners' lung cancer, including a possible hereditary predisposition. In addition, he observed that the measured doses of radon gas from the European mines did not seem to be high enough to cause health problems.

It was not until 1951 that two researchers, William Bale and John Harley, explained this discrepancy. They identified the importance of the decay products of radon (radon daughters, or progeny), which can attach themselves to mine dust. Miners inhaled and concentrated these products in lung tissue, with the result that delivered doses were up to one hundred times higher than the amount of radon gas alone indicated (Archer et al. 2004). Mechanical ventilation in the mines could significantly reduce the radon daughter risks to the miners by dispersing them (Holaday 1969).

By the late 1940s, there was growing evidence, based upon a pilot study by AEC medical researchers Merril Eisenbud and Bernie Wolf, that the "European experience" was likely to play out among US uranium miners (Eisenbud and Wolf 1948; Ringholz 2002). In response to these concerns, the US Public Health Service (USPHS) began what eventually became a massive study of US underground uranium miners during the summer seasons of 1950 and 1951. Duncan Holaday, a senior sanitary engineer with the USPHS, served as the principal investigator. The study had two interrelated goals: (1) to identify uranium mine environmental exposures, and (2) to conduct a medical evaluation of the miners (Holaday, David, and Doyle 1952; Holaday and Doyle 1952).

According to Holaday, the role of the USPHS was to gather and disseminate data concerning the uranium experience. The agency had no authority to shut down mines if they were not complying with health and safety regulations. Nor could USPHS investigators enter privately owned mines without permission of the owners. To get data, the USPHS agreed not to warn miners of radiation hazards or inform them directly of the health study findings. Even as late as 1960, a USPHS medical consent form failed to apprise miners about the risk of lung cancer and other health problems related to working with radiation in mines. Holaday later stated that the USPHS procedure was routine and had been followed in previous industrial studies (ACHRE 1996). The muzzling of the researchers and the latency of the lung damage caused by uranium mining made it impossible early on for miners to recognize a connection between work exposures and health problems. According to the Advisory Committee on Human Radiation Experiments, "Had they been better informed, they could have sought help in publicizing the fact that working conditions in the mines were extremely hazardous, which might have resulted in some mines being ventilated earlier than they were" (ACHRE 1996:365).

USPHS researchers presented the initial findings of the study in two different reports, the *Progress Report* of January 1952 and the *Interim Report* of May 1952, both focusing on uranium mine and mill exposure levels on the Colorado Plateau (Holaday and Doyle 1952; Holaday et al. 1952). Summarizing the exposure data from forty-eight mines, Holaday and Doyle reported exceptionally high concentrations of radon. Moreover, they compared these radiation levels with those in the European studies and found that the median level of radiation exposures in US mines was higher than exposure levels found to be related to lung cancer among the European miners (Holaday and Doyle 1952).

Greatly concerned by the excessive radon daughter levels in the mines, the researchers organized two conferences in August 1951 at the USPHS Salt Lake City Field Station. Representatives from the AEC, the US Geological Survey, and the US Bureau of Mines; technical experts from eight mining companies; and representatives of five state health departments attended. During these meetings, USPHS researchers presented information regarding mine study findings, radon measuring techniques, and ways to reduce mine radon levels using mechanical ventilation (Holaday and Doyle 1952).

The medical side of the study consisted of giving miners physical examinations, including chest X-rays and urine and blood analyses. The researchers found "no clear-cut etiologic or pathologic patterns" and noted that a majority of the workers had been employed for just a short time. Since an extensive latency period characterized the diseases that European miners had suffered, the absence of strong evidence of mine-induced disease in the Americans was not surprising (Holaday et al. 1952:6).

Almost thirty years after the *Interim Report* appeared, Holaday testified in a deposition given to Stewart Udall, attorney and secretary of the interior under the Kennedy and Johnson administrations. Holaday spoke about a document he had written in 1964, in which he stated:

> It is now 14 years since the uranium study was started. At times, this project has been quite active; for other periods it has been quiescent. The study was undertaken with the belief that all that was required was the evaluation of environmental conditions in the industry and comparison of the results of the

> studies with the data on human experience which was available in the literature. Measures to control the exposures of the workers to toxic materials could then be recommended. This belief was a delusion. (Holaday 1981:26)

Udall was then a private attorney. He brought two lawsuits on behalf of uranium miners.

After the reports were issued in the early 1950s, there was some progress made in reducing radiation risks in uranium mines. Some mine owners improved ventilation, and the states of Colorado, New Mexico, and Utah established minimum standards for radon concentrations; however, enforcement was generally inadequate, and AEC commissioners did not move to establish national standards regarding radon exposure limits. When Udall asked Holaday in 1981 whether AEC officials took recommendations made in the early 1950s seriously, Holaday said, "There was no reaction from them" (Holaday 1981:28). The AEC position, later stated by Jesse Johnson, director of the AEC's Raw Materials Division, was that the AEC had no authority to regulate uranium mines (J. Johnson 1959), despite the fact that the AEC did regulate beryllium (ACHRE 1996; Ringholz 2002). Not until 1971 did the Environmental Protection Agency (EPA) adopt a more stringent federal standard on mine exposures (Cross et al. 1974). This action was prompted by a growing awareness by the miners and the public of the health problems associated with the uranium mining industry (Eichstaedt 1994).

