001

Chapter 1: Keep it Secret: The Environmental Effects of Nuclear Armament in the Soviet Union and the United States

Tuomas Räsänen

Introduction

War has always involved profound damage to nature and to our living environment, but with the development of nuclear weapons, the potential for environmental destruction has risen to an unprecedented scale. At their most extensive in the 1980s, the world's nuclear weapon states possessed a total of approximately 60,000 nuclear weapons. The largest individual test explosions destroyed all life for a radius of tens of kilometres. A full-blown nuclear war would have annihilated entire countries and, in the worst-case scenario, made large parts of the earth uninhabitable for millennia. Luckily for humanity and for nature, no full-strength nuclear weapon has been launched in an offensive against an enemy since 9 August 1945. However, even concealed in their silos, nuclear weapons have silently and invisibly sown destruction for decades. Millions of people have either directly or indirectly suffered from radioactive substances present in the environment from nuclear weapons production processes. In many places the living environment has suffered near irreversible damage.

In this chapter, I will examine the direct and indirect environmental and health effects of nuclear armament, concentrating on the environmental effects of the arms race between the two most prominent Cold War nations, the United States and the Soviet Union. Although other nuclear weapon states have been left out of this inquiry, their armaments have also led to serious pollution.[1] During the first three decades of the atomic age in particular, significant amounts of toxins spread into the environments surrounding nuclear weapons production sites. In addition, many radioactive substances such as plutonium are heavy metals and dangerous, not only because of their radioactivity but also because of their toxicity.[2] Yet in this chapter, I deal solely with the radioactive pollution resulting from nuclear weapons production and development. This pollution has also had ecological effects, at least at the local level, to which I refer intermittently. Understandably, during the most intense years of nuclear armament, researchers paid almost no attention to ecological changes at nuclear production sites. Furthermore, concerns about the increase in radioactive pollution to this day continue to concentrate primarily on the effects on human health. Little information exists on the impact of arms-race radioactive pollution on nature. Hence, this chapter focuses on both the pollution in the natural living environment and the resulting health effects on human beings.

As source material, I rely on studies conducted since World War II on nuclear arms production and its effects on the environment and human health. In such studies, extremely limited amounts of documentary source material have been cited, partly because the studies are not historical, but also because there continues to be very little documentary source material available. Though the United States has allowed researchers some access to archival sources that shed light on the effects of nuclear arms production, many documents remain secret. For former Soviet areas, it is unlikely that any authentic source material exists. Based on radioactive decay, researchers have been able to model an overall picture of environmental pollution, but studies on human health and cases of death are often based on data gathered indirectly. The quality and amount of radioactive pollution have been compared to the much-studied Hiroshima and Nagasaki, and to the health effects of the Chernobyl power plant accident. Furthermore, in individual cases, it is nearly impossible to prove that radioactive pollution caused a specific illness.

World War II and the Nuclear Arms Race

Nuclear armament began during World War II. The Manhattan Project, initiated by the United States and Great Britain in 1942, was an inherent part of a nuclear arms race between the opposing parties: the Axis, led by Nazi Germany, and the Allies. The trigger for the Allies' nuclear program has often been considered the famous 1939 letter to President Roosevelt signed by Albert Einstein and drafted by his colleagues Leo Szilard and Eugene Wigner. These renowned physicists warned that due to rapid strides in nuclear physics, it might soon be possible to release the enormous energy concealed in the nucleus of the atom for military use, and that Germany was in all likelihood working on developing such a superbomb. After the Japanese attack on Pearl Harbor, the United States began to take the threat of a German nuclear weapon seriously – Japan's nuclear arms project was rather modest – and determined to develop a nuclear weapon as rapidly as possible in order to defeat the Third Reich in the nuclear arms race.[3] As a result of the Manhattan Project, three years later in 1945 American scientists and their European colleagues who had fled the Nazi regime manufactured the world's first three nuclear bombs, one of which was test detonated at Los Alamos, New Mexico, on 16 July 1945; the other two were detonated over Hiroshima and Nagasaki on 6 and 9 August 1945. About 110,000 people died in Hiroshima and Nagasaki within twenty-four hours of detonation, which forced Japan to an unconditional surrender a few days later on 14 August 1945.[4] Thus, the dramatic nuclear strikes targeted against Japan ended World War II.

In the early stages of the Manhattan Project, the project's military leader, General Leslie Groves, predicted that the enemy against which the United States would eventually arm itself would be the communist Soviet Union, not Nazi Germany. While the world war still raged, numerous researchers and US government officials warned the political leadership that nuclear armament, executed unilaterally and in secret from the Soviets, would lead to a nuclear arms race once hostilities ended. The warnings fell on deaf ears. US leaders envisaged the nuclear weapon as a tool for diplomatic pressure that could be used to force the Soviet Union to yield in the international political conflicts anticipated after the war.[5]

When the United States dropped the nuclear bombs on Hiroshima and Nagasaki, Stalin understood that the era of traditional warfare was over. Stalin's comment in the presence of his closest associates and the scientific director of the Soviet Union's nuclear arms project, Igor Kurchatov, reveals his unease: "A single demand of you, comrades. Provide us with atomic weapons in the shortest possible time. You know that Hiroshima has shaken the whole world. The balance has been destroyed. Provide the bomb – it will remove a great danger from us." In response to this plea, they promised Stalin that the Soviet Union's nuclear weapon would be ready within a maximum of five years.[6] When the world war ended in Allied victory, Europe was in ruins, and the European great powers' role as worldwide colonial forces was over; the United States and the Soviet Union rose to predominance as the powers defining a new, conflicted, bipolar world order.

The Soviet Union carried out its first successful nuclear test on 29 August 1949, only four years after Stalin's appeal to the physicists. The Soviet Union succeeded in building a nuclear weapon more rapidly than the United States, which was at least partially explained by information provided by Manhattan Project researchers such as German-born physicist Klaus Fuchs, who spied for the Soviet Union. The nuclear arms race between the superpowers thus began during World War II. The Soviet Union's own nuclear test signified the restoration of the balance of power between the superpowers, but it intensified the arms race on both sides of the Cold War. Both sides developed the nuclear bomb but then shifted to greatly expanded nuclear arms production. They also began to develop more technologically advanced weapons, most significantly the hydrogen bomb, or H-bomb, which meant a vast increase in the destructive power of the nuclear weapons. When the United States carried out the Bravo nuclear test on 1 March 1954 as part of the Castle series of nuclear tests, the energy released in this first "superbomb" explosion was equivalent to 15 megatons of TNT. The blast, about a thousand times more powerful than the Hiroshima bomb, destroyed all life within a radius of over 20 kilometres.[7] Yet it remained clear that the "window of vulnerability" closed by the spring 1954 series of nuclear tests could reopen, which it did on 22 November 1955, when the Soviet Union detonated its first superbomb at the Semipalatinsk nuclear test site in Kazakhstan. Although this time the explosive charge was 1.6 megatons, the parties in the arms race were once again on approximately the same level.[8]

From the 1950s onwards, the acceleration of the arms race became a self-feeding mechanism. Politicians could only try to keep their own nation at the forefront of the advances. In order to reduce costs, they cut back traditional armies, but with nuclear arms there was only one direction: an increased number of more advanced weapons. In the 1950s, the Atomic Energy

Commission (AEC), which was responsible for nuclear arms production in the United States, grew to become one of the nation’s largest single agencies, employing about 150,000 people in 1953.[9] At its largest, in the mid-1960s, the arsenal of the United States contained about 32,000 nuclear weapons. At the same time, the Soviet Union had fewer than 10,000 nuclear weapons in its stores, but their number subsequently climbed at a rate of several thousand per year. The Soviet Union had its largest number of nuclear weapons, slightly over 40,000, in 1986.[10]

The destructive power of the weapons increased. In 1961, at the height of the Berlin crisis, the Soviet Union conducted the largest-ever explosion at the Novaya Zemlya nuclear test site in the Arctic Ocean. The enormous explosion was 50 megatons, with the glare from the blast visible at a distance of 1,000 kilometres, and yet it was only about half of what had been originally intended.[11] The development of intercontinental missiles made it possible to directly threaten all of the enemy’s major cities and targets of strategic importance with nuclear warheads of several megatons. But missile defence systems also continuously improved, which forced the superpowers to develop systems to circumvent them in order for the threat of nuclear weapons to remain effective. In short, nuclear armament became the supreme security doctrine of both countries that nothing could be allowed to threaten, either from within or without society.

Nuclear Waste and the Environment in the United States

During the Cold War, over 257 tons of plutonium and about 2,300 tons of high-level uranium were produced for military use alone. The United States and the Soviet Union accounted for over 90 per cent of this amount. As the production of one kilogram of plutonium results in about 1,300 litres of high-level nuclear waste, over 200,000 litres of low-level waste, and almost 10 million litres of contaminated cooling water, a rough picture emerges of the amount of nuclear waste generated in the production of US nuclear weapons.[12] Under any circumstances, such enormous amounts of nuclear waste were a serious environmental problem, and neglect of environmental safety exacerbated the situation.

Hanford, in the state of Washington, is a good example of the waste treatment practices that prevailed at US production facilities.[13] There, at the nation's most important plutonium production facility, a total of 1.4 million litres of high-level waste was generated by 1980. Its critical components were cesium-137 and strontium-90, both of which are exceptionally radioactive and extremely dangerous substances for health. With regard to the environment, the most destructive time was the era prior to 1970: between 1944 and 1966, 450 million litres of liquid high-level waste were released intentionally into the soil.[14] The remainder of such toxic nuclear waste generated at Hanford was buried in the ground in metal or carbon steel tanks. However, leaks were detected, particularly in tanks buried before 1970, because double-shell tanks were not in use at that time. As a result of the leaks, about 2.8 million litres of high-level waste were released into the soil. The radioactive substances leaked into the environment from the tanks alone contained enough raw material for the equivalent of over fifty Nagasaki bombs.[15] In terms of low-level waste, the figures are even more staggering. At Hanford, 800 billion litres of liquid low-level waste ended up in the soil during the Cold War without the slightest protection.[16] The notion of low-level waste is, however, misleading. The classification of low-level waste downplays the fact that such waste is made up of radioactive substances that are dangerous to human health. Also, the American standards used to classify waste during the first decades of the atomic age made it possible to handle certain types of waste as low-level waste, even though its radioactivity was high and its classification should have been high-level. The radioactivity of the low-level waste generated at Hanford alone was tens of millions of curies.[17] By comparison, 50 to 80 million curies of radioactivity were released in the 1986 accident at the Chernobyl nuclear power plant. Thus the radioactivity of the low-level waste dumped in Hanford's soil was almost on the same scale as what was released at Chernobyl.

