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CHAPTER THREE

Experiments on Humans

WHEN GENERAL LESLIE GROVES asked the DuPont Corporation to become the primary contractor for the Hanford Works nuclear weapons production facility, Walter Carpenter, the company's president, hesitated and then demanded that a $20 million claims fund be established to protect against unforeseeable radiation-induced harm to workers. Carpenter eventually accepted the challenge with that caveat and two others: that the company be indemnified by the U.S. government and that the facility be located in a remote area, "for safety's sake . . . because of unknown and unanticipated factors."[1]

When the project began, the technology was so young and poorly understood that a 1946 DuPont report concluded that there had been "no established tolerance limits for certain of the hazards which would be encountered."[2] Even though the federal government had not established limits for human radiation exposure, DuPont created its own standard of 0.1 roentgens per twenty-four-hour period for total body irradiation, with the caution, "It is better to spread this dose out over as long a period as possible. When the tolerance level is exceeded, we can make no definite estimate of the time required for recovery. In other words, if a man receives 26 roentgens in one day we cannot say that by removing him from exposure for 360 days we would eliminate all possible trouble, as with such exposure irreparable damage might have occurred."[3]

The medical supervisor's most serious warning was that averaging exposures over long periods may not prevent significant damage. This argument would recur continually in twentieth-century environmental science, and ran counter to tendencies by government agencies to average the exposures over many years, which disguised the severity of intense short-term exposures.

Groves recalled his own reservations about the safety of nearby communities, concerns that centered more on the possibility of a dramatic accident than on chronic exposures: "Reactor theory at this time did not overlook the possibility that once a chain reaction was started, it could . . . get out of control and increase . . . to the point where the reactor could explode. . . . We knew, too, that in the separation of plutonium we might release into the atmosphere radioactive and other highly toxic fumes which would constitute a distinct hazard . . . I was more than a little uneasy myself about the possible dangers to the surrounding population."[4]

Herbert Parker, a British radiologist, led the health and safety program at Hanford. Prior to 1946, Parker studied the movement of radionuclides in air, water, vegetation, and soil. He then explored how iodine-131 was absorbed by livestock. Parker knew that iodine-131 was emitted from Hanford's stacks in particular amounts; the next step was to measure how much of the isotope had been taken up. He directed soldiers and technicians to roam the countryside near the plant in jeeps and trucks, stopping to rope sheep, cattle, and other domestic animals. The workers then held Geiger counters to the animals' thyroids to test them for the presence of iodine-131, recording the detected levels in their notebooks. Most of the measurements were taken without the knowledge or consent of the livestock owners. One of Parker's assistants recalled visiting farms and pretending to work for the Department of Agriculture as an expert in animal husbandry. The deception was useful: "I was successful in placing the probe of the instrument over the thyroid at times when the owner's attention was focused on the next animal or some concocted distraction."[5]

Parker worried that he and other Hanford scientists did not understand how the iodine-131 releases made their way to the animals' thyroids. He was concerned that Hanford workers, and others living in the vicinity of the plant, were also being harmed by thyroid absorption of iodine-131. Even less was known at the time about the long-term effects of chronic exposure to radioactive isotopes of iodine-131, cesium-137, and strontium-90—all isotopes present in the immediate environment.[6]

Most of those who worked at the Hanford plant lived in Richland, a government-owned town built primarily to house the military servicemen and contractors. One could not live in Richland during World War II unless employed by the AEC or one of its affiliated corporations. The government also regularly warned residents against drinking milk from the animals that grazed nearby; milk was instead imported from Yakima or other distant communities. The town's extensive milk-testing program was described as an effort to track both "bacterial count and butterfat content. . . . And although more distant cities obtained their drinking water from the Columbia River, Richland purposely relied on well water, because the scientists at Hanford knew what contaminants they were discharging directly into the river. This intensity of monitoring, the restrictions, and the warnings collectively imply that the government knew something about environmental contamination and especially the vulnerability of the milk supply, all information kept from residents.[7]

Those who managed the Hanford Works struggled with the ethical dilemma of knowing that the hazardous materials they routinely released to the surrounding environment threatened the surrounding population—and of being unable to tell those people of the danger they faced. Residents of government-owned Richland were warned that they should be careful to grow lawns to prevent allergies that could be exacerbated by dusts. They were unaware that radionuclides released from Hanford's stacks had likely settled on Richland's soils, and were blowing in the wind. Residents were also prohibited from owning livestock such as chickens and cattle, due to concern that they might concentrate the radionuclides. And when the scientists found that sagebrush tended to absorb radionuclides, they told Richland residents to remove it from their property to reduce pollen-induced allergies. Together these policies were crude attempts to reduce the residents' exposure.[8]

GREEN RUN

During the late 1940s, scientists had monitored stack releases from Hanford, as well as from the Oak Ridge National Laboratory in Tennessee. While radionuclides were detected nearly fifteen miles from Oak Ridge, they seemed to extend only two miles from Hanford. These results might be explained by the differing sensitivity of detection equipment, or variation in the monitoring efforts between the two areas.

