Global Nuclear Environmental History

A Photographic Essay

Introduction

The following photographic slide show, with photographs drawn from a variety of online sources – webpages, libraries, government and business archives, news media sites, an private collections – offers a global environmental history of the nuclear age from the first atomic bombs of the United States in 1945 to the frenzied construction of “fleets” of nuclear power stations in India in the 2020s, and from the hopeful ”Atoms for Peace” programs of the 1950s to challenges in dealing with the nuclear legacy in the twenty-first century. Capturing nuclear history across the globe, it considers milling, mining and processing of uranium ore; the production of plutonium; weapons testing; the development of nuclear power plants (NPPs); the variety of settings for these projects; and how people have promoted, participated in, were employed by, struggled with, and opposed this modern technology. Being developed within a few decades, it seems that the social and environmental effects of nuclear technologies are never fully considered, in part because their rapid diffusion, and in part because of the massiveness of the nuclear enterprise and the investedness of its hundreds of thousands of employees and national governments.

Specialists have thoroughly studied large scale technological systems of twentieth century to understand their origins, history and diffusion; their real and future environmental impacts; and their risks, costs and benefits to societies. These technologies include automobiles, plastics, agribusinesses, computers and so on. The following photographic essay suggests that the nuclear enterprise has been the most violent of them, born in dozens, then thousands of nuclear explosions. They reveal that it is one of the most environmentally unsound technologies to develop in the last 100 years, even if nuclear power is touted today by environmentalists, industrial representatives, the United Nations and other organizations and individuals as a hedge against climate change in the pursuit of electrical energy.

Conceived in a military race in the search for unheard of explosive power to decimate the enemy, and leading to the serial production of tens of thousands of nuclear warheads (weapons of mass destruction); tested in the atmosphere and on the earth's surface with disregard for radioactive fallout; and pushed from the laboratory to the experimental reactor and to the almost 450 industrial nuclear power plants (NPPs) that massively occupy riverine, lake and ocean ecosystems, nuclear technologies require constant evaluation of their environmental impacts both because of the quantities of waste and because of its toxicity and longevity.

From the first days of the nuclear era promoters, officials, industrialists and specialists have asserted that nuclear weapons prevent war, that power production is clean, that the vast quantities of waste produced will be handled safely and stored properly, and that the exposures of the world's citizens to low level ionizing radiation, including from extensive fallout in the 1950s, or that leaks into the environment from poorly constructed and temporary storage facilities, or from a series of industrial catastrophers has had negligible impacts on health. Promoters once promised energy ”to cheap to meter,” and now they promise inherently safe reactors.

But the millions of cubic meters of solid and liquid wastes, the spent nuclear fuel (SNF) and so much other dangerous detritus provides no quarter. National security and secrecy protocols prevented until the end of the Cold War a full examination of the waste and its disposition. In fact, trillions of dollars, rubles, francs and euros have been spent on the military atom, and proliferation of weapons continues. In fact, substantial cost overruns, tremendous delays in construction targets and the danger of catastrophic accidents characterize the civilian nuclear enterprise. In fact, cleanup costs will also run into the hundreds of billions of dollars. The following photographs argue with the sanguine assertions of the benefits of nuclear technologies and with their underlying scientific, ecological and historical foundations. They document the troubled relationship along the human-environment-atom nexus. A bibliography accessible through this website lists the many sources that were consulted in underpinning and explaining the context for these analytical conclusions.

Dawn of the Nuclear Age:
Industrialization of the Atom in Secrecy

Dawn of the Nuclear Age

↑ Soviet a-bomb project director Igor Kurchatov and Stalin's secret police chief Lavrenty Beria. US Manhattan project director J. Robert Oppenheimer and military director General Leslie Groves→. Source: Wikimedia

- On the eve of World War II scientists had yet to come to grips with the scale of the mining, milling and enrichment effort to produce enough fissile material for bombs
- Environmental concerns were of secondary importance to specialists and military leaders in the race to be first to develop a nuclear weapon in war time.
- In addition, the environmental impacts of refining processes, weapons testing and so on were often poorly understood.
- During the Cold War, national security interests and secrecy measures prevented coming to grips with environmental impacts.

Burgeoning new nuclear research, development and production centers spread from the US to the USSR, to the UK, France and China and throughout the globe

- For example, the Hanford, WA, reservation at 1,290 km^2 used eight reactors and five plutonium processing complexes to produce more than 60,000 nuclear weapons.
- Military and public officials selected the site – and other such sites in other countries – precisely for their seeming distance from inhabited areas, ignoring Native Americans, and considered them empty, undervaluing flora and fauna, where they could locate a “hazardous manufacturing area,” laboratories, and housing.

Hanford, Washington, USA, Reactor Reservation for Plutonium production

Changing the Columbia River basin environment

- Removal of local people from area “devoid of habitation”
- Production of plutonium and dumping of waste
- This process of producing plutonium is extremely inefficient. Decades of plutonium production generated millions of tons of solid waste and contaminated soil, as well as billions of gallons of liquid waste. Cleaning up those wastes constitutes Hanford’s current mission for the Department of Energy.
- None of Hanford’s 8 reactors are in operation any more with the last reactor, the N Reactor, being shut down in 1988. Beginning in the 1990s, workers began the process of “cocooning” the reactors.

Los Alamos National Laboratory:
Trailers and barracks stretching across the desert

Oak Ridge National Laboratory (ORNL)

These images are from the US DOE (or predecessor organization) employee. As a work of the US government, they are in the public domain.

ORNL X10 Reactor (1947)

Source: Atomic Heritage Foundation

Oak Ridge, Tennessee, Housing

- Population in Oak Ridge rose from 3,000 to 75,000 from 1943 to 1945.

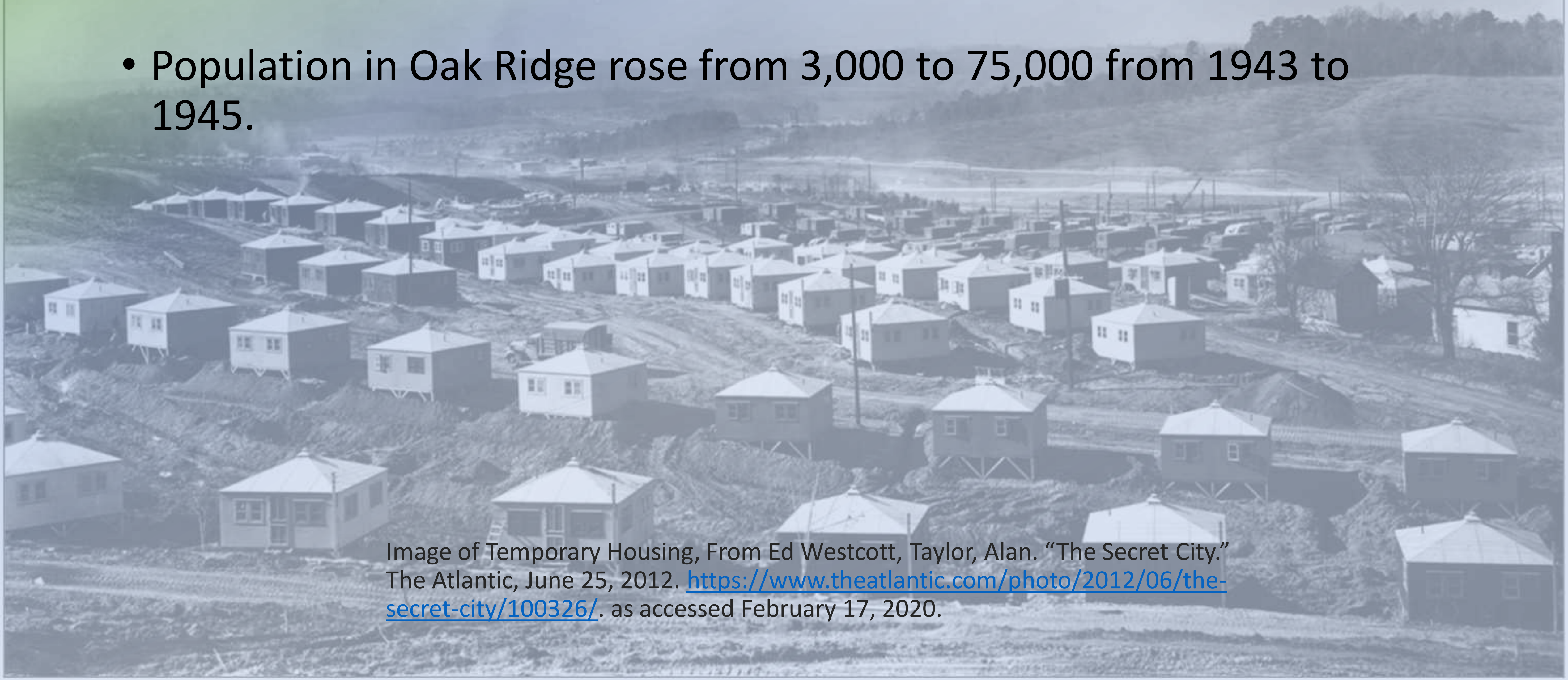


Image of Temporary Housing, From Ed Westcott, Taylor, Alan. “The Secret City.” The Atlantic, June 25, 2012. https://www.theatlantic.com/photo/2012/06/the-secret-city/100326/. as accessed February 17, 2020.

Uranium miners paid for their contribution to the national defense with their health

- Another massive operation was uranium mining and processing.
- From 1944 to 1986, nearly 30 million tons of uranium ore were extracted from Navajo lands under leases with the Navajo Nation. Many Navajo people worked the mines, often living and raising families in close proximity to the mines and mills, and even using radioactive riff-raff in building houses. Today the mines are closed, but a legacy of uranium contamination remains, including over 500 abandoned uranium mines (AUMs) as well as homes and water sources with elevated levels of radiation.

https://www.epa.gov/navajo-nation-uranium-cleanup/abandoned-mines-cleanup

Indigenes and Uranium: Mt. Taylor, New Mexico, and the Navajo Nation

…Mount Taylor can be seen rising from the San Mateo mountains 100 miles in any direction…[It] has long been considered a place of cultural and spiritual significance [as]..a pilgrimage destination for at least 30 indigenous communities, including the Navajo Nation, the Hopi and Zuni peoples, and the Acoma and Laguna Pueblos.
--Kendra Chamberlain at https://nmpoliticalreport.com/2020/01/10/an-inactive-uranium-mine-located-on-a-sacred-mountain-will-finally-close/

Mount Taylor uranium mine, side gate signage. New Mexico. Photo credit: Eve Andree Laramee By Netherzone - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=79787586

Extensive Uranium Ore Mining occurs in Kazakhstan, Australia, Namibia, Canada, Uzbekistan, Niger, Russia and Elsewhere

With deposits discovered in 1976, the Inkai Uranium mine now serves Kazakhstan with commercial production commencing in 2009 and a processing plant commissioned in 2010.

Inkai Uranium Mine Wellfield development drills in Kazakhstan By NAC Kazatomprom JSC - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=94651832

The “Nuclearity” of Africa

- Crucial and environmentally costly uranium mining to supply the world’s bombs and power stations
- Central place in world’s (uranium) commodity chain: Namibia alone with 10% of global output and Niger with 5% of global output
- Great occupational hazards to miners with radon and other exposures

See Gabrielle Hecht, *Being Nuclear: Africans and the Global Nuclear Trade* (2011)

Roessing Mine, Nambia.
Source: Namibian Uranium Association

WORLD NUCLEAR ASSOCIATION

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Kazakhstan	19,451	21,317	22,451	23,127	23,607	24,689	23,321	21,705	22,808	19,477
Australia	5983	6991	6350	5001	5654	6315	5882	6517	6613	6203
Namibia	3258	4495	4323	3255	2993	3654	4224	5525	5476	5413
Canada	9145	8999	9331	9134	13,325	14,039	13,116	7001	6938	3885
Uzbekistan (est.)	2500	2400	2400	2400	2385	3325	3400	3450	3500	3500
Niger	4351	4667	4518	4057	4116	3479	3449	2911	2983	2991
Russia	2993	2872	3135	2990	3055	3004	2917	2904	2911	2846
China (est.)	885	1500	1500	1500	1616	1616	1692	1885	1885	1885
Ukraine	890	960	922	926	1200	808	707	790	800	744
India (est.)	400	385	385	385	385	385	421	423	308	400
South Africa (est.)	582	465	531	573	393	490	308	346	346	250
Iran (est.)	0	0	0	0	38	0	40	71	71	71
Pakistan (est.)	45	45	45	45	45	45	45	45	45	45
Brazil	265	326	192	55	40	44	0	0	0	15
USA	1537	1596	1792	1919	1256	1125	940	582	58	6
Czech Republic	229	228	215	193	155	138	0	0	0	0
Romania	77	90	77	77	77	50	0	0	0	0
France	6	3	5	3	2	0	0	0	0	0
Germany	51	50	27	33	0	0	0	0	0	0
Malawi	846	1101	1132	369	0	0	0	0	0	0
Total world	53,493	58,493	59,331	56,041	60,304	63,207	60,514	54,154	54,742	47,731
tonnes U_3O_8	63,082	68,974	69,966	66,087	71,113	74,357	71,361	63,861	64,554	56,287
% of world demand	87%	94%	91%	85%	98%	96%	93%	80%	81%	74%

* Data from the World Nuclear Association. NB: the figures in this table are liable to change as new data becomes available.

Mine wastes outside the Davis Uranium Mine in Colorado. https://www.epa.gov/radtown/radioactive-waste-uranium-mining-and-milling

← Source: World Nuclear Association

Atomic Bomb Projects Required the Contribution of the Economies of Entire Nations

The US Manhattan Project Major Project Facilities

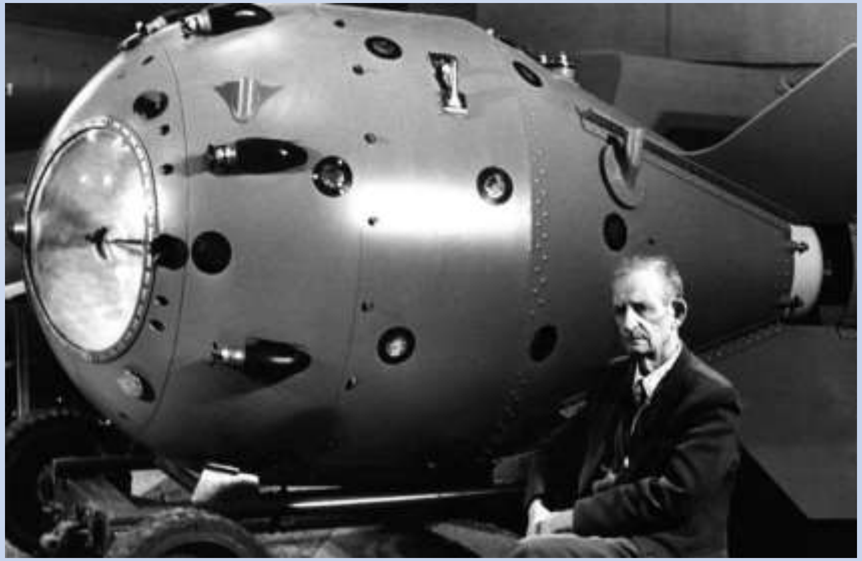
Soviet Closed Military Cities (ZATOs) in Pursuit of Weapons of Mass Destruction

- Even today there are over forty ZATOs (Closed Administrative-Territorial Formation) in Russia with a total population of more than 1 million residents that house Russia's military-industrial complex: Cheliabinsk-65 (now Ozersk, home of the major Soviet plutonium production facility); Tomsk-7 (now Seversk, home of a fuel reprocessing factory and of a major nuclear accident in 1993); Krasnoiarsk-24 (now Zheleznogorsk, home of another plutonium processing facility); Sarov (Arzamas-16, where bombs were designed); the shipbuilding center Molotovsk (today Severodvinsk, on the North Sea); and many others.

Siberian Chemical Combine going back to nature after the Cold War in Tomsk-7 at https://pressoboz.ru/?p=1399

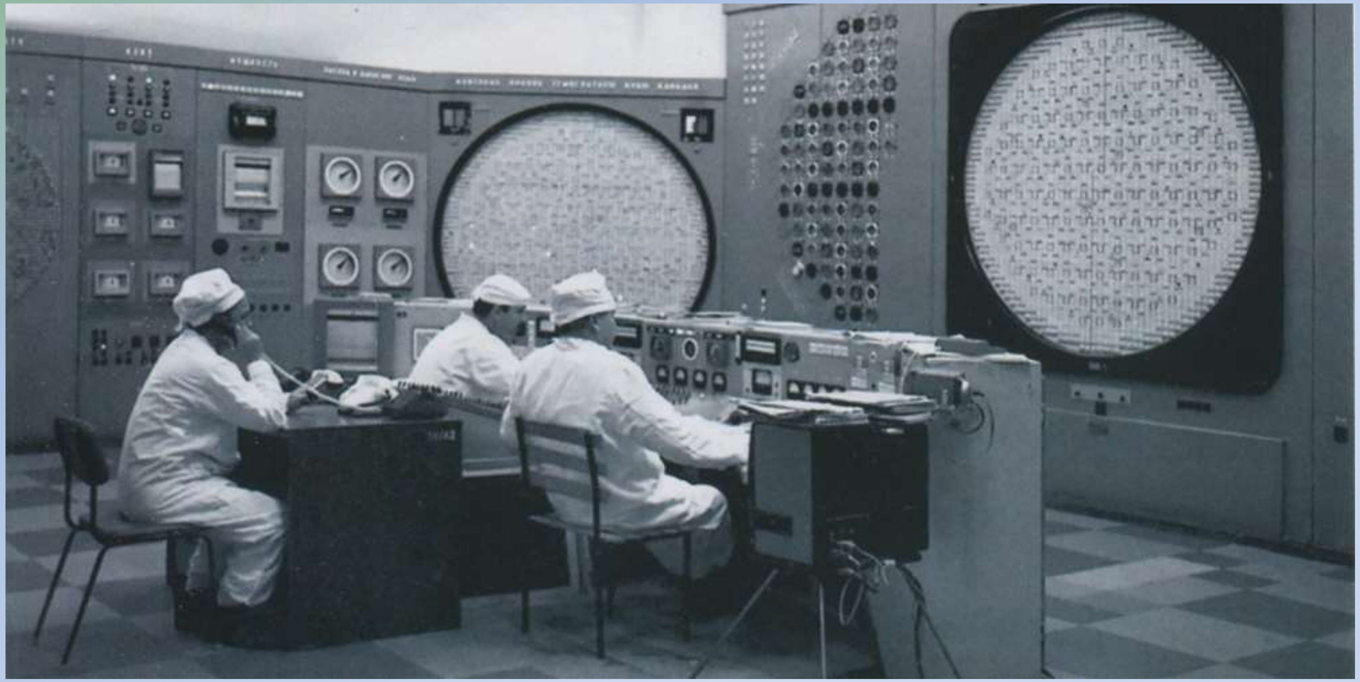
Arzamas-16

- Most Soviet atomic weapons were designed at the ZATO Arzamas-16, site of the All-Union Scientific Research Institute of Experimental Physics (1946-present). The city, formerly site of the Sarov Monastery, desecrated by the Bolsheviks in the 1920s and with many of the monks executed, grew to some 90,000 inhabitants by 1989 – bomb designers, workers and their families.



Physicist-designer Iulii Khariton in Arzamas museum
with mockup of first Soviet atomic bomb. Widely available photos

Cheliabinsk-65 and the Maiak Factory



Here the control room of the AV-3 production reactor that operated from 1952-1991. It satisfied the need to increase Pu production from 23 kg in 1949 to 340 kg in 1954. Source: Rosatom

- The Soviets built their first reactor in the late 1940s at the Maiak Plutonium Production facility at Cheliabinsk-65, a city of 90,000 inhabitants.
- Maiak itself employs 15,000 individuals and covers 90 km^2. It is one of the most heavily polluted industrial sites in the world, and the site of major radiological accidents in 1957 and 1964.
- Today Maiak reprocesses spent nuclear fuel from submarines and decommissioned nuclear weapons.

The Closed Nuclear Bomb Manufacturing City of Ozersk, Russia: ”Do not enter.”

Ozyorsk closed administrative territorial entity (ZATO) By Ecodefense/Heinrich Boell Stiftung Russia/Slapovskaya/Nikulina, Attribution, https://commons.wikimedia.org/w/index.php?curid=15911505

Learning about Blast, Shock and Radiation -- and Their Effects on the Environment

Bombs and their fission products ("fallout") were a learning experience

Alamagordo base camp for the first atomic bomb, "Trinity," July 1945

Trinity

- July 16, 1945
- A base camp was constructed, and there were 425 people present on the weekend of the test.
- Yield 16.7 kT

Nuclear Testing Sites:
Seeking thinly settled areas or with indigenous people – or colonies

- Nevada Test Site
- Semipalatinsk, Kazakhstan
- Novaia Zemlia, Russia
- Algeria (France)
- Tahiti (France)
- Aboriginal Australia (UK)

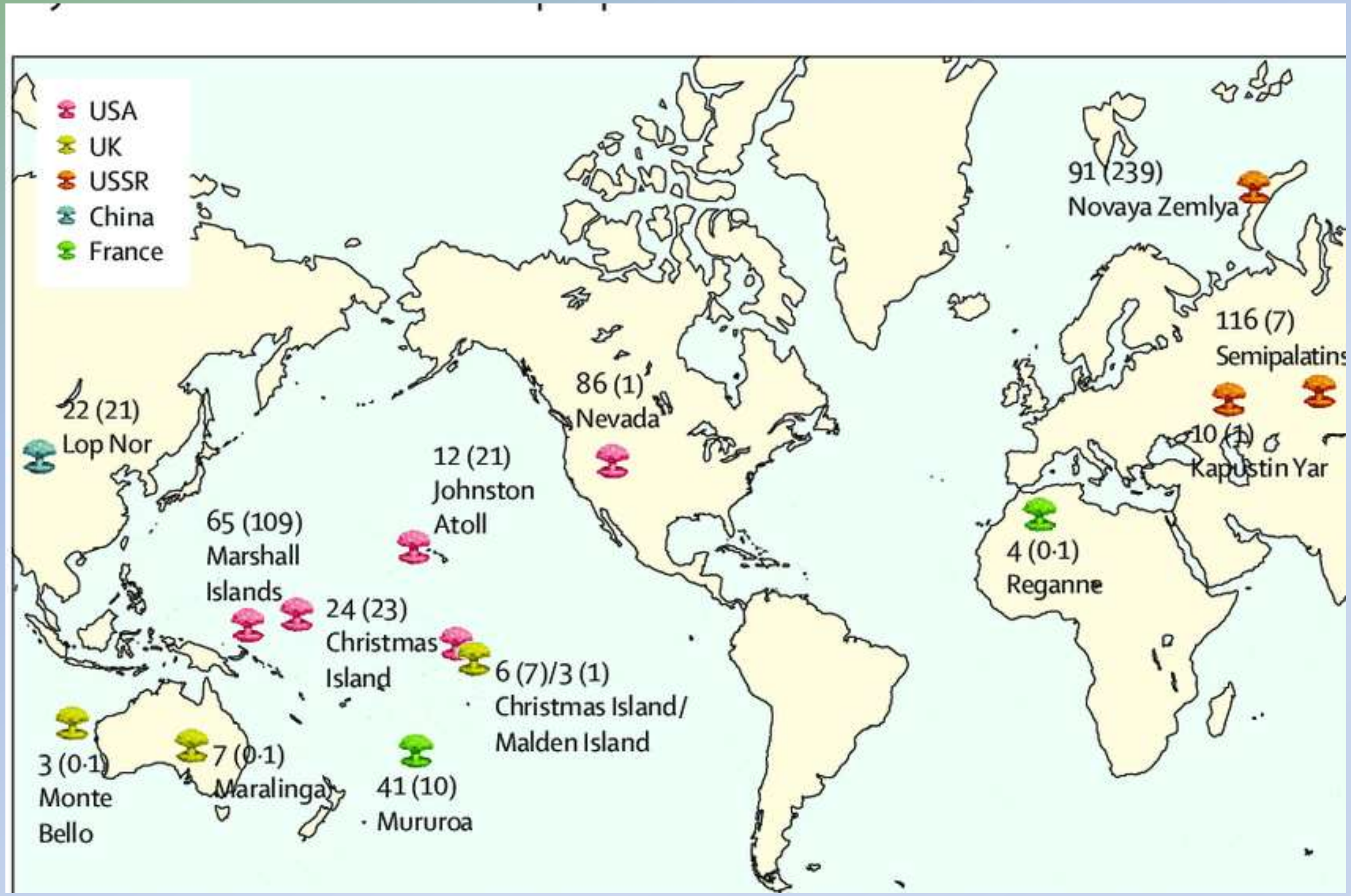
The Nenets in the USSR’s Far North

- Throughout the globe indigenes have paid the price for the development of the atom in terms of their health and destruction of their homelands. Navajo miners in the American southwest saw their homes destroyed and suffered high rates of lung and other formers of cancer for their service to the US in providing uranium ore to fuel the arms race. Tahitians and Algerians lost their lands to the French for testing bombs, as did Aborigines in Australia, Bikinians to the Americans in the Pacific, Nenets in the Russian Far North and Kazakhs in Kazakhstan.

On impacts on local indigenes of nuclear testing around the world, see among many other studies: Lorna Arnold and M. Smith, *Britain, Australia and the bomb: The nuclear tests and their aftermath* (Basingstoke; New York: Palgrave, 2006); Bengt Danielsson and Marie-Therese Danielsson, *Poisoned Reign: French Nuclear Colonialism in the Pacific* (Ringwood: Penguin Books,1986); Mariam Kahn, “Tahiti Intertwined: Ancestral Land, Tourist Postcard, and Nuclear Test Site,” *American Anthropologist*, New Series, Vol. 102, No. 1 (Mar., 2000), pp. 7-26; Dorothy Nelkin, “Native Americans and Nuclear Power,” *Science, Technology and Human Values*, vol. 6 (1981), pp. 2-12; and Testing Bombs in French Tahiti, July 14, 2016, at https://cas.uab.edu/peacefulsocieties/2016/07/14/testing-bombs-french-polynesia/

Photo: Thomas Nilsen on Bellona Site; Узнайте о народе кереки — исчезающем народе Севера России с 3000-летней историей: http://culture.ru/news/50908

Main Atmospheric Nuclear Weapons Test Sites, 1945-1980



- The numbers shown at each test site indicate the number of tests with the total energy yield in equivalent MT of TNT shown in parentheses.