Figure 1.1 here

Figure 1.1. Nuclear waste disposal at the Idaho National Laboratory (INL). *Source*: US Department of Energy.

In the United States, transuranic waste (including plutonium, americium, and neptunium) was stored primarily at Hanford and the Idaho National Laboratory (INL), as well as in lesser amounts at numerous other production locales.[18] Prior to the 1970s, transuranic waste was treated as low-level waste. At the Savannah River production facility in South Carolina, millions of litres of nuclear waste containing transuranic substances were burnt in the open in the 1950s and 1960s. Until the 1970s, nuclear waste containing about a ton of plutonium was buried in the soil at the INL in cardboard, wooden, and plastic boxes and steel barrels. This amount of plutonium was enough to build two hundred nuclear bombs. The waste was buried on the vast Snake River plateau, from whose groundwater deposits over 200,000 people got their daily drinking water. When waste dumping began at the INL, the authorities assumed that the radioactive substances would not travel down to the groundwater for tens of thousands of years. Researchers currently estimate that it takes only a few decades.[19]

As environmental awareness expanded in the 1960s, some criticized such pollution. The AEC received much attention from the growing anti-pollution movement, which accused it of indifference to the health of citizens.[20] This criticism targeted the AEC's public operations, but the AEC feared the publicity would spread to secret nuclear production facilities. To avoid this problem, the authorities in the 1970s began to implement improvements in environmental protection at production facilities. At this time, the majority of transuranic waste was stored and monitored, and high-level waste began to be treated in double-shell tanks, which were more likely to prevent the release of radioactive material into the soil and the groundwater.[21] Despite the environmental awakening in society, there was astoundingly little information about the treatment of nuclear waste. Some transuranic waste continued to be buried in the soil as before, albeit in double-shell tanks. There were no changes in the treatment of low-level waste until the 1980s, and radioactive substances from containers and wastewater ponds have continued to leak into the environment.[22]

Nuclear Waste and the Environment in the Soviet Union

When the Soviet Union collapsed in the 1990s, information trickled to the West about environmental catastrophes that had taken place at various locations around the country. One of the worst forms of pollution was radioactive pollution, mostly from nuclear weapons production facilities. Radioactive substances escaped or were intentionally released from Soviet nuclear production facilities into the environment in amounts that make the US pollution figures appear modest by comparison. The most important waste reprocessing and plutonium production facility in the Soviet Union was Mayak (officially Tšeljabinsk-65), located in the southern Ural Mountains. Between 1948 and 1956, a total of 78 million cubic metres (almost 3 million curies) of high-level nuclear waste from Mayak were intentionally released into the nearby Techa River.

When a secret study conducted in 1951 revealed that 124,000 people who lived along the river had been seriously exposed to radiation, high-level waste began to be directed to Lake Karachay, a landlocked lake south of Mayak, and to a lesser degree into reservoirs dug for it. Low-level waste continued to be released into the Techa River, but the upper reaches of the river were dammed to confine the pollution to a restricted area.[23] In the period from 1951 to1967, radionuclides corresponding to an astonishing total of 1.2 billion curies were dumped into Lake Karachay, making it one of the most polluted places on the planet.[24]

Most nuclear waste after 1967 was buried near nuclear fuel production facilities known by the code names Krasnoyarsk-26 and Tomsk-7. It was estimated that over 4.5 billion litres (0.7–1 billion curies) of radioactive material were dumped directly into the soil at Krasnoyarsk; in addition, nuclear waste corresponding to 120 million curies' worth of activity was released into reservoirs dug to contain it.[25] For almost thirty years until 1989, cooling waters from the production facilities' nuclear reactors were conducted directly into the Yenisei River. As a result, the river's banks were polluted for a distance of hundreds of kilometres, and elevated levels of radiation have been detected in fish at a distance of 350 kilometres.[26] Tomsk-7 buried nuclear waste in the soil or released it into the Tom River, which led to the Ob River, amounting to activity above a billion curies. The pollution has spread from the soil into the groundwater in the Tomsk area, and the traces of pollution stretch hundreds of kilometres along the river to its lower reaches.[27]

The US and Soviet "permanent repositories" for nuclear waste provide a small but glaring example of the ways nuclear nations attempted to rid themselves of the embarrassing nuclear waste problem. In addition to the locations mentioned, both superpowers buried smaller amounts of nuclear waste in numerous other places, including at sea. The United States sank about 90,000 containers of low-level nuclear waste into the sea before 1970; according to environmental authorities, at least 25 per cent were already leaking in the 1990s.[28] Between 1959 and 1991, the Soviet Union dumped hundreds of thousands of cubic metres of nuclear waste in many locations off its shores. As late as the 1990s, Russia announced that it was forced to continue dumping nuclear waste at sea, because its storage and reprocessing facilities did not have the capacity to deal with the waste problem.[29]

Accidents at Nuclear Weapons Production Facilities

The exploitation of nuclear energy always includes the risk of accidents, and accidents occurred. In the United States, where safety standards were stricter than in the Soviet Union, numerous accidents took place in conjunction with nuclear arms production, and many employees developed radiation sicknesses.[30] At the Rocky Flats production facility about 25 kilometres from Denver, which manufactured components for nuclear weapons, two serious fires broke out in 1957 and 1969. After the 1969 fire, measurements revealed the highest plutonium content ever recorded near an urban area, including at Nagasaki in August 1945. At Nagasaki, however, the plutonium was in a significantly more dangerous form as a result of the nuclear explosion. Luckily the fire at Rocky Flats was extinguished before it could burn a hole in the roof of the facility.[31]

In the Soviet Union, the two most serious and best-known accidents took place at the Mayak production facility. The first is considered the second-worst peacetime nuclear catastrophe after the Chernobyl accident.[32]An enormous nuclear waste repository was established at the Tšeljabinsk-65 production facility in 1953 to end the practice of releasing nuclear waste into rivers. In September 1957, the repository's cooling mechanisms failed, and a 300,000 litre tank full of nuclear waste exploded. Radioactive material with an activity level of about 20 million curies was released into the air. About one tenth spread across a rather densely populated area of 15,000 square kilometres, polluting the air, water, and soil. Over the next year and a half, all coniferous trees died within a radius of 20 square kilometres. As a result of the pollution, a total of 272,000 people in 217 villages were exposed to dangerously large doses of radiation. The most badly contaminated area was closed off as a nature preserve, which by 2000 the Soviet/Russian authorities had not even tried to clean.[33]

Another serious accident took place in 1967. Because Karachay is a lake without outlets, the authorities incorrectly believed that the radioactive material released there would not threaten the local populace. But in 1967, a low-rain winter and an early spring dried up the shallow lake, and powerful winds in April and May blew radioactive dust from the dry lakebed, spreading it tens of kilometres from the site.[34] In the affected area, 41,500 residents were seriously exposed to radiation, including some who had been victims of an accident a decade earlier.[35] After 1967, authorities preferred to dump nuclear waste in the soil at production facilities to prevent similar accidents. The result was contamination of soil, rivers, and groundwater. In many cases, although the authorities were well intentioned, steps to improve the condition of the environment proved inadequate.

Radioactive Contamination Resulting from Nuclear Testing

Nuclear tests form their own chapter in the history of nuclear arms production. Tests had significant environmental effects, especially prior to 1963 when the United States, the Soviet Union, and Great Britain signed the Limited Test Ban Treaty. The treaty banned conducting nuclear tests in the atmosphere, underwater, and in outer space. Since then, the major powers – with the exception of China and France – have intentionally detonated underground nuclear charges only.[36] The Limited Test Ban Treaty was signed because opposition from the scientific community and the press began intensifying in the 1950s; it also improved relations among the major powers. The treaty did nothing to slow nuclear armament, but it did reduce global radioactive fallout to as little as a tenth of the level prior to 1963.[37]

Before signing the limited nuclear test ban, the United States and the Soviet Union conducted about 430 atmospheric nuclear tests, which released radioactive substances into the atmosphere in amounts much larger than the 1986 Chernobyl nuclear power plant accident.[38] Global fallout was at its greatest between 1955 and 1966, when most of the atmospheric nuclear tests were conducted, as well as in the years immediately following their cessation.[39] The pollution was not distributed evenly across the globe; radiation values twice as high as anywhere else were encountered in the temperate zones of the northern hemisphere. Amounts of radiation dozens of times greater than elsewhere were measured in both game and domestic animals in the southern parts of the Soviet Union.[40]

However, the most severe effects from nuclear tests in the atmosphere were concentrated in areas in close proximity to the nuclear test sites, or downwind of the test sites in areas above which the radioactive clouds regularly moved.[41] The United States carried out a total of 226 nuclear explosions in the atmosphere, 120 on its own soil, initially in New Mexico and from 1951 onwards primarily in Nevada. The rest were carried out in the South Pacific: 43 on the

