CHAPTER 5

75 Years of Nuclear Testing: Economic Assessment of Environmental Damage

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Introduction

July 16, 2020, marks the 75th anniversary of the world's first nuclear tests. During the time that has elapsed since then, the world has realized the destructive power of nuclear weapons and came to the conclusion that it is necessary to ban natural tests, which was necessitated, among other things, by the understanding that nuclear tests could pose a threat to the environment and the health of the population living near the test sites.

Today, US experts and the media are debating whether countries should resume nuclear testing or confirm their commitment to nuclear disarmament by ratifying the nuclear test ban treaty and under what conditions. It seems that the world has forgotten about the cost of nuclear tests, which presents itself as damage to the environment and the health of veterans who participated in tests and of local residents.

Methodology

Methodologically, the research is based on Russian and foreign authors' theoretical approaches in the field of the world economy and world politics. In Russia, the work of scientists of Moscow State University of Foreign Affairs, National Research University Higher School of Economics, Institute of World Economy and International Relations of the Russian Academy of Sciences, Moscow State University, and others have contributed to the

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https://doi.org/10.1007/978-3-030-75405-1_5

study of the problem of nuclear tests. Although the topic of the nuclear factor in international relations has been well researched, and medical and environmental studies have shown that radioactive materials left over from explosions and weapons tests pose a threat to the environment and health of the population living near test sites, insufficient attention has been paid to the direct economic consequences of nuclear tests. The research contains statistical reports and analytical materials from international organizations, such as the international economic forum, the Brookings Institution, the Stockholm International Peace Research Institute, the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), and others. We used general scientific methods: comparative analysis and complex and systematic approaches.

Results

Today, nine countries—China, India, Israel, France, North Korea, Russia, the UK, and the United States—possess nearly 15,000 nuclear weapons.[1] This is enough to destroy our planet hundreds of times. Throughout the twentieth century, most countries that developed nuclear weapons tested them. According to the Stockholm International Peace Research Institute, more than 2,000 nuclear tests were conducted worldwide during 1945–2020 (consider how much money was spent on this). During the 75 years of the atomic era, the number of nuclear tests conducted by different countries began to be measured in tens and hundreds. The majority (85%) was conducted by the United States (1,054 tests) and the USSR (715 tests) in 1945–1992, 14.5% (300 tests) was conducted by Great Britain, France, and China, and less than 1% by India (6 tests), Pakistan (7 tests), and North Korea (1 test) (Bergkvist & Ferm, 2000). Probably, a joint nuclear test was conducted by South Africa and Israel (Belous, 2010).

Below is a graph showing the number of nuclear tests in different environments by the time they were conducted (Fig. 5.1).

Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons since 1940 provide a pie chart of the U.S. spending on nuclear weapons. Costs include, among other things, nuclear waste management and environmental remediation ($365 per bomb) and compensation for bomb victims ($2.1 billion) (Schwartz, 1998) (Figs. 5.2 and 5.3).

No other country in the world has spent on these goals as much as the United States. The United States spent about $400 million on dismantling old bombs, managing nuclear waste, and cleaning up the environment (Schwartz, 1998).

[1] Five other countries have warheads (Belgium, Germany, Italy, the Netherlands, and Turkey), and 23 other countries are members of nuclear alliances (Albania, Australia, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Greece, Hungary, Iceland, Japan, Latvia, Lithuania, Luxembourg, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and South Korea).