Operation Crossroads (1946), Bikini Atoll Nuclear Explosion

The *Baker* test (23 kT, July 25, 1946, called Helen of Bikini. It was detonated 27 m underwater. Radioactive sea spray caused extensive contamination

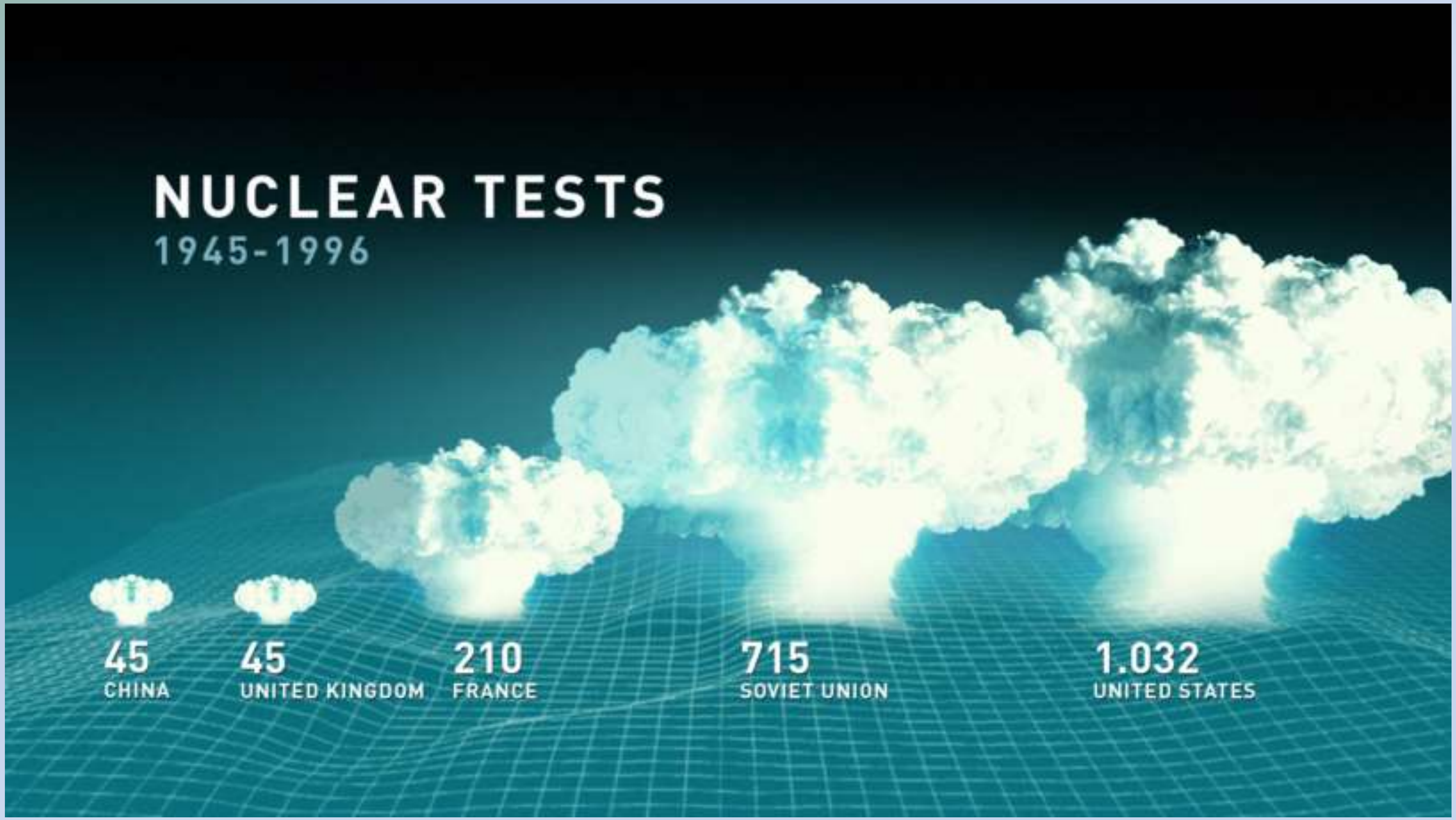
Operation Crossroads. By Original: United States Department of Defense (either the U.S. Army or the U.S. Navy)Derivative work: Victorrocha (talk) – Operation Crossroads_Baker_(wide).jpg, Public Domain, https://commons.wikimedia.org/w/index.php?curid=6931019

Operation Crossroads

- Bikini Atoll: in all at least 23 tests. https://www.youtube.com/watch?v=1BUJ4qralls
- February 1946 removal of 167 Micronesians to test bombs for "the good of mankind and to end all world wars."
- On site, a vast nuclear system: a support fleet of more than 242 ships that provided quarters, experimental stations, and workshops for more than 42,000 personnel.
- The islands were primarily used as recreation and instrumentation sites before being incinerated and seeded with radioactive fallout.
- To support the nuclear bomb testing program, Seabees built bunkers, floating dry docks,75 ft (23 m) steel towers for cameras and recording instruments and other facilities:
  - the "Up and Atom Officer's Club" and the "Cross Spikes Club"

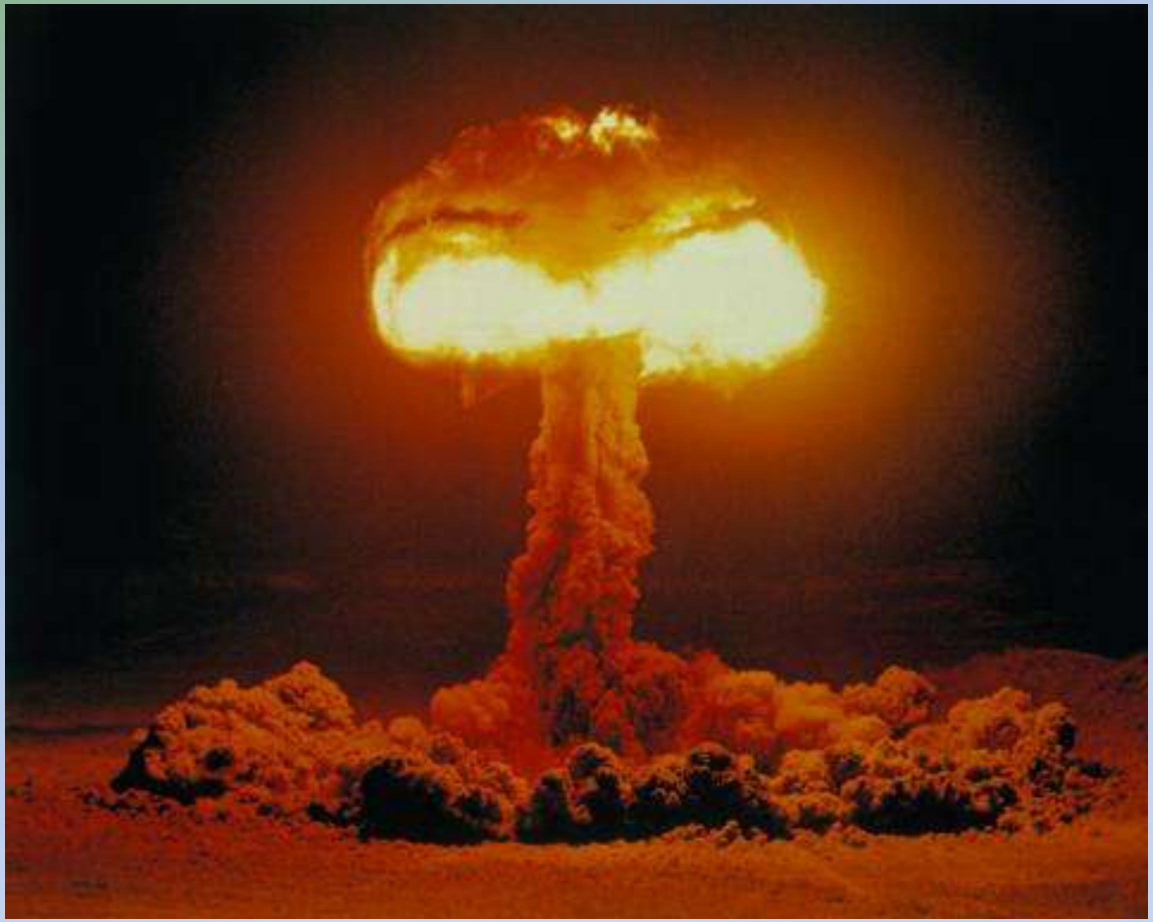
Arthur Beaumont, "The Cross Spikes Club," *Navy Historical Center*. Department of the Navy, at https://www.history.navy.mil/content/history/nhhc/our-collections/art/exhibits/conflicts-and-operations/operation-crossroads-bikini-atoll/cross-spikes-club.html

Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO)



Source: CTBTO

Nevada Test Site (NTS), USA, 1951-1992



- On January 27, 1951, nuclear testing at the NTS officially began with the detonation of Shot Abel, a 1-kiloton bomb, as part of Operation Ranger. Between 1951 and 1992, the U.S. government conducted a total of 1,021 nuclear tests here. Out of these tests 100 were atmospheric, and 921 were underground. Test facilities for nuclear rocket and ramjet engines were also constructed and used from the late 1950s to the early 1970s.

https://www.atomicheritage.org/location/nevada-test-site

Nevada Test Site Craters

Nevada Site Office Photo Library under number NF-474. At https://commons.wikimedia.org/w/index.php?title=Special:Search&limit=20&offset=40&profile=default&search=Nevada+Test+Site&advancedSearch-current={}&ns0=1&ns6=1&ns12=1&ns14=1&ns100=1&ns106=1#/media/File:Nevada_Test_Site_craters.jpg

From the first Soviet bomb “RDS-1” to a vast bomb making enterprise

- From their first nuclear test in August 1949, the USSR’s scientists and military leaders worked feverishly to design and test nuclear bombs with larger yields, more or less radioactivity, in the atmosphere, on the earth’s surface and underground, and even for peaceful purposes of excavation, creation of underground domes for storage, building dams and canals, and putting out oil well fires, for a total of 981 devices, a total yield of 300,000 kTs, and with 135 of them in 1961-62, or one-seventh of the total, at a time of great international tension over the Berlin Wall and the Cuban Missile Crisis, and when the world’s citizens, including those in the USSR, anticipated nuclear annihilation.
- https://www.ctbto.org/nuclear-testing/the-effects-of-nuclear-testing/the-soviet-unionsnuclear-testing-programme/

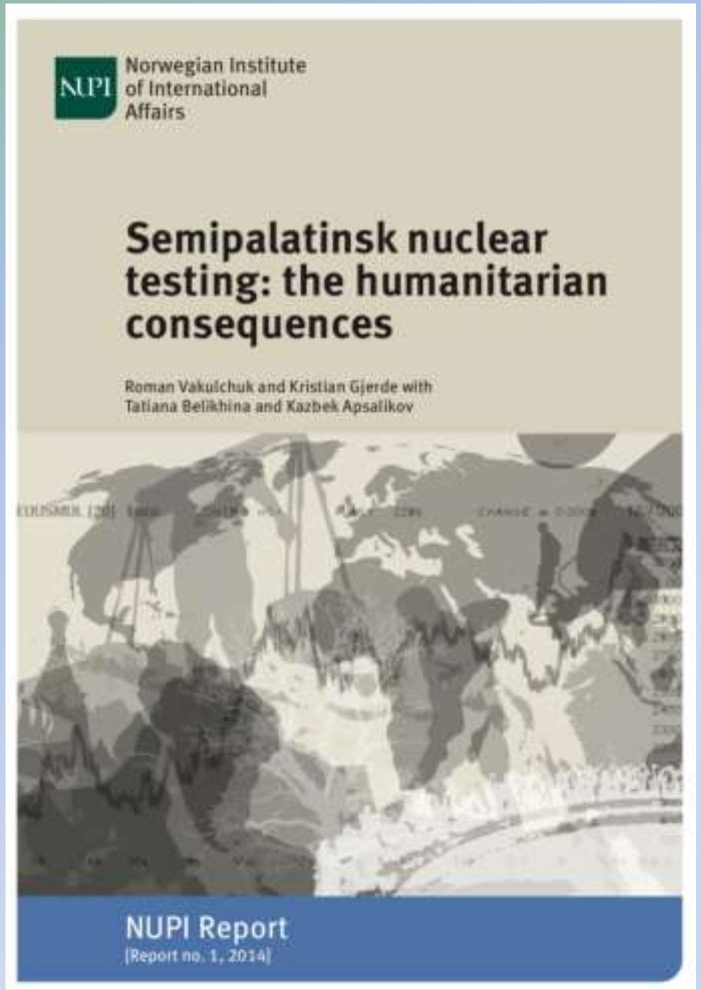
Semipalatinsk, Kazakhstan, Test Site

- The USSR exploded 456 nuclear devices, 456 at the Semipalatinsk Test Site (STS) b Between 1949 and 1989. Five of the surface tests were unsuccessful and resulted in the dispersion of plutonium into the environment, with the first test on 29 August 1949 unexpectedly contaminating villages to the northeast of the STS.
- The approximate cumulative explosive yield of the tests conducted before 1963, when the Soviet Union signed the Partial Test Ban Treaty (PTBT), was 6.4 MT, or roughly six times greater than the explosive yield of the above ground tests at the Nevada Test Site and about six percent of the yield of the tests conducted in the Marshall Islands.

https://www.ctbto.org/nuclear-testing/the-effects-of-nuclear-testing/the-soviet-unionsnuclear-testing-programme/

Consequences of Nuclear Testing in Kazakhstan. (Photo by Alain Nogues/Sygma/Sygma via Getty Images) at https://www.gettyimages.com.mx/detail/fotograf%C3%ADa-de-noticias/consequences-of-nuclear-testing-in-kazakhstan-fotograf%C3%ADa-de-noticias/607389144?adppopup=true

STS (Kazakhstan): Human and Environmental Consequences



More than 300 test explosions were conducted underground after 1961. Semipalatinsk's Degelen Mountain nuclear test facility was the largest underground nuclear test site in the world, consisting of 181 separate tunnels.

A test of 12 February 1989 resulted in a leakage of large amounts of the radioactive noble gases xenon and krypton, according to Gusev et al. in *The Semipalatinsk nuclear test site: a first assessment of the radiological situation and the test-related radiation doses in the surrounding territories.* Peterson et al. describe how the radionuclides emanating from these tests resulted in atmospheric and environmental contamination in *Diagnosis of benign and malignant thyroid disease in the east Kazakhstan region of the Republic of Kazakhstan: a case review of pathological findings for 2525 patients.*

https://www.ctbto.org/nuclear-testing/the-effects-of-nuclear-testing/the-soviet-unionsnuclear-testing-programme/

The Russian Arctic as a Nuclear Test Site: Novaia Zemlia

The USSR used Arctic regions for nuclear submarine naval bases with reactor fuel storage and reloading; to test nuclear weapons; and as a waste “dump.” There has been significant radiological contamination.

The Soviet Tsar Bomba (1962), at 58.1 MT, spread fallout through the Northern Hemisphere

- https://www.youtube.com/watch?v=Lh5ybvSspjM

The USSR exploded the world's largest hydrogen bomb with significant fallout throughout the northern hemisphere.

Castle Bravo Test, Bikini Atoll, March 1, 1954

- The detonation, expected to produce 4 to 6 megatons, produced a yield at 15 megatons, equivalent to 1,000 times more powerful than the bomb dropped on Hiroshima in 1945. It was the largest thermonuclear weapons test in history in Bikini Atoll
- Castle Bravo grew within seconds to be 5 km across. Ten million ton of coral were coated with radioactive debris from the fusion reaction and sucked up into the rising fireball. The fireball rose to over 13 km in the first minute, leaving behind a 7 km wide stem of radioactive debris." After five minutes cloud reached an altitude of more than 35 km, and after ten minutes the head of the mushroom cloud.
- Thomas Kunkle, Byron Ristvet, CASTLE BRAVO: FIFTY YEARS OF LEGEND AND LORE A Guide to Off-Site Radiation Exposures (Kirkland, NM: US DTRA, January 2013). See also Alex Wellerstein, "Castle Bravo revisited," *Restricted Data: The Nuclear Secrecy Blog*, June 21, 2013, accessed November 22,2021, at http://blog.nuclearsecrecy.com/2013/06/21/castle-bravo-revisited/.

This image is of the US Government and in the public domain.

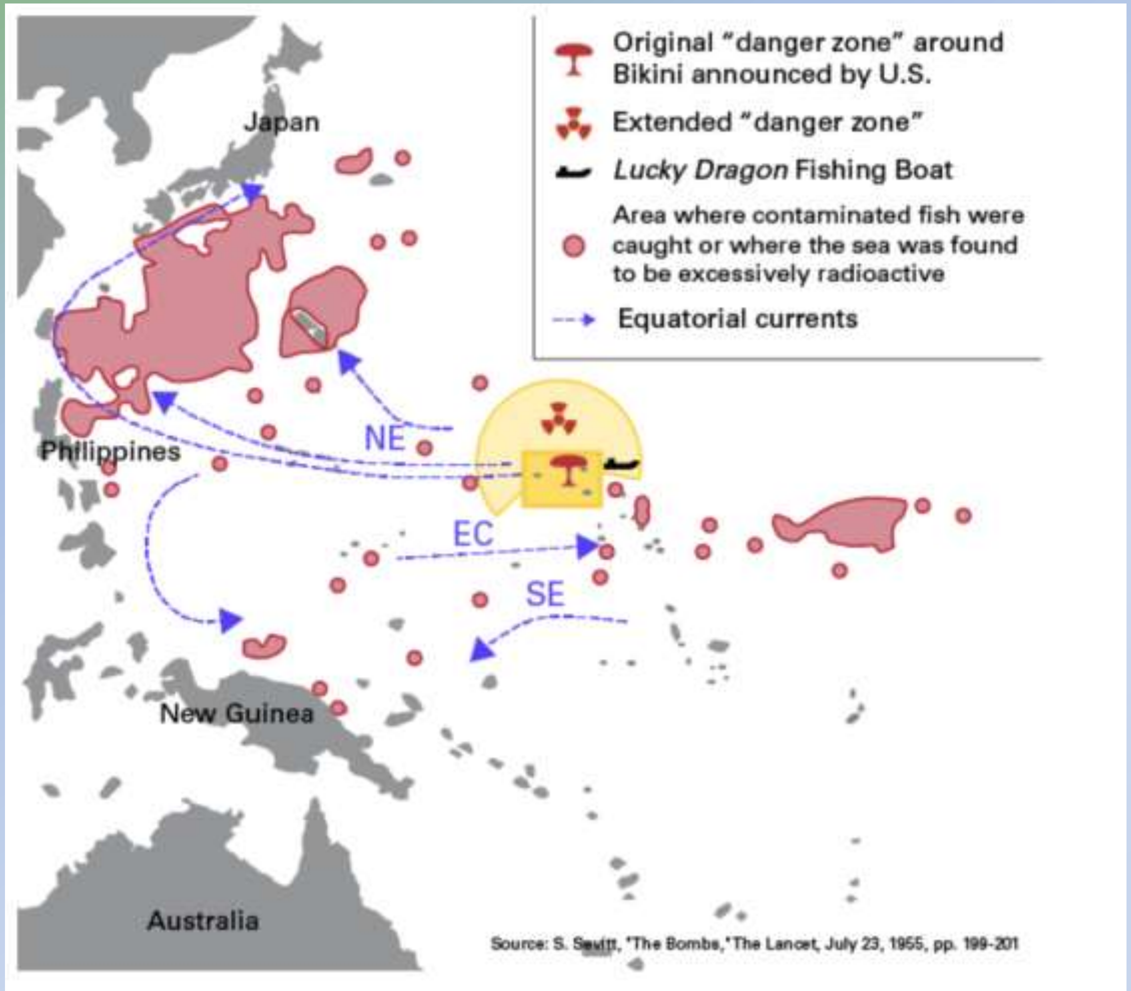
Radioactive contamination of Rongelap Atoll

- The Rongelap Atoll was coated with up to 2 cm (0.79 in) of snow-like irradiated calcium debris and ash.
- Virtually all the inhabitants experienced severe radiation sickness, including itchiness, sore skin, vomiting, diarrhea, and fatigue.
- Only three days later were they were relocated to Kwaijalein for medical treatment.
- Six days after the Castle Bravo test, the U.S government set up a secret study of the medical effects of the weapon on the residents
- Photo source: https://marshallislandsnarrative.wordpress.com/2014/04/15/june-1954/

Seven-year-old Rongelap girl contaminated with fallout: beta ray hair loss at 28 days and complete regrowth some 6 months later.

Blistering and depigmentation on upper surface of bare feet by beta rays from fallout sticking to moist, thin skin, at 28 days after burst (left) and recovery 6 months later (right).

Castle Bravo and the “(Un)lucky Dragon



Daigo Fukuryū Maru (第五福龍丸, *F/V Lucky Dragon 5*), a Japanese tuna fishing boat, was contaminated by fallout from Castle Bravo. The crew suffered from acute radiation syndrome. Their cargo was later sold in Japan, causing a contamination disaster of its own.

This map shows how fallout spread over the South Pacific Ocean. Lewis Strauss, chairman of the AEC put it, “the wind failed to follow the predictions, but *shifted* south of that line and the little islands of Rongelap, Rongerik and Utrik were in the edge of the path of the fallout . . . The 236 Marshallese natives appeared to me to be well and happy . . . “

- Lewis Strauss, Press conference about Bravo with President Eisenhower, March 12, 1954, Washington, DC

A “Lucky Dragon” Fisherman and Japanese Inspection Team

“Castle Bravo Nuclear Test - Lucky Dragon Fishing Boat Incident - Daigo Fukuryū Mar,” at https://www.flickr.com/photos/rocbolt/12279221734

A portrait of a crewmember of the fishing boat DaiGo Fukuryu Maru (Lucky Dragon No. 5). Hitoshi Yamada / NurPhoto via Getty Images

Film Clips of Atomic Energy Commission of NTS Activities in the 1950s

All in the Public Domain

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Operation Castle Bravo

- https://www.youtube.com/watch?v=C03ZAZSRJys

King Ivy 500kt 1952

- https://www.youtube.com/watch?v=O69Kc1i01tA

Atomic Bomb Tests in Mercury, Nevada

- https://www.youtube.com/watch?v=QL_YzlhqpbY

Atomic Tests In Nevada: The Story of AEC's Continental Proving Ground

- https://archive.org/details/AtomicTestsInNevada

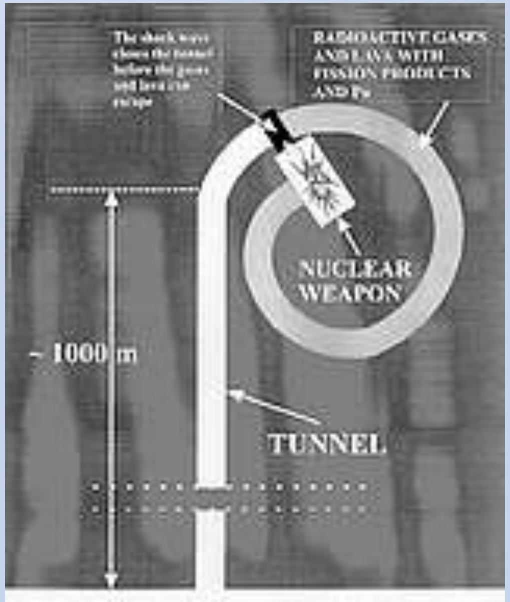
French tests in colonies (Algeria, Polynesia)

- The French carried out nuclear tests first in a desert of Algeria, at that time a colony of France, and the South Pacific atolls of Mururoa in the attempt to avoid exposure of too many people to fallout. Of course, rodents were used for exposure experiments in the first tests in Algeria.

Sources of Photos: AFP/Getty Images; Al Araby.

France tests in the Algerian desert to avoid contamination at home

- France was the fourth nation to join the “Nuclear Club” when it successfully detonated a large nuclear device in Algeria in 1960. Over the next five years, France conducted 17 nuclear weapons tests at two locations in Algeria. Four were atmospheric tests and 13 were detonated underground.
- A 2005 International Atomic Energy Agency report describes the failed Béryl test on 1 May 1962 that vented between 5 and 10 percent of the test product’s activity as lava, aerosols and gaseous products.

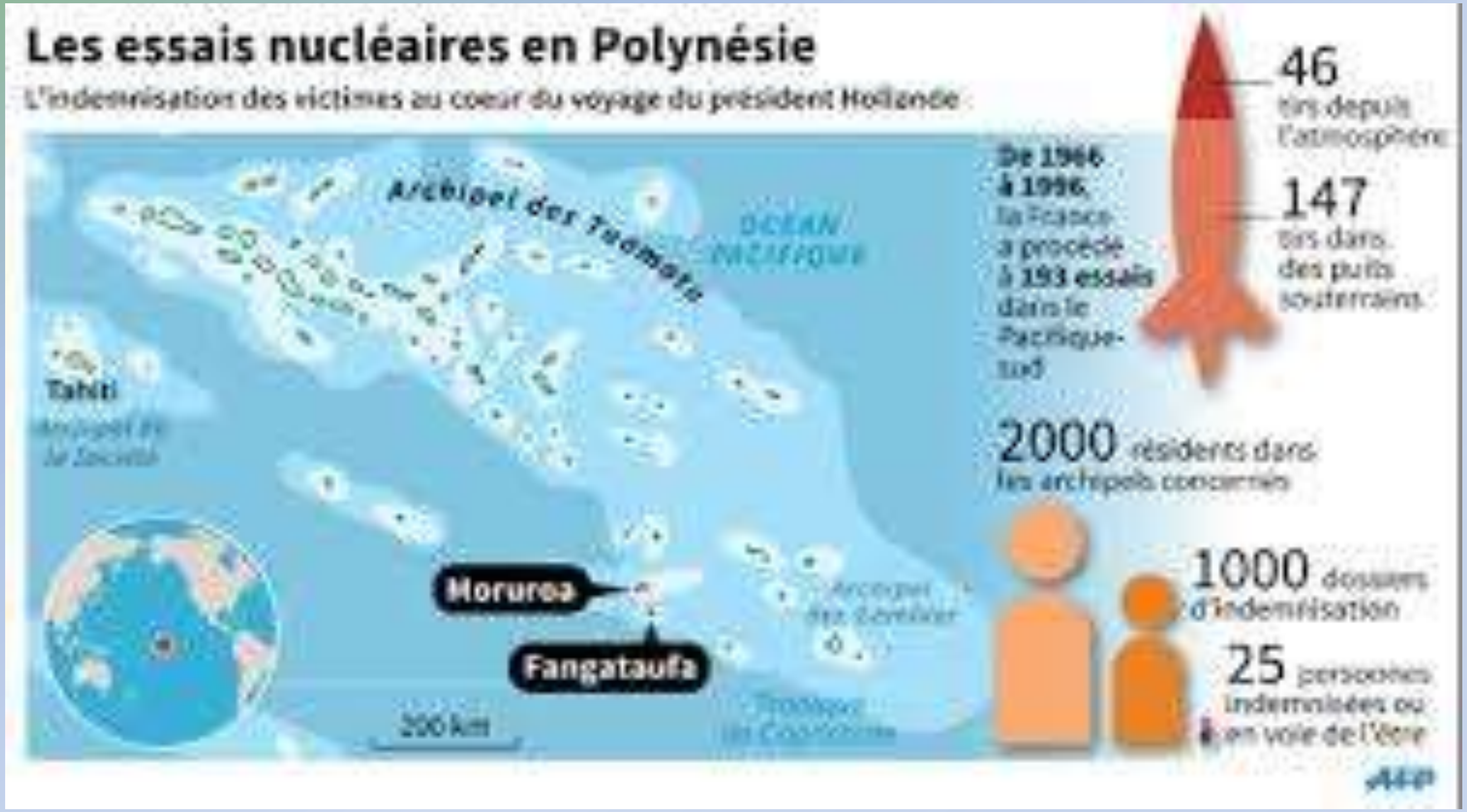


French Polynesia

- With Algeria's independence in 1962, the French moved their testing to the uninhabited islands of Moruroa and Fangataufa in the South Pacific claiming that only 5,000 inhabitants lived within a 1,000 km radius of the proposed testing areas. Yet Tureia atoll, with roughly, 60 inhabitants, was only 100 km away from Moruroa and thus remained within the zone designated as dangerous.
- "The total amount of plutonium-239 dispersed as a result of the 45 announced French atmospheric tests, including the four in Algeria, would be about 6750 curies, assuming 150 curies per test. On this basis, the amount of cesium-127 and strontium-90 dispersed into the atmosphere would have been 1.7 million curies and 1.1 million curies of strontium-90 [see Chart 1] respectively. About one half of the cesium and strontium remains in the atmosphere, on the ground, and in water bodies. French testing in the Pacific was the source of almost all the atmospheric fission product contamination, due to the much larger number of tests and the far greater yields of the French tests there than in Algeria"

See: http://canterbury.cyberplace.org.nz/peace/nuchealth.html and https://www.ctbto.org/nuclear-testing/the-effects-of-nuclear-testing/frances-nuclear-testing-programme/

Mururoa, Tahiti, French Test Site



Between 1966 and 1996 the French carried out 193 tests, in Polynesia, until 1974 -- 46 of them atmospheric tests, destroying massive coral reefs. A recent study reveals that approximately 110,000 people were affected by fallout, many with cancers, almost the entire Polynesian population at the time.

See Disclose, Interpt and Princeton SGS, at https://moruroa-files.org/en/investigation/moruroa-files

Polynesia Environmental Impacts

↑ 'Mururoa Atoll bomb test', URL: https://nzhistory.govt.nz/media/photo/mururoa-atoll-bomb-test, (Ministry for Culture and Heritage), updated 17-Jun-2014

↑ Source: AFP

- From 1975, all nuclear blasts were carried out underground, causing both short-term and long-term environmental damage: fracturing of the atoll surface triggered landslides, tsunamis and earthquakes. A report by the IPPNW and the Institute for Energy and Environmental Research on the Environmental Effects of French Nuclear Testing found evidence that radionuclides were vented into the environment.
- Possible long-term effects also include leakage of fission products to the biosphere and transfer of dissolved plutonium from the lagoon to the ocean and the food chain.
- A number of scientific missions to Moruroa described severe impairment to the atoll. The damage included fissures in the limestone which are propagated by the testing, and surface subsidences of large areas of the atoll.