Enewetak Atoll, 40 on Christmas Island and the Johnston Atoll, and 23 on the Bikini Atoll. The largest explosions were in the Pacific Proving Grounds, where the total charge of the explosions was 152 megatons.[42] These massive explosions vapourized entire islands, and the effects of their pressure and heat temporarily destroyed all life for a radius of up to 10 square kilometres and seriously damaged the environment over a much greater area. Even though plants began returning within a year of the devastation, large numbers of diseases and abnormalities were detected in many plant species years later. The soil and the water have remained contaminated to this day, and the radioactive substances produced are still moving up the food chain and into humans.[43] After the atmospheric nuclear tests, those regions downwind from the test areas – in the Pacific Ocean, countless nearby islands, and the western United States – were polluted repeatedly by radioactive clouds that moved over areas thousands of kilometres away from the site of detonation. Radioactive fallout spiked after tests in numerous inhabited areas to amounts hundreds of times greater than normal radiation levels.[44]

Before the 1963 limited test ban, the Soviet Union conducted 117 atmospheric explosions at the Semipalatinsk nuclear test site in Kazakhstan and 88 at Novaya Zemlya in the northern Arctic Ocean. The total charge at Semipalatinsk was 6.6 megatons and at Novaya Zemlya about 250 megatons.[45] No research data has been published on the immediate effects of the Soviet Union’s nuclear tests on the plant and animal life in the test areas, but doubtless the destruction was similar to that at the US test sites. Radiation levels repeatedly rose dangerously high in the vicinity of the test sites. After the first nuclear test conducted at Semipalatinsk, people living nearby – as well as, of course, vegetation and animal life – were exposed to radioactive radiation over a million times greater than that of the normal level in the atmosphere.[46]

A Culture of Denial

Cold War nuclear armament resulted in uninhabitable environments surrounding many production sites and a significant increase in global radioactivity. Attention paid to pollution prevention was limited. Lack of information on radioactive pollution is often offered as an excuse. In 1991, for example, the head engineer at the Mayak production facility responded to queries about the high level of pollution in the early years of nuclear production: "The Academicians of those times knew as much about the atom as ninth-graders do today."[47] Yet schoolchildren do not build nuclear bombs!

Perhaps ignorance can be used to defend the large amount of soil and water contamination over the decades during the Cold War years; it was not understood that the radioactive substances travelled in the soil, water, and the atmosphere extremely far from their source of origin. But, by the 1940s, science was well aware of the direct health effects from exposure to radioactive substances. Otherwise there would have been no reason for researchers at Hanford to initiate extensive programs to monitor the exposure of employees and the level of environmental pollution starting from the World War II years.[48] Carroll Wilson, the first general manager of the US Atomic Energy Commission noted the AEC's ignorance of pollution in the early years: "Chemists and chemical engineers were not interested in dealing with waste. It was not glamorous; there were no careers; it was messy; nobody got brownie points for caring about nuclear waste. The Atomic Energy Commission neglected the problem."[49] Historian Ian Stacy has demonstrated that the AEC did not totally ignore the problem of pollution and gave directives on the matter to the operators of production facilities. But after 1949 when nuclear armament intensified after the Soviet Union acquired its own nuclear weapons, the growing need for nuclear weapons grade material took precedence over dealing with pollution. In the United States, physicists at the production facilities noted that pollution of the environment was inevitable.[50] The authorities, responsible for the production of nuclear weapons and paradoxically also for environmental protection, faced a difficult choice to increase nuclear arms production and thereby sacrifice the environment and endanger people's health. The Cold War atmosphere made nuclear arms production an absolute priority. In the totalitarian system of the Soviet Union, this choice did not even arise; pollution was viewed with complete indifference, as indicated by the dumping of high-level waste into waterways.

Certainly the scarcity of economic resources in the Soviet Union contributed to its giving priority to resources for weapons production and its neglect of pollution.[51] Even in the wealthy United States, economic calculations overrode environmental safety. Between 1940 and 1996, the United States spent about 5.5 billion dollars (calculated at 1996 levels) in the production of nuclear weapons, making it the nation's third-largest target of revenue in this period.[52] From an economic perspective, environmental protection was a waste of resources. In the Soviet Union, the need for the "expedient allocation" of resources was even greater. The nation had suffered greatly during World War II, and it needed large-scale reconstruction at the same time as it strove to keep up with military and economic competition from the West. It substituted the extensive use of forced labour for its lack of resources. Without tens of thousands of prisoners, building the first nuclear weapon in 1949 probably would have been impossible.[53]

Soviet ideology also contributed to its inattention to environmental issues. Until the 1970s, socialist theorists believed that only a capitalist social order could be responsible for serious pollution and that Soviet pollution would be a passing phenomenon inherent in the period of societal transition.[54] Also, the ideology demanded the subjugation of the good of the individual or the group to the success of the party and justified indifferent treatment of both people and the environment. In the end, as nuclear arms production could not wait for thorough studies or careful planning, both nations contributed to potential environmental catastrophe with enormous, far-reaching miscalculations regarding the treatment of waste. The thinking and operating model that emerged among the authorities responsible for nuclear arms production in both superpowers was surprisingly similar. Its central trait was the conscious and systematic denial and concealment of the environmental and health effects of nuclear weapons production.

Since the early stages of the Manhattan Project, US nuclear arms production has been characterized by strict secrecy. The secrecy was intended to prevent information leaking out about the manufacture of nuclear weapons to maintain an American strategic advantage and a nuclear monopoly. Access to critical information on nuclear arms production was limited to a privileged few.[55] In 1989, US Deputy Secretary of Energy W. Henson Moore described this process: "[The production of nuclear weapons was] a secret operation not subject to laws … [N]o one was to know what was going on. [It was] our business, it [was] national security, everybody else butt out." Under the mantle of national security, the AEC became a state within a state, with its own procedures at nuclear production sites for interpreting the law and legal processes, almost independent of federal government standards.[56]

Fear of the spread of nuclear weapons contributed to the strict controls around nuclear production facilities. Perceived threats of such production also bubbled up among some American citizens. The bombs that exploded in Hiroshima and Nagasaki were shocking and controversial. During the Cold War, the US nuclear authorities understood that residents were concerned, particularly about the radioactive fallout from nuclear tests.[57] After the Bravo H-bomb test was conducted in 1954 on the Bikini Atoll in the Marshall Islands, a wave of protests broke out in the United States, Canada, and Western Europe. Residents who lived outside the precautionary area, later judged to be too small, were not evacuated for days after the test, and many suffered serious injury from radiation. The *Lucky Dragon*, a Japanese trawler, sailed less than 200 kilometres from the point of detonation and into the path of the explosion's radioactive cloud. All crew members became ill, and one died of radiation exposure. The media communicated this information around the world, alerting millions to the dangers of nuclear armaments; a wave of protests in Western countries expressed the opposition of the anti-nuclear peace movement.[58]

To maintain the AEC's legitimacy and continue the production of nuclear weapons, the agency hid environmental and health problems. Authorities minimized the pollution resulting from nuclear arms production, even though the AEC's own studies found that production facilities released significant amounts of radioactive substances into the environment. Such results were not public, and no limits were placed on the use of polluted soil.[59] Citizens were told there was no cause for concern about nuclear tests if they stayed inside during the tests. With growing opposition to atmospheric nuclear tests, the authorities withdrew behind the shield of scientific uncertainty, as science in the 1950s had not conclusively demonstrated that radioactive fallout from nuclear tests was a health threat to people. Radioactive fallout, despite its potentially grave side effects, was considered a small price to pay for national security; admitting the health risks could have threatened the nuclear tests in the Nevada desert. Only later when people got sick was there a flood of court cases against the AEC.[60]

Americans in the western states often found it hard to believe the authorities' assurances about the harmlessness of nuclear tests when thousands of grazing domestic animals during the testing died in mysterious ways. However, the court cases that livestock breeders brought against the federal government encountered setbacks: the authorities concealed evidence and falsified research results, and the court cases dragged on for years, eventually sinking into oblivion.[61] Even the ban on atmospheric nuclear tests did not end the evasion of publicity. A study started in 1982 on the health effects of the radioactive iodine released in nuclear tests revealed that it spread from contaminated grain into cow's milk and from there into humans; it caused an estimated 10,000 to 75,000 cases of thyroid cancer. Yet the study results were not made public until 1997.[62]

In the Soviet Union, the culture of denial was taken even further than in the United States. While US production facilities were isolated sites, in the Soviet Union their very existence was known only to a select few; facilities were not even marked on maps.[63] The secrecy made it almost impossible for people living near the production facilities to demand their rights. Those doctors who treated the victims of pollution from nuclear production did not, for fear of severe punishment, dare to reveal the emerging environmental catastrophe, let alone protest against it.[64] Radioactive pollution caused by army-controlled facilities was of no concern to citizens because they received no information about nuclear waste, for example that released from Mayak into the Techa River between 1948 and 1956, or about the polluting fallout from nuclear tests in inhabited areas.[65] In 1951, the authorities imposed strict limits on the use of water from the Techa River, but did not publicize the reasons for the restrictions. As a result, residents did not observe the prohibitions and continued to use the water for drinking, household use, and swimming. In 1957 the populace was not informed about an accident at Mayak. Only a few people living in the polluted area were relocated. Some limitations were placed on agriculture and the raising of livestock, but people's everyday lives went on as before because they were unaware of their unsafe environment.[66]

The Victims of Nuclear Armament

There is no such thing as radioactive radiation that is harmless to people! Large doses of radiation can rapidly cause the death of a person exposed to it, while illnesses, such as various kinds of cancerous tumours, can result from exposure to smaller amounts of radiation. The number of people who fall ill in comparison to the number of people who are exposed does decrease as the radiation dose decreases.[67] Yet it remains extremely difficult to estimate the number of people who were victims of nuclear armament. As efforts were made to systematically conceal the pollution and its effects, it was not possible to conduct independent studies.[68] In addition, notably more people get cancer regardless of radiation rather than because of it, so it is impossible to say when a case of cancer has resulted from exposure to radioactive radiation. Indeed, estimates regarding the number of victims of radioactive pollution vary greatly.