Hoping to track particles over longer distances, the Air Force designed an experimental release of radionuclides into the atmosphere at Hanford, code-named "Green Run," in 1949. The Green Run was only one of thirteen intentional releases in the United States, including experiments conducted at Los Alamos, New Mexico; Dugway, Utah; and Oak Ridge, Tennessee.[9] All of the tests were designed to better understand the movement and fate of atmospheric radionuclides. Normally fuel elements were cooled for ninety to a hundred days before being dissolved, which allowed for more radioactive decay and lower emissions of radiation. Elements for the Green Run test, however, were cooled only for sixteen days, and scrubbers, normally used to remove radioactive gases from stack releases, were turned off. Significantly, Healy had assumed that the fuel had cooled for twenty days, a miscommunication that was to lead to his further underestimate of the magnitude of xenon-133 that would be released.

On the day of the test, December 3, 1949, a weather front stalled near Hanford for several days, and radionuclides swirled slowly in clouds near the plant, settling in far higher concentrations than expected. In the end, nearly 8,000 curies of iodine-131 and 20,000 curies of xenon-133 vented from the stack, settling over large areas of southeastern Washington and northeastern Oregon. A radioactive cloud lingered over the plant and other communities within one hundred miles, including the city of Spokane.

The detection equipment itself became so contaminated that the Hanford staff realized their readings could not be true. Radiation levels in vegetation were found to be 400 times higher than concentrations that would injure livestock. A report of the experiment was prepared by the Atomic Energy Commission in 1950, but was classified as secret for nearly forty years. As Healy later recalled:

> At first, everything went fine. The wind was blowing from the south to the north, which was relatively uninhabited. The inversion held well. That was one of our criteria for dissolving [proceeding with the experiment]. But the problem was that at about two o'clock in the morning, we got a dead calm, and then the wind reversed direction 180 degrees. Generally, the

> noble gases come out first and the iodine comes out a bit later. About two o'clock in the morning, we had the calm; and then the wind, instead of blowing to the north, began to blow down the river over Richland, Pasco, and Kennewick[, Washington]. This, I believe, was the reason for the high [iodine] levels that we got on the Green Run. . . . Because the iodine had deposited on the ground. People would go out and back in, step on the shoe and foot counters, and set them off. That disrupted their operations very badly. I was very unpopular, believe me. . . . My calculations showed that we managed to contaminate an area about twice the size of the Windscale[, England, nuclear plant] accident [in 1957], with about one-fifth of the amount of iodine released. . . . When we replaced Bob Thorburn from under the stack in the Green Run [in Washington State], you could read him with a Geiger counter from here [in New Mexico].[10]

Reflecting on the Hanford experiments decades later, Healy remembered:

> The biggest problem, as it turned out in the long run, was that Herb and I did not see the milk-to-man pathway. Although, I had inklings that Herb later did begin to see the problem. . . . The real thing was that it was a pathway from the air to the ground. We knew that the iodine deposited very heavily on the ground. We knew that from our own experience. There was also the fact that A. C. Chamberlain in England had done some experiments releasing iodine on a cricket pitch and found that it deposited very heavily on the grasses. In fact, when I went over to England for the Windscale review, A. C. greeted me like a long-lost brother, because everybody else doubted his experiments, but our experience backed his findings very closely. From the grass, the iodine went to the cow and then to milk, which was then consumed by the most sensitive portion of the population: the children. Now, I'm sure that if Herb had realized this pathway existed, he would have put up a fight as only Herb Parker could. . . . I'll repeat that if I hadn't been so ignorant, and had caught on to the air-grass-cow pathway, I think the Green Run would never have taken

> place. We had a Biology Group by that time. They were busy feeding iodine to sheep. But no one who really was in the business caught on.[11]

Questions about Green Run, as well as the degree of hazard posed by Hanford's day-to-day operations, would remain unanswered for decades. How much radiation was released from the plant's facilities? What concentrations of various radionuclides were emitted to the air, to the soil, and to the Columbia River? Was well water contaminated? Once released, where did the radionuclides go? How far could they travel? Could they accumulate in plant, fish, wildlife, and human tissues? What are the effects of exposure to different radionuclides, and other chemical compounds released to the environment as waste or pollution?