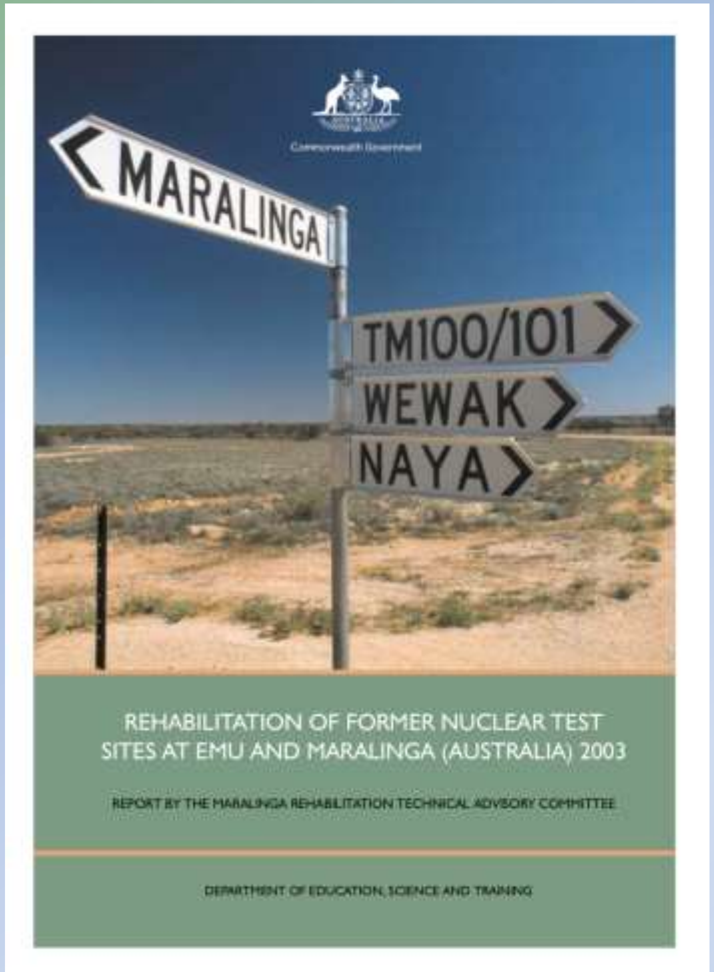
The United Kingdom Tests in Maralinga, Australia

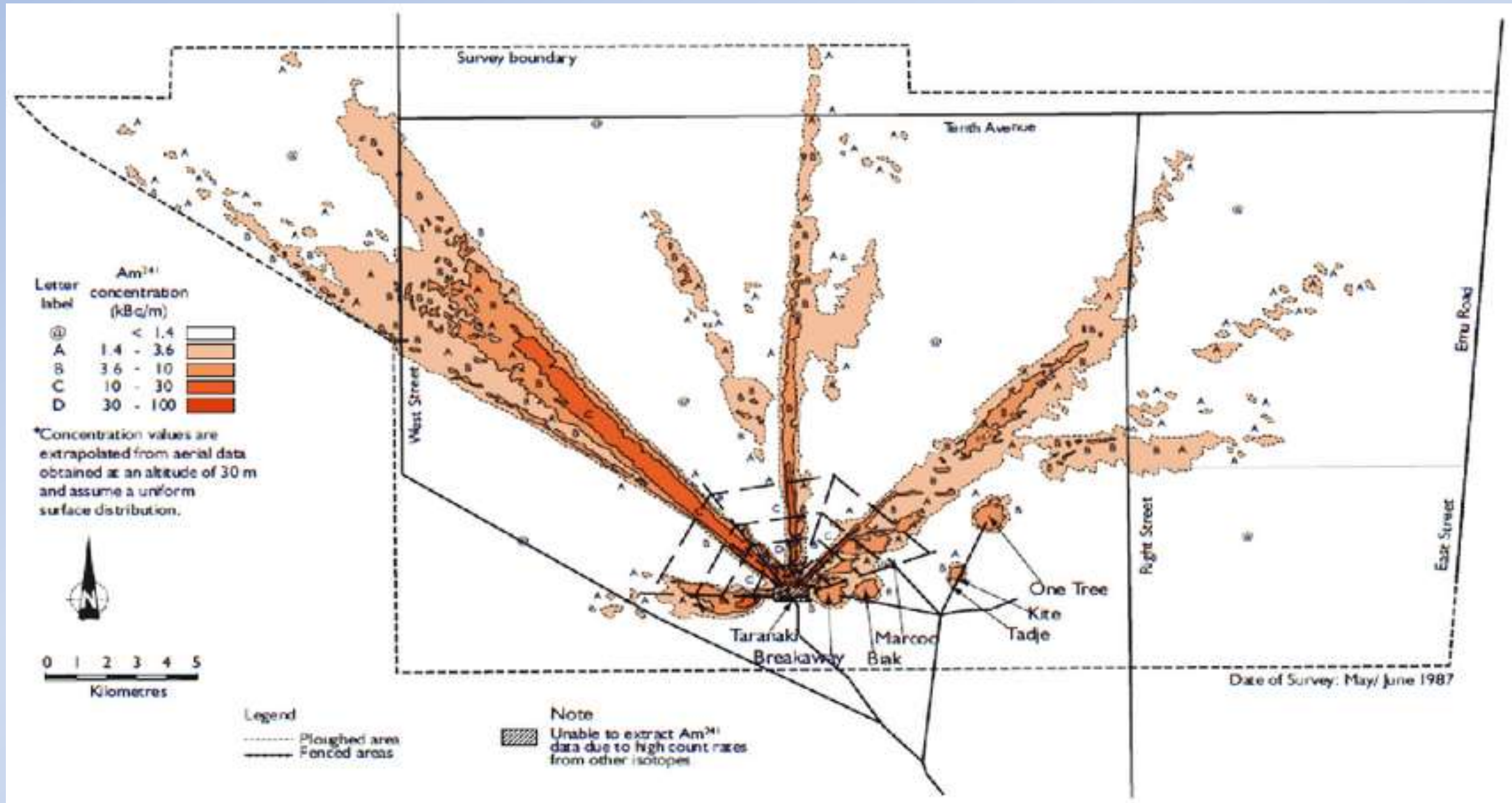
- Between 1957 and 1963 the UK conducted 7 nuclear tests in the Woomera Prohibited Area, an air force range. There was extensive radioactive pollution and inadequate cleanup of the region that included plutonium fallout in the homeland of the Maralinga Tjarutja.

See also Liz Tynan, *Atomic Thunder* (2016) and Alan Parkison, *Maralinga: Australia's Nuclear Waste Cover-up* (2007);

Archival photo at https://www.sbs.com.au/nitv/the-point-with-stan-grant/article/2016/09/27/maralinga-nuclear-tests-60-years-what-do-we-know-now

The cleanup of the firing range and deserts of Maralinga have been slow, inadequately funded and incomplete





Report by the Maralinga Rehabilitation Technical Advisory Committee, *Rehabilitation of former nuclear test sites at Emu and Maralinga (Australia)* (2013), p. 18.

Blak Douglas (b. 1970), *"Tjarutja Tragedy," (*2016). Synthetic polymer on canvas
100 x 200 cm. © Blak Douglas. At https://artblart.com/tag/blak-douglas-tjarutja-tragedy/

Impact of Maralinga on Tjarutja expressed in song: Paul Kelly and the Coloured Girls, “Maralinga” (1987)

- First we heard two big bangs
  We thought it was the great snake digging holes
  Then we saw the big cloud
  Then the big black mist began to roll
  This is a rainy land
- A strangeness on our skin
  A soreness in our eyes like weeping fire
  A pox upon our skin
  A boulder on our backs all our lives
  This is a rainy land
- This is a rainy land
  No thunder in our sky
  No trees stretching high
  But this is a rainy land
- My name is Millipuddy
  They captured me and roughly washed me down
  Then my child stopped kicking
  Then they took away my man to town
  They said do you speak English?
  He said
  I know that Jesus loves me I know
  Because the bible tells me so
  I know that Jesus loves me I know
  Because the bible tells me so

The physical damage of Nagasaki

- Ultimately, the major focus of nuclear technology has been the development of weapons of mass destruction. Two such weapons have been used – on Japan at Hiroshima (August 6, 1945) and Nagasaki (August 9, 1945)
- "The foremost characteristic of the physical damages caused by the Nagasaki atomic bombing was the tremendous, instantaneous destruction wreaked by the blast wind and the subsequent fires. These fires broke out simultaneously with the destruction of buildings over a wide area. The complete destruction and burning of wooden buildings extended beyond a distance of two kilometers from the Nagasaki hypocenter."
- In Nagasaki 14,000 or 27% of 52,000 residences were completely destroyed and 5,40O, or 10% were half destroyed. Only 12% remained undamaged.

← Physical Damages Caused by the Nagasaki Atomic Bombing at https://www.genken.nagasaki-u.ac.jp/abomb/pdamage

The Loss of Human Life at Hiroshima and Nagasaki

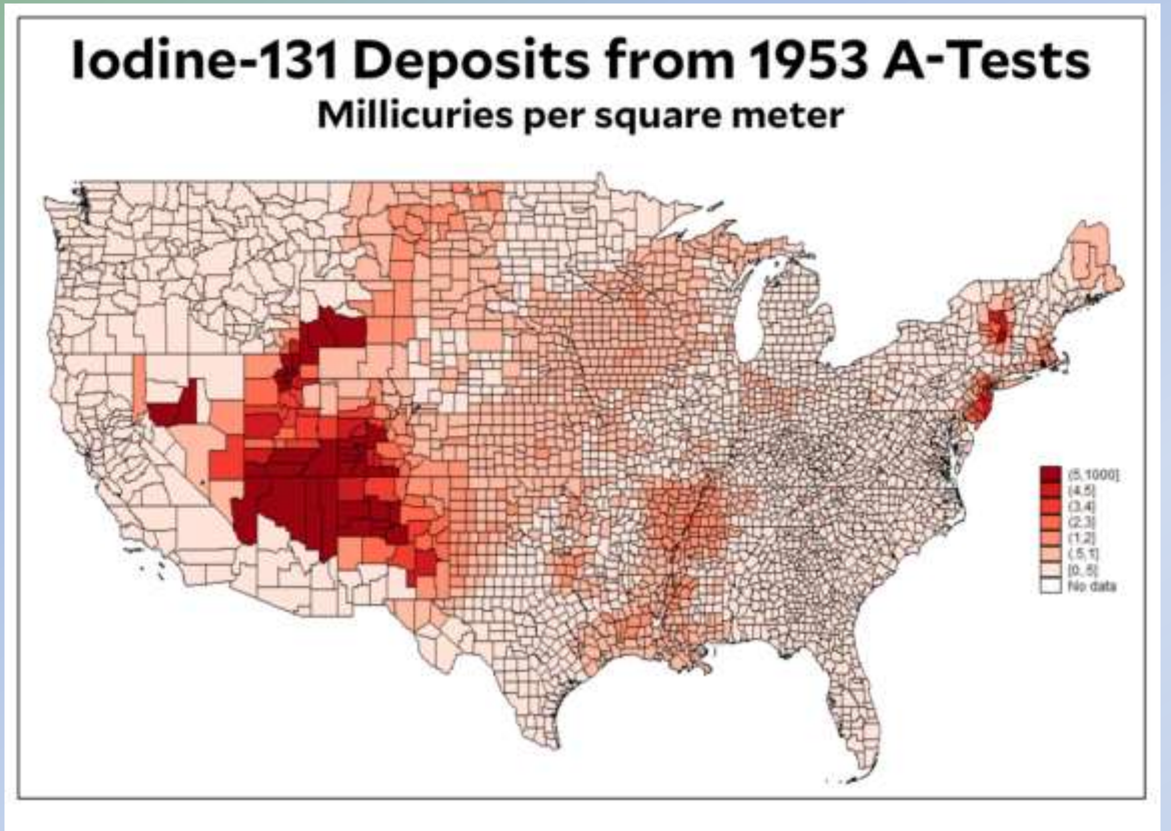
- The two bombings killed between 129,000 and 226,000 people, most of whom were civilians.
- From the date of the bombings over the next two to four months, the effects killed between 90,000 and 146,000 people in Hiroshima and 39,000 and 80,000 people in Nagasaki; roughly half of the deaths occurred on the first day. For months afterward, large numbers of people continued to die from the effects of burns, radiation sickness and injuries, followed by illness and malnutrition.

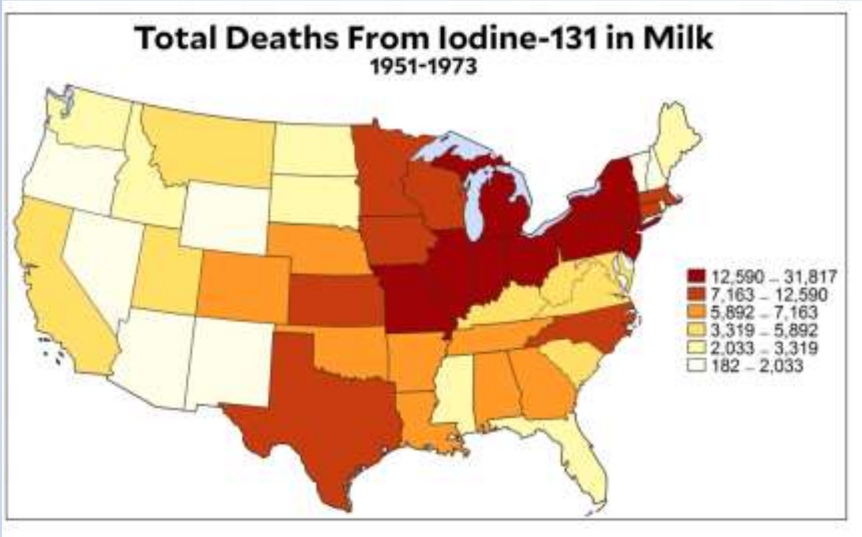
Not the mushroom cloud, but the firestorm cloud at Hiroshima.
Source: USG, public domain. →

Human Subjects Research

As part of the environment, human interaction with the atom – through background radiation, as downwinders from experimentation, as nuclear veterans, as willing, and all too unwilling, subjects of experimental protocols – has been profound, frightening, and laden with uncertainties. The uncertainties include at what levels ionizing radiation is dangerous to human health. This understanding has evolved as more data have become available and, unfortunately, as officials have changed exposure levels to permit personnel in the nuclear enterprise, miners and servicemen and women among them, to receive greater doses. The experiments included children and institutionalized patients.

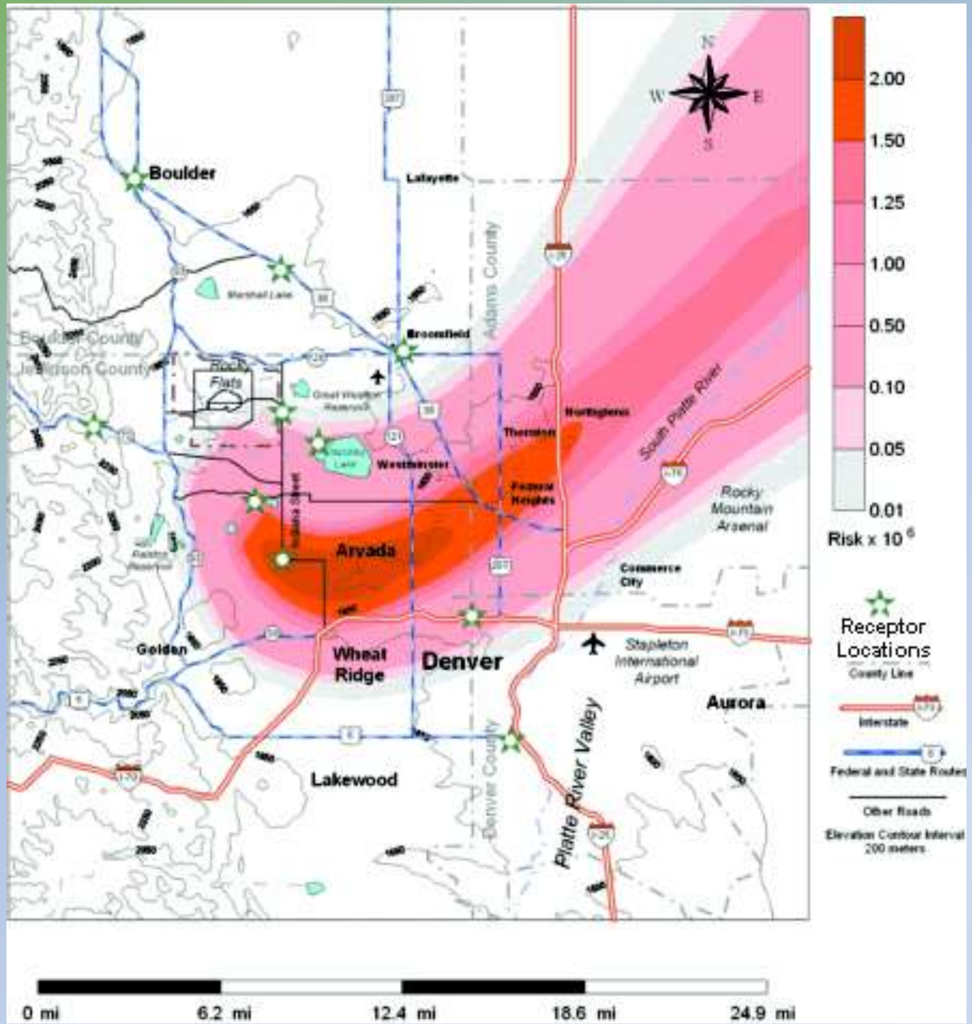
Downwinders faced significant risks from Exposure to radioactive fallout





- Source: *Mother Jones* at https://www.motherjones.com/kevin-drum/2017/12/atomic-tests-during-the-1950s-probably-killed-half-a-million-americans/

Plutonium Production as Human Subjects Exposure



- Manufactured in Military Production Reactors and in "Breeder Reactors" – usually built with liquid metal (sodium) coolant
- Because it emits alpha particles, plutonium is most dangerous when inhaled. When plutonium particles are inhaled, they lodge in the lung tissue. The alpha particles can kill lung cells, which causes scarring of the lungs, leading to further lung disease and cancer. Plutonium can enter the blood stream from the lungs and travel to the kidneys, meaning that the blood and the kidneys will be exposed to alpha particles. Once plutonium circulates through the body, it concentrates in the bones, liver, and spleen, exposing these organs to alpha particles.

On plutonium, see https://world-nuclear.org/information-library/nuclear-fuel-cycle/fuel-recycling/plutonium.aspx; on health risks, see Centers for Disease Control, "Radioisotope Brief: Plutonium," at https://www.cdc.gov/nceh/radiation/emergencies/isotopes/plutonium.htm#:~:text=Because%20it%20emits%20alpha%20particles,further%20lung%20disease%20and%20cancer.

↑ Plutonium Plume from Fire at Rocky Flats, Colorado, USA, Weapons Production Facility at https://en.wikipedia.org/wiki/Radioactive_contamination_from_the_Rocky_Flats_Plant

US military personnel, all wearing large googles, sit on Adirondack-style chairs as they witness a nuclear test in the Marshall Islands, April 7, 1951, Photo by PhotQuest/Getty Images

Nuclear Veterans as another kind of “downwinder”

Camp Desert Rock during Operation Buster-Jangle. Source: DOE, NNSA-Nevada Site Office.

Two soldiers crouch in their foxhole awaiting the blast.
Source: DOE, NNSA-Nevada Site Office.

Not only indigenes and local people were exposed to radioactivity, but military people (soldiers) as well.Some 400,000 US soldiers were exposed to some of the 200 US atmospheric conducted from 1946 to 1962 by the US either as observers or in cleanup.

US House of Representatives, Subcommittee on Energy Conservation and Power, *American Nuclear Guinea Pigs: Three Decades of Radiation Experiments on US Citizens* (Washington, DC: USGPO, 1986); CTBTO, “The Soviet Union's Nuclear Testing Programme”; William Robert Johnston, “Totsk Nuclear Test,” at http://www.johnstonsarchive.net/nuclear/radevents/1954USSR1.html; and Judith Perrara, “Forty Year Old Secret Explodes…” *New Scientist*, December 18, 1993, at https://www.newscientist.com/article/mg14019041-400-forty-year-old-secret-explodes/

Hundreds of Thousands of Nuclear Veterans Were Exposed to Significant Amounts of Radiation

Only in the 1990s did the US recognize the need to compensate some of the military people who were physically present at NTS, the Trinity test site, the Marshall Islands, Christmas Island or other site during a test or within six months of the taste. They might, according to restrictive criteria, qualify for $75,000 tax free.

The following were the primary cancers covered under the program: Bile ducts, Bladder, Brain, Breast(male and female), Colon/Rectal, Esophagus, Gall Bladder, Leukemia(other than CLL or chronic lymphocytic leukemia), Liver(except if there is evidence of cirrhosis or Hepatitis B), Lung, Multiple Myeloma, Nasal Pharynx, Lymphomas(other than Hodgkin's disease), Ovary, Pancreas, Salivary Gland, Small Intestine, Stomach and Thyroid.

The USSR, at the Totsk site in the Arinbuk region of the Southern Urals on September 14, 1954, exposed 44,000 men to excessive radiation. The authorities required those involved in the test to sign secrecy agreements. The soldiers were dressed in ordinary uniforms, rubber boots and gas masks, without any shelter, to watch a 40-kt bomb explode above their heads, about 3 km away. Years later they died off from cancers and other illnesses.

Original Soviet film: “Atomnyi Vzryv – Totskie Ucheniia,” at https://www.youtube.com/watch?v=GZSc7I13sPU. See also “Derevnia Posle Vzryva Atomnoi Bomby! Ispytaniia na Totskom Poligone,” at https://www.youtube.com/watch?v=UMxeK26QTw8

Photo: Corporal Alexander McCaughey, https://www.archives.gov/exhibits/picturing_the_century/images/postwar_078_v121.jpg, Public Domain, https://commons.wikimedia.org/w/index.php?curid=685917

Operation "Plumbbob"

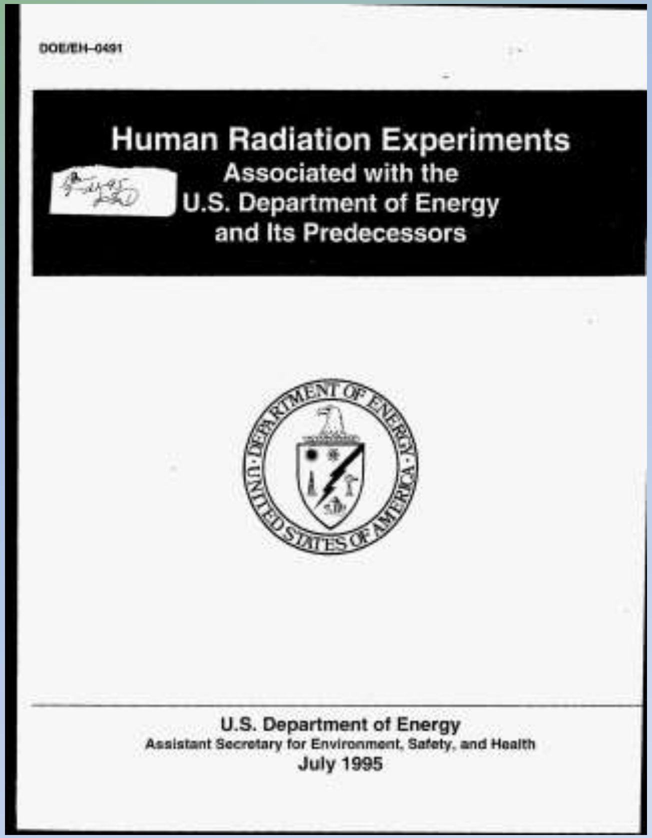
An Army colonel is swept off in an effort to rid him of radioactive dust following an inspection tour of the blast area. Source: DOE, NNSA-Nevada Site Office.

Soldiers participating in Desert Rock watch the mushroom cloud. Source: DOE, NNSA-Nevada Site Office.

Between May 28 and October 7, 1957, a series of 29 atomic bombs were detonated as part of a study of the effects that nuclear explosions had on structures, people and animals. About 16,000 American troops were exposed.

Declassified documents reveal that the Plumbbob test series released approximately 58,300 kilocuries of radioiodine (I-131) into the atmosphere over a four month period. This produced total civilian radiation exposures amounting to 120 million person-rads of thyroid tissue exposure (about 32% of all exposure due to continental nuclear tests).

https://www.atomicheritage.org/history/operation-plumbbob-1957



DOE/EH-0491

Human Radiation Experiments
Associated with the
U.S. Department of Energy
and Its Predecessors

U.S. Department of Energy
Assistant Secretary for Environment, Safety, and Health
July 1995

Table. Some Examples of Radiation Experimentation on Humans

Date	Description	Institution

- Sources include: Atomic Heritage Foundation, “Human Radiation Experiments,” *AtomicHeritage* , July 11, 2017, at https://www.atomicheritage.org/history/human-radiation-experiments and McCally M, Cassel C, Kimball DG. U.S. government-sponsored radiation research on humans 1945-1975. Med Glob Surviv. 1994 Mar; 1(1):4-17.

Washington and Oregon State Penitentiary Experiments

- Dr. C. Alvin Paulsen used X-rays on the testicles of 64 prisoners at the Washington State Penitentiary in Walla Walla during the 1960s to find the dose that would make them sterile.

Response to Query

AEC HUMAN TESTICULAR IRRADIATION PROJECT

Beginning in 1963, AEC funded a series of radiation experiments using as subjects inmates at the Oregon State Prison. The inmates were irradiated at varying levels to determine the effects of such exposures on human fertility. The actual irradiations were completed in 1971. AEC continued to provide support for data analysis, and ERDA is currently providing funds to maintain custody of various medical specimens which were collected for preparation of scientific reports.

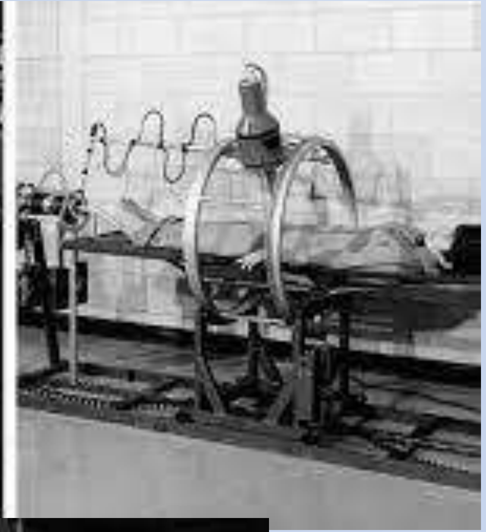
Willamette Week, a small Oregon weekly newspaper, printed a story dealing with the experiments on February 17, 1976.

Background

The experiments involved 67 prisoners at the Oregon State Prison at Salem. Dr. Carl C. Heller of the Pacific Northwest Research Foundation, Seattle, was the senior investigator. In December 1972, Dr. Heller suffered an incapacitating stroke; on February 22, 1973, Mavis J. Rowley, his senior

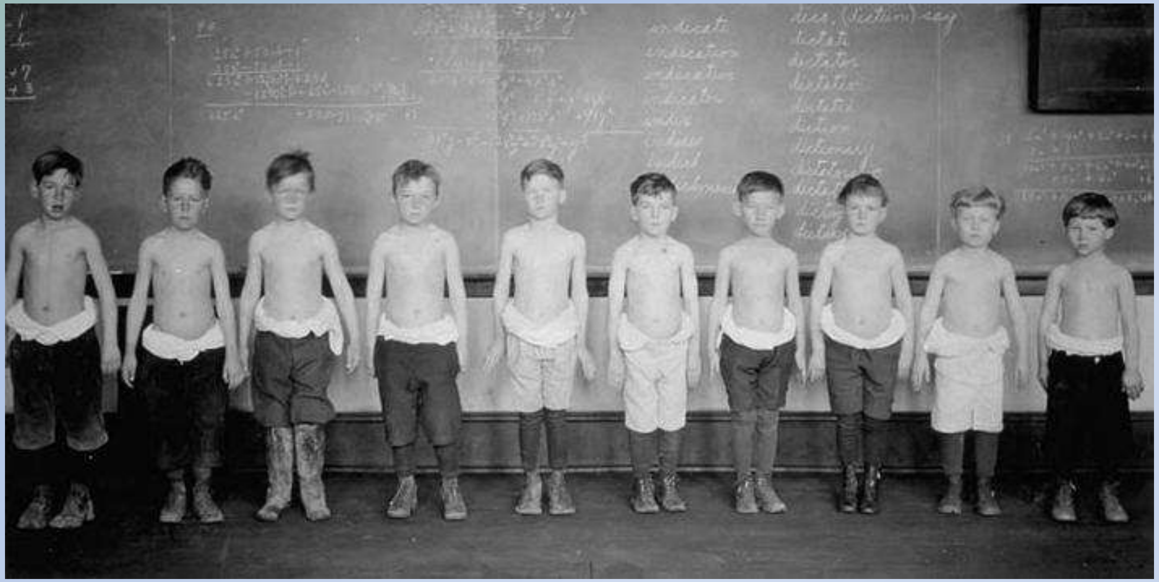
Experiments on Radiation, Health and Reproduction

- From 1963 Carl Heller received over$1 million in AEC funding on how radiation affects male reproductive function, and specifically on the doses of radiation that would produce changes or induce damage in spermatogenic cells. He designed a machine in which the subject lay face down with his scrotum in a small plastic box filled with warm water to encourage the testes to descend. A set of x-ray tubes produced beams that irradiated the scrotum.