People who did the greatest amount of practical work in the production of nuclear weapons have suffered the most from the dangers of radiation when calculated in relative terms. During the Cold War, over half a million people worked in US nuclear production facilities; over half were exposed to amounts of radiation that exceeded the upper limits of the radiation safety regulations of the time. In the first two decades of nuclear weapons production, as many as 90 per cent of the employees at the most dangerous production facilities occasionally received an amount of radiation exceeding the safety regulations. In the final years of the Cold War, the limits were stricter than in the first years of the nuclear era. Yet at Hanford, for instance, it is estimated that during a six-month period thousands of employees received radiation doses currently defined as the maximum lifetime limit.[69] The majority of studies that have clarified the health effects of the radiation such employees received indicate they have experienced increases in various types of cancer. Such employees had no comprehensive health coverage; when some tried to apply for workers' compensation, the Department of Energy contested their claims. US authorities did not admit the true amount of radiation received by employees until 1994, many years after the collapse of the Soviet Union.[70]

The health effects of radioactive radiation in the Soviet Union were similar to those in the United States. In Mayak, the annual radiation dose received by employees exceeded by a further 30 to 80 per cent the average dose received by the employees working at the most dangerous production facilities in the United States.[71] At least about 5,000 people working at Mayak were continuously exposed to a radiation dose of over 1 sievert a year. Hundreds of employees received an annual dose of as much as a 4 sieverts. Exposure to radiation was at its greatest in the 1948 to 1958 period, when radioactive pollution caused at least 1,828 cases of radiation-based sickness.[72] One study estimated that radioactive radiation caused 300 to 600 lethal cancer cases among Mayak employees. The estimates in studies are probably too low.[73] The figures provided from the first decades of nuclear production are generally highly suspect and probably low. Doctors did not, for fear of punishment, diagnose cases of illness and death as radiation sickness. So the number of known cancer cases among Mayak employees is not nearly as high as one would expect from comparative studies of Hiroshima and Nagasaki.[74]

Army personnel were severely exposed to radiation as participants in nuclear test explosions. In the Soviet Union, no figures about the military personnel who became victims of nuclear pollution have emerged. In the United States, cancer cases were found among those soldiers who participated in nuclear tests, but it has not been possible to demonstrate a clear correlation between their illnesses and nuclear tests. Research was hampered by the destruction of archived material in a fire in 1978. Before the fire, many civilians and military personnel raised the possibility of a correlation between their cancer-related illnesses and exposure to radiation. The government indirectly admitted that military personnel were exposed when it enacted a law in 1988 to permit veterans with cancer to apply for compensation. All 62,000 veterans who worked at the Nevada nuclear test site between 1951 and 1962 were covered by the law.[75]

In the United States, two to three thousand military personnel unknowingly were human guinea pigs in nuclear tests.[76] AEC reports have revealed that in the 1950s it was a common practice to order soldiers to march or pilots to fly through the radioactive clouds resulting from a nuclear test.[77] Scientific tests on civilians were conducted as well, sometimes with their consent and sometimes without their knowledge. Radioactive substances were also experimentally released among humans on numerous occasions; for example, in 1965 a nuclear reactor at the Nevada nuclear test site was intentionally detonated, and its effects on nearby residents were studied. The radioactive cloud generated by the "accident" travelled all the way to Los Angeles.[78]

Many who were victims of testing on people often were on the margins of society or were considered appropriate test subjects; they were representatives of aboriginal populations, prisoners, disabled children, hospital patients, and pregnant women who were exposed to radioactive substances. One purpose of the 1,400 tests involving over 23,000 people conducted with radioactive substances was to discover the possible physiological and psychological effects of nuclear strikes. These tests on humans did not become public until 1993, and produced immediate public outrage. In President Bill Clinton's cabinet, Secretary of Energy Hazel

O'Leary released the information and commented on the tests: "The only thing I could think of was Nazi Germany."[79]

Many average citizens have suffered from the dangers of radiation, both those who lived near production facilities and people around the world exposed to the increased amount of radioactive pollution in the atmosphere. In the vicinity of the Semipalatinsk nuclear test site – where the amount of radioactivity in certain critical spots was greater than in the Chernobyl area in 1986 – over 1.5 million people were exposed repeatedly to dangerously high amounts of radiation prior to 1963, either directly through radioactive fallout or indirectly through food.[80] Studies conducted after the Cold War ended indicate a clear cancer risk and an increase in cancer cases among those people who lived in the most badly polluted areas.[81] In the fifteen years following the first nuclear test detonation by the Soviet Union, the risk of getting cancer doubled among residents of nearby areas, and the risk of leukemia in particular was multiplied.[82] As late as 1988, the number of cancer cases in such areas was 70 per cent above the national average.[83] The pollution has most seriously affected children, who are more susceptible to radiation sicknesses than adults.[84] Genetic mutations also appear from 1.5 to 1.8 times more frequently in people exposed to radiation than in reference groups.[85]

The environmental catastrophe that has afflicted the area of Chelyabinsk for decades has had a fatal effect on the lives of hundreds of thousands of people. People who live in the numerous villages along the Techa River as well as downwind of the 1957 explosion were exposed to radiation of over 1 sievert a year. It is no surprise that the area has also been called the cancer capital of the Soviet Union/Russia. Researchers have proposed that at least 800 to 1,600 deadly cases of cancer in the Chelyabinsk area are the direct result of radioactive pollution. In reality, the figure is probably much higher.[86] In addition, thousands of people were evacuated from their homes or forcibly relocated. Those who could, moved out of the area, but the majority did not have the opportunity.[87]

In the United States, the residents of the areas near the production facilities were exposed to serious radiation over the decades. Before the 1960s, 250,000 people were exposed to radioactive iodine, totaling about 700,000 curies of radioactivity, that was released from Hanford into the atmosphere.[88] The number of cancer cases among residents was exceptionally high, and miscarriages significantly exceeded the national average.[89] Similar types of polluting took place in the environment of several other production facilities, with an increase in radiation illnesses a likely consequence. Clear evidence of the correlation between the increased cases of illness in the vicinities of production facilities and radioactive emissions has, however, been difficult to demonstrate, because during the Cold War statistics on the amount of emissions were often falsified.[90]

The nuclear tests conducted in Nevada are estimated to have caused tens of thousands of cases of thyroid cancer, as radioactive clouds travelled over inhabited areas without residents being aware enough to protect themselves against the threat. Cases of leukemia**,** in particular among children, increased in downwind areas.[91] The populace of the islands used as test sites in the Pacific Ocean was forcibly relocated prior to the commencement of massive hydrogen bomb tests. A few years later, however, people were allowed to return to their homes because the AEC scientists saw an opportunity to study the health effects of environmental pollution. The result has been the spread of thyroid cancer, leukemia, and brain tumours among the people living on the islands used in nuclear testing and on nearby islands. Hundreds of people have died. Child mortality, miscarriages, and the numbers of malformed or stillborn children have increased. The Polynesians who suffered from nuclear testing have since the 1980s received compensation for their ruined health and their home islands' degraded environment. In addition, over 10,000 people suffering from radiation sicknesses have received medical care paid for by the United States.[92] According to Edward Martell, a nuclear researcher who participated in the AEC from 1954 to 1962, many cases of sickness could have been prevented if the authorities had protected people seriously: "The fact that they have so completely neglected to carry out a more comprehensive and objective assessment of the role of ionizing radiation in the induction of the most common human cancers is clearly a matter of criminal negligence."[93] This statement equally applies to the Soviet authorities. People who worked at the Soviet Union's nuclear test sites have indicated that when nuclear tests were conducted, almost no attention was paid to the well-being of people or the environment. In the area of Semipalatinsk alone, nuclear tests caused thousands of cases of cancer and numerous other health-related problems, such as birth defects, immune system disturbances, chromosomal changes, and mental illnesses.[94]

Environmental justice offers an interesting perspective on the nuclear issue. With unusual frequency, polluting has been concentrated on what the centres of power consider the periphery. Until the 1950s, uranium mining operations that fed US nuclear arms production were concentrated primarily in the Congo, southern Africa, and Australia. In these raw material–producing countries, almost no attention was paid to the working conditions in the mines. Of the uranium used in the United States, two thirds came from underground quarries, where radium and radioactive substances, especially radon gas, threatened health, so that many employees have died of lung cancer and other lung diseases.[95] When self-reliance in US uranium production increased in the 1950s, the mining was concentrated in the barren mountain regions of the west. These areas were often where aboriginal populations lived. In 1990 a radiation exposure compensation act was passed for uranium miners who had worked between 1947 and 1971. The

American desert in the southwest became a nuclear zone, which included scientists and nuclear production plants. Considered a wasteland but inhabited by aboriginal people, after many nuclear tests and much waste storage of nuclear materials in a highly militarized landscape, the unreclaimed nuclear sites in this desert area were referred to in some scientific reports as "sacrifice areas" that were unfit for human habitation. Seeing aboriginal people as expendable or invisible, nuclearism in this area amounted to nuclear colonialism and environmental racism.[96]

Another such periphery involved the production of nuclear components in Canada and its mining of uranium ore deposits for export to the American nuclear arms industry. As in the United States, uranium miners were exposed to harmful substances and got sick, while aboriginal people living near uranium mines were exposed to the industry's toxic pollution, which affected their health and livelihoods.[97] Gilbert Oskaboose, a Canadian from the Ojibwe community, discussed the actions of European peoples that created injustices for his people:

> White people came here a long time ago, took all the furs, trapped all the beaver out, and the otter and the mink … They went away and they left us with the bush and the rocks. It wasn't too much later they came back again. They call that logging. Cut down all the trees – white pine, red pine, cut it all down. And they left us on the bare rock. Then they discovered uranium here. And the old man said, "Now the sons-a-bitches are back for the rocks."[98]

The Soviet Union imported most of the uranium it used from East Germany and Czechoslovakia. In East Germany alone, 450,000 miners toiled to keep the mines producing twenty-four hours a day, and big brother's uranium refineries sated. About 6,000 miners have died of primarily radon-caused lung cancer.[99] Mines have always been dangerous work environments, but the atrocious workplace safety of the uranium mines cannot be explained by lack of information. The role of radon in the development of lung disease was confirmed in the 1920s, and by the 1950s the prevailing notion was that it was not possible to set a safe lower limit for exposure.[100]