Despite the lack of an official response from the AEC to its recommendations, the USPHS continued to study the Colorado Plateau uranium miners, adding new miners to the study in 1951, 1953, 1954, 1957, and 1960 (Archer et al. 1962). Researchers gathered baseline health data for each miner so that investigators could develop a mortality assessment. In this way, the causes of miners' deaths as reported on death certificates could be compared with a control group of males of similar age and ethnicity in the states where the miners worked. The study eventually included approximately four thousand American Indian and non-Indian underground uranium miners. The major problem with this type of study was that the miner had to die for comparisons to be made.

In the 1970s, the study was transferred to the National Institute for Occupational Safety and Health (NIOSH). The first publication showing a statistically significant excess of lung cancer deaths among uranium miners appeared in the *Journal of Occupational Medicine* in 1962 (Archer et al. 1962). Further investigations produced several other published reports including Archer 1981; Archer, Gillam, and Wagoner 1976; Archer, Wagoner, and Lundin 1973; Holaday, Archer, and Lundin 1968; Hornung and Meinhardt 1987; Lundin et al. 1969; Lundin et al. 1971; Roscoe 1997; Roscoe et al. 1995; and Wagoner et al. 1964. Reports that included the USPHS findings, along with pertinent data from other studies, also appeared in print (see Archer et al. 2004; Gofman 1981; Lubin et al. 1994; National Academy of Sciences 1988).

Cumulatively, the uranium miner studies produced several important findings. They demonstrated a linear relationship between cumulative exposure levels and lung cancer, with the cancer risk per unit of exposure in the lower cumulative radiation categories greater than in the higher ones. In other words, cancer-causing radon progeny are more efficient at causing cancer at lower levels than higher ones (see Archer 1981; Gofman 1981; Hornung and Meinhardt 1987; Lubin et al. 1994; Lundin et al. 1971). The studies also documented an extensive latency period of about twenty years between exposure and health outcomes. In addition, whether or not a person smoked did not explain the positive relationship between exposure and lung cancer; however, smokers who were also miners had a shorter latency period than did exposed nonsmokers (see Archer et al. 2004; Lundin et al. 1969; Roscoe et al. 1989).

But the higher incidence of lung cancer among uranium miners was only part of the story. Beginning with the 1952 USPHS *Interim Report*, evidence showed that uranium miners were also developing nonmalignant respiratory disease (Holaday et al. 1952). The longitudinal progression of the study data confirmed this finding. For example, Roscoe's 1997 update found statistically significant excesses of lung cancer, pneumoconiosis, tuberculosis, chronic obstructive respiratory disease, emphysema, benign and unspecified tumors, and diseases of the blood and blood-forming organs among miners (Roscoe 1997).

While we focused on the USPHS-NIOSH study, other significant contributions to the literature concerning uranium mining and health effects included studies conducted largely in New Mexico and on the Navajo Nation (Gottlieb and Husen 1982; Mapel et al. 1997; Samet, Kutvirt et al. 1984; Samet, Young et al. 1984; Samet et al. 1991; Samet et al. 1994). In general, these studies both supplemented and complemented the aforementioned research.

Miners were not the only people affected by the US nuclear weapons and power industries. In the next section we will review the history and pertinent studies of the atomic downwinders, focusing on radioactive fallout produced by the Nevada Test Site.

US Atomic Downwinders

Shortly after World War II ended with the detonation of atomic bombs at Hiroshima and Nagasaki, the US military needed to know much more about the environmental and human impacts of the new technology. The military undertook a nuclear testing program in the Marshall Islands, Micronesia, that lasted from July 1946 to August 1958. In the end, the United States conducted sixty-seven nuclear tests at Bikini and Enewetak (Republic of the Marshall Islands 2005). Even though government officials considered the Pacific testing successful, having the test site outside the continental United States posed a range of problems, including difficulties in transporting service personnel and materials and maintaining a high level of security. Therefore, the US military began a search in 1947 for a test site within the continental United States, resulting eventually in the selection of the Nevada Proving Ground, later known as the Nevada Test Site (Titus 1986).