- Pacific Northwest Research Foundation, proposal for Atomic Energy Commission, Division of Biology and Medicine, February 1963 ("Effects of Ionizing Radiation on the Testicular Function of Man") (ACHRE No. DOE-122994-A-2); Carl Heller, Pacific Northwest Research Foundation, 27 April 1967 ("Fifth Yearly Proposal, June 1, 1967-May 31, 1968") (ACHRE No. DOE-122994-A-2); Carl Heller, Pacific Northwest Research Foundation, May 1972 ("Effects of Ionizing Radiation on the Testicular Function of Man: 9 Year Progress Report") (ACHRE No. DOE-122994-A-2); Mavis Rowley, Division of Nuclear Medicine, Tumor Clinic, Swedish Research Hospital, undated ("The Effect of Graded Doses of Ionizing Radiation on the Human Testis: Progress Report, October 1, 1975-September 30, 1976") (ACHRE No. DOE-011895-B-3).

We suspect that nuclear researchers in a large number of countries carried out experiments on unknowing humans – fellow citizens.



AEC-funded MIT/Harvard Experiments on Children 1946-46 involving radioactivity.
Source: AHRP.

- The Boston Experimental School for Teaching became the Walter Fernald State School after its third superintendent who was a eugenics supporter.
- In 1946, Quaker Oats Company joined MIT and Harvard University researchers with AEC support to carry out a seven-year study on children's nutrition at the school. Neither the children nor their parents knew that the study involved putting radioactive tracers in the iron in the oats and the calcium in the milk to study how iron and calcium were absorbed into the body.
- As with the other "experiments" this one clearly lacked informed consent, took advantage of institutionalized children and was altogether morally specious. Did it differ in any way from experiments on nuclear soldiers?

From the first days of testing, military and scientific specialists studied radiation effects on flora and fauna

A twenty-five pound pig is removed from an aluminum barrel used during the Franklin shot's medical effects test. The pig containers were positioned at various distances from ground zero to measure radiation doses. Source: DOE, NNSA-Nevada Site Office.

A variety of farm and other animals were also anchored in nuclear bomb test zones to subject them to blast, burn and radiation and evaluate the impact of nuclear weapons on them.

At the NTS, for example, the US used the ”Priscilla” explosion of the Plumbbob series to test effects on 2,000 pigs and on other animals, including testing out special “protective” clothing for the animals.

On Operation Plumbbob - U.S. Army nuclear medical experiments on pigs at https://www.youtube.com/watch?v=nWHZFHX1gvI . See also Mary Jo Viscuso, et al., *Shot Priscilla: A Test of the Plumbbob Series, 24 June 1957, DNA 6003F* (Washington: DNA, February 27, 1981),

The Military World:
Production and Delivery of Nuclear Warheads

- Airplanes
- ICBMS
- Submarines

Soviet SS4 ICBM in Red Square

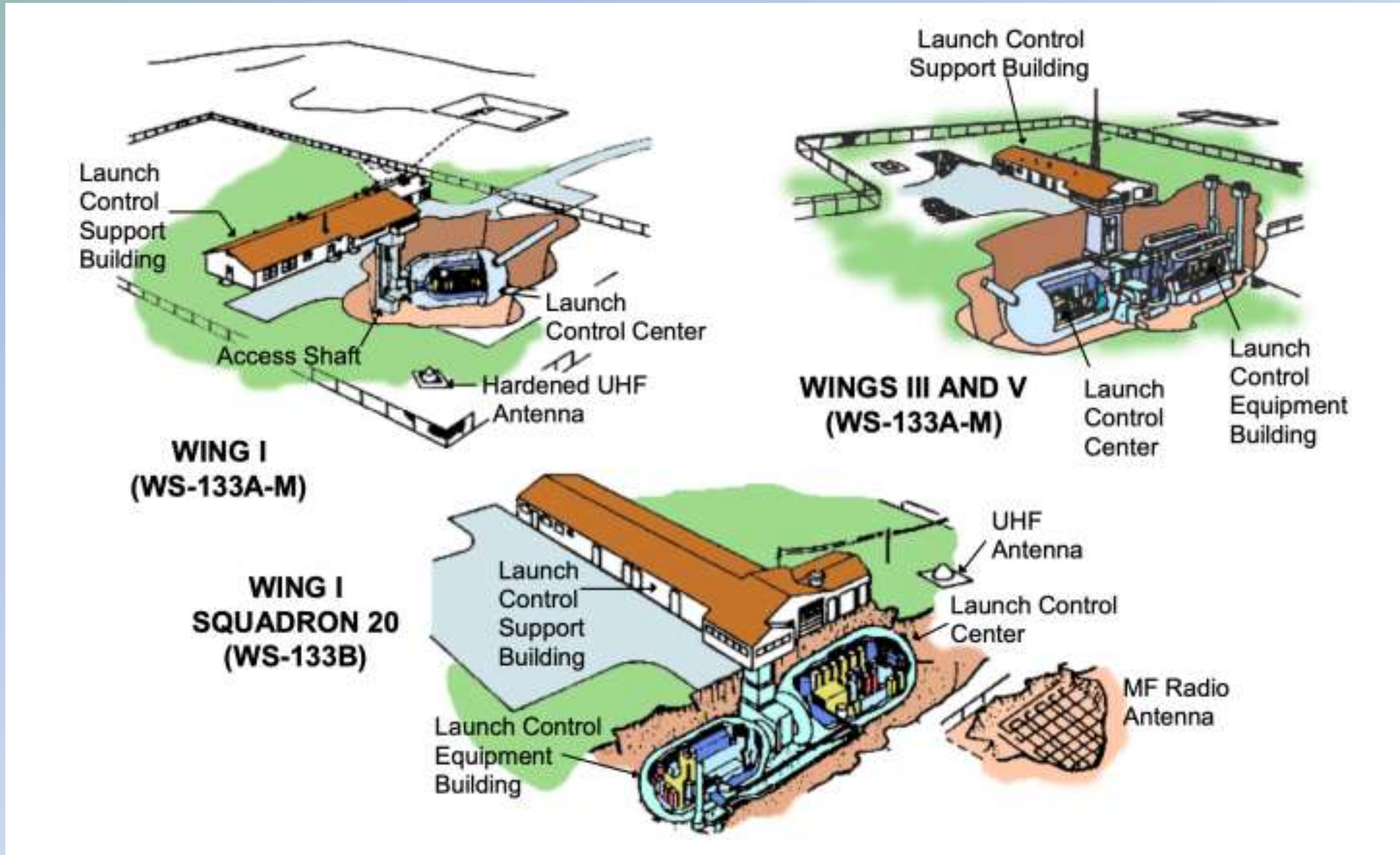
CIA reference photograph of Soviet medium-range ballistic missile (SS-4 in U.S. documents, R-12 in Soviet documents) in Red Square, Moscow.

By Central Intelligence Agency - http://www.gwu.edu/~nsarchiv/nsa/cuba_mis_cri/photos.htm, Public Domain, https://commons.wikimedia.org/w/index.php?curid=10213987

Minuteman III Missile Silo, Cooperstown, North Dakota

This facility was deactivated in 1997. By Chad Kainz - originally posted to Flickr as Minuteman ICBM Silo, https://commons.wikimedia.org/w/index.php?curid=10561613

Minuteman Missile Alert Facility



ICBM Prime Team, TRW Systems, *Minuteman Weapon System History and Description* (July 2001), p. 8. Declassified under FOIA

Jet Bombers Were Prepared Around the Clock to Deliver Nuclear Bombs: the B52s

- The US developed a fleet of B-52H Stratofortress bombers in preparation for nuclear war. They were attached to 25 air force bases around the world, mostly in the US. At any time a large number of B-52s was in the air at altitudes up to 15,000 m, prepared to carry out attacks.
- Introduced in the late 1950s, the US built 744 B-52s at 50 m long each with a range of 14,000 km and a maximum gross weight of 219,000 kg. The later models could carry up to twenty air-launched cruise missiles, and with advanced radars and targeting pods it could "see" targets day and night, in good weather or bad, using precision laser-guided bombs, conventional bombs and GPS-guided weapons). B-52s will be the mainstay of bomber defense until 2050.

- https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104465/b-52h-stratofortress/#:~:text=A%20total%20of%20744%20B,20%20air%2Dlaunched%20cruise%20missiles.

From Air Force Bases the World's Belligerents were Prepared to Annihilate the Enemy

- One of the major US bases, Minot in North Dakota, opened in 1957, and was designated a Strategic Air Command base in the 1960s, with nuclear ICBMs, manned bombers (B52s) and aerial refueling aircraft. The US had over 5,000 fixed-wing aircraft including bombers. B-52 runways were at least 3 km in length to handle the weight of the bombers.
- In 1961, the Air Force selected the land around Minot AFB for a Minuteman ICBM complex. By the 1970s, there were 150 missile sites around the region, from 15 to 120 km from Minot. They were located on leased farmland.

Minot, North Dakota, AFB

Submarines are a central part of the global nuclear environmental history

- From their nuclear reactors – with many submarines carrying two reactors – to their nuclear tipped SLBMs (submarine-launched ballistic missiles) to all of the enriched uranium and plutonium to power the boats and arm the SLBMs, to the waste generated in their operation and to their haphazard "retirement" (dumping in the oceans) and disposal, to accidents, and to post-Cold War decommissioning, nuclear manufacturing, submarines have been a major component of military environmental history.
- From the late 1950s through the end of 1997, the Soviet Union, and later Russia, built a total of 245 nuclear submarines, more than all other nations combined.
- According to the Federation of American Scientists, from 1973 the Soviet Union deployed ten different attack submarine classes, including five new types since 1980. In 1989 the Soviet Union also had sixty-six guided missile submarines for striking the enemy's land targets, surface combatant groups, and supply convoys.

Photo https://kipmu.ru/pochemu-v-sssr-moryaki-srochniki-sluzhili-dolshe-suxoputnyx/

Radioactive Waste Strewn Throughout the Globe

- A draft 2011 report to the Russian president later confirmed Rosatom indicated "enormous finds of radioactive waste and spent nuclear reactors in Arctic seas" that includes 17,000 containers of radioactive waste, 19 ships containing radioactive waste, 14 nuclear reactors, including five that still contain spent nuclear fuel; 735 other pieces of radioactivity contaminated heavy machinery, and the K-27 nuclear submarine with its two reactors loaded with nuclear fuel.
- In Andreeva Bay near Murmansk, Russia, in 1982, 600,000 of toxic water leaked from a nuclear storage pool into the Barents Sea. The navy kept spent fuel from more than 100 submarines in rusty canisters under the open sky.
- Eventually Russia and Western countries authorized billions of dollars to decommission and dismantle 197 Soviet nuclear submarines, dispose of strontium batteries from 1,000 navigation beacons and begin removing fuel and waste from Andreeva Bay and three other dangerous coastal sites.

It may be that Russia is finally cleaning up this area of the Kara Sea because of plans to accelerate oil and gas production in the region.

See Charles Digges, "Russia announces enormous finds of radioactive waste and nuclear reactors in Arctic seas," *Bellona*, August 28, 2012, at http://bellona.org/news/nuclear-issues/radioactive-waste-and-spent-nuclear-fuel/2012-08-russia-announces-enormous-finds-of-radioactive-waste-and-nuclear-reactors-in-arctic-seas.

Image credit: *Barents Observer*, March 8, 2020

In case of massive retaliation and nuclear annihilation ("Mutually Assured Destruction"), the leaders were protected

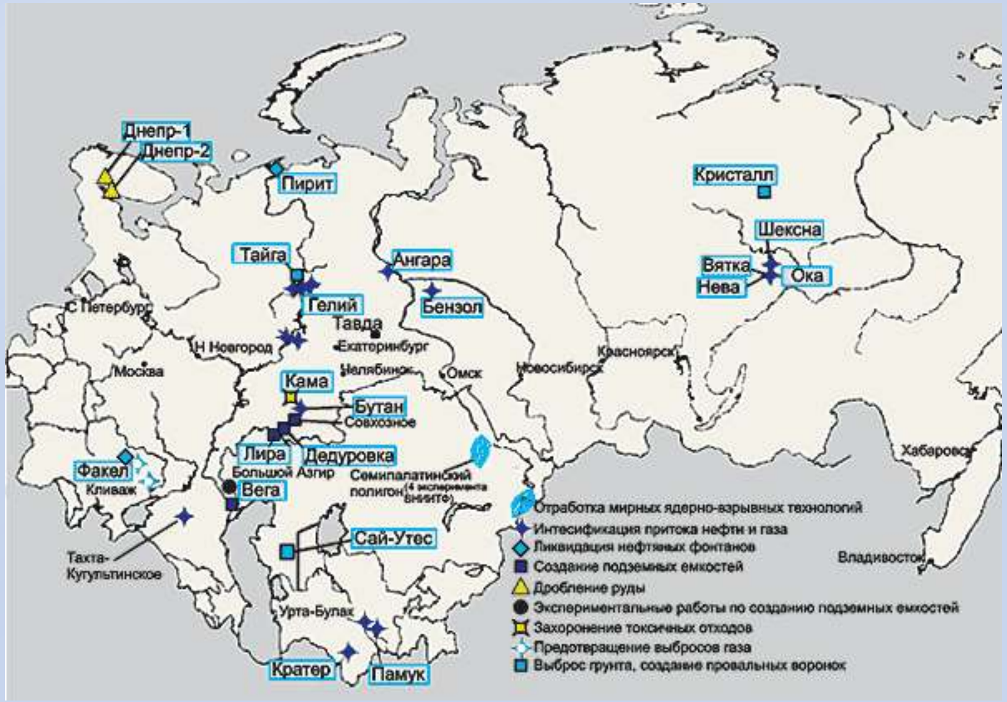
- Near White Sulphur Springs, West Virginia, a dormitory was built for lawmakers inside a nuclear bunker beneath Greenbrier, a four-star resort . The 34,000 m^2 bomb shelter, completed in 1961, included enough beds and supplies to house all 535 lawmakers and one staff member each

Peaceful Nuclear Explosions

PNEs (Peaceful Nuclear Explosions)

Both the United States and the Soviet Union pursued extensive programs for PNEs. The idea involved making the atom less frightening to the public, demonstrating to Cold War opponents that one's research and development program was on target to engage on any level, and finding economic value in the nuclear explosions. It was also to continue to test nuclear devices after the signing of the NPT.

Indeed, Leonid Brezhnev ordered the acceleration of the Soviet program in the 1960s at the time of increasing tension between the superpowers to demonstrate the technical skills of Soviet weapons designers and to contribute to the national economy. The Soviets conducted over 120 PNEs, 116 from 1965-1988, many at the 5-10 kiloton range, but also at 10-20 kilotons and even larger, with some local venting and pollution.



Nuclear Canals

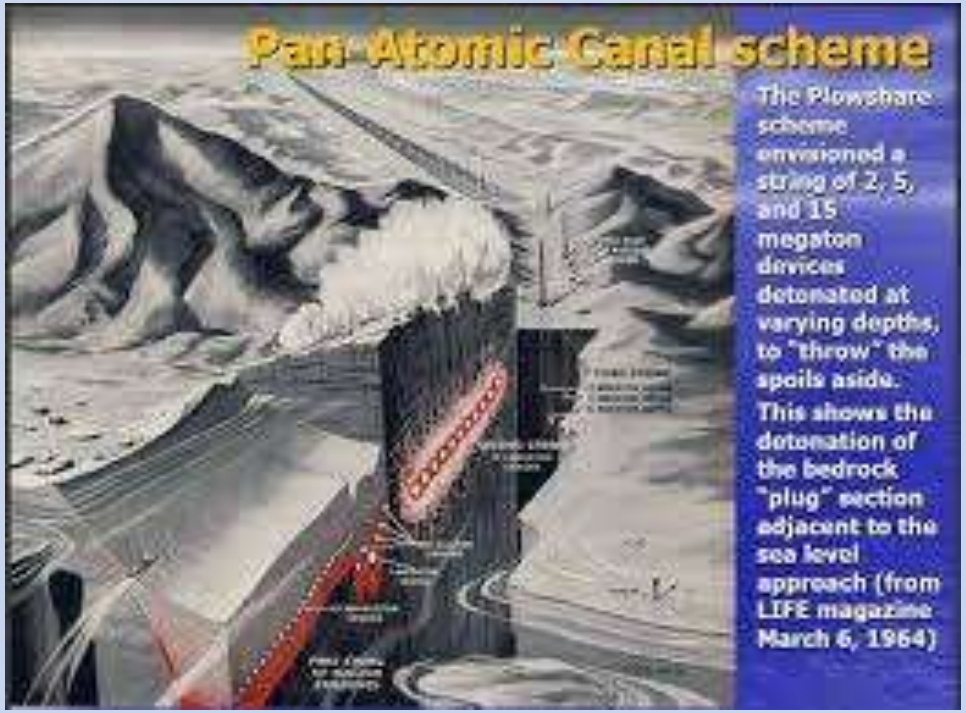
What couldn’t nuclear weapons do? They could put out runaway oil well fires, build underground storage caverns for hazardous waste, in a few moments create an earthen dam.

Yet there are a great deal of hazardous substances used and disposed of during production of nuclear weaponry. These include plutonium, uranium, benzene, polychlorinated biphenyls (PCBs), strontium, cesium, mercury and cyanide.

The Far-fetched: The Panatomic Canal Through Nuclear Excavation

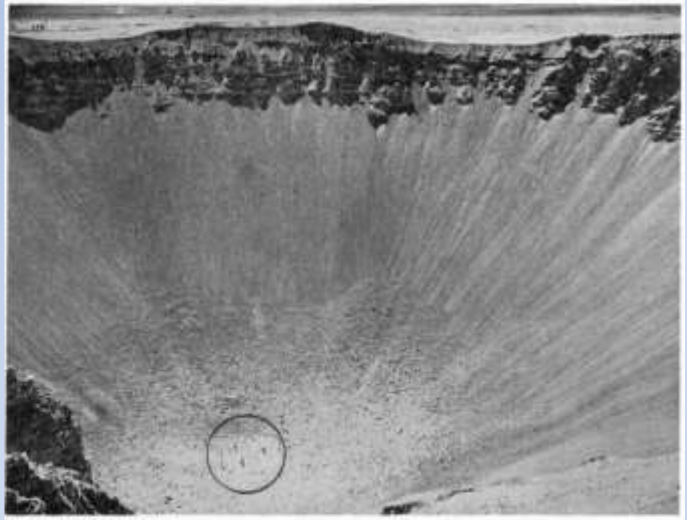
Advocates claimed that PNEs were the most economically feasible method of carrying out large engineering projects. For example, they provided one of only means of managing large gas field fires and destroying chemical weapons. (At the Deep Horizon BP Gulf of Mexico, oil well fire disaster in 2010, the idea to use a PNE to douse the well came up again.)

Yet, of course, PNEs were risky. They vented radioactivity. They produced fission products no matter what. And commercial use would lead to increasing numbers of nuclear devices, their location, and the risk of theft, misuse and terror.



The "Sedan" Thermonuclear PNE, Nevada

- The Sedan thermonuclear PNE (July 1962) at 104 kt was detonated 200 m underground. It ejected 12 million tons of debris and left a crater nearly 400 m across and 100 m deep
- The radioactive fallout from the test contaminated more US residents than any other nuclear test. Sedan shot a radioactive cloud that separated into two plumes, rising to 3.0 km and 4.9 km (10,000 ft and 16,000 ft). The plumes headed northeast and then east towards the Atlantic Ocean dropping fallout in particular in eight counties in Iowa and one county each in Nebraska, South Dakota and Illinois.



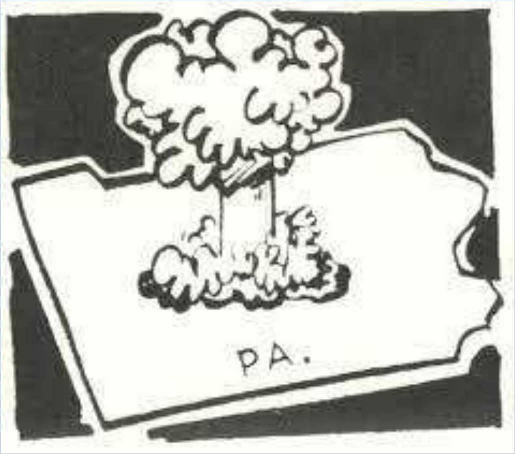
Project SEDAN Crater
Note Men Circled

Photos: Nevada Test Site - Nevada Operations Office (NVOO) Atomic Energy Commission Factbook 1969. For video of the test and plumes, https://www.youtube.com/watch?v=EeyEXkVAifM

The proponents of PNEs rarely addressed environmental issues, but spoke hopefully of profound economic impacts.

- Of the dozens of PNEs proposed, several were in highly populated regions, and all had the great potential to disrupt ecosystems including “Carryall” in the Mojave Desert, California, to cut through the Bristol Mountains while building Interstate Highway 40; project “Ketch” to create gas storage in the highly populated mid-Atlantic region in Pennsylvania; and the Tennessee/Tombigee Waterway in Northeast Mississippi to excavate 8 km at up to 100 m wide as part of a 250-mile long canal. It would have used 81 bombs with total yield of 1.9 MT .

- On Ketch, see Krygier, J. B. “Project Ketch: Project Plowshare in Pennsylvania.” *Ecumene* 5, no. 3 (1998): 311–22. http://www.jstor.org/stable/44252111. Image from Penn State Archives



The Real Environmental Dangers: PNE of Lake Chagan, Kazakhstan

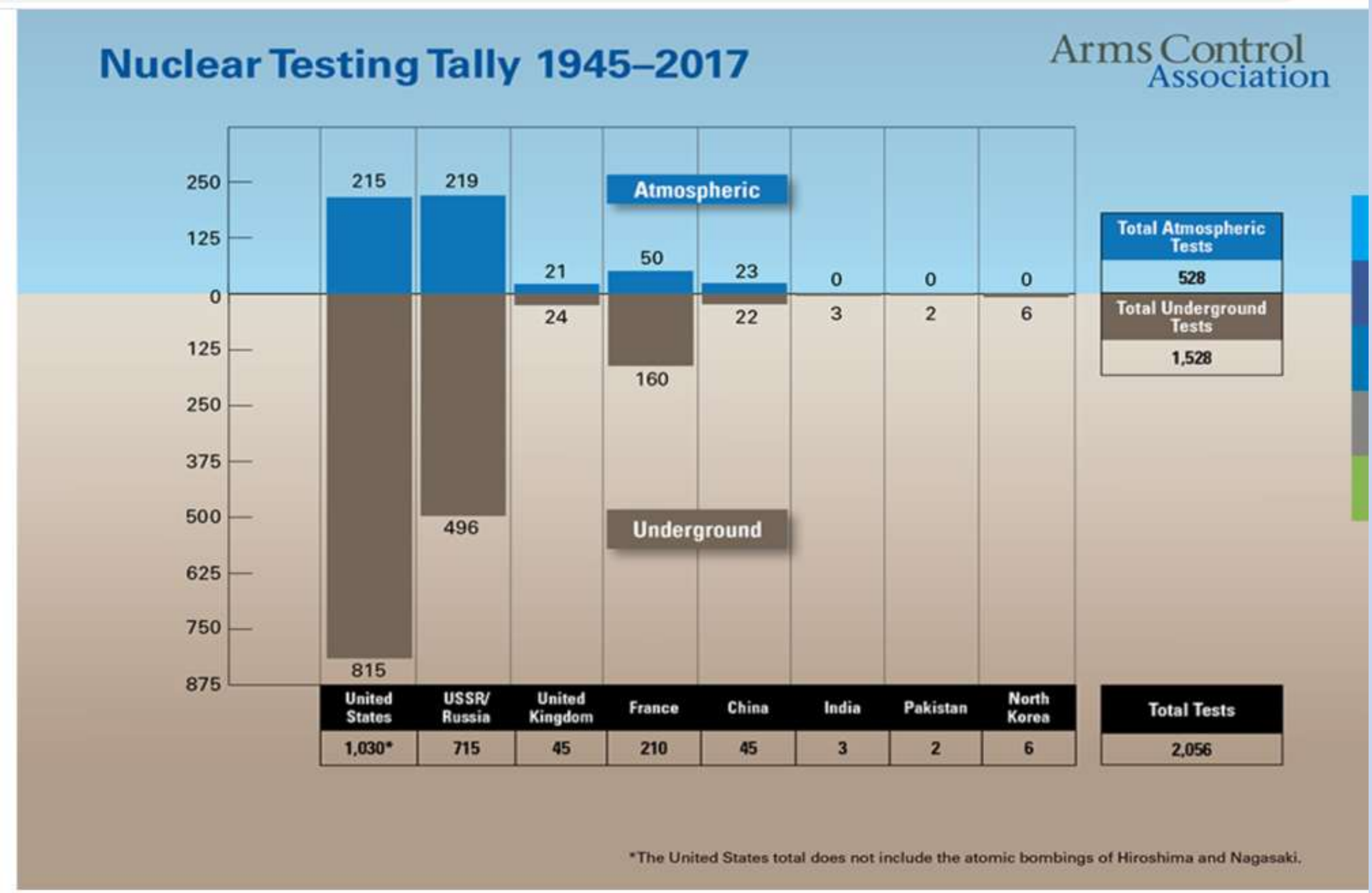
- Lake Chagan was excavated with a 140-kt underground nuclear explosion, on January 15, 1965. Chagan was the first and largest of the Soviet PNEs for earth-moving purposes, on the dry bed of the Chagan River, a tributary of the Irtysh River, selected for the explosion to dam the river during the spring freshet precisely to create a reservoir. The crater formed by the Chagan explosion had a diameter of 408 m and a depth of 100 m.
- The lake was an abject failure in all ways owing to the intense radioactive residues and rocks left behind, although to this day Russian newspapers report it as being a success. Roughly 20% of the radioactive fission particles from the explosion escaped into the atmosphere, and some of it was detected as far away as Japan.
- Fifty years later the lake had 100 times more than the permitted level of radionuclides in drinking water, and radioactivity reached background levels only 150 meters from the shore.

See Olga Bugrova, "Ne Pei Voditsu, Mutantonm Stanesh': Kak v SSSR Delali Ozera," *Radiosputnik*, January 15, 2021 at https://radiosputnik.ria.ru/20210115/chagan-1593021557.html; Elanur Ural, "Kazakhstan's Atomic Lake," at https://erainstitute.org/kazakhstans-atomic-lake-what-you-should-know/. For the test explosion at Chagan, see "Chagan. Atomic Lake," December 20, 2009, at https://www.youtube.com/watch?v=ZAoSUIASET0.

PNEs for Mining in the Russian Arctic: Khibiny Mountains, Kola Peninsula

- PNEs conducted 30 km from Kirovsk in the Khibiny Mountain range indicate both the hopefulness of the physicists, engineers and planners to find economic value in nuclear explosions, and the great risks and dangers they must ignore when they justify bold and powerful explosions in the name of peace.
- The goal was experimental nuclear explosions at the mines of the Apatit combine in Kirovsk, itself built with prison labor in the 1930s. The major question was if PNEs could be used for underground mining to crush ore. A first explosion was conducted in September 1972, followed by another in 1984. The operations, designated Dnieper-1 and Dnieper-2, were carried out in utmost secrecy. The explosions were powerful enough to pulverize the ore into fine granules and dust, apparently saving cost for ore grinding.
- But the explosion was for naught, both because of radioactivity and because the planners failed to build roads to get heavy equipment to the mines.