Due to the highly secret nature of the project, these questions were not publicly asked or debated, even if those Hanford scientists who knew the plant's purpose and dangers grew increasingly concerned. Still, such worries were eclipsed by the sense of urgency that grew from World War II, the Korean War, and the Cold War, conflicts that encouraged aggressive experimentation with nuclear weaponry. To national leaders facing threats to national security, the risks associated with these new technologies seemed reasonable.

THE STORY OF RADIUM

In the 1950s, the field of health physics—the study of how human illness could be induced by radiation—grew quickly. Although people were increasingly being subjected to radiation as part of medical diagnoses and treatments, and in occupational settings, little was known about the long-term effects of such exposures, which generally occurred at levels that produced no obvious and immediate symptoms.[12]

Radiologists and physicists within the AEC were well aware of the history of radium, especially the deaths of young women who had worked for the U.S. Radium Corporation in New Jersey during the 1920s. The "Radium girls" had worked from their homes, painting radium on watch dials to make them glow in the dark. The industry grew quickly during World War I to meet the military's demand for luminescent dials. But in 1926, a New Jersey dentist noticed that several of the young women were suffering from similar degeneration of their jawbones. The women, by licking their paintbrushes to make a point, had exposed themselves to disfiguring and sometimes lethal doses of radium.

During the 1920s, radium was widely touted as a therapy for conditions as diverse as nervousness, baldness, diabetes, and high blood pressure.[13] Patented medicines and therapies containing radium continued long after the watch-dial controversy was common knowledge. Radium capsules were inserted into the nose to treat children with middle ear infections, with little research on the long-term health damage that might result. The Navy and Air Force experimented with similar therapies for those suffering from inner ear disorders that worsened when air pressure changed rapidly. And in the 1940s, Johns Hopkins University researchers experimented with the capsules on several hundred children to understand the potential of radium to prevent deafness.[14]

The ambiguity of risk associated with radioactive isotopes, together with the growing impression of their diagnostic and therapeutic value, helped to lessen public anxiety over the nuclear weapons program. Moreover, health physicists were not yet able to identify safe levels of exposure to the unstable elements created by weapons testing. This uncertainty meant that those responsible for producing and releasing hazardous technologies and substances had little chance of being held accountable and responsible for adverse health effects. It was argued that if medical experts could not identify with precision a threshold between a safe and dangerous exposure, there was little need to control environmental releases, or to monitor what happened to the isotopes once they had been released into the air, soil, and water. By dodging this responsibility, too, the AEC perpetuated the cycle of inadequate information: the lack of surveillance left environmental concentrations unknown, which in turn made it impossible to estimate human doses. The absence of evidence provided cover for the AEC's aggressive and covert experimentation—a strategy rationalized by the scientists' belief that they were already pursuing the most essential goal, that of preserving national security.

EARLY EXPERIMENTS ON CHILDREN

The crude scientific experiments conducted by the AEC were extended to the realm of human testing: in particular, testing children for radiation exposures. Beginning in 1944, and continuing until 1974, the year before the commission became part of the U.S. Department of Energy, the U.S.

government sponsored pediatric research with radioactive compounds to better understand children's physiology, the pathology of the radiation in children, and the potential of newly minted diagnostic tools. The AEC conducted nearly 4,000 radiation experiments during this period, most often with the intent to use radioactive tracers to understand physiological processes, rather than the hazards to humans. The nature and extent of these studies was kept quiet until the mid-1990s, when a committee within the Department of Energy brought to light nearly eighty such studies, and further found that twenty-one of those supported by federal funds were "non-therapeutic," that is, offered no possible benefit to the participating child. The committee also found very little evidence regarding how authority was obtained to conduct these studies, leading it to conclude that authorization by parents or guardians was not likely sought.[15]

In fact, the AEC disguised these studies of radioactive compounds in the human body as "nutritional" research. In the late 1940s and early 1950s, Massachusetts Institute of Technology scientists participated in research to understand the relations between nutrient intake and radionuclide behavior in children. Students living at the Walter E. Fernald School, a Massachusetts institution for "mentally retarded" children, were fed breakfast food containing radioactive iron and calcium. Nine boys between the ages of ten and fifteen, and one twenty-one-year-old, were divided into two groups, with the first receiving an intravenous injection of calcium-45, and the second eating it in tainted breakfast cereals. Several letters were sent to the parents of students to encourage them to join the study; they were promised that the children would be welcomed into the "Science Club" if they agreed to participate.[16] The second letter, sent in May 1953, explained:

> Dear Parent: In previous years we have done some examinations in connection with the nutritional department of the Massachusetts Institute of Technology, with the purposes of helping to improve the nutrition of our children and to help them in general more efficiently than before. For the checking up of the children, we occasionally need to take some blood samples, which are then analyzed. The blood samples are taken after one test meal which consists of a special breakfast

> meal containing a certain amount of calcium. We have asked for volunteers to give a sample of blood once a month for three months, and your son has agreed to volunteer because the boys who belong to the Science Club have many additional privileges. They get a quart of milk daily during that time, and are taken to a baseball game, to the beach and to some outside dinners and they enjoy it greatly. I hope that you have no objection that your son is voluntarily participating in this study.
> The first study will start on Monday, June 8th, and if you have not expressed any objections we will assume that your son may participate.
> Sincerely yours,
> Clemens E. Benda, M.D., Clinical Director and
> Malcom J. Farrell, M.D., Superintendent[17]

The research was classified as "nutritional" with no mention of the children's exposure to radioisotopes, or the risks such compounds pose. The breakfasts involving a "certain amount of calcium" give no hint that the additive is radioactive. When some children resisted the offers, one of the MIT researchers wrote, "it seemed to [him] that the three subjects who objected to being included in the study [could] be induced to change their minds . . . [by emphasizing] the Fernald Science Club angle of our work."[18] The Massachusetts Task Force on Human Subject Research, which in the 1990s investigated the use of radioisotopes at state-owned facilities in Massachusetts, concluded that these practices violated the children's human rights.[19]

Another study was conducted in Tennessee at the University of Tennessee College of Medicine, and the John Gaston Hospital. In 1951, two African-American women, ages twenty-two and thirty-three, were administered iodine-131 while nursing their four-month-old infants. Both mothers had been diagnosed with thyroid disease. The infants continued to nurse, and the levels of iodine-131 were monitored in the mothers' breast milk and thyroids, as well as in the infants' thyroids. Observing that the infants' accumulation of iodine-131 in their thyroids was significant, the researchers warned against the administration of iodine-131 to lactating women. The study not only is appalling for its lack of concern for the mother and infant subjects, but also shows how early the AEC recognized that atmospheric fallout could contaminate mother's milk, and that this contamination concentrated dangerously in the thyroids of infants nursing from affected mothers.[20]

Researchers at Harvard Medical School, Massachusetts General Hospital, and Boston University School of Medicine conducted an experiment by administering radioactive iodine to seventy students at the Wrentham State School for "mentally retarded children" in 1961. The experiment was designed to understand whether nonradioactive iodine could block thyroid uptake of radioactive iodine-131. If it had a protective effect, health loss following nuclear war might be significantly reduced.[21]

In another study, conducted by a University of Rochester graduate student, seven subjects younger than twenty-one were placed on an iodine-restricted diet, then drank milk from a cow fed iodine-131 for a minimum of fourteen days. One of the children developed a benign thyroid nodule that was surgically removed.[22]

In 1953, pediatricians at Harper Hospital in Detroit administered iodine-131 to sixty-five premature infants, hoping to understand thyroid uptake and function.[23] Twenty-five newborns at the University of Iowa were also administered iodine-131, eight by oral administration and seventeen by injection, demonstrating more rapid thyroid uptake via injection.[24]

Researchers at the University of Iowa administered iodine-131 to pregnant women about to have therapeutic abortions in 1953. Following the procedure, levels of iodine-131 were measured in the embryos. From this experiment, the scientists learned that iodine-131 could cross the placental barrier, possibly endangering developing fetal thyroids.[25]

Between 1945 and 1949, scientists at Vanderbilt University Hospital administered the radioactive isotope iron-59 to 829 women who were between 10 and 25 weeks pregnant, discovering that the more developed the pregnancy, the more the isotope was absorbed. The children born were followed between 1964 and 1967, although no health problems were anticipated. Among the 679 children exposed in utero, one developed leukemia and two developed sarcomas. There were no malignancies in the control group, which consisted of 705 children.[26]

University of Utah researchers studied the metabolism of cesium-137 and rubidium-83 between 1965 and 1972. Subjects included five infants, five healthy children between five and ten years old, three children between the ages of four and eleven who had muscular dystrophy, six pregnant women, and twenty-three nonpregnant adults. The children with muscular dystrophy retained the lowest amounts of the two isotopes, supporting the researchers' hypothesis that cell membrane permeability was somehow associated with the illness.[27]

In yet another instance, researchers at Johns Hopkins University injected iodine-131 into thirty-four children ages two months to fifteen years who had been diagnosed with hypothyroidism. An unknown number of healthy children were also injected as a control group.[28]