From 1951 through 1992, the United States conducted one hundred atmospheric and more than eight hundred underground nuclear tests at the Nevada Test Site (Boutté 2002; Makhijani et al. 1995). Despite plentiful evidence from previous scientific research indicating the dangers of such tests for people within reach of the fallout, the AEC did not make health and safety a top priority during the nuclear testing program. Agency officials ignored studies demonstrating the adverse health effects of radium, including research on Madame Curie's work and the radium dial painters (see Clark 1997; Reid 1974). As Fradkin wrote:

> As the tests got underway at the Nevada Site in 1951, it was known within the scientific community that radiation caused superficial injuries, leukemia, malignant tumors, genetic defects, and such miscellaneous ailments as cataracts, obesity, impaired fertility, and shortened lifespans. Also, an association had been found between the fallout from the Hiroshima and Nagasaki bombs and leukemia. (1989:183)

The exposure of a broad public to radiation raises different questions than exposure of workers in nuclear-power-related industries, and protection from radiation becomes far more difficult. For example, whereas children are not allowed to work in the uranium industry, they still can be exposed to fallout or other forms of environmental radiation. In addition, exposure of the general public can involve significantly larger numbers of people than exposure of worker populations (*Irene Allen et al. v. United States*, Civil No. C 79-0515-J, 1984).

Unfortunately, just as the government agencies involved failed to notify the uranium miners of the risks they faced, they also failed to warn the public about nuclear testing, even those directly in harm's way. The AEC used several tactics to promote nuclear testing, invoking the need for protection against the communist threat and the potential for peaceful uses of atomic energy. Despite the existence of evidence to the contrary, the agency told people that fallout was safe and any exposures would not result in long-term health problems (Titus 1986). The AEC's public information program received close scrutiny during the *Irene Allen et al. v. United States* case, in which atomic downwinders sued the United States for redress. Judge Bruce S. Jenkins summarized the evidence as follows:

> This court is convinced that that part of the program of public safety, the public information program was badly flawed, and that during the operation of that program, the information given to the off-site public as to the long-term biological consequences of exposure to ionizing radiation was woefully deficient—indeed, essentially non-existent...[and] failed to adequately, contemporaneously, and thoroughly measure and monitor such fallout so as to be able to inform persons at risk of the extent of the hazard faced by each. (315–16)

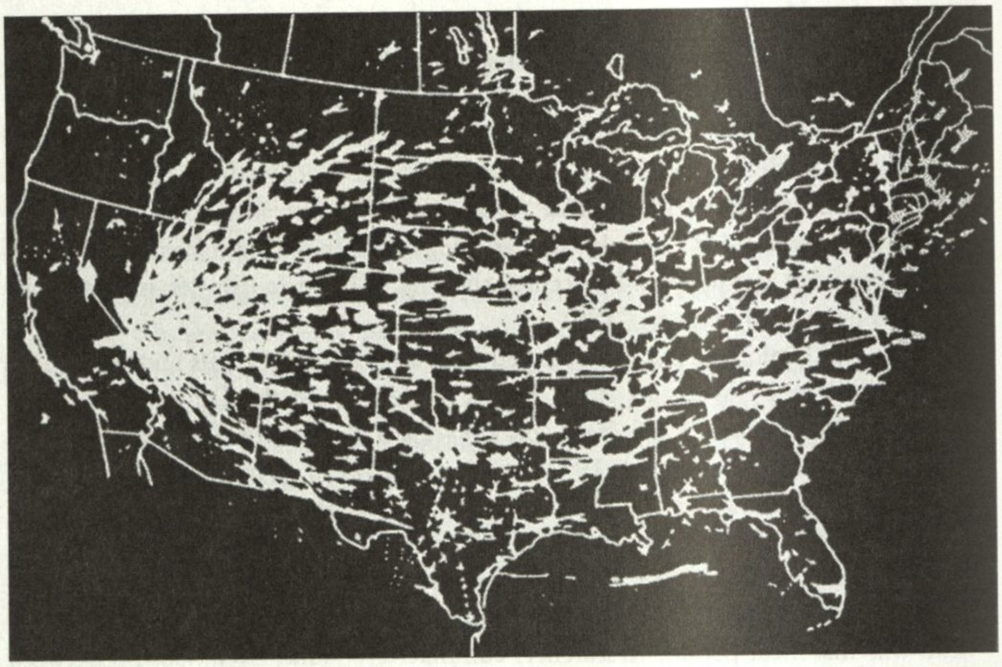
In addition to ignoring the research that existed, the AEC did not have sufficient knowledge to evaluate the dangers posed by nuclear testing. At the beginning of the testing program, the agency believed that radioactive fallout would spread through-out the global atmosphere. In reality, air currents and other atmospheric conditions, such as rainstorms, created radioactive hot spots, so that specific places suffered higher concentrations of radiation. Furthermore, the AEC emphasized that people would be exposed to radiation externally for the most part—on the skin—rather than by ingesting it through such sources as milk and food (Metzger 1972). Citing Representative Chet Holifield as quoted in the *New York Times*, Metzger wrote: "Representative Holifield branded the AEC 'grossly tardy and negligent' in telling the nation the truth about fallout from atomic tests. He accused the AEC of intentionally playing down the effects and dangers of radiation" (86).