Photo: A. Marakhovets at
https://yablor.ru/blogs/dlya-chego-ustraivali-yadernie-vzri/6670866


Nuclear Testing Tally 1945–2017
Arms Control Association
250
125
0
125
250
375
500
625
750
875
215
219
21
50
23
0
0
0
24
22
3
2
6
160
496
815
Atmospheric
Underground
Total Atmospheric Tests
528
Total Underground Tests
1,528
United States
USSR/ Russia
United Kingdom
France
China
India
Pakistan
North Korea
1,030*
715
45
210
45
3
2
6
Total Tests
2,056
*The United States total does not include the atomic bombings of Hiroshima and Nagasaki.

Nuclear Power and the Environment

Nuclear Power and the Environment

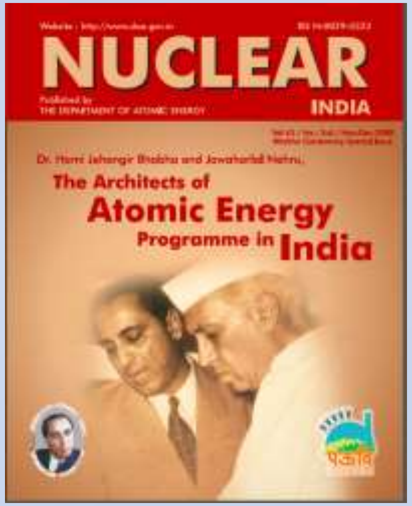
- In the early 1950s a number of nuclear nations began to pursue peaceful nuclear applications and in particular nuclear power. They moved quickly from experimental reactors to industrial prototypes and full scale models within twenty years. The understanding of engineers of the potential environmental impacts including accidents was incomplete at best, and in many cases they refused to consider fully those costs: thermal pollution, land use, water use and waste management issues all remained.

“Atoms for Peace” and the Rise of Atomic Energy

- In December 1953 US President Dwight David Eisenhower addressed the United Nations, calling for the nations of the world to pool their uranium resources, nuclear technologies and know-how to support the development of peaceful nuclear programs. He counted on the participation of the USSR in the creation of an International Atomic Energy Agency under UN auspices.
- He believed that through “Atoms for Peace,” and the international cooperation and mutual understanding it engendered, the nations of the world might avoid an ever-accelerating arms race and the growing threat of nuclear war. And like many people in the 1950s, he believed in the unlimited power of the atom to improve the human condition through “energy too cheap to meter,” nuclear medicine, agricultural applications, and even nuclear transportation.
- ”Atoms for Peace” indeed led to the spread of nuclear technologies, including crucially NPPs, throughout the globe with the environmental impacts covered in this photographic essay.

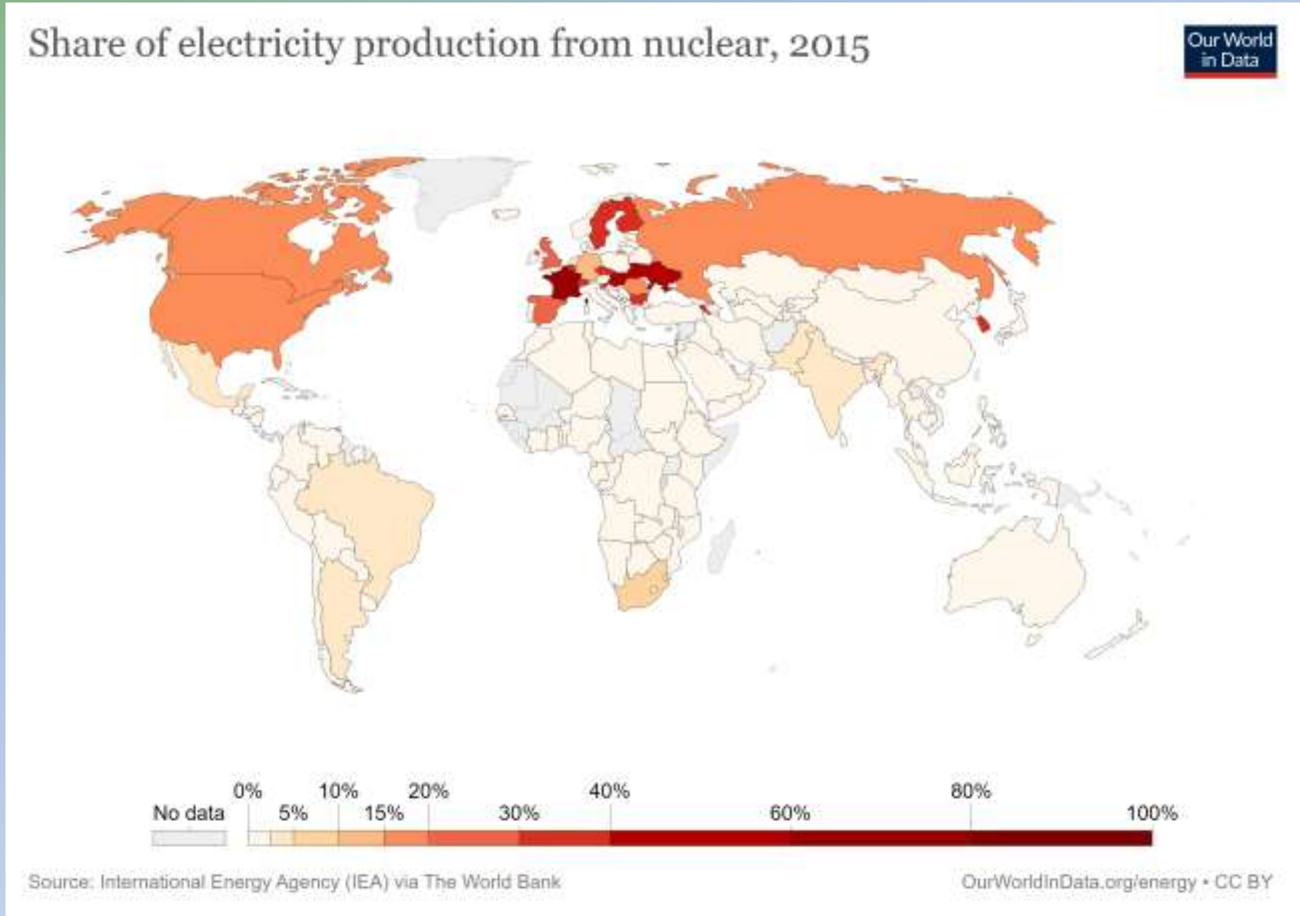
Within a few years of Eisenhower's speech, the nations of the world embarked on building hundreds of NPPs.

Source: https://www.flickr.com/people/nrcgov/.
These photos are in the public domain



- In India, reactors as "temples" of the future, and its leaders claimed that democracy's success depended on electricity.
- "Atoms for Peace" exhibitions were held throughout the world.

Share of Electricity Production from Nuclear, 2015



For many nations, nuclear energy is an energy independence lifeline and a hedge against reliance on fossil fuels.

Yet when it came to where to site stations, what safety systems were sufficient, the appropriate operating culture, and other questions tied to the environment, they assumed that nuclear power fully met their design criteria.

Share of electricity production from nuclear, 2015. Uploaded a work by Our World in Data from https://ourworldindata.org/grapher/nuclear-energy-electricity-production?tab=map&time=2015 with UploadWizard

The first nuclear power stations

- Reactor technology developed quickly in a race to commercialize nuclear power – and to demonstrate to the world unquestioned scientific leadership.
- The Soviets built the first reactor to power the civilian grid at Obninsk at 5,000 kW that started operation in 1954.
- In some ways, this station was a forerunner of the Chernoybl type RBMK that was 200 times larger.
- For a 1955 film on this station, see: https://www.youtube.com/watch?v=c3gYniHy4Vk (Научно-популярный фильм о первой в мире промышленной атомной электростанции, построенной в СССР в г. Обнинске. ЦСДФ, 1955

Obninsk construction

From the early days, visions of the use of atomic energy to control and conquer nature prevailed.

- The Soviets saw nuclear power as a way to power arctic exploration and assimilation with small reactors, ice breakers, and other nuclear technologies.
- A notable case was the Bilibino NPP in Chukotka.

"From whence we came and whither we go. →

[Билибинская АТЭЦ](). **[ippe.ru]()**
774-279 от 8 октября 1965 г. О проектирова →

The US response to Soviet achievements was to build the Shippingport, Pennsylvania, USA, NPP

Shippingport NPP, the first US full-scale nuclear power generating station which began operating in 1957. A 60-MWe PWR, it was decommissioned in 1982. Its cost per kW was about ten times that for subsequent reactors (e. g. Yankee Rowe, the next station). But its importance was to demonstrate the peaceful atom before the Soviets and the world.

Video tour of "Atomic Power at Shippingport : Nuclear Power Plant – 1957" at https://www.youtube.com/watch?v=_Ig5l5pxkB0

Source: http://www.mbe.doe.gov/me70/history/photos.htm (originally; now 404. Mirrored on [1]), Public Domain, https://commons.wikimedia.org/w/index.php?curid=249584

Rivers serve nuclear power: An Ohio River nuclear biography

- Because of demands for water for cooling, cleansing, and so on, rivers were often selected as sites for NPPs and other facilities.
- The Ohio River boasts Shippingport; the Zimmer NPP near Cincinnati, to be built with two GE BWRs but cancelled due to cost overruns and falsified safety records; Beaver Valley, PA, with two PWRs, on 400 hectares near Shippingport; the Marble Hill, Indiana, site, with 2 PWRs, abandoned at $2.5 billion in 1984, where construction problems led to a six-month NRC inspection; and the Padukah, Kentucky, Uranium enrichment site, in operation from 1952 to 2013, and the site of extensive pollution.

Source: George Campbell at https://commons.wikimedia.org/wiki/File:93-01-xx,_Zimmer_Power_Plant,_Cooling_Tower_(6707491805).jpg

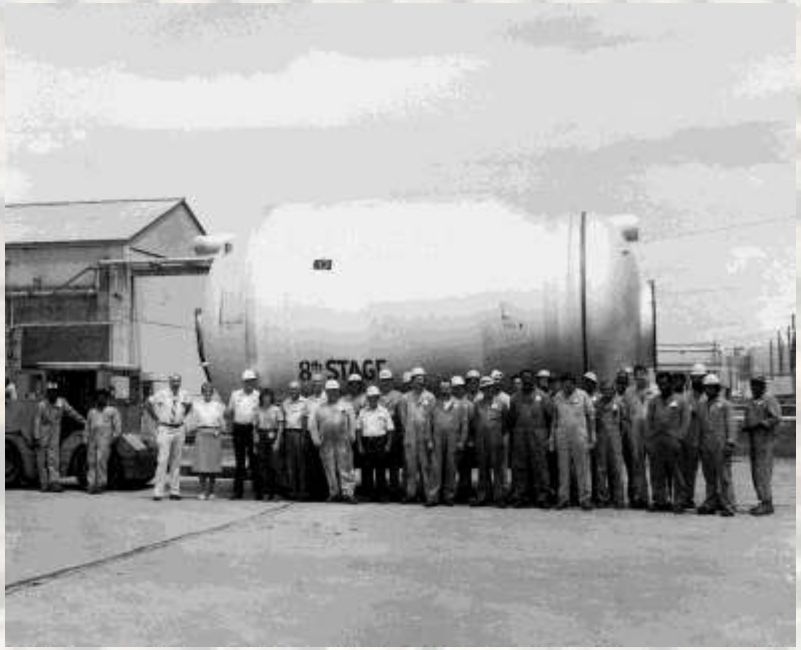
Abandoned nuclear power stations sit on the Ohio River (that empties into the Mississippi River)

Here, the Marble Hill, Indiana, site, on the Ohio River, with 2 PWRs, abandoned at $2.5 billion in 1984.

https://orangebeanindiana.com/2020/01/09/marble-hill-nuclear-plant/

Paducah, Kentucky, Gaseous Diffusion Plant (PGDP) on the Ohio River

- The Paducah Gaseous Diffusion Plant (PGDP) was constructed in 1952 to produce enriched uranium, initially for the nation's nuclear weapons program and later for nuclear fuel for commercial power plants.
- More than 60 years of uranium enrichment operations and support activities generated hazardous, radioactive, mixed (both hazardous and radioactive), and non-chemical (sanitary) waste. Past operations also resulted in soil, groundwater, and surface water contamination. Environmental investigations have been conducted since the 1980s to understand the extent of contamination. More than $2 billion already spent. https://www.energy.gov/pppo/paducah-site/paducah-environmental-remediation



A converter at the Gaseous Diffusion Plant in Paducah, Ky., formerly used to "enrich" uranium. In the public domain. https://commons.wikimedia.org/wiki/File:A_converter_at_the_Gaseous_Diffusion_Plant_in_Paducah,_Ky._(14492442327).jpg; Waste barrels, Department of Energy

In July 2020, the U.S. Attorney's Office and FBI charged the speaker of the Ohio House of Representative and four others in a $61 million scheme to use $1 billion in ratepayers money to keep two decrepit nuclear power plants (Davis-Besse and Perry) operating.

Ryan Haggerty, USFWS, "Nuclear Power Plant on the Ohio River" at https://digitalmedia.fws.gov/digital/collection/natdiglib/id/15315

Pastoral Images: The Machine in the Garden

Pastoral Images: The Machine in the Garden

Many of the images we have of NPPs are those of clean, shiny buildings in pastoral settings as if to indicate the compatibility of nuclear power with environmental balance -- the need to produce electricity, but to do so safely and with low risk and cost.

Dukovany, Czech Republic, NPP Four Soviet-made PWRs (VVER), online from the 1980s
Public Domain,
https://commons.wikimedia.org/w/index.php?curid=363064

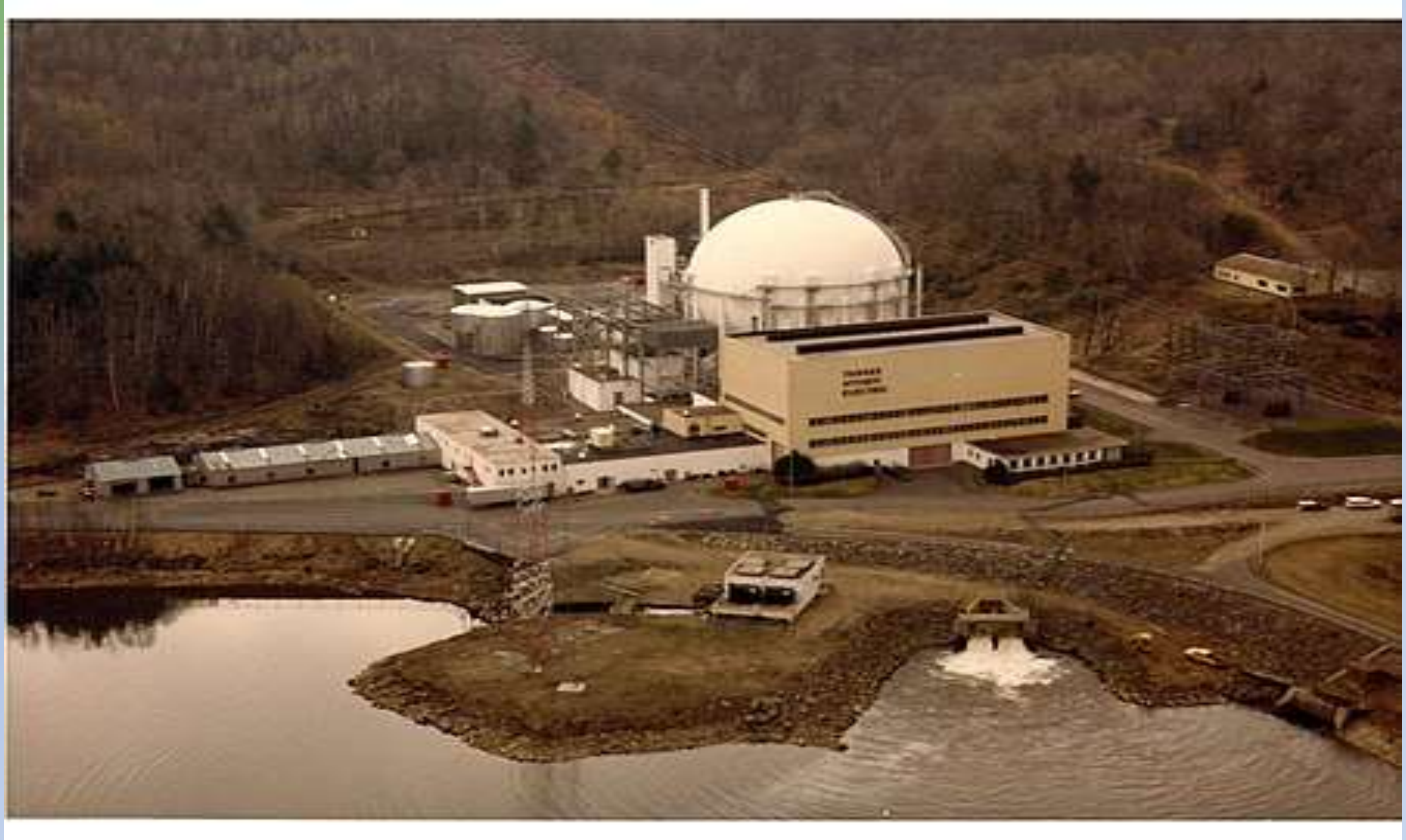
Representations of the first NPPs showed simple, geometric structures, most often in fields or meadows.

"Atoms to Kilowatts" PR brochure, published by Commonwealth Edison.

The Dresden, IL NPP, on the Des Plaines River, 110 km southwest of Chicago. It was the first privately financed NPP in the US. It experienced 25 fined accidents between 1970 and 1996. Unit 1 was retired in 1978; units 2 and 3 (BWRs) have been extended to 60 years operation. See GE, "Atomic Venture" (1961) on Dresden (https://youtu.be/WmaPc27Avvw).

Credits: American Nuclear Society and https://atomicpowerreview.blogspot.com/2011/06/atomic-history-dresden-1.html?m=1

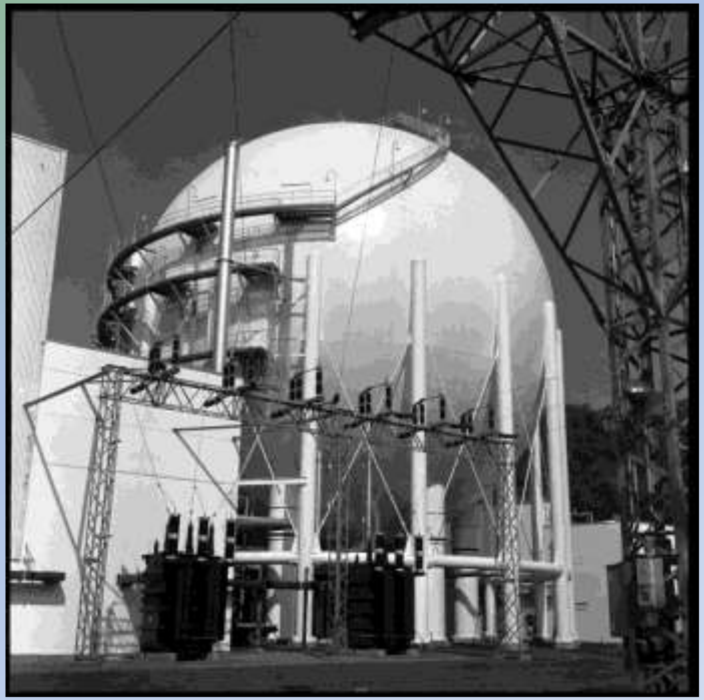
Cooling towers are up to 200 meters tall and 100 meters in diameter. Many NPPs have multiple towers to deal with the effluent and coolant water. See J. C. Hensley, Ed., *Cooling Tower Fundamentals, 2nd Edition* (Marley Cooling Tower Co., 1985).



The steep decline of the Deerfield River in Western Massachusetts powered hydroelectric stations. The Yankee Rowe NPP, 1960-1992 (185 MW) was built here in the late 1950s.

Photo source: NRC. On decommissioning
https://www.yankeerowe.com/decommissioning.html

“Yankee Atomic” (1960)



Yankee Atomic: view from above over the plant and the Deerfield River; and view of the spherical containment building, both July 12, 1960. University of Massachusetts Amherst Photo Negative Collection (RG 171). Special Collections and University Archives, University of Massachusetts Amherst Libraries

Liquid Metal Fast Breeder Reactors (LMFBRs)

Superphenix (1974-1998 when shut down because of massive cost overruns and miserable performance record) at Creys-Malville, Isère, France at https://commons.wikimedia.org/wiki/File:Superph%C3%A9nix.jpg. Yann Forget. © Yann.

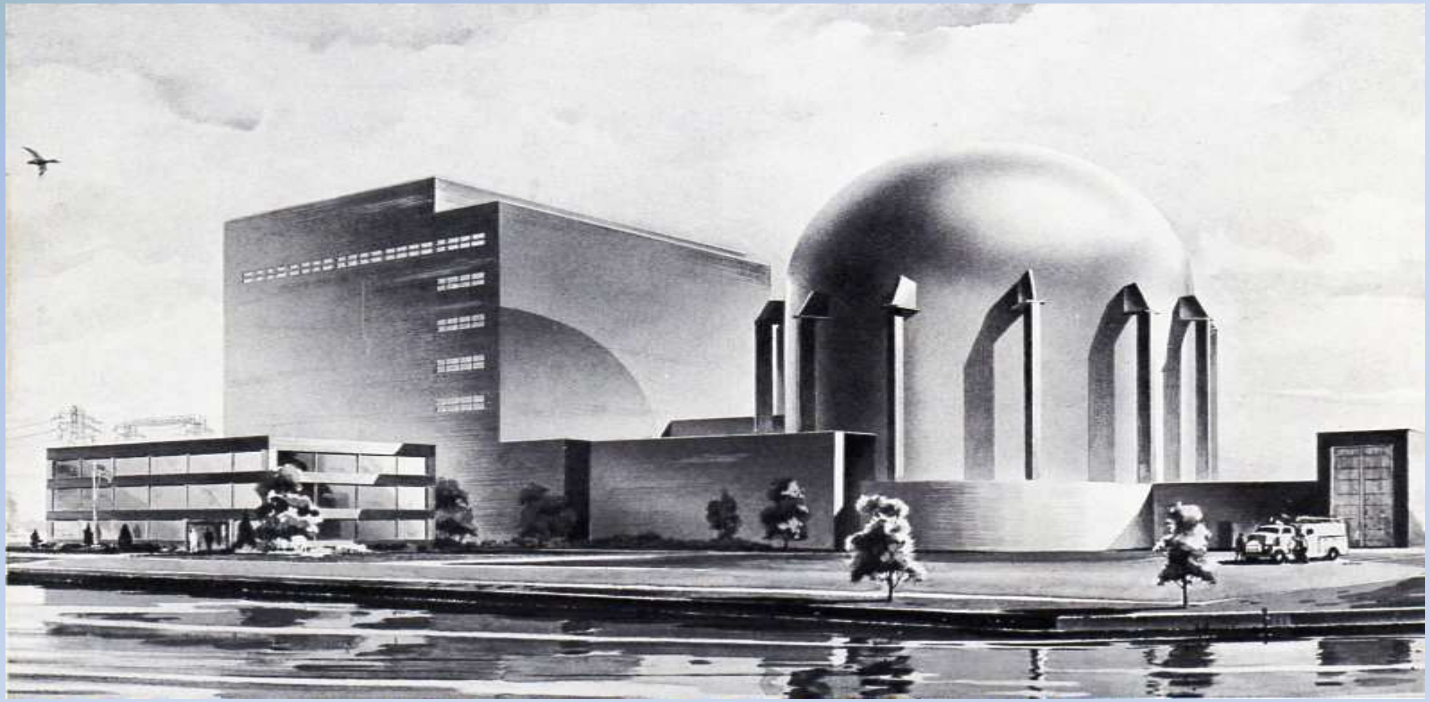
LMFBRs "breed" plutonium. They use fast neutrons to transmute non-fissile uranium 238 in the reactor core into fissionable plutonium 239 which could be used to fuel other reactors – or for nuclear weapons.

Breeder reactors have had a checkered history throughout the world in Japan, France and the former USSR. They have suffered cost overruns, accidents, sodium spills and fires.

At present only Russia is pursuing this technology

The Enrico Fermi LMFBR (Detroit, MI).

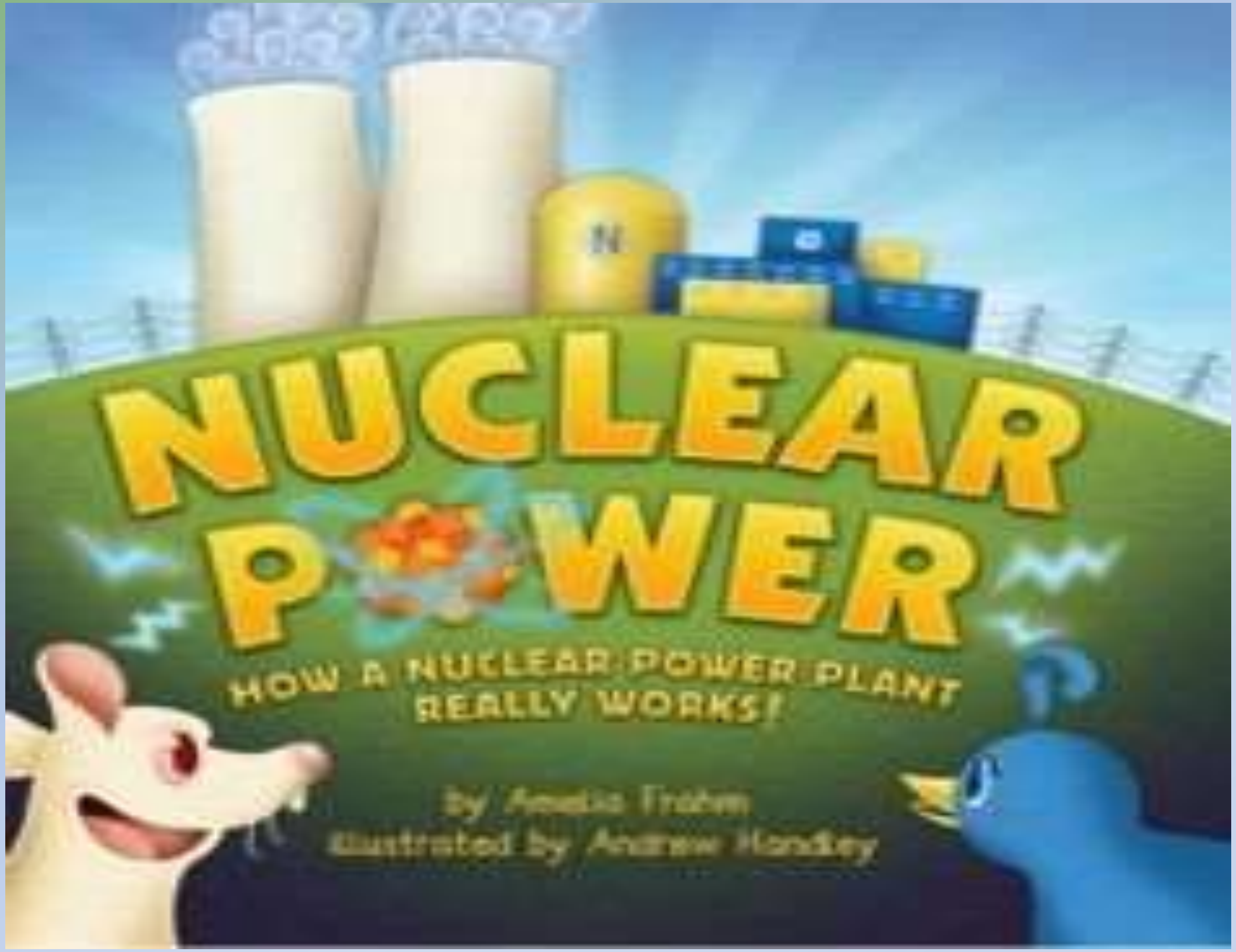
The US permitted the operation of the Fermi LFMBR in the early 1960s when there was no experience or procedures to deal with an accident and coordinate the responses of plant, state and federal officials. The reactor achieved criticality in 1965. Subsequent testing revealed difficulties in controlling power level, temperatures in the sodium coolant higher than normal, fuel assemblies having abnormally high temperatures. On October 5, 1966, the reactor suffered a meltdown, radiation entered the building triggering alarms, and operators determined only 10 minutes later to scram the reactor manually – the reactor had failed to shut down automatically. The meltdown could have caused havoc in one of the largest cities in the US. By 1972 the utility had given up hope and shut the facility down. It stored radioactive sodium on site until 1984.