For reasons of safety and secrecy, nuclear production facilities were located far from the major cities, and nuclear charges were not detonated in densely populated areas, such as the east coast of the United States or the western areas of the Soviet Union. At the same time, the negative effects of the nuclear weapons industry were concentrated in the surrounding environments with wilderness, rural areas, and people, often aboriginal peoples – Polynesians, American Indians, Kazakhs, or the Nenets of Novaya Zemlya – who were forced to move out of the way or live with and suffer the effects of the nuclear policies. Occasionally such policies had overtly racist characteristics, as demonstrated by a statement made by one of the AEC members in 1956 concerning the Marshall Islands and their inhabitants: “[It] is by far the most contaminated place in the world … [W]hile it is true that these people do not live, I would say, the way Westerners do, civilized people, it is nevertheless true that they are more like us than the mice.” With this statement, the AEC member attempted to defend the exploitation of the island’s inhabitants in research investigating the health effects of radioactivity.[101]

The global increase in radioactivity resulting from atmospheric nuclear tests did not choose its victims, but evenly targeted all ethnic and social groups. For the world population, even a minuscule increase in the amount of radiation resulted in large numbers of radiation sicknesses. According to one study, the dose of radiation received by all people by the end of the twentieth century has caused and will cause by 2100 an estimated 430,000 fatal cases of cancer.[102]

The Legacy of Nuclear Armament

The theoretical capabilities for the construction of a nuclear bomb have existed in principle since before World War II. But without the war, the superpowers would not have developed nuclear weapons so early; without the Cold War, the massive nuclear weapons development programs, which the superpowers began in preparation for the third and probably final world war, and the vast increase in nuclear weapons likely would not have happened. World War III never broke out, and both Nazi Germany and the Soviet Union have disappeared. However, the shadow of nuclear armament will linger for countless generations. In evaluating its legacy, we must consider the political and social conditions under which decisions affecting future generations were made. In the first decades of the atomic age, there was not much information about pollution and its effects. Once the nuclear bomb was developed, neither the United States nor the Soviet Union had, in the context of the Cold War, any choice but to keep up with the self-perpetuating vicious circle of nuclear armament. The alternative was the supremacy of the enemy in the arena of international politics as well as the global victory of a competing way of life.

However, for decades pollution was approached in both the Soviet Union and the United States in a way that was irresponsible. As a result, the legacy of nuclear armament for the world has been destructive. Tens of thousands of people have been forced to leave their homes in order to avoid deadly radiation. There have been many deaths. Hundreds of thousands, even millions of people have fallen ill and will fall ill from exposure to radioactive substances that were released from nuclear weapons production into the environment. The majority of victims have been the very people whom the superpowers claimed to be protecting through the development of nuclear weapons: the average citizens of both the United States and the Soviet Union.[103]

The effects of nuclear armament have appeared in their most destructive form in those places where, as a by-product of the manufacture of tens of thousands of nuclear weapons, the nuclear industry created 10 billion curies worth of nuclear waste.[104] Yet, it has not been possible to develop one single, completely safe solution to neutralize its destructiveness. Most waste has been buried in the territories of the United States and the former Soviet Union or is waiting in storage for final disposal. Studies have shown that even in the 2000s, radioactive substances have leaked into the environment from these repositories, locally polluting the wells of nearby residents and threatening in the near future to contaminate the groundwater needed by millions of people for their everyday use.[105] If an accident occurred, the stored waste could pollute large areas so badly that they would be uninhabitable.[106] In addition, stores of nuclear waste are dangerous as possible targets of terrorists.

Although a large proportion of this waste's activity will disappear over time, numerous radioactive substances have half-lives of thousands of years. For instance, the half-life of the plutonium isotope used in nuclear weapons (plutonium-239) is 24,110 years. Maximum radioactive substances remain dangerous to humans for the equivalent of ten half-lives; over the past seventy years humans have created a problem that may remain a concern for coming generations for thousands of years.

Since the end of the Cold War, authorities have been planning production facility cleaning programs, which take many years and cost hundreds of billions of US dollars.[107] Cleanup of the environment at many production sites has proven so effective that their future use is already feasible, as it has been possible to greatly reduce the risk of dangerous accidents. But even in the United States, with more resources for cleanup than Russia, cleanup projects have not always progressed according to plan. In some places, from the safe storage of high-level waste deep underground to the treatment of waste that has gotten into the groundwater, restoring the environment to a safe condition for humans has proven ineffective, problematic, and has not been resolved. In some cases, converting the most seriously contaminated areas into a habitable condition is perhaps not feasible.[108] The only option in such situations is to store the waste in containers that are as safe as possible and isolate the areas. For this reason, the US authorities have planned for nature preserves in such areas.[109]

Similarly, in the former Soviet Union, some places cannot be saved. Lake Karachay, for example, had radioactivity in 1990 still at about 120 million curies, twice the amount of the radioactivity released at Chernobyl. The lake has subsequently been covered with a concrete shell, but it continues to emit deadly pollution into the surrounding environment, in some areas at levels where in less than an hour an adult in the area is exposed to a fatal dose of radiation.[110] The only option in such cases is to isolate the most badly contaminated areas from society. But pollution cannot always be limited to closed areas, as established in Russia and the United States, because the long-term radioactive isotopes dumped in the soil will spread more widely into groundwater.

Improving the state of the environment at production facilities and cutting off polluted areas from society demonstrate the enormous strides in environmental awareness that have taken place since the first decades of the Cold War. This legacy of nuclear armament exists alongside the damaged environments and human victims. In many Western countries, opposition to nuclear testing flourished from the 1950s and provided the spark for a new kind of environmentalism, where human environmental concern expanded from purely local incidents of environmental pollution to examine the destruction of systems that sustain life on the entire planet. Growing awareness of the dangers of radioactivity influenced diplomacy between the superpowers. The Limited Test Ban Treaty signed in 1963 emerged from the need to prevent global radioactive fallout and as a response to the emerging international movement concerned about pollution and the environment.[111] The treaty decreased the global radioactive fallout to as little as one tenth of the preceding level.[112] Thus the Limited Test Ban Treaty was the first successful international environmental treaty covering the entire planet.

Nevertheless, the threats that originated in the military technology of World War II remain a grim reality. Mayak is still functioning, and although the production of nuclear weapons has ceased, nuclear waste generated by nuclear power plants in Russia, Europe, and Southeast Asia is reprocessed there. According to the Russian environmental authorities, the radioactivity of the Techa River has once more risen alarmingly in the 2000s, because radioactive substances are continuously released directly from the reprocessing facility into the river.[113] In Hanford, scientists have found that liquid nuclear wastes have migrated downward into the groundwater and contaminated soils more than 60 metres below the surface. The concentration of radionuclides escaping into streams and rivers in Hanford, Savannah River, and elsewhere is currently relatively low. However, unsafe old storage tanks, some of which were built back in the 1950s, are still there, containing millions of litres of high-level waste and posing a continuous risk to the drinking water supplies of hundreds of thousands of people.[114]

Figure 1.2 **here**

Figure 1.2. Karl Marx Street in Muslyumova village near Techa River, 50 kilometres east of the Majak. *Source*: Robert Knoth, by courtesy of Greenpeace.

The legacy of nuclear arms production will remain with us very far into the future, perhaps in perpetuity. Plans for maintaining the environment assume that nuclear waste remains under human control. This idea is unrealistic because the activity of many radionuclides will exist for thousands of years. It is as if humanity has not learned anything from the dangerous decades of the Cold War nuclear arms race. There are over sixty nuclear power plants currently under construction without any idea, in most projects, of how to get rid of the nuclear waste permanently. The nine nuclear weapon states still have altogether thousands of missiles in their silos. As tensions between the superpowers are growing again, nuclear disarmament seems at the moment a distant dream. On the contrary, history shows that the diffusion of any technology cannot be undone forever. Sooner or later there will be more states or, even worse, non-governmental actors with nuclear weapons. This could once again speed up the vicious circle of the production of nuclear weapons, no doubt with terrible costs to the environment and human health.[115]

Notes

[1] Great Britain, France, and China are considered the traditional nuclear weapon states, in addition to the United States and the Soviet Union/Russia. Since the Treaty on the Non-Proliferation of Nuclear Weapons signed in 1968, at least India, Israel, Pakistan, and North Korea have joined the nuclear weapon states. During the Cold War, the Republic of South Africa had its own nuclear weapon, but it gave it up in the 1990s. Some security analysts also believe that Iran can be considered a de facto nuclear weapon state, because in their view Iran could manufacture a nuclear weapon very rapidly if desired. For a short overview of the environmental effects of nuclear armament in these other states (excluding Iran), see, for example, Arjun Makhijani, Howard Hu, and Katherine Yih, eds., *Nuclear Wastelands: A Global Guide to Nuclear Weapons Production and its Health and Environmental Effects* (Cambridge, MA: The MIT Press, 2000).

[2] Plutonium is an exceptionally dangerous substance. It is estimated that 500 mg of plutonium is a lethal dose if it makes it into the digestive system. This amount is five times greater than a lethal dose of cyanide. Inhaled botulinum is 1,000 times more deadly than plutonium. Because of its long half-life, plutonium is also not as radioactive as many other radioactive substances produced during the exploitation of nuclear energy. On the dangers of plutonium, see W.G. Sutcliffe et al., *A Perspective on the Dangers of Plutonium* (Livermore, CA: Lawrence Livermore National Laboratory, 1995).

[3] See, for example, Joseph Cirincione, *Bomb Scare: The History and Future of Nuclear Weapons* (New York: Columbia University Press, 2007), 1–4.