Outrage over such unethical human experiments occurred only after Eileen Wellsome wrote a series of articles in the *Albuquerque Tribune* in 1993 identifying individuals who had been injected with plutonium during government-sponsored medical experiments. The subjects had been hospitalized for other ailments and had received the "treatments" without their consent, all in the name of Cold War national security. The outcome of the experiments was expected to guide the setting of standards for protecting workers who processed and disposed of nuclear materials. Hazel O'Leary, Secretary of Energy during President Clinton's administration, read Wellsome's 1993 articles and expressed shock that the agencies and officials responsible could have operated with such disregard for human rights. The Department of Energy she managed had grown from the AEC. She and others convinced President Clinton to create the Advisory Committee on Human Radiation Experiments to find and disclose all cases of government experiments with radiation. The committee's report resulted in the public release of hundreds of thousands of formerly classified documents. The cases provide insights into a secret society of government, industry, and academic scientists, and into the moral logic they relied on to justify their research. The cases also demonstrate the absence of government principles or standards to protect the rights of citizens who were exposed without their knowledge or consent.

The experiments conducted on children were especially haphazard in design, and overlooked essential information about dosages and safety. O'Leary's committee concluded in 1994: "It is evident that investigators using radioisotopes in children were not employing available information on organ weights in children to calculate tissue exposures at least until the mid-1960s. . . . [Thus] investigators may have significantly and systematically underestimated effective tissue dosages in children [that is, those dosages that caused a change in tissue]. It is notable that the highest levels of risk posed in the experiments reviewed were to infants administered iodine-131."[29]

In this context, it may seem surprising that the AEC's Isotope Division in 1949 created rules to evaluate research proposals submitted for government funding of radioisotope experiments on "normal children": "In general the use of radioisotopes in normal children is discouraged. However, the Subcommittee on Human Applications will consider proposals for such use in important researches, provided the problem cannot be studied properly by other methods and provided the radiation dosage level in any tissue is low enough to be considered harmless. It should be noted that in general the amount of radioactive material per kilogram of body weight must be smaller in children than that required for similar studies in the adult." Regardless of this recommendation, O'Leary's committee noted the absence of any requirement for informed parental consents, and that "important researches" and "harmless" were not defined by the AEC. Although all twenty-one pediatric studies examined in the early 1990s might be construed to be important, eleven of these experiments were found to pose greater than minimal risk to the subjects.[30]

ASSESSING CANCER RISK

By 1955 federal scientists understood that everyone in the nation had been exposed to the radionuclides released during nuclear tests. What remained uncertain were how much of a dose people located in various geographic regions had received, the relative potency of the most abundant radionuclides, and the differences in vulnerability of population groups, especially children, to these contaminants. Did radioactive isotopes produced by nuclear weapons testing and the experimental release of radiation cause mutations, genetic damage, and cancer? The answer requires an explanation of "dose-response" relations—that is, the relation between exposure and either cancer or genetic damage. For much of the past seventy years, generally two theories regarding cancer etiology have governed debates over acceptable levels of exposure to carcinogens. One theory suggests a "threshold effect," meaning that a specific dose must be exceeded to pose any risk of cancer, and below that dose there is little chance of health loss. The second theory, by contrast, claims that the relationship between exposure and cancer risk is linear: any exposure increases one's risk, and radiation risks accumulate through life. Of the two, the threshold theory is more comforting, since few people experience exposures that are high enough to cause immediate illness or death.

Not surprisingly, the AEC's risk assessments assumed the threshold-effect theory. It was far better for the AEC's long-term goal of nuclear-weapon development to support claims that low-level exposure was completely safe, and to allow the radionuclides to either remain undetected, or to be averaged with milk or grains that had been pooled among various farmers or regions before testing. Federal scientists also avoided the identification of "hot spots" where fallout and exposures might exceed safe thresholds.

Yet scientific evidence was building for the opposing theory. In 1956 a U.S. National Academy of Sciences (NAS) committee reported that any exposure is potentially dangerous, due to the isotopes' capacity to induce genetic mutations that are transmissible to future generations. The committee that prepared the report warned that nuclear war could make the earth uninhabitable. They also found that Americans, on average, were using up one-third of their lifetime radiation limit on medical and dental X-rays.[31]

Indeed, the debate over the safety of radionuclides increasingly focused on the concept of a "maximum permissible dose." In the mid-1950s this was defined initially for workers at energy facilities, and those who might be exposed occupationally in the military. In 1957, the AEC issued a classified report to the National Security Council that had more dire implications regarding a contaminated national food supply than was revealed to the public. "Certainly 450 roentgens received during a short period of time is lethal. Presumably, more than a few billionths of a gram of strontium, Sr90, received in the skeleton structure will also be lethal."[32]