Nuclear Modernism

Artist's conception of Enrico Fermi NPP (LMFBR)(1955) at https://www.ans.org/news/article-1786/nuclear-power-reactor-technology-1950-1953-part-ii/. See also John Fuller. 1975. *We Almost Lost Detroit* (New York: Reader's Digest Press, 1975); Union of Concerned Scientists (UCS). 1970?. "Fermi Unit 1," http://www.ucsusa.org/sites/default/files/legacy/assets/documents/nuclear_power/fermi-1.pdf accessed December 24, 2016.

Green Visions of Nature in Coloring Books



Industry appeals to children through comforting coloring books and posters of happy animals and green pastures. These images are intended to establish calm, confidence and trustworthiness. The children in turn help shape parents’ beliefs.

Fauna are at home with nuclear power: reindeer in the Arctic feed nearby; according to industry, fisheries thrive.

- The Kola NPP is the first to be built in a difficult Arctic climate in the 1970s; there are plans to add at least one 600 MWe PWR by 2030.
- The station uses coolant water effluent drawn from Lake Imandra to raise sturgeon and salmon in the NPP’s fishery.

Source: Kola NPP

Nuclear power also powers the city, turns on the lights, heats homes, and strengthens commercial centers where before there were only fields and meadows.

Here the Khmelnitskaia NPP in Ukraine, home to two 1000 MWe PWRs with two under construction. Ukraine generates over half its electricity from nuclear power, even post-Chernobyl.

Photo source: Khmelnitskaia NPP.

Power station operators and utilities stress the commensurability of NPPs with natural surroundings, habitat and biodiversity

Duke Energy owns 58,200 MW of electricity operated by approximately 29,000 employees in a service area of 270,000 km^2 with 402,700 km of distribution lines. The company operates 11 nuclear units at six sites. Yet employees, stations, power lines and so on "are a great place for wildlife."

When NPPs are decommissioned, or when they are halted by bankruptcies, paradoxically they may become places for recovery of ecosystems

- Shoreham NPP consisting of GE BWRs on Long Island Sound, built 1973-1984, and had initial power tests, was shut down over the absence of an evacuation plan after the Three Mile Island and Chernobyl accidents. This cost the utility, LILCO, $6 billion. The site has become a nature reserve of sorts.

Photo source: http://architectdenied.blogspot.com/2014/06/alternative-portfolio-2.html

Decommissioning will become more frequent and more challenging as the number of reactors retired increases

YEAR	GLOBAL NUCLEAR POWER CAPACITY	NUMBER OF REACTORS
31 Dec. 1997	348 GW	434
31 Dec. 2007	372 GW	439
31 Dec. 2017		
WNA (including reactors in long-term outage)	392 GW	447
WNISR (excluding reactors in long-term outage)	353 GW	405

- Excluding reactors in long-term outage, the number of reactors has declined by 29 over the past 20 years, while capacity has grown by a negligible 1.4% (5 GW). Over the past ten years, the reactor count is down by 34 and capacity is down by 9.5% (19 GW). To meet this problem, the industry is extending and extending the operating lives of reactors intended to operate for 20 years, perhaps 30 years. The average age of reactors in 2017 was 29.3 years, and over half have operated for 31 years or more.
- The International Energy Agency forecasts a "wave of retirements of ageing nuclear reactors" and an "unprecedented rate of decommissioning," with almost 200 reactor shut-downs between 2014 and 2040.
- International Atomic Energy Agency predicts 320 GW of retirements by 2050 – "in other words, there would need to be an average of 10 reactor start-ups (10 GW) per year just to maintain current capacity. The industry will have to run hard just to stand still."

Decommissioning and Cleanup costs for NPPs may make pastoral parables harder to proffer.

- Shippingport closed on October 1, 1982. Dismantlement of the facility began in September 1985. Three years later its nearly 1,000 T reactor pressure vessel assembly was lifted out of the containment building to prepare for shipment for burial at Hanford, Washington. The site has been cleaned up and released for unrestricted use. Nearby Beaver Valley NPP Units 1 and 2 continue to produce electricity.
- Promoters of nuclear power say the $98 million (1985 estimate) cleanup of Shippingport demonstrates successful reactor decommissioning, while critics point out that Shippingport was smaller than most commercial which are about 1,000 Mwe. Maine Yankee (860 MWe PWR) decommissioning took 8 years and cost $500 million.
- Thus, a recent NRC estimate that decommissioning and cleanup at $300 to $400 million a reactor is likely a significant undercount, and there have been no provisions for who ultimately will pay.

Decommissioning of Maine Yankee.
Source: Manafort Brothers

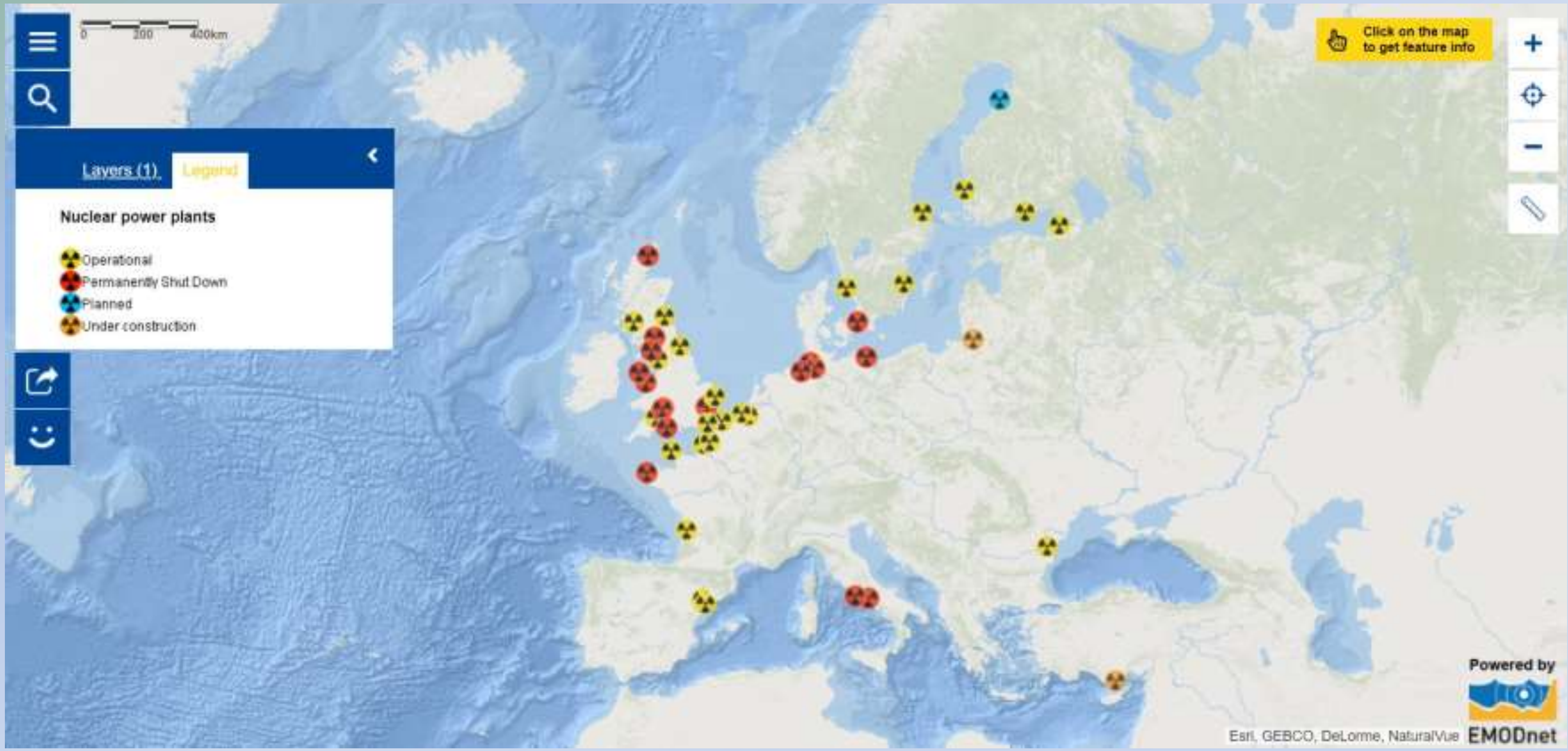
Ecosystems: Oceans and Deserts

Oceans and the Atom

Nuclear power stations located on Indian, Japanese, US and European coasts; dumping sites for nuclear waste including high level waste – spent nuclear fuel, reactor carcasses, and other material; a place of violent megaton and higher nuclear blasts: this is the nuclear ocean. Russia alone has dumped in the Arctic Ocean, mostly in the Kara Sea, 17,000 containers of radioactive waste, 19 ships containing radioactive waste, 14 nuclear reactors, including five that still contain spent nuclear fuel; 735 other pieces of radioactivity contaminated heavy machinery, and several nuclear submarines.

See Jacob Hamblin, *Poison in the Well: Radioactive Waste in the Oceans at the Dawn of the Nuclear Age* (New Brunswick, NJ: Rutgers University Press, 2008); Kasperski, Tatiana, "From Legacy to Heritage: The Changing Political and Symbolic Status of Military Nuclear Waste in Russia," *Cahiers du Monde Russe*, vol. 60, n°2-3, 2019, pp. 517-538. See also A. V. Yablokov, et al., *Fakty i Problemy Sviazannye so Sbrosom Radioaktivnykh Otkhodov v Moria, Primykaiushchie k Territorii Rossiiskoi Federatsii* (Moscow : Priemnaia Pezidenta Rossiiskoi Federatsii, 1993), and Charles Digges, "Russia announces enormous finds of radioactive waste and nuclear reactors in Arctic seas," *Bellona*, August 28, 2012, at http://bellona.org/news/nuclear-issues/radioactive-waste-and-spent-nuclear-fuel/2012-08-russia-announces-enormous-finds-of-radioactive-waste-and-nuclear-reactors-in-arctic-seas

European Coastal Nuclear Power Plants



- **Coastal Nuclear Power Plants, *Emodnet, 1*9** July 2019, at https://emodnet.ec.europa.eu/en/map-week-%E2%80%93-coastal-nuclear-power-plants

Oceans: Bikini Atoll

A coral reef in the Marshall Islands consisting of 23 island surrounding a 594.1 km^2 central lagoon. The US Army removed the atoll's residents 1946 and carried out 23 nuclear exploisions until 1958. Promised they would be able to return to their homes, to this day the Bikinians have not owing to significant radiological dangers.

Bikini Atoll. Public Domain, https://commons.wikimedia.org/w/index.php?curid=103678

The Runit Radioactive Waste "Dump"


Runit Dome on the Enewetak Atoll of the Marshall Islands. (The Asahi Shimbun/Getty Images)

The 115 m diameter Runit Dome nuclear-waste site (an atomic bomb crater) contains 87,800 m^3 of radioactive waste that 4,000 US servicemen filled with plutonium-contaminated soil and other atoll radioactive waste. They covered the crater with a 45-cm thick, non-load-bearing concrete cap to protect the waste mound. But seawater is leaking in from below, and rising waters may crack or submerge the concrete. Yet the DOE disquietingly noted that the inventory of fallout radionuclides in atoll lagoon sediments is so great that the "catastrophic failure" of the concrete dome "and instantaneous release of all its contents into the lagoon will not necessarily lead to any significant change in the radiation dose delivered to the local resident population."

Terry Hamilton, A Visual Description of the Concrete Exterior of the Cactus Crater Containment Structure, LLNL-TR-648143. (Livermore, CA: DOE, LLNL, 2013), p. 1.

Hinkley Point NPP, England

Site of decommissioned Magnox reactors dating to the late 1950s and 1960s (using 16 hectares), Hinkley Point, on the southwestern coast of England, is now the site of construction of two EDF 1,630 MWe PWRs that are years behind schedule and billions of pounds over cost. The site is 174 hectares.

The plant includes a 900 m seawall 11.5 m high to intended to withstand stormsurge, Tsunami and sea level rise.

Hinkley Point Nuclear Power Stations (A left, B right) from the South West. By Richard Baker, CC BY-SA 2.0, https://commons.wikimedia.org/w/index.php?curid=4404731

Diablo Canyon NPP, San Luis Obispo, California

- On the Pacific Coast
- 2 @ Westinghouse PWRs ~ 1120 Mwe
- Massively overcost and delayed
- A 300 hectare site
- Built near active earthquake faults
- To be shut down in 2025 in response to Fukushima

The nuclear fueled Diablo Canyon Power Plant — in San Luis Obispo County, California. By Marya from San Luis Obispo, USA - Flickr, CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=1372113

The Indian Ocean: Seven of India’s 10 NPPs -- and 23 of its 33 reactors – are on its eastern and western coasts.

- Jaitapur NPP, near Mumbai, India
- When finished, the station will be largest in the world at 6 x 1650 MWe Fromatome reactors on 968 hectares
- At early stage of development.
- 400 kilometers south of Mumbai, with cooling water drawn from Rajapur Bay of the Arabian Sea rich in perch, mackerel, sardines. But these fisheries are already under threat from warming ocean temperatures.
- Moderate risk of earthquakes
- Significant protests; repressive police response.

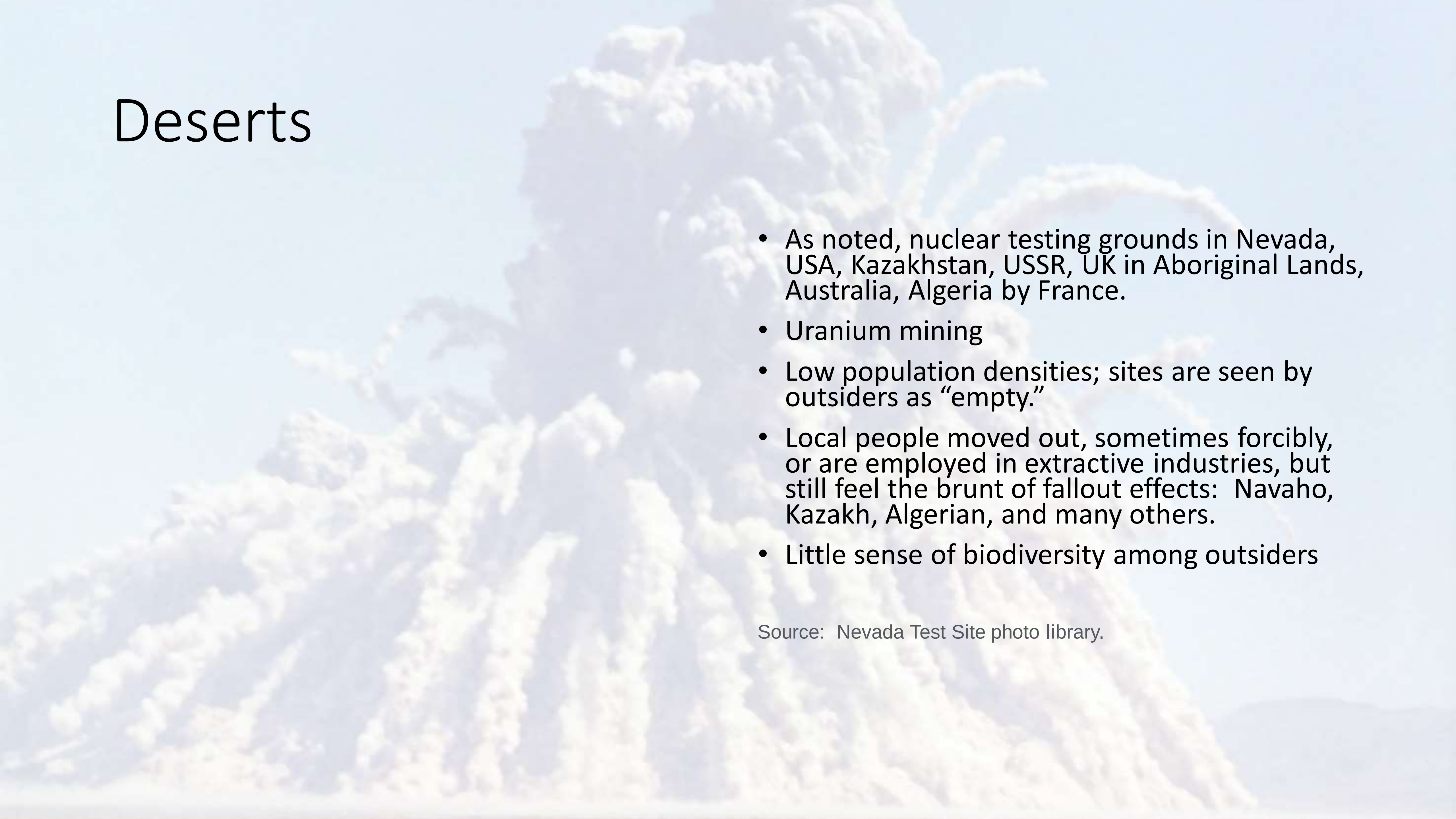
Kundakulam NPP on southeastern Indian coast near Sri Lanka

- "We are, and have always been, fisher folk; we rely on the sea for our livelihood. The people here – their ancestors have been in this region for hundreds, perhaps thousands of years. This has always been our land. If we give our land up, we become rudderless, our lives will become rudderless. Our movement is a struggle – a struggle for our land – what else? The people here, all of us who took part in this, we did it to tell that government that this land isn't barren, that it is inhabited by people, that the people rely on the land here, so please build your nuclear plant elsewhere."

Chandra Kesava Varigonda Kesava, "Anti-nuclear Movements in India: The Case of Kovvada, Andhra Pradesh," *ISAS* (Institute of South Asian Studies National University of Singapore) Working Paper No. 259 (June 15, 2017), p. 12.

Deserts

- As noted, nuclear testing grounds in Nevada, USA, Kazakhstan, USSR, UK in Aboriginal Lands, Australia, Algeria by France.
- Uranium mining
- Low population densities; sites are seen by outsiders as “empty.”
- Local people moved out, sometimes forcibly, or are employed in extractive industries, but still feel the brunt of fallout effects: Navaho, Kazakh, Algerian, and many others.
- Little sense of biodiversity among outsiders

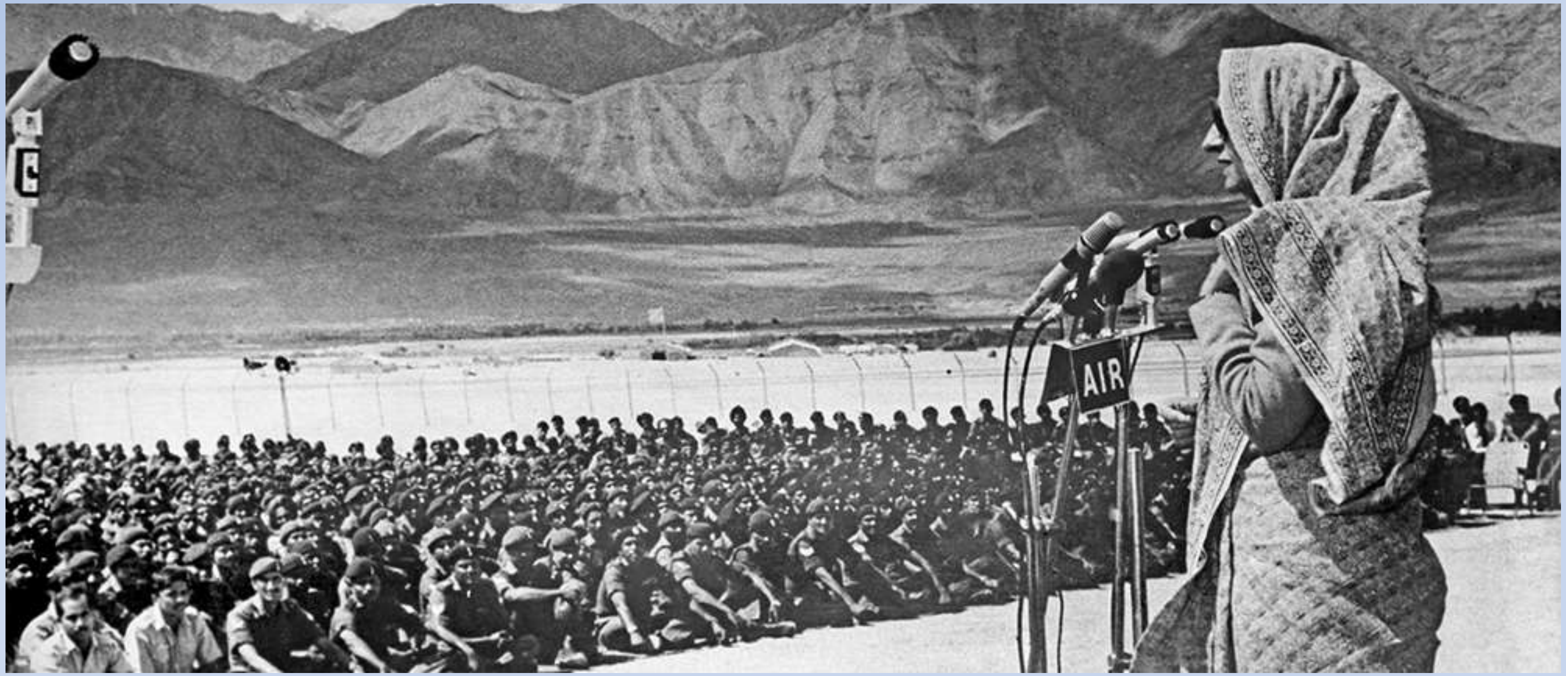


Source: Nevada Test Site photo library.

Indira Gandhi Addresses Soldiers at Thar Desert Nuclear Test Site (Pokhran), India, 1974

The Thar Desert occupies an arid region in the northwestern part of the Indian subcontinent with an area of 200,000 km² and forms a natural boundary between India and Pakistan. India tested its nuclear weapons here including its first, “Little Buddha.”

Of course, Buddhist thought condemns any kind of violence.



Source: https://indiragandhi.in/en/milestones/index/nuclear-program

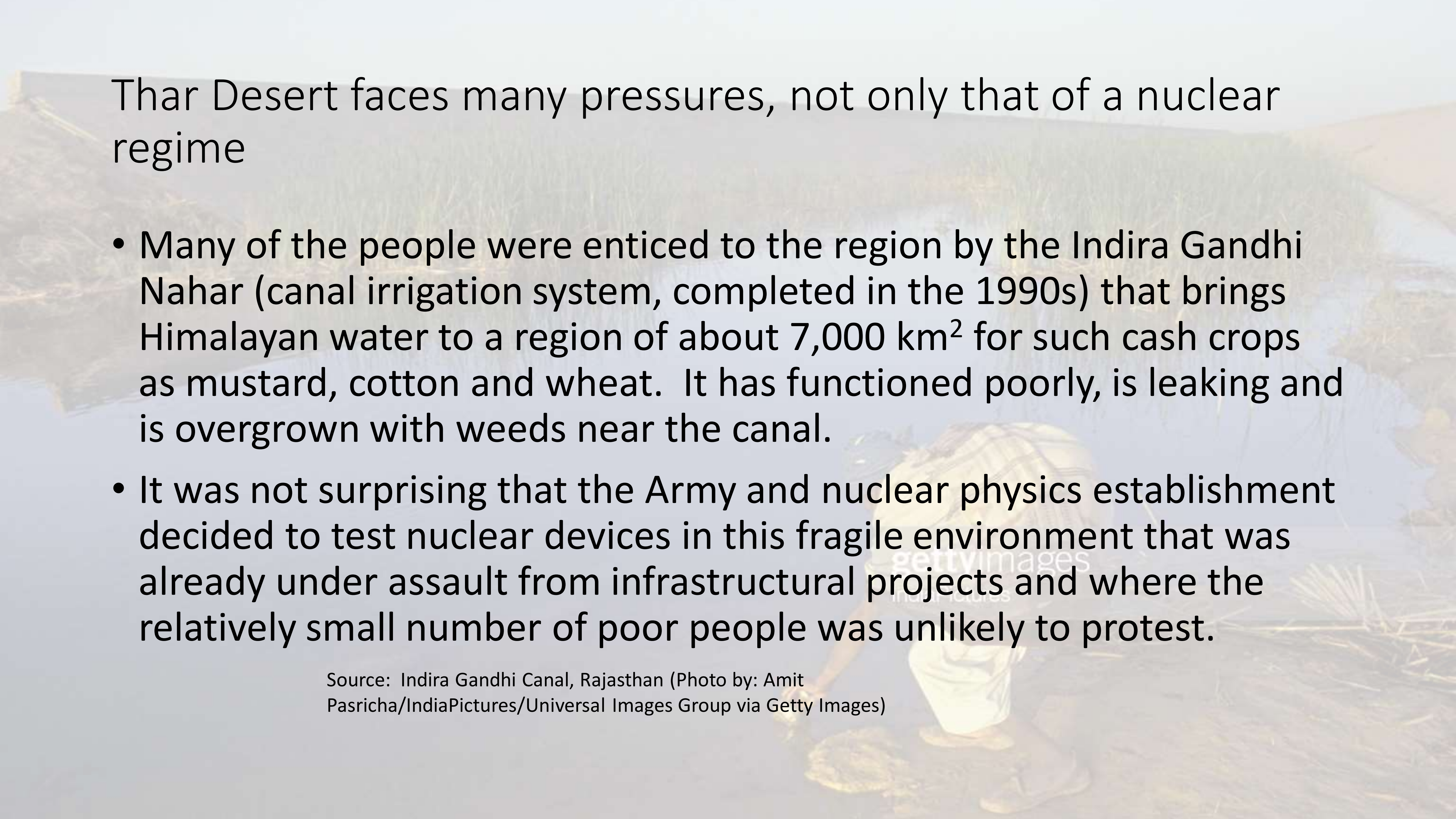
Thar Desert: Not barren, nor a place for nuclear tests

Source: https://www.urmul.org/the-thar/

- The hot arid western regions of Rajasthan have annual rainfall of less than 50 centimeters and with data indicating that drought cycles are increasing.
- Colonial rule and technology contributed to accelerated migration into the desert that continued after independence. The British pursued tree planting and irrigation to transform what they perceived as unproductive and wasted land into farmland, at the same time increasing the tax base.
- The Thar desert is the most populated desert of the world and has grown from 3 to 16 million with a human density of 75/km^2. Lions, cheetah, caracal and other animals were fairly common, but hunters have destroyed their populations. Settlers have transformed grassland into cropland with little left for wild species, while livestock have grown from 10 to 23 million in the last 30 years, depleting vegetation resources bringing with them field rodents and termites.

Thar Desert faces many pressures, not only that of a nuclear regime

- Many of the people were enticed to the region by the Indira Gandhi Nahar (canal irrigation system, completed in the 1990s) that brings Himalayan water to a region of about 7,000 km^2 for such cash crops as mustard, cotton and wheat. It has functioned poorly, is leaking and is overgrown with weeds near the canal.
- It was not surprising that the Army and nuclear physics establishment decided to test nuclear devices in this fragile environment that was already under assault from infrastructural projects and where the relatively small number of poor people was unlikely to protest.



Source: Indira Gandhi Canal, Rajasthan (Photo by: Amit Pasricha/IndiaPictures/Universal Images Group via Getty Images)

The Footprint of Nuclear Power Stations

The Footprint of Nuclear Power Stations

- Stations tout limited impact on ecosystems
- They point to no contribution to greenhouse gas emissions that make NPPs a great alternative to fossil fuel burning boilers
- Yet they require copious amounts of water to operate
- The land takings to build NPPs, especially since more and more of them are built in “fleets” of several require and require a large exclusion area, are not negligible.