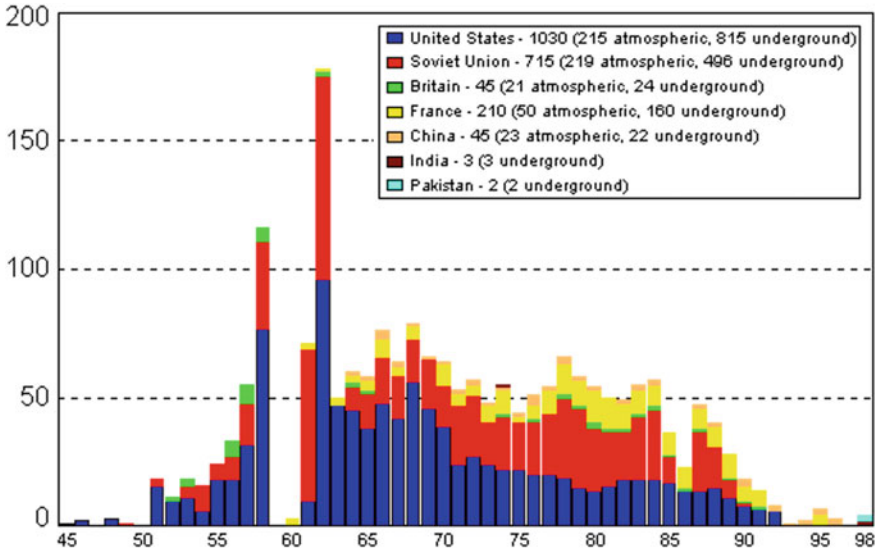

Fig. 5.1 Global nuclear testing—1945 to 1998. 2,050 Tests (528 Atmospheric, 1522 Underground) (*Source* Brookings, U.S. Department of Energy: Natural Resources Defense Council, Nuclear weapons Databook project)

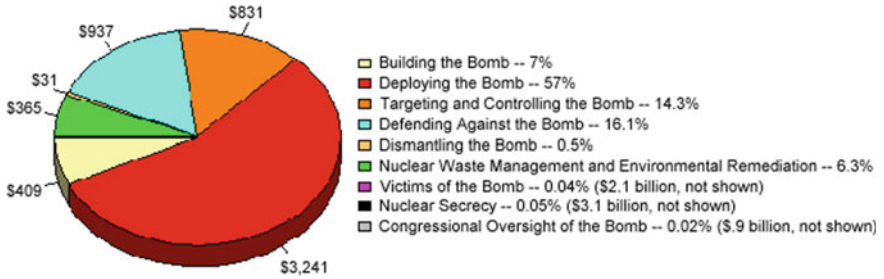

Fig. 5.2 U.S. spending on nuclear weapons (*Source* Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons since 1940 [Brookings Institution Press, 1998])

Let us take a closer look at the most striking pages of the history of nuclear tests in different countries from the point of view of the damage caused to the environment and health of the population.

We shall start with the United States. In 1954, some of the atolls (Rongelap, Utrik, and others East and Southeast of Bikini) were affected by radioactive fallout. Fallouts caused pollution over an area of more than 11,000 square km and resulted in spreading traces of radioactive material to Australia, India, Japan, the United States, and parts of Europe (CTBTO). Radiation contamination reached the Japanese fishing boat Lucky Dragon