[4] All told, by the end of 1945 the numbers of those who died in Hiroshima rose to 140,000 (±10,000) and in Nagasaki to 70,000 (±10,000). *Summary of Relief Measures for Atomic Bomb Survivors* (City of Hiroshima, Social Affairs Bureau, Atomic Bomb Survivors Relief Department, 2003), accessed 12 February 2013, http://www.city.hiroshima.lg.jp/shimin/heiwa/relief.pdf. The figures presented here are based on studies on the effects of radiation on those who survived the nuclear explosion; these studies were conducted by Hiroshima University, a US and Japanese joint foundation called the Radiation Effects Research Foundation (RERF), and the Hiroshima A-Bomb Casualty Council. The human suffering caused by the Japanese nuclear strikes did not, of course, come to an end in 1945: many people fell ill and died due to radiation sicknesses in the decades that followed, and many were forced to live out the remainder of their lives with permanent injuries.

[5] "Report of the Committee on Political and Social Problems (the Franck Report)," 11 June 1945, The Atomic Archive, accessed 12 February 2013, http://www.atomicarchive.com/Docs/ManhattanProject/FranckReport.shtml; "Niels Bohr's Memorandum to President Roosevelt, July 1944," The Atomic Archive, accessed 12 February 2013, http://www.atomicarchive.com/Docs/ManhattanProject/Bohrmemo.shtml; David Holloway, "The Soviet Union and the Origins of the Arms Race," in *Origins of the Cold War: An International History*, eds. Melvyn P. Leffler and David S. Painter (London: Routledge, 1994), 100–1; Martin J. Sherwin, "The Atomic Bomb and the Origins of the Cold War," in Leffler and Painter, *Origins of the Cold War*, 83–91.

[6] Holloway, "The Soviet Union and Origins of the Arms Race," 100. See also Vladislav Zubok and Constantine Pleshakov, *Inside the Kremlin's Cold War: From Stalin to Khrushchev* (Cambridge, MA: Harvard University Press, 1996), 27–9, 44–5. During the war, Stalin still believed and hoped that, upon Germany's defeat, cooperation between the Allies would continue on equal footing.

[7] Ronald Clark, *The Greatest Power on Earth: The Story of Nuclear Fission* (London: Sidgwick & Jackson, 1980), 269–70. The United States detonated the first H-bomb in 1952; the Soviet Union detonated its first H-bomb in 1953. These nuclear tests were, however, much smaller in scale than the Bravo nuclear test. The Mike nuclear test device detonated by the United States in 1952 would have been classifiable as a superbomb based on the force of its explosion, but the bomb was far too large to transport into enemy airspace by aircraft.

[8] "The Soviet Nuclear Weapons Program," The Nuclear Weapon Archive, accessed 12 February 2013, http://nuclearweaponarchive.org/Russia/Sovwpnprog.html. The revelation of the enormous destructive power of the H-bomb and Stalin's death in 1953 did, indeed, spark momentary hopes for curbing the arms race. Among Soviet leaders, a policy of detente was supported particularly by Lavrentiy Beria and Georgy Malenkov. When the former was executed in 1953 and the latter banished to Asia, Nikita Khrushchev's rise to power ended a brief "interregnum" and at the same time smothered the opportunity for a more Western-friendly policy. Wilfried Loth, *Overcoming the Cold War: A History of Détente, 1950–1991* (Wiltshire: Palgrave, 2002), 19–24, 34–5; Zubok and Pleshakov, *Inside the Kremlin's Cold War*, 166–8.

[9] Stephen I. Schwartz, ed., *Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons since 1940* (Washington, DC: Brookings Institution Press, 1998), 356. The Energy Research and Development Administration (ERDA) replaced the Atomic Energy Commission in 1974. However, ERDA only functioned for a few years, and from 1977 to the present day, the exploitation of nuclear energy has been the responsibility of the US Department of Energy (DOE).

[10] "Nuclear Notebook: Nuclear Arsenals of the World," Bulletin of the Atomic Scientists, accessed 16 September 2016, http://thebulletin.org/nuclear-notebook-multimedia. With the term "nuclear weapons," I refer here to both individual nuclear bombs as well as nuclear warheads. It is possible for one nuclear missile to hold several warheads.

[11] Linda J. Appleby, "Overview of the Proceedings and Papers of the NATO/SCOPE-RADTEST," in *Atmospheric Nuclear Tests: Environmental and Human Consequences*, ed. Charles S. Shapiro (Berlin: Springer, 1998), 18; Zubok and Pleshakov, *Inside the Kremlin's Cold War*, 257–8.

[12] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 580–1; Michael Renner, "Environmental and Health Effects of Weapons Production, Testing and Maintenance," in *War and Public Health*, eds. Barry S. Levy and Victor W. Sidel (Oxford: Oxford University Press, 1997), 126.

[13] Hanford is perhaps the most polluted of all nuclear production facilities located in the United States, for which reason it and certain other production facilities receive special attention in this chapter. In the final moments of the Cold War, there were a total of over 3,200 production

facilities in the United States at over 100 different locations. Renner, "Environmental and Health Effects," 127.

[14] Marc Fiorovanti and Arjun Makhijani, *Containing the Cold War Mess: Restructuring the Environmental Management of the U.S. Nuclear Weapons Complex* (Tacoma Park, MD: Institute for Energy and Environmental Research, 1997), 151.

[15] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 55, 220–3, 249–52; Renner, "Environmental and Health Effects," 127.

[16] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 223.

[17] Fiorovanti and Makhijani, *Containing the Cold War Mess*, 16; Arjun Makhijani and Scott Saleska, *High-Level Dollars, Low-Level Sense: A Critique of Present Policy for the Management of Long-Lived Radioactive Waste and Discussion of an Alternative Approach* (New York: The Apex Press, 1992), 22–6. The curie (Ci) is a unit of measurement of radioactivity that describes the activity of the source of the radiation, in other words the number of disintegrations of the atoms' nuclei. Nowadays the more commonly used unit of measurement is the becquerel (Bq). 1 Bq corresponds to one disintegration per second. 1 Ci = $3.7 \cdot 10^{10}$ Bq. In this chapter, I use the older unit because with large figures the scale of radioactivity is easier to understand in curies than in becquerels.

[18] Transuranic waste is waste that includes elements that are heavier than uranium. According to the practices followed in the United States, waste is transuranic if it includes substances exceeding the atomic number of uranium and whose half-life is longer than twenty years. In addition, the activity of the waste must be greater than 100 nanocuries per gram.

[19] Fiorovanti and Makhijani, *Containing the Cold War Mess*, 8–12; Arjun Makhijani and Michele Boyd, *Poison in the Vadose Zone: An Examination of the Threats to the Snake River Plain Aquifer from the Idaho National Engineering and Environmental Laboratory* (Tacoma Park, MD: Institute for Energy and Environmental Research, 2001), 12–13, **[Do you mean 12-13 here?. Please revise.]** 86–8, 92–3. The name of the INL was changed in 1977 to Idaho National Engineering Laboratory (INEL); in 1997 it was renamed the Idaho National Engineering and Environmental Laboratory (INEEL), and in 2005 the name was restored to the original Idaho National Laboratory (INL). See Max S. Power, *America's Nuclear Wastelands: Politics, Accountability, and Cleanup* (Pullman: Washington State University Press, 2008), 15, reference 3.

[20] On charges against the authorities responsible for nuclear production, see, for example, Eric W. Mogren, *Warm Sands: Uranium Mill Tailings Policy in the Atomic West* (Albuquerque: University of New Mexico Press, 2002), 123–33, 143–4.

[21] Fiorovanti and Makhijani, *Containing the Cold War Mess*, 8, 154–5.

[22] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 215, 223, 238; Makhijani and Boyd, *Poison in the Vadose Zone*, 22–3, 33–4, 73–4.

[23] Makhijani, Hu, and Yi, *Nuclear Wastelands*, 326–8; Sergei Kolesnikov and Aleksander Yemelyanenkov, "Nuclear Pollution in the Former USSR," in *War or Health? A Reader*, ed. Ilkka P. Taipale et al. (London: Zed Books, 2002), 421. In later studies, it has also been demonstrated that traces of the waste dumped into the Techa River are detectable thousands of kilometres away, all the way to the lower reaches of the Ob River.

[24] Murray Feshbach and Alfred Friendly Jr, *Ecocide in the USSR: Health and Nature under Siege* (New York: BasicBooks, 1992), 175. In a study conducted in the 1960s, it was detected that pollution had travelled from the lake into the groundwater. High-level waste was released into Lake Karachay prior to 1953, at which time a waste storage unit was completed at Mayak, as well as again in 1957 after an accident that occurred at the storage unit. Low-level waste was released into the lake continuously. Makhijani, Hu, and Yih, *Nuclear Wastelands*, 331–2, 337–8.

[25] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 344–5; *Nuclear Wastes in the Arctic: An Analysis of Arctic and Other Regional Impacts from Soviet Nuclear Contamination*. OTA-ENV-623 (Washington, DC: U.S. Government Printing Office, 1995), 43–4. The estimates of various researchers and official sources on the amount of buried nuclear waste vary clearly after 1967 as well. The amount mentioned here is based on the report *Nuclear Wastes in the Arctic*, which emerged from cooperation between Alexander Penyagin, a former chair of the Soviet committee on nuclear energy, the governments of the United States, Russia, and Norway, and several NGOs.

[26] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 346–50.

[27] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 356–7; *Nuclear Wastes in the Arctic*, 42–3.

[28] Makhijani and Saleska, *High-Level Dollars, Low-Level Sense*, 27–8.

[29] *Nuclear Wastes in the Arctic*, 27–30; Aleksander Yemelyanenkov and Andrei Zolotkov, "Military Pollution – Nuclear Waste: Sailing Directions Classified," in Taipale et al., *War or Health?*, 417–9.

[30] Eileen Welsome, *The Plutonium Files: America's Secret Medical Experiments in the Cold War* (New York: Delta, 1999), 15–19 **[Do you mean 15-19 here? Please revise]**, 109–13, 184–6.