Professor Barry Commoner testified in 1959 that understanding the health threat posed by strontium-90 would be difficult. "How harmful is the strontium-90 that comes to rest in the bones and teeth? There is no simple answer to this question. Since strontium-90 is so new we do not yet have any direct medical experience with its effects. Damage to humans might take 30 to 40 years to show up."[33] That same year, the Consumers Union collected milk from forty-eight cities in the United States and two in Canada. The group found levels of strontium-90 higher than those previously reported, but more importantly, they found considerable geographic variability.[34]

The government's failure to establish a public and national food monitoring program grew in part from the AEC's recognition that strontium-90 was discoverable in milk and bone almost whenever it was tested. The human experiments just described also reveal that private food companies had conducted their own secret tests of food contamination. While government officials feared loss of support for the weapons testing program, corporate leaders feared an international food scare and potential loss of profitability. The collective effect was widespread public ignorance and a gradual increase in tissue concentrations during the 1950s as the United States and Soviet Union tested ever more powerful weapons.

The damage to human health may seem insignificant when an individual's average dose is considered, but when the probability of cancer or loss of life is applied to the entire world's population, the numbers become more sobering. As Commoner testified,

> Dr. Edward Teller contended that the effect of fallout on health is trivial. To support this claim he estimated that the fallout from one large bomb will subtract from the life of the average American only three one-hundredths of a day, or about three-quarters of an hour. Most people would probably feel, he argued, that three-quarters of an hour out of their life is an acceptably small price to pay for whatever national security is derived from this kind of a test. Assuming uniform distribution of fallout, the total cost of fallout damage from one bomb to the entire human race would be 300,000 man-years. This is equivalent to 1 year off the life of 300,000 people. It is also equivalent to killing 10,000 people at the age of 40. The same calculations show that tests concluded up to 1957 will cost in human life more than the battle deaths in World War I.[35]

The U.S. National Cancer Institute (NCI) has developed the most definitive estimate to date of cancer risk associated with atmospheric testing. It concluded in 1997 that 5 billion people in the world were exposed to radionuclides released by nuclear weapons testing. Between 11,300 and 212,000 additional cases of thyroid cancer were likely to result in the United States alone from exposure to iodine-131 that resulted from the seventeen-year atmospheric weapons testing era.[36]

The NCI estimates, which broke down likely exposures by county

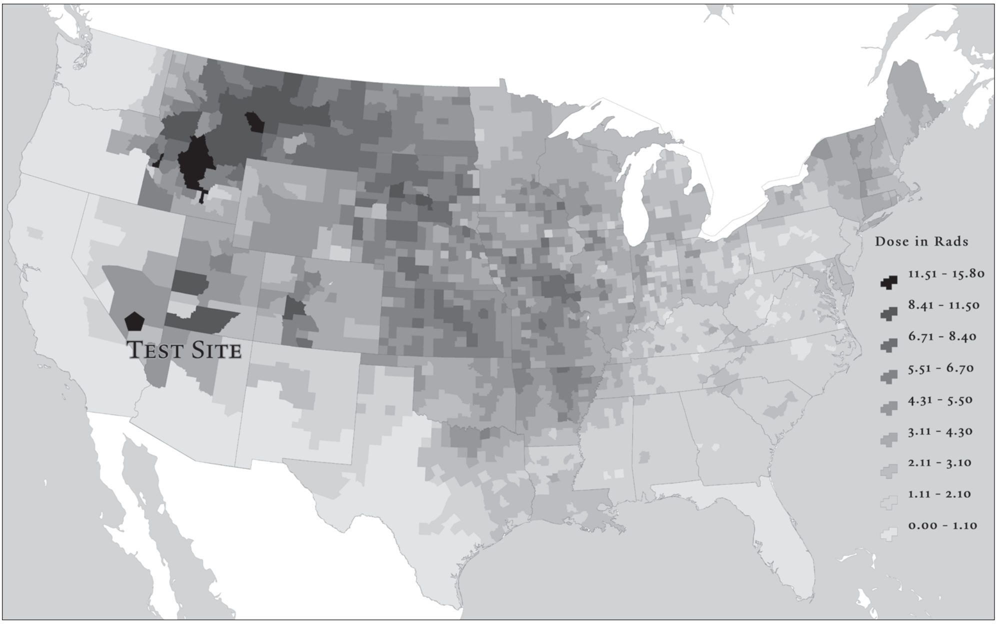

FIGURE 3.1. Cumulative exposure to iodine-131 from Nevada tests, 1951–1962. Scientists with the National Cancer Institute and Centers for Disease Control and Prevention reconstructed spatial patterns of iodine-131 exposure attributable to the U.S. weapons testing era. Little fallout reached Pacific coastal states due to prevailing winds, and the patchiness elsewhere is explained predominantly by the fact that greater fallout occurred when the dust cloud met up with storms, and sometimes this did not occur until the debris had reached the East Coast or beyond. *Sources:* National Cancer Institute and Centers for Disease Control and Prevention.