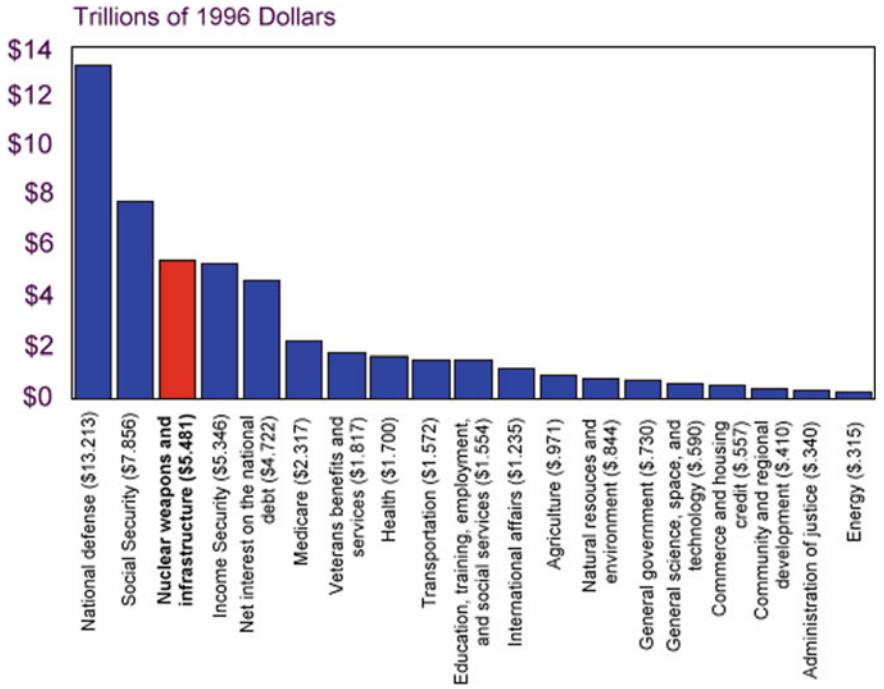

Fig. 5.3 U.S. Government Historical Obligations by Function, 1940–1996* (*Sources* Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons Since 1940 [Brookings, 1998], p. 5; Office of Management and Budget, Budget of the United States Government, Fiscal Year 1998 [GPO, 1997], pp. 42–49)

Number 5, located about 145 km from the explosion point. Many of the Lucky Dragon crew members went sick, and one of them died. Rongelap Atoll, which was about 170 km downwind, was also covered in radioactive particles. Several of Rongelap's 64 residents experienced immediate radiation sickness, including vomiting, skin damage, and hair loss. In Bravo for the Marshallese: Regaining Control in a Post-Nuclear, Post-Colonial World (Bravo for the Marshallese, 2012), anthropologist Holly Barker describes an epidemic of congenital disabilities, cancer, mental retardation, and suicide, in addition to thyroid disorders, among the locals.

Meanwhile, the time between radiation and cancer development can be from 10 to 40 years. Radiation exposure is still preserved on the islands today. Coconuts in Bikini are still radioactive. In addition to premature death, severe congenital disabilities, cancer, and other complications caused by radiation exposure, nuclear tests in the United States have changed entire communities' lives that led to repeated relocations.

In 1986, the US Congress admitted responsibility for causing physical and financial damage to the people who lived on the atolls most affected by nuclear

tests—Bikini, Enewetak, Rongelap, and Utrik. A $150 million trust fund for nuclear claims was established. $30 million were also allocated to assist in implementing the healthcare system with the aim of damage control and $3 million to pay for medical screening and radiological monitoring. As of August 15, 2000, at least 42% of the 712 applicants died without compensation.

In addition, underground tests in the United States turned out to be dangerous. Tests conducted in 1962 left behind radioactive contamination in parts of Iowa, Nebraska, South Dakota, and Illinois, exposing millions of people to radioactive fallout. The health consequences of nuclear tests were an increase in leukemia and other forms of cancer in military personnel. This was the subject of lawsuits in the United States. As of July 2010, more than 22,716 claims for $ 1.5 billion had been approved for victims of radiation caused by nuclear tests and their families in the States of Nevada, Utah, and Arizona. Workers who participated in ground tests, uranium mining, and ore transportation also received compensation. As of 2014, the US government approved 28,000 880 claims totaling $1.9 billion as compensation to military personnel on test sites and the population exposed to radioactivity (Curious Droid).

The tests of the USSR also caused damage. The nuclear weapons tests conducted at the Totsky test site in the Arinbuk area of the southern Urals on September 14, 1954, continued to have a severe impact on human health and the environment decades later. People living in the blast region were exposed to ionizing radiation 42 years later, with plutonium-239 levels in the soil being five times higher than normal level. High levels of cesium-137 contamination were also reported. The population of the region suffers from a shorter lifetime and 1.8 times more frequent mortality than in other similar areas, high infant mortality, and a high level of physical disability in children.