[31] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 241–2; Renner, "Environmental and Health Effects," 127. Naturally no plutonium was detected at Hiroshima, as uranium was used in nuclear fission.

[32] Despite its seriousness, the Fukushima power plant accident in 2011 will probably not affect this assessment.

[33] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 334–6; Kolesnikov and Yemelyanenkov, “Nuclear Pollution in the Former USSR,” 420; Renner, “Environmental and Health Effects,” 131.

[34] Feshbach and Friendly, *Ecocide in the USSR*, 175.

[35] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 332–3.

[36] Since 1963, at least two accidents involving nuclear explosions have taken place during military exercises in the Soviet Union. Appleby, “NATO/SCOPE-RADTEST,” 16. In addition, in 1965 the Soviet Union conducted an underground nuclear detonation at the Semipalatinsk site with the intent of creating a reservoir. Because the detonation was carried out so close to the surface of the earth, it led to serious pollution of the environment. For this reason, it has often been classified as an above-ground test. See *Radioactive Heaven and Earth: The Health and Environmental Effects of Nuclear Weapons Testing in, on, and above the Earth*. A Report of the IPPNW International Commission to Investigate the Health and Environmental Effects of Nuclear Weapons Production and the Institute for Energy and Environmental Research (New York: The Apex Press, 1991), 100.

[37] Jozef Goldblat and David Cox, “Part I. Summary and Conclusions,” in *Nuclear Weapon Tests: Prohibition or Limitation?* eds. Jozef Goldblatt and David Cox (Oxford: Oxford University Press, 1988), 9; A.C. McEwan, “Environmental Effects of Underground Nuclear Explosions,” in Goldblat and Cox, *Nuclear Weapon Tests*, 83; Loth, *Overcoming the Cold War*, 77–8. Radioactive substances have also escaped into the atmosphere from some underground nuclear tests.

[38] Appleby, “NATO/SCOPE-RADTEST,” 11; Anatoly Matushchenko et al., “Some Characteristics of Atmospheric Nuclear Tests at the USSR Test Sites (1949–1962),” in Shapiro, *Atmospheric Nuclear Tests*, 63; “SIPRI Nuclear Testing Tally Table,” Comprehensive Nuclear-Test-Ban Treaty Organization, accessed 16 September 2016, https://www.ctbto.org/nuclear-testing/history-of-nuclear-testing/world-overview. Slightly diverging figures appear in the literature with regard to the number of atmospheric nuclear tests conducted by the United States and the Soviet Union. The reasons for this include the fact that data has been updated as new sources come to light, and in addition, nuclear tests that have been conducted in the atmosphere have been defined in slightly different ways. A small proportion of atmospheric nuclear tests were so-called peaceful nuclear explosions conducted with an eye to economic use.

[39] *Nuclear Wastes in the Arctic*, 33–4. Approximately 41 million curies of cesium-137 and strontium-90 alone were released in atmospheric tests, whereas approximately 6.8 million curies of corresponding radionuclides were released at Chernobyl.

[40] Rudolph M. Barkjudarov, "Radiological Consequences of Global Fallouts of Nuclear Explosion Products over the USSR Territory in 1966–1986," in Shapiro, *Atmospheric Nuclear Tests*, 262–4.

[41] It must be added to the environmental effects listed here that, as a result of underground nuclear tests conducted since 1963, the earth and bedrock of nuclear test sites may have been seriously polluted. For instance, millions of curies of radioactive substances remain under the surface of the earth at the US test site in Nevada. McEwan, "Environmental Effects," 82–3; Makhijani, Hu, and Yih, *Nuclear Wastelands*, 225–6. It is possible that the radiation will travel from the soil to the groundwater and, via upheavals of the earth's crust, into the atmosphere as well.

[42] Appleby, "NATO/SCOPE-RADTEST," 11.

[43] Bill Freedman, *Environmental Ecology: The Impacts of Pollution and Other Stresses on Ecosystem Structure and Function* (San Diego: Academic Press, 1989), 309; Mark D. Merlin and Ricardo M. Gonzalez, "Environmental Impacts of Nuclear Testing in Remote Oceania, 1946–1996," in *Environmental Histories of the Cold War*, eds. J.R. McNeill and Corinna R. Unger (Washington, DC, and New York: German Historical Institute and Cambridge University Press, 2010), 178, 183–7, 199. Eight percent of the original surface area of Enewetak Atoll disappeared as a result of nuclear explosions.

[44] Appleby, "NATO/SCOPE-RADTEST," 41–3; B.W. Church et al., "Overview of the Department of Energy's Off-Site Radiation Exposure Review Project (ORERP)," in Shapiro, *Atmospheric Nuclear Tests*, 133.

[45] Appleby, "NATO/SCOPE-RADTEST," 17–18. **[Do you mean 17-21? Please revise.]**

[46] R.I. Bersimbaev et al., "Minisatellite Mutations and Biodosimetry of Population Living Close to the Semipalatinsk Nuclear Test Site," in *Workshop on Dosimetry of the Population Living in the Proximity of the Semipalatinsk Atomic Weapons Test Site*, eds. Carita Lindholm et al. (Helsinki: Publications of the Radiation and Nuclear Safety Authority Finland, STUK-A187, 2002), 40–1; O.A. Pavlovski, "Radiological Consequences of Nuclear Testing for the Population of the Former USSR (input information, models, dose, and risk estimates)," in Shapiro, *Atmospheric Nuclear Tests*, 221. See also Appleby, "NATO/SCOPE-RADTEST," 49–51.

[47] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 327.

[48] Ian Stacy, "Roads to Ruin on the Atomic Frontier: Environmental Decision Making at the Hanford Nuclear Reservation, 1942–1952," *Environmental History* 15 (July 2010): 415–48.

On the inadequacy of scientific data on the spread of radioactive substances, see also Toshihiro Higuchi, "Atmospheric Nuclear Weapons Testing and the Debate on Risk Knowledge in Cold War America, 1945–1963," in McNeill and Unger, *Environmental Histories of the Cold War*, 304–5.

[49] Makhijani and Saleska, *High-Level Dollars, Low-Level Sense*, 37.

[50] Stacy, "Roads to Ruin," 425–8.

[51] Makhijani and Saleska, *High-Level Dollars, Low-Level Sense*, 103–5; Mogren, *Warm Sands*, 45–7.

[52] Schwartz, *Atomic Audit*, 4–5.

[53] Zubok and Pleshakov, *Inside the Kremlin's Cold War*, 150. For instance, over 65,000 prisoners and over 100,000 soldiers participated in the digging of Krasnojarsk-26, quarried into a mountain. Makhijani, Hu, and Yih, *Nuclear Wastelands*, 340.

[54] Feshbach and Friendly, *Ecocide in the USSR*, 27; Charles E. Ziegler, *Environmental Policy in the USSR* (Amherst: University of Massachusetts Press, 1987), 3–6.

[55] Schwartz, *Atomic Audit*, 434–5.

[56] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 3–4.

[57] *Radioactive Heaven and Earth*, 50, 54–7. In order to protect locals but also out of fear of their opposition, attempts were made to minimize the detrimental effects of explosions to human health and livelihood in the selection of nuclear test sites. In the selection process, the decision was made to locate the nuclear test site in Nevada despite the fact that the prevailing west wind would spread radioactive fallout from Nevada over a large part of the country. The best option in terms of wind would have been the nation's East Coast, but it was too densely populated, and in addition it was feared that the radioactive fallout from the nuclear tests would harm Atlantic fishing.

[58] Lawrence S. Wittner, *Resisting the Bomb: A History of the World Nuclear Disarmament Movement, 1954–1970* (Stanford, CA: Stanford University Press, 1997), 1–3. On the US discussion on radioactive fallout, see Higuchi, "Atmospheric Nuclear Weapons Testing," 313–20. The precautionary area for the Bravo nuclear test proved to be too small because the explosion was much more powerful than was initially estimated. Some researchers have interpreted that the US authorities intentionally exposed the residents of nearby islands to the radioactive pollution in the Bravo test to get an opportunity to study the effects of pollution on humans. The authorities were aware of the change in winds in good time before the test, and yet they did not cancel it. See Merlin and Gonzalez, "Environmental Impacts," 192–3.

[59] Schwartz, *Atomic Audit*, 411–13 **[Do you mean 411-13 here?]**, 423.

[60] Barton C. Hacker, "'Hotter than a $2 Pistol': Fallout, Sheep, and the Atomic Energy Commission, 1953–1986," in *The Atomic West*, eds. Bruce Hevly and John M. Findlay (Seattle: University of Washington Press, 1998), 157–9; Higuchi, "Atmospheric Nuclear Weapons Testing," 314–19; Welsome, *The Plutonium Files*, 257–60.

[61] Hacker, "Hotter than a $2 Pistol," passim.

[62] Schwartz, *Atomic Audit*, 407.

[63] *Nuclear Wastes in the Arctic*, 44.

[64] Feshbach and Friendly, *Ecocide in the USSR*, 172–5, 183–4; Kolesnikov and Yemelyanenkov, "Nuclear Pollution in the Former USSR," 420–1.

[65] The leaders of the Soviet Union had a tendency in their statements to blame the atmospheric nuclear tests conducted by the United States for increased radioactive pollution. In contrast, the effects of their own nuclear tests were forgotten or belittled in the international arena; at home, they were not discussed at all. Ziegler, *Environmental Policy in the USSR*, 136.

[66] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 4–5, 327–8, 334–7. Information about the Soviet Union's nuclear catastrophes did not begin to appear in the Western press until the end of the 1970s, as a result of the revelations of a scientist who defected from the Soviet Union. Yet people in the West did not initially believe or want to believe the claims. The Soviet Union systematically denied everything. See Clark, *The Greatest Power on Earth*, 295; Feshbach and Friendly, *Ecocide in the USSR*, 174.

[67] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 71.

[68] Because of this, researchers have primarily relied on studies that were conducted on the survivors of the Hiroshima and Nagasaki explosions.