Several epidemiologic studies occurred between the early 1960s and the 1990s, including studies by Weiss in 1961, Knapp in 1963, and the Centers for Disease Control in 1965 (see Ball 1986; Beck and Krey 1983; C. Johnson 1984; Kerber et al. 1993; Lyon 1979; Rallison et al. 1974; Stevens et al. 1990). The geographic focus of these studies was the states of Arizona, Nevada, and Utah, which were immediately downwind of the Nevada Test Site. The publications *Justice Downwind* (Ball 1986), *Under the Cloud* (Miller 1986), *Fallout* (Fradkin 1989), and "The United States" in *Nuclear Wastelands* (Makhijani et al. 1995) describe the studies and their findings within this historical period. Researchers cumulatively found a relationship between fallout exposures and increasing leukemia, thyroid cancer, and certain other cancers. In this chapter, we did not discuss nuclear testing with onsite participants because they were not a focus of our research.

Unfortunately, the AEC held up public access to the early studies by Weiss and Knapp. The 1961 Weiss study report suggested that, for those living in southwestern Utah, fallout contributed to an increase in leukemia deaths. AEC personnel received the report for review in 1961 but did not release it publicly until 1978, for fear, in part, that its release might threaten the nuclear testing program (see Ball 1986). Moreover, Knapp's 1963 study of fallout contaminants in fresh milk was also sequestered until 1978, when journalists succeeded in forcing the AEC to release it in response to Freedom of Information Act requests (see Ball 1986). These early studies provided evidence that US continental testing program fallout contributed to significant health problems, yet the AEC continued to assure the public that fallout was essentially harmless.

Controversy concerning the extent of fallout and its health effects continues to this day. Scientists and concerned citizens became increasingly worried in the 1980s that the atmospheric tests in Nevada had produced excessive levels of fallout that had not been studied adequately. Miller (1986) demonstrated that fallout trajectories blanketed major portions of the United States. (See map 6.1.)

In the late 1980s, Congress mandated, under Public Law 97-414, a national study to indicate exposures of the US public to iodine-131 fallout from Nevada nuclear atmospheric bomb tests conducted during the 1950s and 1960s. The NCI conducted this study and in 1997 released a report showing that the major pathways of exposure to iodine-131 were drinking cow's milk (considered the single most important route);



Map 6.1. This map by Richard Miller was first published in his 1986 book Under the Cloud. *Miller used publicly accessible records to trace the significant movement across the United States of fallout from nuclear weapons detonated at the Nevada Proving Ground. Miller's map does not include fallout from subsurface tests or from nuclear detonations outside the continental United States.*

breathing contaminated air; and eating contaminated foods such as cottage cheese, eggs, goat's milk, and leafy vegetables. The NCI also identified counties in the states of Colorado, Idaho, Montana, South Dakota, and Utah that had the highest concentrations of fallout (NCI 1997). These geographic areas indicate a much larger area of heavy fallout than what Congress considered when it wrote compensation legislation for fallout victims.

Scientific Studies and Reparations

Scientific studies, including those we have documented in this chapter, played a major role in providing evidence of the connection between exposures and health outcomes that could be used in court to claim redress for people who suffered from radiation produced in nuclear weapons programs. Yet the limitations of science and the fact-finding process meant it took a very long time for miners and downwinders to substantiate their claims of radiation-induced illness. Government agency secrecy, latency, sample size and levels of significance in epidemiologic studies, and differences among scientific publication venues all present major challenges to those investigating the relationship between uranium exposure and health outcomes.

Government Agency Secrecy

Some of the early studies that sounded the alarm about radiation-related health problems among miners and downwinders did not reach the public for many years because government entities refused to make them public. The early USPHS reports circulated among government and uranium industry personnel, but miners never saw them. Indeed, the USPHS gained access to private mines only after agreeing not to disclose the hazards of radiation exposures to workers. Only in the 1960s and afterward did miners begin to be notified of the risks they faced at work.

Miners and mines now fall under jurisdiction of the Mine Safety and Health Administration (MSHA), created in 1969. MSHA is similar to the Occupational Safety and Health Administration, created in 1970 to provide and enforce health and safety regulations. The AEC suppressed the 1961 Weiss study of leukemia in Utah and the 1963 Knapp study of radioactive iodine in the food chain. Neither became available to the public until 1978 (see Ball 1986). Secrecy not only meant the continuation of nuclear mining and testing and the poisoning of growing numbers of people but also retarded the development of scientific knowledge, since the majority of scientists had no access to pioneering studies for many years.

Latency

Two types of epidemiologic study are critical to establishing the link between radiation exposures and health outcomes: cohort studies, which compare the health outcomes of those who are exposed with the outcomes of those who are less or not exposed; and case-control studies, which compare people with health problems with those who are well (see Sumner et al. 1995). These two research designs are invaluable in making connections between exposure and health outcomes when studying communicable diseases that have a short period between exposure and outcome. But these methodologies do not work as well when a lengthy latency period is involved. According to Gofman:

> Radiation-induced cancer was the first disease to add a new dimension to this problem of cause and effect. This new dimension has been fiercely resisted in many quarters, even ridiculed, in the face of a mountain of evidence that the time period between insult and disease can be measured in decades, not days, weeks, or months. (1981:107)

This situation points out the need to develop stringent exposure standards as a precautionary measure when dealing with toxic substances rather than waiting for, in this case, radiation-induced illness and death. Merril Eisenbud, a former industrial hygienist who worked for the AEC, commented that it is important to develop a conservative exposure standard when dealing with workers who are exposed to toxic materials and then to lower it by five to ten times as a performance standard (see Udall 1994). Early on, Eisenbud and colleagues at the AEC's New York operations office recommended that the AEC include health protection requirements for miners in their contracts with mine operators, but the recommendation was never adopted (see ACHRE 1996).