Between 1949 and 1989, 456 nuclear and thermonuclear devices were detonated at the Semipalatinsk test site in intense secrecy. The explosions were carried out on the surface and in the atmosphere. Five of the surface tests failed and resulted in the dispersion of plutonium into the environment. Along with this, the first test happened on August 29, 1949, unexpectedly polluted villages northeast of the explosion site. The last test took place on February 12, 1989, and resulted in the leakage of a large amount of radioactive noble gases, xenon, and krypton (Gusev et al., 1998). The radionuclides produced as a result of these tests led to atmospheric and environmental contamination. Officially, during the testing program, only residents of the city of Kurchatov lived in the immediate vicinity of the test site. However, it later turned out that hundreds of people who lived within 80 km of the testing area were not taken into account (Elegant, 2002). A number of genetic defects and diseases in the region, from cancer to impotence, congenital disabilities, and other deformities, have been attributed to nuclear tests. Along with the epidemic of children born with severe neurological diseases and severe bone deformities, there were also many leukemia cases and other blood diseases (Lerager, 1992). The director of the Semipalatinsk cancer hospital estimates that at least

60,000 people in the region died from radiation-caused cancer. However, the region is "officially" considered to have the lowest cancer incidence in Kazakhstan (Lerager, 1992). Doctors also warn that the level of genetic disorders in the third generation after exposure may be even higher (CTBTO). N.V. Alishev and others show in their article that "dysimmunity and deterioration of health among special risk units and the population of the regions of Kazakhstan and the Altai territory located near the test site are of a long-term nature, manifested themselves decades after nuclear tests" (Alishev et al., 2012). Following the official closure of the site on August 29, 1991, various studies were conducted to determine the medical, social, and environmental consequences of nuclear tests in response to the government of Kazakhstan's concern about the radiological situation in Semipalatinsk and Western Kazakhstan. According to a study by the International Atomic Energy Agency (IAEA), the region has mostly little or no residual radioactivity directly related to nuclear tests in Kazakhstan, and it is recommended to restrict access to the test area.

In December 1997, a joint mission of the United Nations and the government of Kazakhstan visited Semipalatinsk to study the economic, environmental, and social consequences of Soviet nuclear tests. The population felt deceived by the government. The local economy suffered from the region's negative image that scared off major domestic and international investors. During the years of tests, agricultural land was polluted, and the groundwater cycle was disrupted. The effects of so-called small doses of radiation on health were recorded. Risks of environmental contamination with plutonium were also noted.

In 2012, Russian, American, and Kazakh scientists completed covert 17-year cleaning operations at a cost of $150 million in Semipalatinsk to make the site safe (Curious Droid).

Underground tests destroyed environmental links, which in turn accelerated the process of desertification of the region, which continues up to the present day. Extensive land and water resources were exposed to radiation pollution, and economic activity in the area around the test site was significantly reduced.

As a result of the Chagan project, the cloud from the explosion covered the territory of 11 localities, where about 2 thousand people lived. All of them received a dose of thyroid radiation; people affected most of all had its indicators 28 times higher than the critical level.

Tests on Novaya Zemlya represent the largest source of artificial radioactive contamination in the Arctic. From 1958 to 1962, a large number of atmospheric tests on the islands led to radioactive contamination not only of the Russian territory but also of Alaska and Northern Canada. Norway, located just 900 km from the islands, also received significant radioactive exposure.

Several tests went wrong or caused unexpected damage. On October 30, 1961, the Tsar Bomb, the largest and most powerful nuclear weapon (about 50 MT) ever detonated, was detonated. The Tsar Bomb caused significant

damage to the environment: The surface of the earth, along with the rocks, was completely leveled off.

Later, researchers discovered that a large amount of radioactive material related to nuclear weapon tests was dumped in the Barents and Kara seas (CTBTO). A satellite study conducted by researchers from the Norwegian Institute of international relations has revealed the possible destruction of the ever-frozen layer on Novaya Zemlya.