depicted in Figure 3.1, were seriously hampered by the AEC's haphazard monitoring efforts during the testing era. For most atmospheric tests conducted in the United States, only gross beta radioactivity was measured; none of the isotopes—including iodine-131, strontium-90, or cesium-137—were monitored independently. The absence of monitoring data made it nearly impossible to understand precisely how and where the particles were moving and settling across the nation. Estimating exposure became a sophisticated guessing game, aided by computer simulations of possible radioactive releases, potential pathways across the nation, and weather patterns (Figure 3.2).[37]

The National Academy of Sciences reviewed the National Cancer Institute study in 1999 and agreed broadly with the dose and risk estimates.

FIGURE 3.2. Overlay of Stokes and Shasta test debris pathways on U.S. exposure to iodine-131. Debris would often travel to the north and east of the Nevada Test Site. When the trajectories of debris from the Stokes and Shasta test are superimposed on the iodine-131 exposure map, there appears to be some relation between the data sets. This illustration presents a simplified image of deposition patterns that in fact resulted from many more tests, both by the United States and Soviet Union. *Sources:* U.S. Atomic Energy Commission, National Cancer Institute, and Centers for Disease Control and Prevention.

The NAS concluded that children who were very young at the time of the testing were most at risk for developing thyroid cancer from iodine-131 exposures; their thyroids are approximately ten times smaller than those of adults. Moreover, those children who routinely drank milk from cows that grazed on small farms were claimed to be at highest risk, since they were most likely to have consumed the milk shortly after milking, when iodine-131, with its short half-life, would have been its most potent. Delays in milk consumption, due to milk's being collected, pasteurized, containerized, shipped, and sold, would have made the milk in markets less contaminated with that particular isotope. In addition, milk cooperatives of that era would mix milk from areas of higher fallout with less contaminated milk, diluting the iodine-131 levels. Dilution could also occur if hay or grains stored from previous months or years were used to feed the cattle, because that would have allowed time for the iodine-131 to decay, reducing its energy when consumed. The National Cancer Institute concluded in 2000 that the vast majority of cancer risk from tests conducted at the Nevada Test Site was associated with iodine-131 that tends to build in the human thyroid. The institute scientists also concluded that most of this risk was derived from milk ingestion, and the youngest in society experienced the greatest cancer risk.[38]

The NAS cautioned, however, that even if contamination by iodine-131 had been reduced, nearly 200 radionuclides had been released by atomic fission or fusion: other compounds including carbon-14, cesium-137, and strontium-90 would have entered the human body via tainted milk and other routes, accumulating in various tissues and posing additional cancer and other risks not well understood.[39] The NAS committee recommended that total radiation exposure should be limited to 10 roentgens from human sources during the first thirty years of life, above and beyond average background levels, which were believed to be 5 roentgens. The committee estimated that average doses from fallout would not likely exceed 0.5 roentgens over a similar thirty-year period. It warned the medical community, however, to be more careful in the use of medical and dental X-rays, and condemned the practice of taking X-rays of fetuses to demonstrate their perfect form to expectant mothers, as well as their use to fit shoes.

SCRIPTING THE NARRATIVE

Not surprisingly, knowledge of the presence of radionuclides in the bones and teeth of nearly every child in the world was unsettling to most Americans, especially when it was accompanied by projected estimates of expected cancers and birth defects among the nation's young and their offspring. Public discontent led the AEC to redirect its public relations efforts to convince the nation and the world that the doses from fallout were insignificant—even as behind the scenes, the committee was coming to a different conclusion. The tone of the AEC's then-secret annual report to the National Security Council in 1955, for example, demonstrates the group's growing concern over the scale of pollution caused by thermonuclear testing the previous year. According to the report, "Debris from the CASTLE [high-energy nuclear] tests continues to fall out all over the world, apparently because considerable amounts are still in the stratosphere. The milk from cows contains strontium-90 at about the same levels as the soils. Human bones contain it at somewhat lower levels than the soil, children and young people having more than older people, presumably because of the more rapid growth."[40]

The report remained classified for nearly four more decades, but electoral debates in 1956 led to greater transparency and disclosure. Adlai Stevenson, the Democratic candidate for president, warned of three dangers associated with weapons testing: genetic hazards to future generations; the risk of bone cancer and other illness to the current population; and the inability to conduct medical investigations due to background contamination levels in human tissues.[41] Stevenson also charged that President Eisenhower and the AEC had withheld vital information regarding strontium-90 in the nation's milk supply.