Background: The Kashiwazki-Kariwa NPP, 7 BWRs, 8,000 MWe on 240 hectares of land on the Sea of Japan

The need for water resources

Seabrook NPP on the Bio-rich Hampton-Seabrook Estuary:

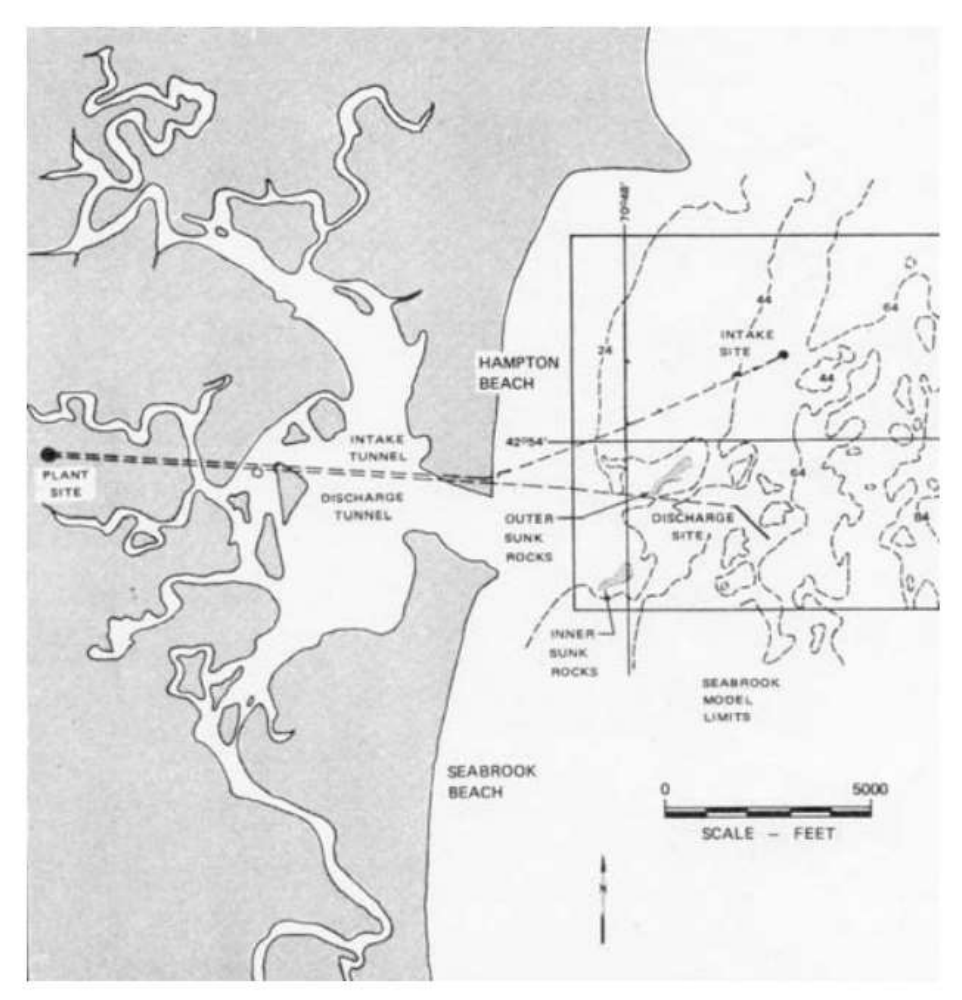
Biodiversity impacts are almost always s considered temporary and local.

- According to its owner, NextEraEnergy, “Seabrook Station is located on 900 acres on the seacoast of southern New Hampshire. The plant is operated in a highly responsible manner and is dedicated to protecting the environment while meeting the energy needs of New England.” Its Westinghouse PWR at 1250 MWe has been re-licensed to 2050 or to 60 years effective operation after extension in 2019.
- At 5000 acres, the Hampton-Seabrook Estuary contains the largest amount of salt marsh in the state. These marshes, along with their associated tidal flats, provide critical habitat for breeding and migratory birds, particularly shorebirds and salt marsh sparrows.
- A 1977 study on tide, water current, temperatures, salinity, phytoplankton, fish and invertebrates determined that impacts of the NPP would be temporary and local, mostly during the construction phase especially since species were spread over the entire Gulf of Maine. Acknowledging that “organisms too large to pass through the condenser cooling system such as squid and finfish may be drawn into the intake…trapped…impinged..and death unless escape is possible.”

- See Normandeau Associates, *Summary Document: Assessment of Anticipated Impacts of…Seabrook Station* (Bedford, NH: 1977), p. 5.0-67.Photo sources: Jim Richmond, Salt Flats at Wikipedia; Fisherman casts his line in an estuary near Seabrook NPP, Matthew Trump (2004), Wikipedia Commons.

Water requirements for once-through cooling

- Seabrook's one reactor (two were proposed, but Public Service of New Hampshire went bankrupt in 1992 trying to build the station) requires 2 million liters of cooling water daily. This need is met by once-through cooling utilized the Atlantic Ocean for intake and discharge. Environmental considerations dictated the intake and discharge ports to be over one mile off of the shore line, as well as local economic, public and other considerations. This resulted in the use of a hard rock tunnel and shaft system. The tunnels were TBM bored at 7 m diameter for a combined length of 10,000 m.
- PSNH failed because of "mismanagement by both PSNH and by government regulators. A three-year regulatory imbroglio over the environmental effects of the plant's cooling system was extremely costly in the mid-1970s. By the time this problem was belatedly resolved, the project had begun to outstrip the financial resources of its owners. These resources were seriously weakened by a political battle over how to pay for construction costs. Bupp, Irvin C. (1985) "Seabrook: A Case Study in Mismanagement," New England Journal of Public Policy: Vol. 1: Iss. 1, Article 6. Available at: http://scholarworks.umb.edu/nejpp/vol1/iss1/6
- Illustration Source: UCSUSA



Fisheries and NPPs

- NPPs coolant effluent raises the ambient temperature of waters 5 – 10 ^{o} C.
- The industry touts mastery of management of effluent so that the discharge water does not exceed 7°C above the ambient temperature of the receiving water bodies. For an Indian station, spokespeople claim that marine ecology studies at Jaitapur show no impact on local flora and fauna because the discharges warm only about 0.28 km^2 around the mixing point and mostly on the surface.

Nuclear Power Corporation of India Limited, “Misconceptions about nuclear power and Jaitapur in specific,” https://npcil.nic.in/WriteReadData/CMS/201712230226268356353Misconceptions_final_low_res.pdf, p. 5.

-

The insistent impact of nuclear power on local communities and local fisheries carries long term consequences.

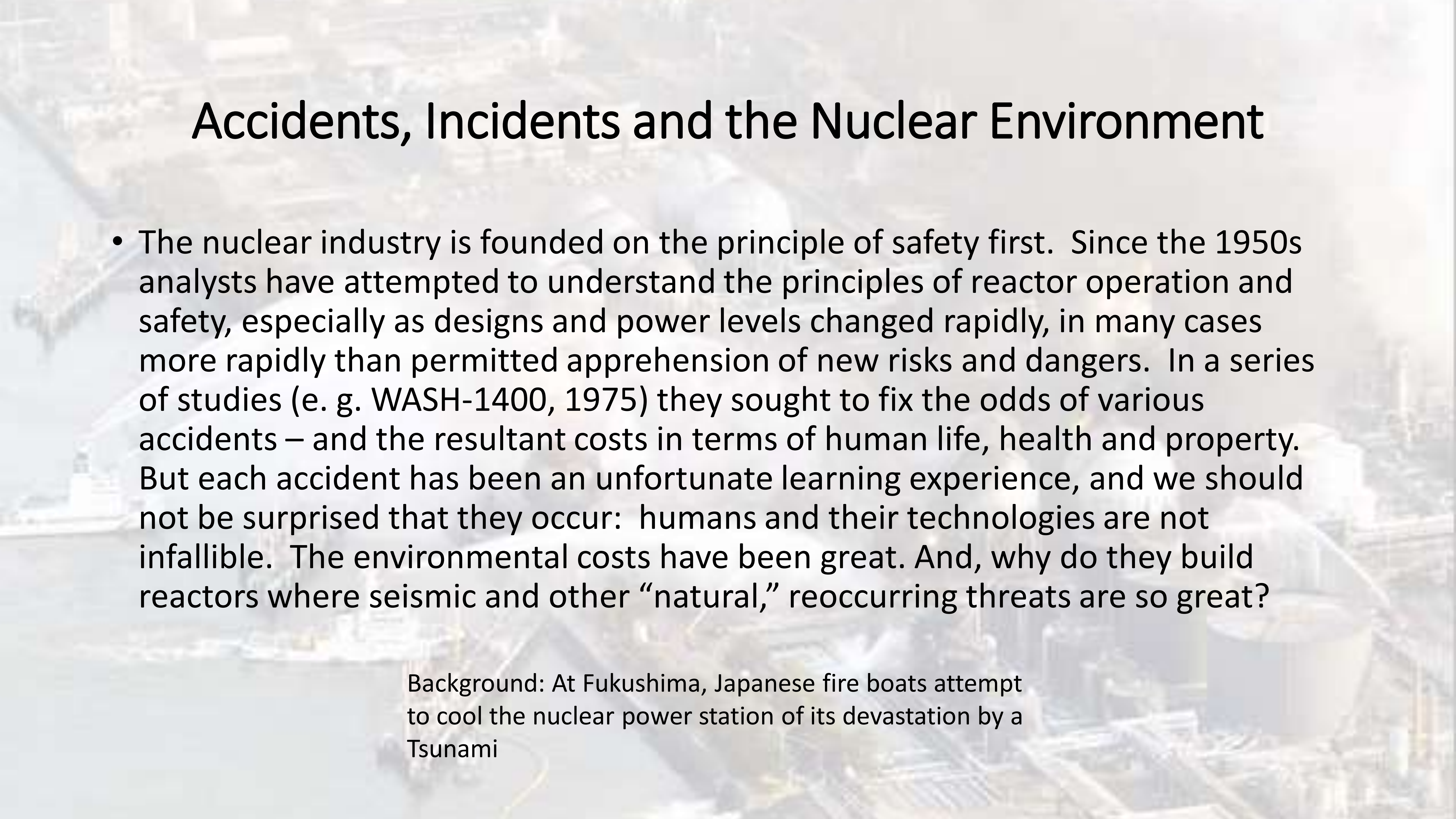
A fisherman with his lobsters on a Theripu day.↑

← Fishermen proceeding towards the Koodankulam Nuclear Power Plant to lay a siege on World Fishermen Day, 2011.

Amirtharaj Stephen
https://atomicphotographers.com/photographers/amirtharaj-stephen/

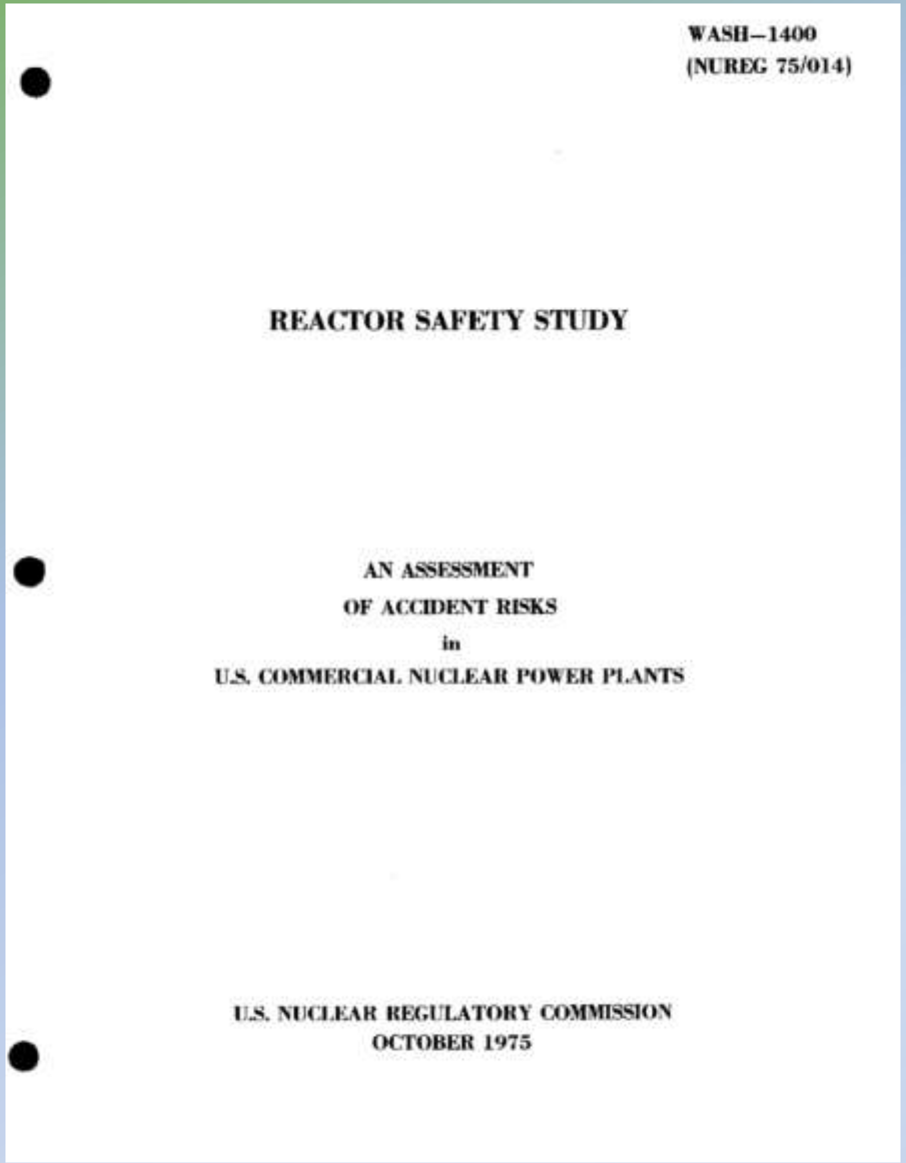
Accidents, Incidents and the Nuclear Environment

Accidents, Incidents and the Nuclear Environment



- The nuclear industry is founded on the principle of safety first. Since the 1950s analysts have attempted to understand the principles of reactor operation and safety, especially as designs and power levels changed rapidly, in many cases more rapidly than permitted apprehension of new risks and dangers. In a series of studies (e. g. WASH-1400, 1975) they sought to fix the odds of various accidents – and the resultant costs in terms of human life, health and property. But each accident has been an unfortunate learning experience, and we should not be surprised that they occur: humans and their technologies are not infallible. The environmental costs have been great. And, why do they build reactors where seismic and other “natural,” reoccurring threats are so great?

Background: At Fukushima, Japanese fire boats attempt to cool the nuclear power station of its devastation by a Tsunami


WASH–1400
(NUREG 75/014)

REACTOR SAFETY STUDY

AN ASSESSMENT
OF ACCIDENT RISKS
in
U.S. COMMERCIAL NUCLEAR POWER PLANTS

U.S. NUCLEAR REGULATORY COMMISSION
OCTOBER 1975

WASH-1400

Reactor Safety Study. An Assessment of Accident Risks in US Commercial Nuclear Power Plants (1975).

The study was strongly criticized on methodological and other grounds for underestimating costs, undercounting fatalities, and misconstruing probabilities.

Accidents, unintentional leaks, and disasters threatened the surrounding regions of these facilities

↑Maiak construction August 1946, Rosatom, at
https://yandex.ru/images/search?text=%D0%90%D1%82%D0%BE%D0%BC%D0%BD%D1%8B%D0%B9%20%D0%B7%D0%B0%D0%B2%D0%BE%D0%B4%20%22%D0%9C%D0%B0%D1%8F%D0%BA%22&from=tabbar&p=4&pos=139&rpt=simage&img_url=https%3A%2F%2Fpbs.twimg.com%2Fmedia%2FEbLPsvfXsAAaqUr.jpg

← 29 September 1957 Kyshtym Explosion
https://yandex.ru/images/search?text=%D0%9A%D0%B0%D1%82%D0%B0%D1%81%D1%82%D1%80%D0%BE%D1%84%D0%B0%20%D0%A7%D0%B5%D0%BB%D1%8F%D0%B1%D0%B8%D0%BD%D1%81%D0%BA%201957%20%D0%B3%20%D0%9C%D0%B0%D1%8F%D0%BA%20%D0%9E%D0%B7%D0%B5%D1%80%D1%81%D0%BA&source=related-duck&from=tabbar&pos=2&img_url=https%3A%2F%2Fsun1-85.userapi.com%2FDVCO79MS1KDoA3RabFKnpmnf0QPk7T31xibRlw%2FhJXNN0fTjjo.jpg&rpt=simage

Kyshtym Nuclear Waste Explosion (1957)

- Beginning in 1948 the authorities began dumping waste into the source of the Techa, the Kyzyltash Lake, where it was diluted five to ten times, and the Techa itself, using the river, “a gutter.”
- From 1949 to 1956 Mayak dumped an estimated 76 million m^3 cubic meters of radioactive waste water into the Techa, a cumulative dispersal of 2.75 MCi (102 PBq) of radioactivity.
- Perhaps the scientists believed that the swampy and slow-moving Techa was an ideal place for sedimentation of radioactivity, even if the tributaries of the Techa, including little streams and brooks, dried up in the summer, and even if there were nearly villages along the river.

Source: https://petitnicolas.livejournal.com/77098.html?thread=828458&rfrom=centuria1972

Dmitriy Evlanov, “The Techa River: 50 years of Radioactive Problems,” 2-4, in IAEA collection at https://inis.iaea.org/collection/NCLCollectionStore/_Public/33/011/33011261.pdf

The East Urals Radioactive Trace (EURT)

- After the initial dumping of waste led to serious radioactive exposures of the population of the villages on the Techa river, the high-level waste began to be stored mostly in tanks.
- On September 29, 1957, 20 MCi (740 PBq) of radionuclides were released by a chemical explosion in a radioactive waste storage tank at Maiak facility.
- Waste spread over 20,000 km^2 where more than 270,000 people lived to form the East Urals Radioactive Trace (EURT)
- More than a quarter of a million people were exposed to high levels of radiation

Techa River, Russia

The Techa River, a nuclear “gutter,” Urals region, Russia, used to store radioactive waste. Hundreds of thousands of individuals exposed over the decades.

Cows and a radiation danger warning sign at the river Techa By Ecodefense/Heinrich Boell Stiftung Russia/Slapovskaya/Nikulina, https://commons.wikimedia.org/w/index.php?curid=15911617

The “technical cascade of reservoirs”: The Techa River as a radioactive dump

- The Mayak enterprise belatedly ceased release into the Techa River of high- and intermediate level wastes.
- The engineers used a number of both natural lakes and artificial ponds that received the names of numbered “reservoirs” constructed roughly 1956-1965.

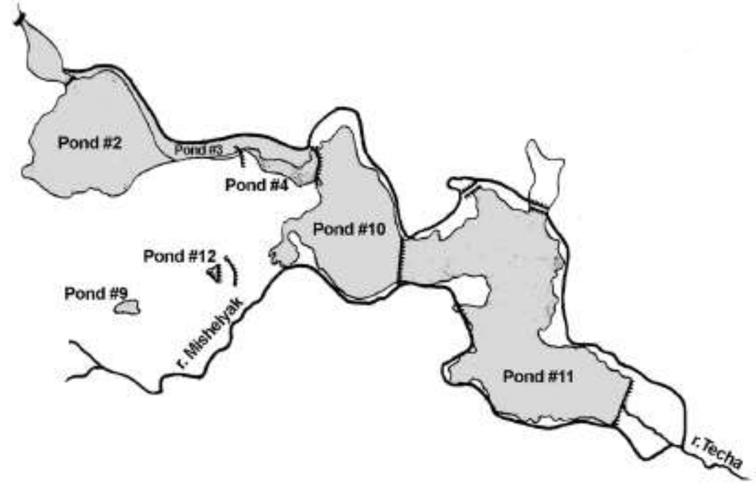


FIGURE 2. The Mayak’s technological ponds system

TABLE 1. The doses were received by inhabitants of localities above. (* Moved inhabitants) [1]

Settlement	Distance from the place of dump, km	Equivalent dose of irradiation, biological equivalent of roentgen				EED,ber
		Marrow	Bone surface	Large intestine	other organs and tissues	
Metlino*	7	164	226	140	127	140
Techa-brod*	18	127	148	119	115	119
Asanovo*	27	127	190	104	90	100
Nadyrovo*	48	95	180	62	44	56
Muslyumovo	78	61	143	29	12	24
Brodokalmak	109	14	31	7	3.3	5.8
Russkaya Techa	138	22	53	10	3.7	8.2
Novopetropavlovskoe	152	28	68	13	4.3	10
Shutiha	202	8	18	2.6	2.2	3.6
Zatechenskoe	237	17	40	8.4	3.2	6.6

…and Lake Karachai

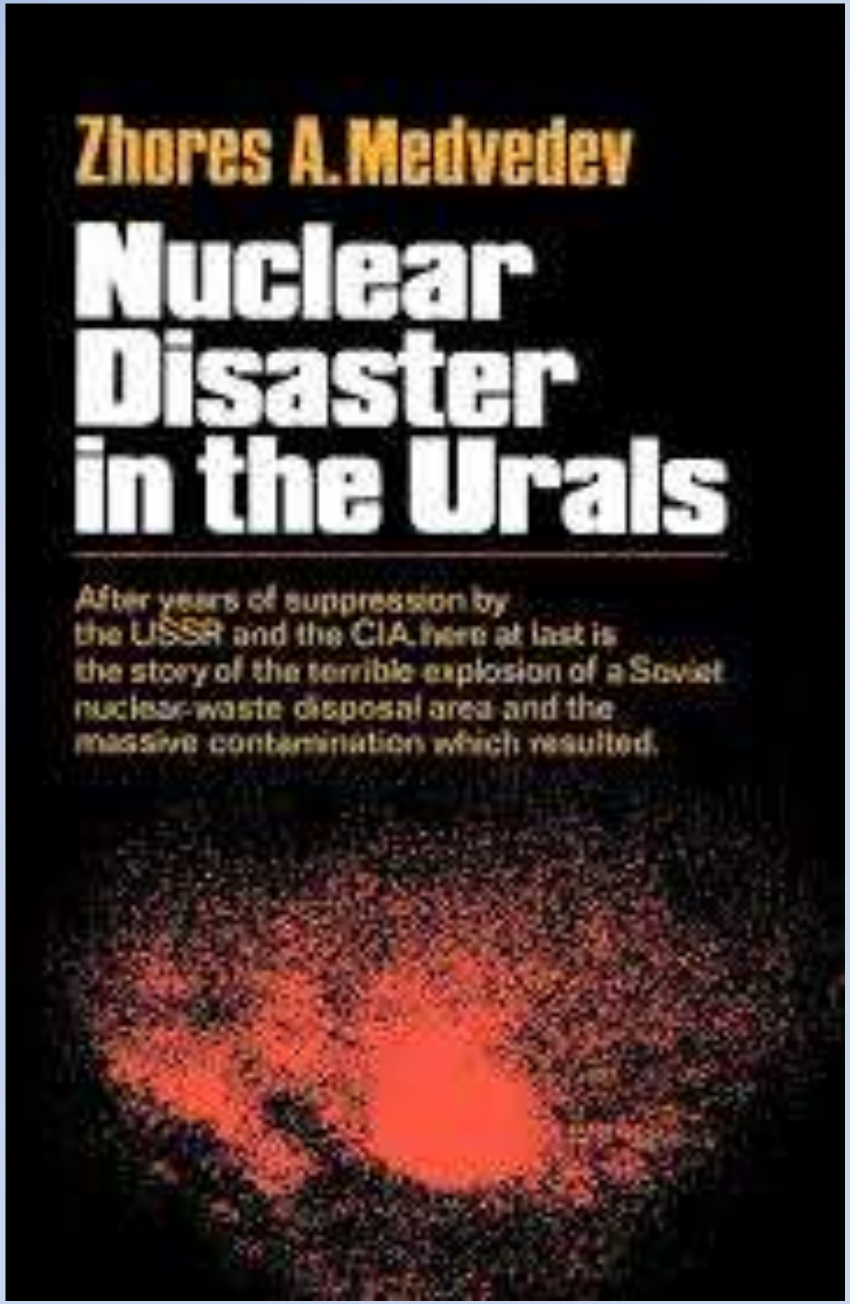
- The cascade of the Techa became the site of the infamous Lake Karachai disaster in 1967. In September 1951 the Soviets stopped discharging high level radioactive waste directly into the Techa and diverted it into Lake Karachai.
- The lake accumulated 600m curies of waste (to compare to the 1986 Chernobyl disaster 50m curies.
- In 1967, the water of the lake partially dried out, radioactive dust from its bed was blown into the air, contaminating thousands of km^2, including the reactor site and 41,500 people in 63 villages
- To this day, Rosatom guarantees the safety of the lake, but cleanup has been impossible.

← Source: Rosatom

Nuclear Engineering International, "Russia's Mayak continues clean-up of Lake Karachai,"November 30, 2016, at http://www.neimagazine.com/news/newsrussias-mayak-continues-clean-up-of-lake-karachai-5684170, A. A. Abagan, et al., " Informatsiia ob Avarii na Chernobyl'skoj AES i ee Posledstviiakh, Podgotovlennaia dlia MAGATE," *Atomnaia Energiia*, vol. 61, no. 5 (November 1986), 301-320.

Nuclear Disaster Beyond the Urals

- In 1976 dissident scientist Zhores Medvedev published an account of the Kyshtym disaster in *New Scientist.*
- Medvedev had painstakingly assembled bits and pieces of information from a variety of Soviet scientific publications about radiological impacts of various isotopes on flora and such fauna as fish, deer, and determined that such information – and isotopes – could only have come from such an event as Kyshtym disaster.



Three Mile Island (TMI, 1979): The worst accident in US history

- Workers from Metropolitan Edison's Three Mile Island nuclear plant stand outside visitors center early on March 30, 1979, as two cooling towers from the nuclear plant lurk in the fog. Officials at the site declared an "on-site emergency" later Friday morning. (Rusty Kennedy/AP)

TMI: A Partial Meltdown

On March 28, 1979, a cooling circuit malfunctioned, allowing the primary coolant to overheat. The reactor shut down immediately. The release valve opened for ten seconds. That allowed enough coolant to escape to reduce pressure and heat. But it got stuck in the open position. As a result, all the coolant was released. There wasn't an instrument that could have alerted engineers that this had happened.

New coolant rushed into the tank, but the engineers now thought that there was too much. They reduced the flow. The remaining coolant turned to steam.

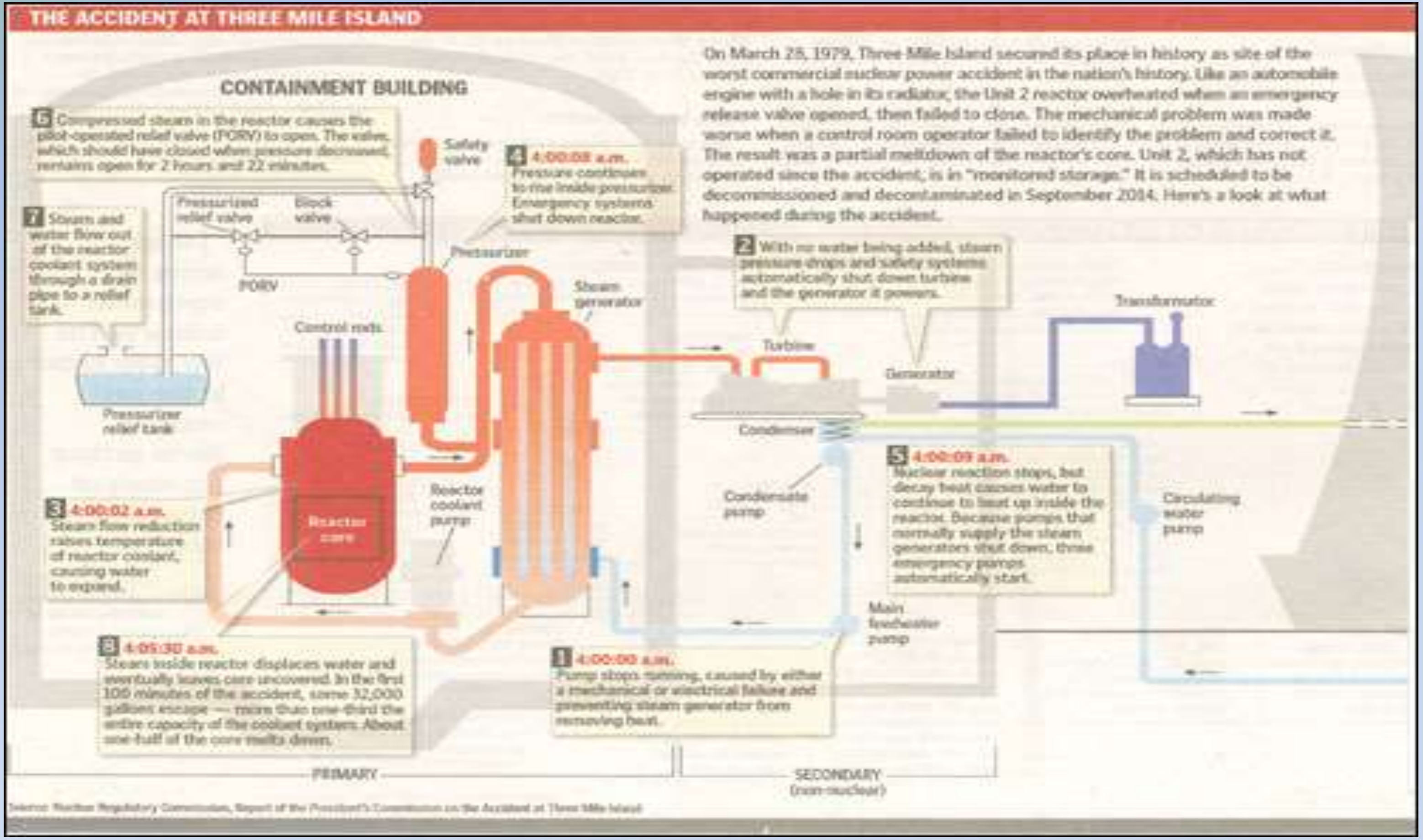
As alarms rang and warning lights flashed, the operators did not realize that the plant was experiencing a loss-of-coolant accident. Their subsequent actions mistakenly starved the reactor core of coolant, causing it to overheat.