The Committee on Special Risk Veterans has 6,000 members who participated in the production of nuclear weapons or control of nuclear tests at the Semipalatinsk and Novaya Zemlya test sites and other less known sites. Ninety percent of the Committee's members are disabled people, and many thousands of veterans have already died. To this date, they have received medical treatment for illnesses caused by nuclear tests but have not received financial compensation.

Residents of Cherdynsky, Krasnovishersky, Chernushinsky, and Osinsky districts of the Perm region began to notice an increase in cancer diseases. Later, in the 1990s, ecologists found traces of plutonium-239 at the site of the explosions, a half-life period of which is 240 thousand years.

As for the UK tests, about 22,000 of its military personnel and 16,000 Australian civilians and military personnel who participated in the tests (CTBTO) were exposed to radioactive fallout during the test period.

The impact of nuclear testing on health and the environment in Australia remains underinvestigated. During testing, many of the indigenous population of Maralinga Tjarutja continued to move throughout the region and could suffer. Up to 600 small-scale tests were also conducted in Maralinga, after which Maralinga was contaminated with approximately 8,000 kg of uranium, 24 kg of plutonium, and 100 kg of beryllium. Plutonium, one of the most toxic radionuclides with a half-life of 24,000 years, remains scattered over a vast territory.

The consequences were not only radiological: Restrictions on indigenous population access to their traditional lands also caused psychosocial and cultural problems. The British government did not pay enough attention to the indigenous population's vulnerability to the radiological consequences of the tests. Some factors as contamination of clothing and food with radioactive materials were underestimated.

British nuclear tests were conducted with a high level of secrecy. On October 15, 1953, a major nuclear test was conducted in the South Australian desert at Emu Field, resulting in a radioactive cloud known as "Black Fog" that covered an area of 250 km^2. The tests did not take into account the aborigines living downwind of the test site.

Nine explosions over Christmas and Malden islands in the South Pacific took place between November 1957 and September 1958. As a result, the effects of radiation (temporary blindness, skin rash, and others) were experienced by veterans who were too close to the explosion's epicenter. The

military personnel was free to move around the island, drink local contaminated water, eat local fruit, swim in lagoons, and breathe in dust. Ingested radioactive particles can remain in the body and continue to harm for many years.

An operation on burying radioactive material (in pits with concrete) was carried out in Maralinga in 1967. In 1999, the British Nuclear Veterans Association interviewed 2,500 veterans, many of whom were in Maralinga. The interview found that 30 percent of men died, mostly in their fifties; the incidence of skeletal abnormalities in veterans' grandchildren was more than five times higher than in the UK; more than 100 children of veterans reported having reproductive difficulties. In addition to the British military personnel, thousands of Australians were exposed to radiation caused by the tests (CTBTO).

The study conducted by the New Zealand Nuclear Test Veteran's Association also found various health links, including disorders in some children of veteran testers.

In 1971, the Commonwealth passed the Compensation Act to compensate the public service personnel if they can prove that their disability resulted from radiation exposure due to tests. The Royal Commission recommended extending this right to civilians in test sites, as well as to aborigines and others exposed to the "Black Fog". In addition, applicants should be entitled to compensation if the government cannot prove that the disability is not the result of radiation caused by the tests. The British government continued to deny both legal and moral responsibility for the consequences of its tests in Australia.

By October 1986, the Australian government had registered a total of 272 claims arising from the testing program, 116 of which were rejected.

In 1986, the Australian government announced a payment of 500,000 Australian dollars (330,000 US dollars) in compensation to the indigenous population for contaminated land during the British testing program. The Australian government spent 108 million Australian dollars (71 million US dollars) to decontaminate the Maralinga and EMU sites between 1996 and 2000. In 1991, the Australian government paid 13.5 million Australian dollars (8.5 million US dollars) to aborigines as compensation.