[69] Schwartz, *Atomic Audit*, 398–401; Renner, "Environmental and Health Effects," 128–9.

[70] Schwartz, *Atomic Audit*, 398–400; Makhijani, Hu, and Yih, *Nuclear Wastelands*, 264–82, 371. Cases of death resulting from leukemia and brain tumours have increased most acutely. Len Acland, *Making a Real Killing: Rocky Flats and the Nuclear West* (Albuquerque: University of New Mexico Press, 1999), 231.

[71] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 368–74.

[72] Bobby R. Scott, "Radiation Effects in Mayak Workers," accessed 12 February 2013, http://www.radiation-scott.org/yell_may.htm. The sievert (Sv) is a unit of measurement for radioactive radiation that measures the biological effect of radiation. About half of those exposed to a one-time dose of 3–4 sieverts die within a few weeks; a one-time dose of 1 sievert causes symptoms of radiation sickness, such as exhaustion and nausea, within 24 hours.

[73] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 376–7.

[74] Ibid., 588.

[75] Schwartz, *Atomic Audit*, 404–6. The amount of compensation was established at 75,000 dollars in said law.

[76] Ibid., 427.

[77] Letter of Congressional Representative Edward Markey to Secretary of Energy Hazel O'Leary, 24 August 1994, Advisory Committee on Human Radiation Experiments, accessed 4 December 2003, http://www2.gwu.edu/~nsarchiv/radiation/dir/mstreet/commeet/meet6/brief6/tab_l/br6l1h.txt .

[78] Markey's letter to O'Leary, 24 August 1994; Jonathan D. Moreno, *Undue Risk: Secret State Experiments on Humans* (New York, London: Routledge, 2001), 153–5.

[79] For more information on radioactive testing on human subjects in the United States, see "DOE Openness: Human Radiation Experiments, Roadmap to the Project," US Department of Energy, accessed 12 February 2013, https://ehss.energy.gov/ohre/roadmap/index.html; Schwartz, *Atomic Audit*, 421–8; Moreno, *Undue Risk*; Welsome, *The Plutonium Files*. Some of the tests were initially conducted for medical use alone, but at times they were later used when pondering issues of radiation. The Soviet Union is also known to have conducted many human tests with radioactive substances.

[80] Bersimbaev et al., "Minisatellite Mutations," 40–1; G. Voigt and N. Semiochkina, "The Present Radioecological Situation of the Semipalatinsk Test Site and Internal Dose Estimations for Selected People Living on the Site," in Lindholm et al., *Workshop on Dosimetry*, 14–15 **[Do you mean 14-15 here?]**.

[81] S. Bauer et al., "Semipalatinsk Historical Cohort: Causes of Death in a Study Group from Settlements Adjacent to the Semipalatinsk Nuclear Test Site," in Lindholm et al., *Workshop on Dosimetry*, 64–5.

[82] Pavlovski, "Radiological Consequences," 247, 251.

[83] Victor W. Sidel, "The Impact of Military Preparedness and Militarism," in *The Environmental Consequences of War: Legal, Economic and Scientific Perspectives*, eds. Jay E. Austin and Carl E. Bruch (Cambridge: Cambridge University Press, 2000), 433.

[84] Z.A. Carr et al., "Thyroid Disease Prevalence and Fallout Exposure in Kazakhstan," in Lindholm et al., *Workshop on Dosimetry*, 55–6. Cancer of the thyroid gland, for instance, develops more easily in children than adults.

[85] Bersimbaev et al., "Minisatellite Mutations," 45.

[86] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 376–87. Heavy industry that has put a big strain on the environment has long existed in the Chelyabinsk area, and this has also had an effect on the health of residents.

[87] Feshbach and Friendly, *Ecocide in the USSR*, passim.; Kolesnikov and Yemelyanenkov, “Nuclear Pollution in the Former USSR,” 421.

[88] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 269; Renner, “Environmental and Health Effects,” 128–9.

[89] Renner, “Environmental and Health Effects,” 129; Sidel, “The Impact of Military Preparedness,” 436.

[90] Schwartz, *Atomic Audit*, 414.

[91] Church et al., “Overview of ORERP,” 128; Makhijani, Hu, and Yih, *Nuclear Wastelands*, 280–1; Sidel, “The Impact of Military Preparedness,” 431–2.

[92] Schwartz, *Atomic Audit*, 415–20; Merlin and Gonzalez, “Environmental Impacts,” 191, 194–5.

[93] Edward Martell’s Letter to Hazel O’Leary, 9 February 1994, accessed 4 August 2011, http://www.serv.org/?page_id=151. In his letter, Martell deals solely with pollution that has taken place on US soil. The policies practiced in the Pacific Proving Grounds do not, however, differ in their “criminality” from the policies carried out on the continent. Quite the opposite: there was even less attention paid to the well-being of the residents in the Pacific than in the United States.

[94] *Radioactive Heaven and Earth*, 92, 95, 99–101.

[95] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 129–45.

[96] Schwartz, *Atomic Audit*, 402; Mogren, *Warm Sands*, 60–4, 71–2; Valerie L. Kuletz, *The Tainted Desert: Environmental and Social Ruin in the American West* (New York: Routledge 1998), 12, 13, 27, 38.

[97] Quoted in Makhijani, Hu, and Yih, *Nuclear Wastelands*, 106. See also Laurel Sefton MacDowell, “The Elliot Lake Uranium Miners’ Battle to Gain Occupational Health and Safety Improvements in the Post-War Period,” *Labour/Le Travail* 69 (Spring 2012): 91–118.

[98] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 106.

[99] Ibid., 148–50. In addition, approximately 15,000 workers died of pneumoconiosis.

[100] Mogren, *Warm Sands*, 9–10, 78.

[101] Schwartz, *Atomic Audit*, 417. This statement was made regarding Rongelap Atoll, located in the northern Marshall Islands.

[102] Ibid., 428–9; *Radioactive Heaven and Earth*, 36–43. Over the coming millennia, exposure to radioactive carbon-14 in particular, with its half-life of 5,730 years, may raise the number of victims into the millions.

[103] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 331–2. Already by 1977, the United Nations estimated that radioactive radiation had caused 150,000 premature deaths and 86,000 birth defects.

[104] Renner, “Environmental and Health Effects,” 127.

[105] For example, Makhijani and Boyd, *Poison in the Vadose Zone*, 24–32; Arjun Makhijani and Sriram Gopal, *Setting Cleanup Standards to Protect Future Generations: The Scientific Basis of the Subsistence Farmer Scenario and Its Application to the Estimation of Radionuclide Soil Action Levels (RSALs) for Rocky Flats* (Boulder, CO: The Rocky Mountain Peace and Justice Center, 2001), 25–8; Makhijani and Saleska, *High-Level Dollars, Low-Level Sense*, 51–67, 94–6; Makhijani, Hu, and Yih, *Nuclear Wastelands*, 223; Power, *America's Nuclear Wastelands*, 119. In 2010, the United States withdrew its long-term plan to permanently store nuclear waste in tunnels to be dug into the Yucca Mountains in the Nevada desert. See, for example, Matthew L. Wald, “Panel on Nuclear Waste Disposal to Propose Above-Ground Storage,” *The New York Times*, 13 May 2011, East Coast edition, A16.

[106] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 223; Renner, “Environmental and Health Effects,” 128; Sidel, “The Impact of Military Preparedness,” 430, 436. As an example of the possibility of accidents, a burned waste container was found at Hanford in 1998 that contained enough plutonium to build twelve nuclear bombs. Sidel, “The Impact of Military Preparedness,” 430.

[107] Schwartz, *Atomic Audit*, 381, 385–9; Power, *America's Nuclear Wastelands*, 7. According to an estimate by the Office of Environmental Management established by the US Department of Energy, cleaning the US production sites will last seventy years and cost 212 billion dollars.

[108] Fiorovanti and Makhijani, *Containing the Cold War Mess*, 32–3; Karen Lowrie and Michael Greenberg, “Local Impacts of US Nuclear Weapons Facilities: A Survey of Planners,” *Environmentalist* 20 (June 2000): 157–68; Power, *America's Nuclear Wastelands*, 118, 146–51.

[109] On turning nuclear production facilities into nature preserves, see Makhijani and Gopal, *Setting Cleanup Standards*, 23–38. Production facilities for which nature preserves are planned are the most badly contaminated areas including Hanford, Washington; the INL in Idaho; Oak Ridge, Tennessee; Rocky Flats, Colorado; and Savannah River, South Carolina.

[110] Makhijani, Hu, and Yih, *Nuclear Wastelands*, 331.

[111] See Higuchi, “Atmospheric Nuclear Weapons Testing,” 309–13, 320.

[112] Goldblat and Cox, “Part I: Summary and Conclusions,” 9; McEwan, “Environmental Effects,” 83; Loth, *Overcoming the Cold War*, 77–8. Global pollution did not end with the treaty between the United States and the Soviet Union, because China and France continued

atmospheric nuclear explosions. Radioactive substances have escaped into the environment from some underground nuclear tests as well.

[113] Russian Environmental Directory. RED Files 11, vol. 7, no. 16 (17 April 2005).

[114] See, for example, Power, *America's Nuclear Wastelands*, 146, 149–51; Arjun Makhijani and Michele Boyd, *Nuclear Dumps by the Riverside: Threats to the Savannah River from Radioactive Contamination at the Savannah River Site* (Tacoma Park, MD: Institute for Energy and Environmental Research, 2004), 39.

[115] An earlier version of this chapter was published in Finnish in *Sodan Ekologia. Sodankäynnin ympäristöhistoriaa*, eds. Simo Laakkonen and Timo Vuorisalo (Helsinki: SKS, 2007). I would like to thank Simo Laakkonen for his support and advice during the research. I am also grateful to radiochemist Jukka Lehto for his valuable comments and Stephen I. Schwartz for providing me with pictures of nuclear waste disposal at the US production sites.