The White House "denied that the nation's milk supply had been contaminated by radioactive strontium 90 in the fall-out from hydrogen bomb explosions." AEC chairman Lewis Strauss responded for the president: "Mr. Stevenson has been misinformed and his public statement is untrue. . . . The purpose of the [Libby] study was to 'determine the feasibility of purifying milk if it were ever contaminated by fall-out should we be attacked by an enemy using atomic weapons.'"[42] But Libby, by then an AEC commissioner, had by this time been monitoring milk for several years demonstrating the presence of strontium-90, and Strauss knew it.

Moreover, soon after the election and within two weeks of Strauss's denial, another AEC scientist publicly reported that a "steep rise" in the radioactive content of metropolitan New York's milk supply had occurred several months earlier, in September 1956. The AEC disclosure was carefully crafted, emphasizing the triviality of all fallout in comparison to the effects of natural radiation. It also declared that, on average, exposure to nuclear testing fallout was far less worrisome than the energy of radon emitted by soils and cosmic rays. It compared the risks of fallout to the effects of nuclear warfare, which would produce devastating physical, chemical, and biological results. (As one AEC official was to report to the president in 1959: "In case of all-out warfare, the world-wide effects of fall-out would be infinitesimal in relation to the losses occasioned in the target areas.") The testing program was sold as preventive medicine, with unpleasant side effects. Finally, the government claimed that atmospheric testing would serve to protect public health, because it offered the opportunity to conduct experiments that would guide the design and use of evacuation routes and shelters to minimize human exposure in the event of war.[43]

Despite these assurances, anxiety grew at the highest levels of government, perhaps in part because of further disclosures by the AEC. In particular the commission revealed that it was disposing of radioactive waste by burying it in soil pits, or by dumping it into rivers, deep wells, or at sea. By 1959 President Eisenhower himself was reconsidering the wisdom of the atmospheric testing program. Notes taken at a White House meeting in March 1959 documented Eisenhower's deep concern: "The President said there seems to be growing evidence that testing is having bad physiological effects. He referred to recent articles about contamination by strontium 90. He is coming to the conclusion that our position should be that we will not test in the atmosphere. We will leave the underground and outer space tests out of any treaty."[44]

Similarly, in notes taken at a meeting the very next day, "the President . . . turned to the question of our position on nuclear testing. He feels it is no longer quite right for us to be rigid in the details of such matters as inspection merely because we have been rigid in the past. All available evidence indicates that nuclear testing is bad. The allowable dose of strontium 90 is being approached in some foods in some areas of the country. With this development the President feels that we would no longer test atomic weapons in the atmosphere."[45] Eisenhower later lamented "the terrible consequences that have arisen out of the discovery of nuclear fission, endangering the whole future of civilization. . . . If the world could be completely free of nuclear weapons, the U.S. would be better off." Also during the meeting, Eisenhower recalled his earlier worry in 1953 that because of atomic weapons, for the first time in the history of the nation "we have reason to fear for the safety of our country."[46]

By 1960, the government had lost control over its nuclear narrative and presidential support for above-ground testing slipped away. Greater inconsistencies emerged between government reports about the dangers of weapons testing and those of respected scientific critics, and were increasingly reported in the popular press. Those concerned about the potential global devastation of nuclear warfare, the worldwide contamination from continued testing, and the likely proliferation of weapons to other nations began to garner broadly based political support for a prohibition against further testing.

The Limited Test Ban Treaty was an outgrowth of this political movement. Adopted in 1963, it prohibited atmospheric, oceanic, and outer-space testing of nuclear devices.[47] It was signed by 108 nations, including the United States and the Soviet Union, but neither China nor France became signatories. France was to carry out fifty atmospheric tests in the Pacific until the mid-1970s, and China conducted twenty-three tests by 1980.

Perhaps most importantly, the international treaty demonstrated broad agreement that above-ground testing placed children, infants, and fetuses at a heightened risk of genetic damage and of developing cancer. The public, once fully informed, considered these exposures unacceptable by-products of the superpowers' weapons development efforts. For the first time in U.S. environmental history, concern for children's health played an important role in reshaping domestic and foreign policy. The nation had learned a fundamental lesson in ecology about the importance of protecting the purity of the food chain for the health of all people, especially children.