On January 21, 2009, a group of more than 1,000 former military personnel who served in the South Pacific in the 1950s filed a case against the British Ministry of Defense for illnesses including cancer, skin defects, and fertility problems that as they claim are the result of radiation exposure during nuclear bomb tests. In May 2010, the Australian government provided 24.2 million Australian dollars (approximately 21.4 million US dollars) over five years to compensate Australian personnel who participated in the British nuclear test program. On July 28, 2011, 1,110 veterans of Britain's nuclear bomb tests of the 1950s won a court case against the Ministry of Defense (CTBTO).

France also conducted nuclear tests that had an impact on the environment of the colonies. For example, Tureia Atoll, with a population of about 60 people, was only 100 km from Moruroa and thus remained in the danger zone. Over the next 30 years, 193 atmospheric and underground tests were conducted in the region. During the tests, several radioactive fallout cases were recorded, that is, rain formed by particles of a nuclear explosion.[2]

As a result of 45 French atmospheric tests, including 4 in Algeria, contamination with nuclear elements was recorded in the atmosphere, ground, and water bodies. Since 1975, all nuclear explosions have been carried out underground, causing both short- and long-term environmental damage. Radionuclides have been found in marine organisms. The marine environment at Moruroa was also used as a test site for burying nuclear materials. A mission from Australia, New Zealand, and Papua New Guinea to Moruroa in 1983 found that plutonium-239 concentrations in the air were about four times higher than in continental France. After the last nuclear test in 1996, the French government applied to the International Atomic Energy Agency (IAEA) to conduct a study to assess the radiological impact of the tests at Mururoa and Fangataufa atolls. There were no attempts in the report to estimate the doses received by residents of the region because of nuclear tests in the atmosphere during those tests.

The French nuclear test veterans' association, Aven, conducted a survey in 2008 of more than 1,000 veterans and found that 35% had one or more types of cancer (including blood and thyroid cancer) and one in five were infertile. The problem has not been officially acknowledged for four decades. No sooner than November 2008, France announced a bill to compensate those suffering illnesses related to nuclear testing among the 150,000 military personnel and civilians who had worked on the tests in Algeria and the Polynesian atolls. On January 9, 2009, France agreed to spend over 80 million US dollars to rehabilitate the atoll of Hao, which was a key military base during the 30 years of nuclear weapons testing in the South Pacific. On March 25, 2009, the French Ministry of Defense offered 10 million euros (13.5 million US dollars) as compensation to victims of its nuclear testing program (CTBTO).

The consequences of nuclear testing in China on human and animal health and the environment are mostly unexplored. 20 million people of various ethnic groups live in Xinjiang. In 2008, China began paying subsidies to personnel involved in nuclear testing. However, the compensation has not been extended to civilian residents of the Xinjiang area, downwind of the Lop Nur test site (CTBTO).

A few hundred thousand people may have died due to radiation from at least 40 nuclear explosions carried out between 1964 and 1996 at the Lop Nur site in Xinjiang (Merali, 2009). Explosions caused the most severe damage

[2] These cases are specified in the report distributed by the International Physicians for the Prevention of Nuclear War (IPPNW) and the Institute for Energy and Environmental Research named "Environmental Effects of French Nuclear Testing."

to local residents in Xinjiang in the 1960s and 1970s, when a mixture of radioactive material and sand formed as a result of rain. Takada estimated that 194,000 people would have died as a result of acute radiation exposure (Takada, 2009). About 1.2 million people could have got doses enough to cause leukemia, cancer, and fetal damage. There is evidence showing that the cancer rates were 30 to 35% higher in the province than the national average (Merali, 2009).

As for India and Pakistan, the openly declared nuclear weapons tests (operation Shakti) took place in two stages at the Pokhran test site in Rajasthan, where a nuclear explosion was conducted in 1974. On May 11, 1998, three nuclear devices were detonated: one (considered thermonuclear) with a power of 45 kT, another with a power of 15 kT, and a third with a power of less than 1 kT. On May 13, two more nuclear weapons with a power of less than 1 kT were tested. It was immediately followed by Pakistan's nuclear tests.