Archer and colleagues reported the latest evidence on latency among US underground uranium miners: the average latency period was about twenty-five years for former miners who were nonsmokers and nineteen for smokers, based on a review of 821 lung-cancer cases among the miners since 1947. The authors concluded that by the government "disregarding the European radon mine exposures and waiting for strong evidence of lung cancer among US uranium miners (ignoring the exposures occurring while waiting during the latency period), the epidemic became inevitable" (Archer et al. 2004:480).

Sample Size and Statistical Significance

Generally, it is impractical for researchers to study an entire population exposed to environmental toxins such as uranium. Typical studies involve taking a sample of a population exposed to radiation and comparing death or illness rates of this sample with one not exposed, the control group. If a control group is unavailable, the exposed group is compared with comparable vital statistics of a region. Since samples do not include everyone in a population, if one were to take multiple, randomly drawn samples one at a time from the same population, there would be random variation from sample to sample. Yet the objective is to determine whether a difference between exposed and unexposed people indicates a true difference or is due to random variation.

To be confident that a difference between exposed and unexposed people reflects actual differences, the researcher applies a statistical formula called a test of statistical significance. Generally, researchers require statistical significance at least meeting the .05 level. The .05 standard means that the probability of a true difference between exposed and unexposed people is ninety-five chances out of one hundred, or nineteen chances out of twenty. In other words, the chance of being wrong is only five out of one hundred or one chance in twenty. This level of statistical significance is more likely to occur with a larger sample size than with a smaller one for a given difference between exposed and unexposed people because the chance variation is less for a larger sample than a smaller one. For example, if a sample of one thousand uranium miners experienced ten deaths from lung cancer, compared with two deaths among a control group of nonminers, this eight-person difference would more likely yield statistical significance with this size sample than with one of only a few hundred. The USPHS study of underground uranium miners, which began in 1950, involved a sample of several thousand workers. Even with this large sample, it took until 1959 for white miners with three or more years of work experience (a subsample of 907) to document a statistically significant elevation of lung cancer. Had this sample been considerably smaller, the elevated levels of lung cancer would not have been statistically significant until more miners had died of the disease.

Brown and Mikkelsen suggest that the standards of proof of statistical significance generally used by medical researchers are too stringent. They argue: "To achieve scientific statements of probability requires more evidence than is necessary to state that something should be done to minimize a health threat" (1990:134). We agree with Brown and Mikkelson when life-and-death issues are at stake. Action should be taken to reduce exposures to toxins to the lowest levels possible even when there are elevated health problems among the exposed sample that do not reach the .05 level. Unfortunately, the commonly accepted standard makes it difficult for small populations to establish statistical significance relating toxic exposures to health outcomes. According to Gofman:

> Some seemingly brainwashed scientists have become such slaves to statistics that they really think that 1 chance in 19 (the 5.26% level of significance) is *meaningfully* or perhaps *magically* different from 1 chance in 20. So we find otherwise serious scientists writing such rubbish as "this result was not found to be significant," when if probed, they will tell you that the findings were at the 5.26% level of significance. (1981:811)

Differences in Scientific Publication Venues

Another critical obstacle for anyone researching the literature on radiation exposures and attendant health problems is the difficulty in obtaining certain scientific publications. In our research on uranium miners and downwinders, we gathered information from the in-house publications of government agencies, which are often not readily available to the public; proceedings from professional meetings, which are not readily available to nonmembers; books and professional journal articles, available chiefly in university libraries; and legal transcripts from court proceedings, available through local, state, and federal court systems. Of all these materials, books and scholarly journal articles were the most accessible. Some government sources were unavailable until then secretary of energy Hazel O'Leary released them to the public in the early 1990s.

The difficulty in getting copies of some publications meant that we expended considerable effort in constructing a coherent understanding of what happened to the miners and downwinders because of gaps in the evidence from documents we could not obtain. These missing or hard-to-access reports were significant obstacles for activists and lawyers seeking compensation for damages from mining and fallout.

To give an example of the difficulties of finding information, we interviewed a medical researcher, one of several authors of an important health agency report, who never saw the final report even after it was published in the 1980s. When we discovered the report in the 1990s, we showed it to the surprised researcher. Furthermore, a major study that we received from another researcher and presented as part of congressional testimony was published only in the proceedings of a professional meeting.

Therefore, it was not as widely disseminated as it would have been if it were published as a journal article. The congressional committee was unaware of the report, even though it had been published years before (US Congress, House Judiciary Committee 1998). Given the difficulty of finding and compiling these data, even when the government is not trying to keep them secret, the average citizen often finds the discovery process overwhelming.

The Struggle for Radiation Victims' Redress

In addition to the collection of scientific evidence of the connection between radiation exposures and health outcomes, attorneys, congressional leaders, journalists, and worker and community activists have worked tirelessly over many years to provide redress for radiation victims. These individuals have made a concerted effort to bring the issue to the public's attention. We will discuss briefly some of these major developments related to miners and downwinders.

In the mid-1970s and 1980s, people whose health had been damaged by nuclear development began to sue the government, and scientific radiation studies began to be used as evidence to determine compensation (see Ball 1986, 1993). The possibility of lawsuits and reparations developed out of grassroots support groups for those who felt they were radiation victims. The downwinders' Committee of Survivors, established at the end of 1978; the Navajo uranium miners' Red Valley Uranium Radiation Victims Committee, founded in 1984; and the Mexican Water Uranium Committee, established in 1985, were among the earliest support groups. Utah citizens also organized grassroots groups, such as Citizens Call, founded by Janet Gordon in 1978, and the Downwinders, which Preston Jay Truman created in 1980. In the same year, Bennie Levy, an ironworker at the Nevada Test Site, organized the Nevada Test Site Workers Victims' Association. These groups testified at lawsuits and congressional committee hearings, educated citizens and workers about radiation issues, developed registries of radiation victims, and provided general support to victims and their families (see Ball 1986; Charley et al. 2004; Dawson et al. 1997).

Journalists played a major role in apprising the radiation victims, the general public, and policy makers about radiation-industry health hazards. The *Denver Post* published some of the earliest journalistic accounts between 1957 and 1967. The first articles reported on the possible connection between mine radioactivity and lung cancer, and by 1967 reporters had documented a more definitive connection between the two (see Pearson 1975). Furthermore, J. V. Reistrup, a science, space, and energy reporter at the *Washington Post*, became aware of underground uranium miners dying of lung cancer. In 1967, after visiting Nucla, Colorado, where he interviewed a dying miner, Reistrup wrote an article for the *Post* in which he documented the workers' plight. He also interviewed Duncan Holaday and Victor Archer, researchers in the USPHS study, who told Reistrup about the mounting illnesses and deaths of uranium miners (see Eichstaedt 1994). In 1977 the *Deseret News* of Salt Lake City ran a series of articles about fallout experienced by residents of Saint George, Utah, a city in the state's southwestern corner. The articles identified the connection between nuclear fallout and the development of such diseases as cancer, leukemia, and thyroid problems (see Miller 1986).

Beginning in the 1960s, some of the uranium miners who became ill sought redress through workers' compensation claims, which proved largely unsuccessful. While Colorado and New Mexico recognized that radiation exposure was a hazard of uranium mining and therefore an occupational illness, Utah did not recognize this category of illness, so uranium miners and their families could not file claims appealing for benefits (Eichstaedt 1994). In congressional testimony, Earl Mettler, a New Mexico attorney, recognized that workers' compensation claims presented several problems, including a very low rate of claimant success, limited benefits, and short statutes of limitation. Mettler stated, "Thus, whether viewed in terms of the number of cases that are successful or the level of compensation received, workers' compensation does not provide an adequate remedy" (US Congress, Senate Energy and Natural Resources Committee 1990:177).

In 1979 attorneys Stewart Udall and Bill Mahoney visited some of the Navajo widows and documented their plight. They filed a lawsuit on behalf of the Navajo uranium miners, *John H. Begay et al. v. United States*, on December 15, 1979 (see Ringholz 2002). Udall and associates also filed a lawsuit on behalf of non-Indian uranium miners, *Sylvia Barnson et al. v. Foote Mineral Col, Vandium Corporation, and the United States*. These miners had worked in the Four Corners area of Arizona, Colorado, New Mexico, and Utah.

Addressing the harms done to people who had not worked in the mines, Dan Bushnell filed a lawsuit, *Bulloch v. United States*, on behalf of southern Utah ranchers whose sheep had died in large numbers due to fallout (see Fuller 1984). Joining forces with attorneys David M. Bell, Dale Haralson, Ralph E. Hunsaker, and J. MacArthur Wright, Udall filed the major case concerning human fallout victims, *Irene Allen et al. v. United States*, in 1982. One of the major stumbling blocks to all these cases was the discretionary function exception of the Federal Torts Claim Act (FTCA). This exception gave the government broad immunity from tort suits (Ball 1986).

In a landmark decision of 1984 in the Allen case, Judge Bruce Jenkins ruled favorably for ten of the twenty-four plaintiffs (Ball 1986). However, the Tenth Circuit Court reversed Jenkins's judgment in 1986, upholding the discretionary function exception of the FTCA. The US Supreme Court denied hearing an appeal from the appellate court, thus ending the plaintiffs' legal challenges. The other radiation-related lawsuits also failed based on the same legal point (Fradkin 1989). Despite the fact that the legal efforts were unsuccessful overall, they added an additional source of scientific evidence and testimony from victims and their families that supported causal linkages between radiation exposures and health problems. (For a discussion of the uranium lawsuits, see Ball 1986, 1993; Eichstaedt 1994; Fradkin 1989; Ringholz 2002; and Udall 1994.)