The consequences of nuclear testing in India and Pakistan on human and animal health and the environment are mostly unexplored. Regarding India and Pakistan, it can be concluded that there are no significant instances of environmental contamination due to the very low number of nuclear tests (Prăvălie, 2014).

North Korea has conducted six increasingly powerful nuclear tests since 2006. The DPRK has enough plutonium to produce 12 nuclear weapons. On December 10, 2015, Kim Jong-un announced that North Korea had a hydrogen bomb. On January 8, 2017, by order of Kim Jong-un, the first thermonuclear bomb was exploded underground near the Chinese border.

North Korea's total defense spending is around $10 billion a year, or somewhere between a fifth to a quarter of its gross domestic product (about $30 billion to $40 billion).

South Korea has estimated the North's nuclear program's cost at $1 billion to $3 billion, with the higher number combining nuclear and missile development. How much it will cost to denuclearize North Korea and compensate for environmental damage is a good question.

Today, 75 years after the advent of nuclear weapons, the earliest victims of nuclear weapons are getting old, and their numbers are declining. Among the most relevant studies of the total collective radiation dose for the world's population are the reports of the UN Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), especially those compiled in 1982 and 1993. Today, about 1,500 veterans and their descendants want official recognition of the sacrifices made. They consider nuclear weapons to be outdated, redundant, and unnecessarily destructive.

Conclusions

1. Nuclear testing is the largest source of artificial radioactive contamination of the planet. They were conducted by states in all environments, namely in the atmosphere, underground, and under water.[3] This can also be related to "peaceful" nuclear explosions.
2. The main radiation impact on the environment and human health occurred at the initial stage of nuclear tests when atmospheric tests of nuclear weapons were conducted. Their consequence was the release of significant amounts of radioactive materials directly into the environment. They caused the most massive collective dose of the world's population from human-made radiation sources.
3. Approximately 90% of all nuclear tests were conducted by nuclear powers in the Northern hemisphere, in the United States, the USSR/Russia, and China, and only 10% (about 208 tests) in the Southern hemisphere, by France and the UK. Thus, the Northern hemisphere is more polluted than the Southern hemisphere.
4. Several tests went wrong or caused unexpected damage. As part of medical and environmental studies, it was shown that radioactive materials left after explosions and weapons tests pose a threat to the environment and a danger to the health of the population living near the test sites.
5. The danger of nuclear materials is also in the long period of their decay. Without proper disposal, many generations of people can be exposed to nuclear materials.

This article attempts to calculate the damage to the environment and health of the population.

Suppose US spending on nuclear waste management and environmental remediation is transparent (the United States has spent about $ 400 million dismantling old bombs, managing nuclear waste, and cleaning up the environment). In that case, there is little to say about the spending of other nuclear nations for these purposes. It is known that in 2012 Russian, American, and Kazakh scientists completed a covert 17-year cleaning operations at the cost of $ 150 million in Semipalatinsk to make the site safe.

Employees of nuclear testing sites and the population living near or downwind of the test sites were most exposed to radiation caused by the tests.

Compensation for victims of nuclear tests in the United States amounted to 2.1 billion dollars. Compensation for victims of nuclear tests and the cost of restoring contaminated areas in Australia amounted to about 400 million US

[3] Approximately 25% (530 tests worldwide) were conducted in the atmosphere (or in some cases under water) and 75% underground (1,517 tests). The United States and the USSR/Russia accounted for 82% of all tests conducted in the atmosphere in 1945–1963, and 86% of those carried out underground in the period 1951–1992.

dollars. France's spending on similar purposes amounted to about 100 million dollars. The data on Chinese government spending are not disclosed.

From the point of view of assessing the damage to public health, it should be noted that there is an influence of radioactive contamination on the increase in the number of genetic defects and diseases in the regions of nuclear tests, the increase in the risk of cancer and impotence among the population.

From a theoretical and practical point of view, it is essential to address the cost of nuclear tests, i.e., the damage to the health of veterans who participated in tests, to the local residents, and the environment.

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