Congressional Efforts: The Radiation Exposure Compensation Act

The struggle for compensation also took place in Congress. Senator Edward Kennedy (D-MA) introduced the first piece of compensation legislation, the Radiation Compensation Act of 1979, or Senate 1965. According to Ball:

> [I]t was an effort to amend the Federal Tort Claims Act to make the United States liable for damages to individuals who were recklessly endangered by governmental actions and omissions. Covered in the proposal were the civilian downwinders and the miners who worked in a Four Corners uranium mine between 1947 and 1961. (1993:83)

The Senate failed to enact Kennedy's bill. In 1981 Senator Orrin Hatch (R-UT) introduced a new compensation bill, Senate 1483, which the executive branch strongly opposed by summoning what Ball called "a mass of persons to testify against the proposed legislation. Bureaucrats in the Reagan administration, especially from the Departments of Energy and Defense and the Veterans Association, argued against Senate 1483" (1993:85). The Hatch bill met the same fate as the earlier Kennedy bill, but Hatch was persistent and reintroduced a modified bill called the Radiogenic Cancer Compensation Act of 1983, or Senate 921. This bill, unlike the two previous ones, had no formal hearings and never made it out of the Senate Labor and Human Relations Committee (see Ball 1993).

Finally, in 1989 Hatch and Representative Wayne Owens (D-UT) introduced legislation that culminated in the passage of the Radiation Exposure Compensation Act (RECA), signed into law by President George H. W. Bush on October 15, 1990, and amended in 2000. The 1990 RECA legislation provided benefits to underground uranium miners, atomic downwinders, and nuclear test site participants. Administered by the Department of Justice (DOJ), RECA provided compassionate payment to those meeting eligibility requirements, including documented radiation-related illnesses and exposures. The legislation was unique in that Congress, in addition to providing compensation, also apologized on behalf of the nation to victims and their families.

The passage of the 1990 RECA bill was largely due to extensive lobbying efforts by activists, attorneys, legislators, scientists, and radiation victims. Senator Hatch and Representative Owens, working jointly, had written a more moderate bill than the previous three efforts. Ball states:

> The legislation came about because, in large part, the public was being made aware, on a fairly regular basis, of the dangers to the health of many hundreds of thousands of civilians in the continental United States as a consequence of implementing the risky national security technology policies that had been in existence for over forty years. The 1990 RECA criteria turned out to be more stringent for claimants than the available scientific evidence indicated they

should be.... For example, the act set the required levels of radiation exposure so high that many sufferers could not qualify for compensation. (1993:87)

According to Brugge and Goble,

> [U]sing the consensus risk estimates of the time from BEIR IV, RECA criteria meant that former workers with lung cancer had to have a risk of six times normal for lung cancer if they were non-smokers, and fifteen times normal if they were smokers. These were extremely stringent conditions for qualification for compensation. (2003:389)

In addition, the downwind geographic areas designated for coverage under RECA were limited. Furthermore, surface miners, millworkers, and ore transporters were not eligible for consideration.

The DOJ also established other stringent eligibility requirements for claimants applying for RECA. For example, initially the officials administering the act did not recognize the validity of traditional Navajo marriages, which did not have formal documentation. The DOJ required marriage licenses as proof of marriage for widows of deceased miners. Also, the act required that all medical records, such as birth and death records, be certified and original copies. Many traditional Navajo elders did not have birth certificates, let alone original records. Often, they had only copies of certain documents such as death certificates. These issues were not fully rectified until the 2000 amendments were passed, and then only through the efforts of attorneys and activists. (For a full discussion of problems associated with 1990 RECA, see Brugge and Goble 2003; Dawson and Madsen 2000; Eichstaedt 1994.)

In the ten years after the passage of RECA, grassroots efforts resurfaced to amend it. These efforts included the Western States RECA Reform Coalition, an umbrella organization for a large number of local grassroots organizations. The lobbying efforts culminated in the introduction of four pieces of legislation in 1999 and passage of the Radiation Exposure Compensation Act amendments of 2000 on July 10, 2000 (Brugge and Goble 2003). The amendments extended the geographic areas for compensation for downwinders and added surface miners, millworkers, and ore transporters to those eligible for compensation. Miners who had smoking histories were no longer required to have significantly higher levels of exposure than nonsmokers to be eligible for compensation. In fact, the changes to RECA made miners eligible if they had either forty working level months (a measurement of radiation exposure) or had established mine employment for one year. The list of compensable diseases was extended to include a wider range of ailments, and certain medical criteria were made less stringent for potential claimants (Department of Justice 2006). For a summary of claims as of January 18, 2006, see table 6.1.

Downwinders are eligible to receive $50,000 in compensation; onsite participants $75,000; and uranium miners, millers, and ore transporters $100,000. Shortly after Congress passed the RECA amendments of 2000, it passed the Energy Employees

Table 6.1. Count of Claims

Claim Type	*# Approved*	*$ Approved*
Downwinder	9,805	$490,220,000
Onsite Participant	960	68,460,816
Uranium Miner	3,800	379,298,560
Uranium Miller	738	73,800,000
Ore Transporter	143	14,300,000
Total	15,446	$1,026,079,376

Department of Justice 2006

Occupational Illness Compensation Program Act (EEOICPA) in October 2000. Under the act, administered by the Department of Labor, miners, millers, and ore transporters who have already won a RECA claim are entitled to an additional $50,000. In the future, such beneficiaries will receive a total of $150,000 (Department of Labor 2003). The combination of RECA and EEOICPA has resulted in compensation awards totaling over $1 billion.

Present Issues Concerning RECA and Compensation

Despite the passage of the RECA amendments of 2000, concern about exposures and compensation persists among purported victims and their advocates. RECA now allows downwinders only in certain counties in Arizona, Nevada, and Utah to be eligible for compensation, even though the 1997 NCI study identified certain counties in Colorado, Idaho, Montana, South Dakota, and Utah as having the highest per-capita thyroid doses from the Nevada Test Site nuclear tests (NCI 1997). Blaine, Custer, Gem, and Lemhi counties in Idaho received heavier doses of iodine-131 than some Utah counties that qualify for RECA (Smith 2004). Idaho downwinders have organized to demand a change in RECA to make fallout victims in that state eligible for compensation. Furthermore, Idaho health officials have instituted a preliminary study to examine whether there is a relationship between multiple sclerosis and nuclear fallout in Idaho (Associated Press 2005).

The National Academy of Sciences has recently held meetings to discuss possibly expanding the geographic areas defined as being downwind in RECA. But once again information circulates among only a small group of officials and academics, and remedies are slow in coming. According to Preston Truman of Lava Hot Springs, Idaho, president of Downwinders, "it's not just Idaho. You've got western Montana, sections of western Colorado, northwest New Mexico, Iowa and upstate New York all with high fallout doses, but not only are they not covered, they haven't been told about this study" (Smith 2004).

More community studies need to be conducted to investigate possible health problems experienced by people who live or have lived in proximity to sources of radioactive exposures. In 1996 the Navajo Nation established a large-scale educational program to apprise its residents of environmental contamination left by the extensive mining and milling of the 1950s and 1960s. According to Charley:

> Uranium mining and milling has left large areas of the Navajo reservation contaminated with abandoned mines, mine waste, and mill tailings and associated radioactive contaminants. There are well documented problems with lung cancer and silicosis in former uranium miners, and there is great concern between uranium millers and other Navajos who reside near contaminated areas about late effects of radiation exposures from these sources. (2000:1)

RECA also excludes post-1971 uranium workers. Only those who were employed in uranium mining, milling, and truck hauling prior to 1972 are eligible for compensation. This cut-off date was based upon government liability related to the federal government procurement program, which ended in 1970 (Madsen and Dawson 2005). Recent scientific evidence suggests that the exposure-limit regulation the EPA adopted in 1971 was not stringent enough to adequately protect underground mine workers over their cumulative working careers (see Archer et al. 1980; Lubin et al. 1994; Madsen and Dawson 2005; National Academy of Sciences 1988). Advocates had lobbied for the inclusion of post-1971 workers in the 2000 amendments to RECA, but Congress declined to include them. The lobbying efforts for changes in the 2000 RECA amendments placed the greatest emphasis on earlier uranium workers.

Summary: Lessons Learned

The Cold War period of uranium production and testing has been a wide-scale human-caused disaster, resulting in widespread illness and death primarily from chronic low levels of radiation. Many scientists in the early nuclear era believed there was a threshold dose of radiation that, if not exceeded, would not cause health problems. As Gofman has explained, these advocates of a threshold dose did not accept a linear relationship between radiation exposures and the development of health problems. Unfortunately, the assumption that the body has mechanisms to repair damage from low doses did not withstand scientific research. Drawing on studies of radiation victims since the 1940s, Gofman concluded, "Therefore, scientifically it is thoroughly reasonable to say that cancer and leukemia induction by radiation is proportional to dose right down to the lowest conceivable doses" (1981:411).

The people presently opposing the possible resumptions of nuclear testing and uranium mining have reason to be concerned. Activist groups, including the Eastern Navajo Allottee Association and the Eastern Navajo Diné Against Uranium Mining are working diligently to stop uranium mining on the Navajo Nation, while the Healthy Environment Alliance of Utah has lobbied against the resumption of nuclear bomb building and testing. Hopefully, history will not repeat itself, and the lessons learned from the Cold War and its aftermath will be translated into sound public policy concerning uranium mining and nuclear weapons testing.

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