The fuel rods overheated, melting their cladding and releasing radioactive material into the coolant. When the steam was released, the radioactive contaminant was released into the surrounding area.

The NRC determined that “fortunately, the amount released was not enough to harm local food supplies, animals, or people.”

Night crew at Three Mile Island nuclear power plant wear protective clothing as they sit in the back of a truck that transported them to the shut-down power plant in Harrisburg, Pa., March 29, 1977, at the beginning of their shift. (Gene Puskar/AP)

TMI Accident Causes



Immediate Response: Confusion

- Visits of local, then state, then national officials (President Jimmy Carter)
- Evacuate or not? Never clear.
- Federal and state authorities were initially concerned about the small releases of radioactive gases that were measured off-site by the late morning of March 28 and even more concerned about the potential threat that the reactor posed to the surrounding population. They did not know that the core had melted, but they immediately took steps to try to gain control of the reactor and ensure adequate cooling to the core.

Harold Stoner carries boxes of provisions as his wife, Hazel, wears a towel over her head preparing to leave their home with grandson Joshua in Harrisburg, Pa., March 30, 1979, after being warned of radiation leaking at Three Mile Island nuclear power plant. (Paul Vathis/AP)

Three Mile Island, ~ Harrisburg, PA, USA

- $1 billion cleanup, $2.4 billion costs in property damage
- Still unclear human health costs, but growing evidence of cancers
- See NRC, "Backgrounder on Three Mile Island Accident," at https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html

President Jimmy Carter in the Three Mile Island Control Room, 04/01/1979. Source: USG.

A study released in 2017

THE Laryngoscope
FOUNDED IN 1896

Triological Society Candidate Thesis

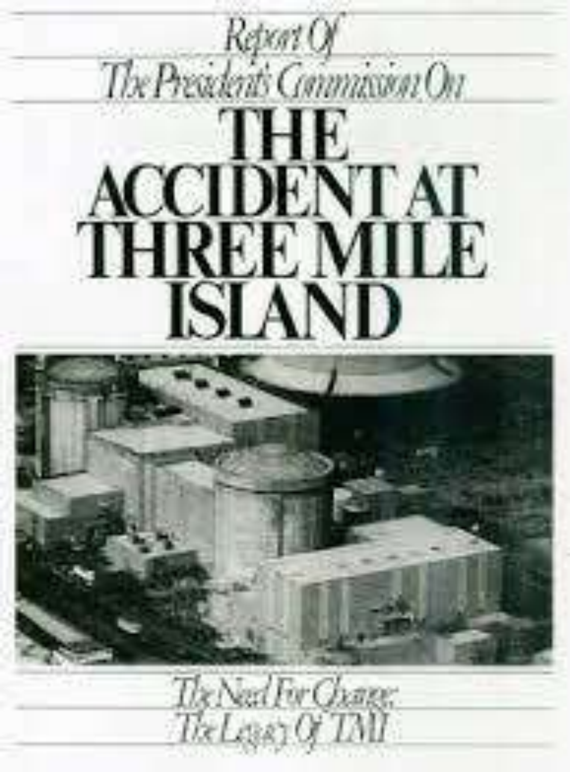
Altered molecular profile in thyroid cancers from patients affected by the Three Mile Island nuclear accident

David Goldenberg MD, FACS, Mariano Russo BS, Kenneth Houser MS, Henry Crist MD, Jonathan B. Derr MS, Vonn Walter PhD, Joshua I. Warrick MD, ... See all authors

First published: 29 May 2017 | https://doi.org/10.1002/lary.26687 | Cited by:1

- A new Penn State Medical Center study has found a link between the 1979 Three Mile Island nuclear accident and thyroid cancer cases in south-central Pennsylvania.
- The findings may pose a dramatic challenge to the nuclear energy industry's position that the radiation released had no effect on human health.
- The study also confirms that even low level radiation has negative health impacts

Kemeny Report



- President Carter appointed a commission to investigate TMI to protect citizens – and the nuclear industry
- The measured and thoughtful *Report of the President's Commission on the Accident at Three Mile Island* (the "Kemeny" report) focused on the "culture" of operation of nuclear power stations and on operator error without indicting the entire industry. They did *NOT* consider environmental or health impacts. The authors wrote,

  "We did not examine the entire nuclear industry….We have not dealt with the question of the disposal of radioactive waste or the dangers of the accumulation of waste fuel within nuclear power plants adjacent to the containment buildings. We made no attempt to examine the entire fuel cycle, starting with the mining of uranium. And, of course, we made no examination of the many other sources of radiation, both natural and man-made, that affect all of us.(Kemeny, 1979)

Chernobyl

↑ Source: http://www.chernobylgallery.com/

← Reuters, Vasily Fedosenko

Chernobyl: Idyllic Before the Accident on April 26, 1986

Heroic pilots tried to douse the smoldering reactor with sand and boron, flying through a killing radioactive plume. Photo source: Russian Helocopters (rch.ero)

Four operating reactors, two in an advanced stage of construction and four more in the planning stage at the “flagship” of the Soviet industry, the Chernobyl Nuclear Power Station (ChNPP), on the eve of the most famous technogenic accident in the world. These reactors were built near the Pripiat Nature Reserve on the Pripiat River that flows into the Dnieper River and directly to the capital of Ukraine, Kyiv, only 90 kilometers away. A town of 50,000 people, Pripiat, was built to house the workers of the ChNPP, who spent the weekends at playgrounds with their children, playing soccer, fishing in nearby rivers and streams, gathering bountiful berries and mushrooms in the woods. Geese came to winter at the Venice-like canals built to carry cooling effluent from the reactors.

In a test of glasnost, Gorbachev belated addresses the nation on the extent of the disaster and radiation dangers (May 14, 1986)

Source: photo widely available on internet

Western newspapers sensationalize the immediate human death toll.

As the result of a risky and foolish "experiment" that led operators to disable safety systems on Chernobyl's unit 4, the Chernobyl reactor experienced an exponential surge in power, the reactor core overheated, the cooling water boiled out of the core (increasing the power further), the core melted down, and a chemical reaction of steam with metal and/or graphite yielded an explosive mixture of hydrogen and oxygen. Two powerful explosions ripped through the reactor destroying it and lifting its lid – at 2,000 tons – into the air and down on its side, and destroying the roof of the standard factory building. One hundred to two hundred MCi (megacuries) of radioactive substances filled the environment over the next ten days falling onto the land and entering the water around the station, and also into the atmosphere where it spread through the northern hemisphere.

The city of Pripiat, 2 km away, was evacuated 3 days later.

Fuel rods, burning graphite and other material scattered on the ground and the roof of reactor unit three next door, which, against the regulations, had a flammable bitumen cover, and instantly caught fire. Inside several other areas caught on fire, but through the heroic – and mortal – action of the firefighters, the most dangerous fire spots were extinguished by 5 am. But the core of the uncontrolled nuclear reactor was open, and its graphite burned, emitting visible fumes and invisible radiation into the environment. The base of the reactor was forced down four meters, the explosion having demolished the supporting structure. Highly radioactive lava of the melted nuclear fuel and construction/building materials flooded lower corridors and rooms of the building

Pripyat Hairdressing salon https://www.chernobyl.one/pripyat-retail/

Jorge Franganillo Priapiat Amusement Park at https://flickr.com/photos/46191841@N00/24495942058

Source: Denis Romanuk, *Charnobyl* (2006).

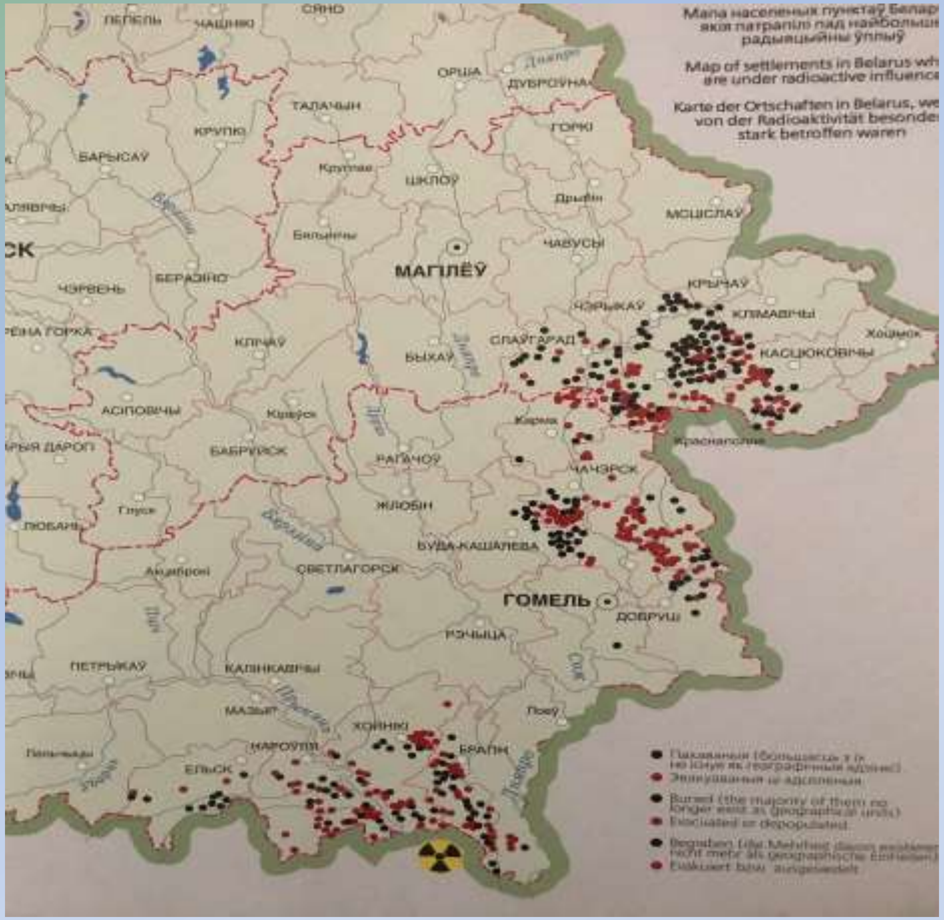
Source: Rossokha Radioactive Vehicle Graveyard at https://chernobyl-exclusive-tours.com/no/blog/cmentarz-rassokha

Five years later, asphalt to keep the radioactive dust down

The authorities ordered the evacuation of the 45,000 residents (including 17,000 children) from Pripiat only 36 hours after the explosion. Evacuation of such heavily contaminated settlements as Chernobyl town (with 20,000 inhabitants) and the Gomel region of Belarus followed later in May. Sometime in August, the evacuation of 166,000 people from eighty-eight towns and villages in Ukraine, Belarus and Russia was complete.

In addition, 60,000 cattle were removed, some of which made it into sausage sold throughout the USSR – except, by secret order, in Moscow province where the elite lived. They authorities used 8,500 vehicles including 2,500 buses in the evacuation – many of which were buried in a vehicle “graveyard” near Chernobyl. Soldiers were sent in to shoot all animals including pets lest they escape the zone.

Villages leveled and buried or abandoned, especially in Belarus

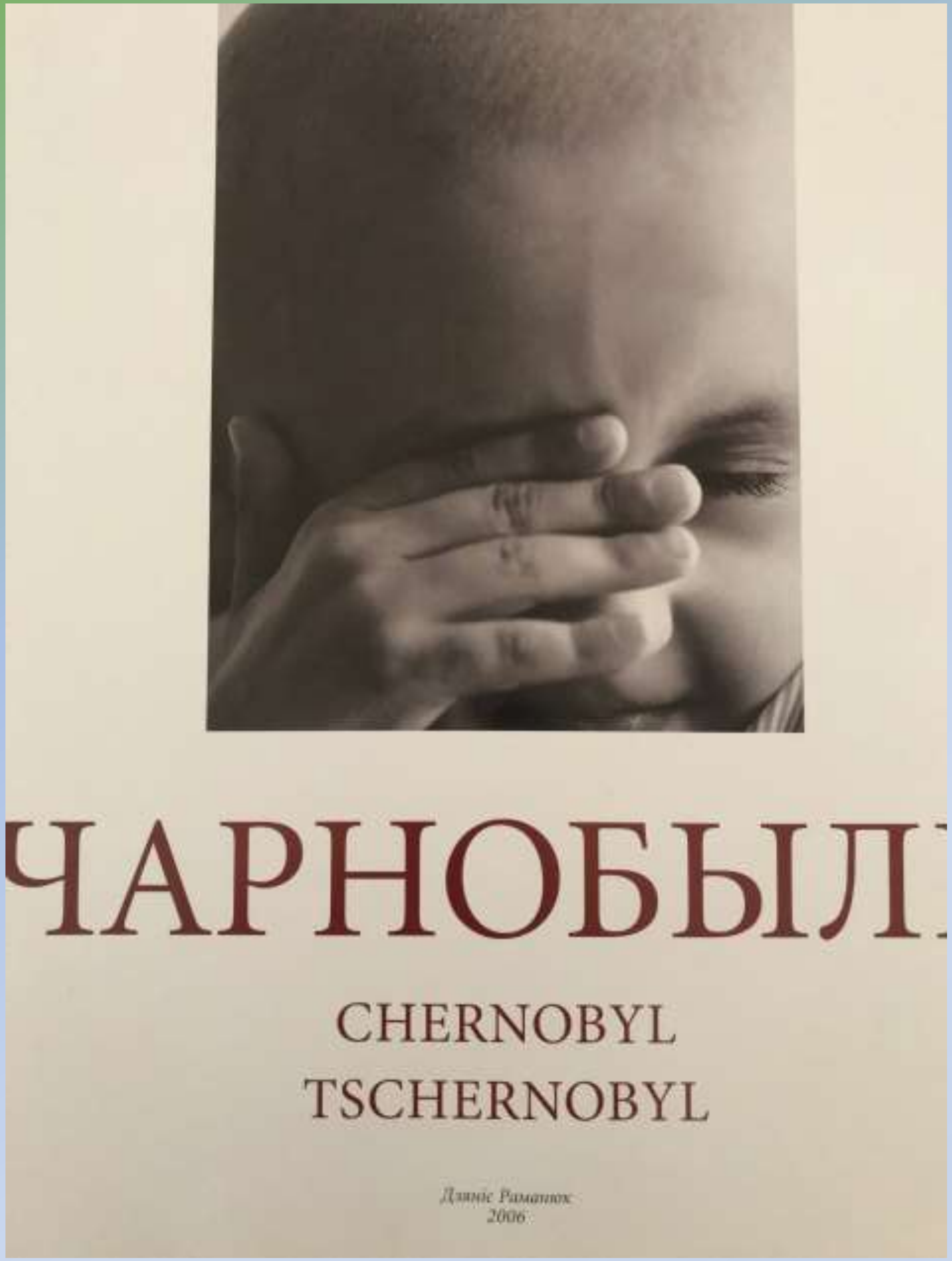


About 70% of the radioactive fallout from the Chernobyl disaster landed in Belarus, heavily contaminating one-fourth of the country, one-fifth of its agricultural land and affecting at least 7 million people. More than 2,000 towns and villages were evacuated, and about a half-million people have been relocated since 1986, according to Chernobyl International, a humanitarian organization with links to the United Nations. -- https://www.chernobyl-international.com/

The Chernobyl “Sarcophagus” Itself Must be Entombed … 30 years later

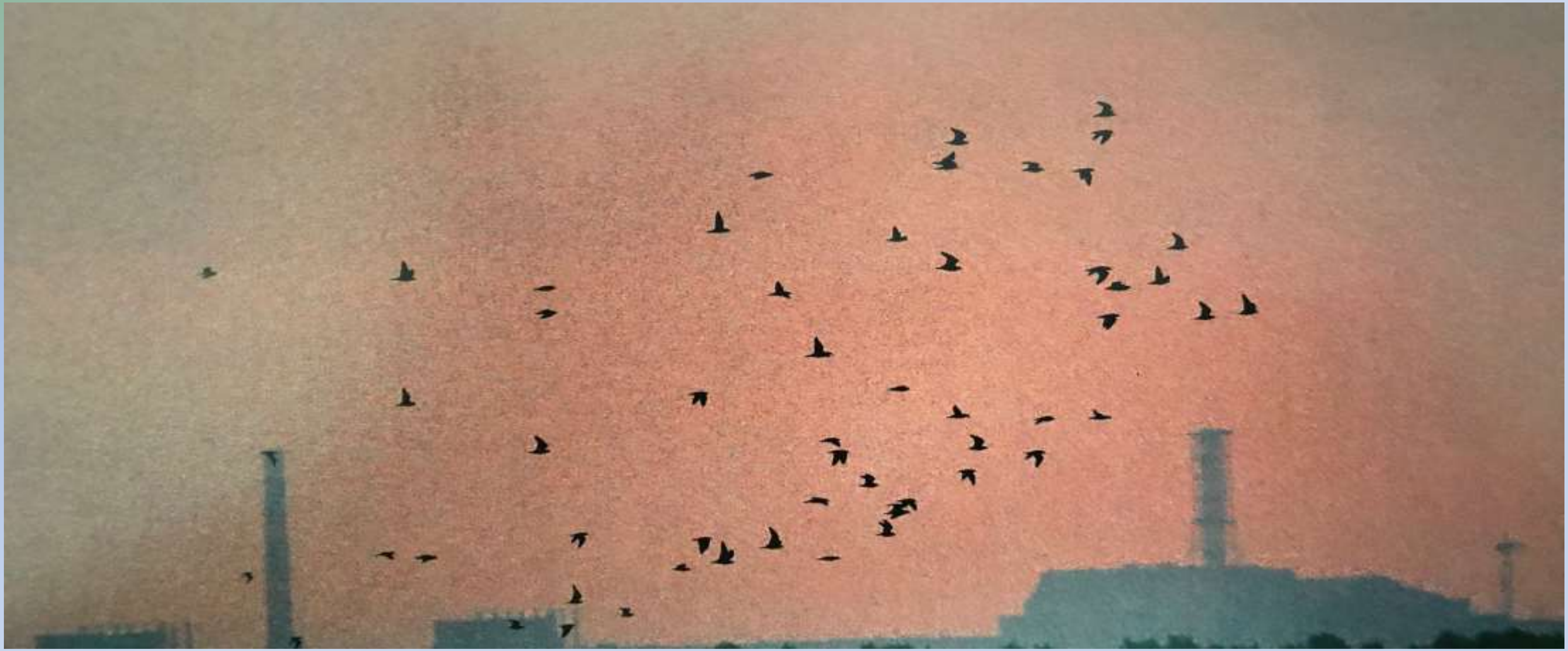
- A lasting monument to the disaster is the Shelter Object built in several months by poorly equipped workers to cover the open reactor as quickly as possible to limit further radioactive contamination. Within the reactor remain 200 tons of the melted, the highly radioactive core, 30 tons of dust, and 16 tons of uranium and plutonium – all lethal to humans after short term exposure. Just three weeks after the explosion, engineers of Minsredmash began design of the sarcophagus; construction commenced in June and was completed in November.
- Working in shifts 15 days on, 15 days off, the men used 400,000 m^3 of concrete and 7,300 tons of metal.
- Perhaps 200,000 men – “liquidators” – were involved in all. In 2017 the decaying sarcophagus itself was covered with the “New Shelter Object.”

- Photo sources: Wikiwand.com and https://www.chnpp.gov.ua/en/ See also Chernobyl’.by, “Ok”ekt ‘Ukrytie’,” at http://www.chernobyl.by/shelter/33-sooruzhenie.html



On Chernobyl, see Svetlana Alexievich, *Voices from Chernobyl*, trans. Keith Gessen (Normal, IL and London: Dalkey Archive Press, 2005); David Marples, *The Social Impact of the Chernobyl Disaster* (New York: St. Martin's Press, 1988) and *Chernobyl and Nuclear Power in the USSR* (New York: St. Martin's Press, 1986); Sonja Schmid, *Producing Power* (Cambridge: MIT Press, 2015); Zhores Medvedev, *Legacy of Chernobyl* (New York: W. W. Norton and Co., 1992); Tatiana Kasperski, *Les politiques de la radioactivité : Tchernobyl et la mémoire nationale en Biélorussie contemporaine* (Paris: Pétra, 2020); and Serhii Plokhy, *Chernobyl*: *The History of a Nuclear Catastrophe* (New York: Basic Books, 2018).

Chernobyl was located and remains in a nature preserve



In the absence of human beings, flora and fauna have undergone remarkable recovery, although with significant genetic, mutagenic, and population impacts.

Abandoned buildings return to dust…

And what of those left behind? Many people, especially old folk, have squatted in the exclusion zone.

Chernobyl Destroyed Family, Farm and Forest Ecosystems

Many animals were evacuated although contaminated. House pets and other mammals were shot and buried by soldiers. And cattle and pigs were killed, butchered and turned into sausage when their radioactivity had declined.

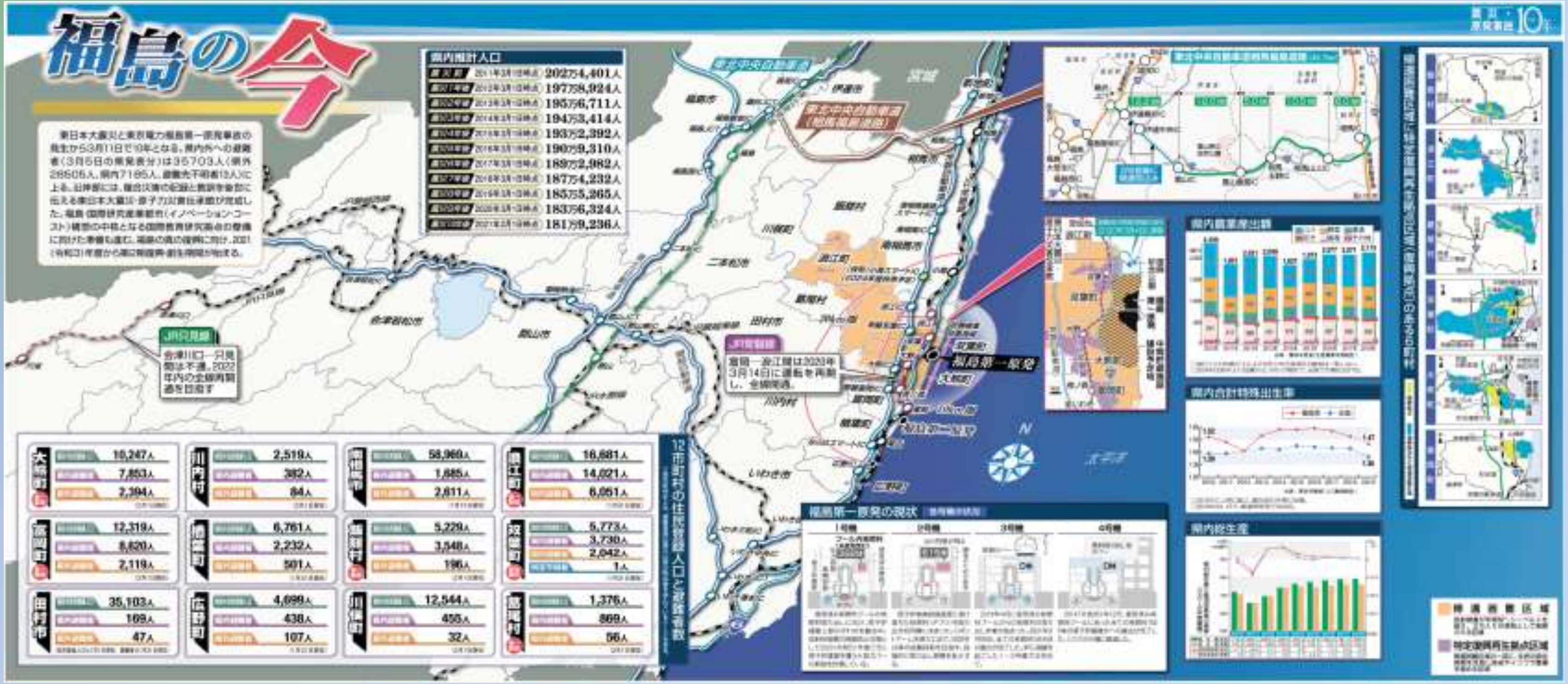
Fukushima Disaster

Injecting water into Unit 3 of Fukushima NPP.
防衛省 - 出典：防衛省ホームページ.
https://www.mod.go.jp/e/jdf/no22/photo/photo10.html, CC BY 4.0,
https://commons.wikimedia.org/w/index.php?curid=88145416

The Tōhoku earthquake and Tsunami of Friday, March 11, 2011 destroyed the Fukushima NPP. The reactors automatically shut down on detecting the earthquake, but because of the shutdown and grid supply problems, the stations' electricity supply failed, and emergency diesel generators automatically started to provide electrical power to the pumps that circulated coolant through the reactor cores.

The massive earthquake also ceeated a 14-meter Ttsunami that crashed over a seawall and flooded parts of reactors 1–4 that swamped and killed the diesel-powered pumps. The led to a loss of coolant failure that resulted in three meltdowns, three hydrogen explosions and the release of radioactive contamination.

165,000 people forced to evacuate



Over the next days radiation released into the atmosphere; as at Chernobyl the government eventually declared an evacuation zone with a 20 km radius, with 165,000 residents forced out. Large amounts of water contaminated with radioactive isotopes were released into the Pacific Ocean. TEPCO (the plant operator) had to build new coastal walls to stop the flow of contaminated water back into the Pacific Ocean.

Source: https://www.minpo.jp/pub/sinsai_data

Source: https://www.nytimes.com/es/2021/03/11/espanol/fotos-fukushima-aniversario.html

Huge amounts of new kinds of radioactive waste

400 tons of contaminated water are produced daily and stored in tanks. TEPCO hopes to release this waste into the ocean.

Photo source: KYODO.

Construction Ruble from the Explosions

Source: Greg Webb, IAEA

The Fukushima cleanup has created new challenges with vast amounts of radioactive waste, plastic-wrapped for now.

https://www.nytimes.com/es/2021/03/11/espanol/fotos-fukushima-aniversario.html

3,519 Containers of Radioactive Sludge

Shipping containers holding reactor maintenance equipment from the plant. Other containers at the site hold rubble or filters full of radioactive sludge. Ko Sasaki for The New York Times

- Source: New York Times

- 64,700 m^3 of Discarded Protective Clothing
- Branches and Logs From 220 Acres of Deforested Land
- Over 13 million m^3 of radioactive soil
- Nearly 1,600 SNF rods
- 200,400 m^3 of Radioactive Rubble

The shell of the Reactor 1 building at the plant. Ko Sasaki for The New York Times

The Fukushima disaster crystalized anti-nuclear protest

Demonstrators Tokyo 2011 @photozou

- Citizens mobilized against the government and its technocratic policies on a national scale, and moved beyond the apolitical tendencies that had characterized society
- In *The Anti-nuclear Movement and Street Politics in Japan after Fukushima* (2018) Alexander Brown describes how people came forth into the streets in the summer and autumn of 2011, occupying city spaces and transforming them into places for democratic practice and debate.

Protest

Anti-nuclear protest arose first in the 1960s, and it accelerated in the 1970s

Anti-nuclear Camp in Turkey: Taksim'de nükleere enerji karşıtı kurulan kamp. By Myrat - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=15447720

Major concerns were:

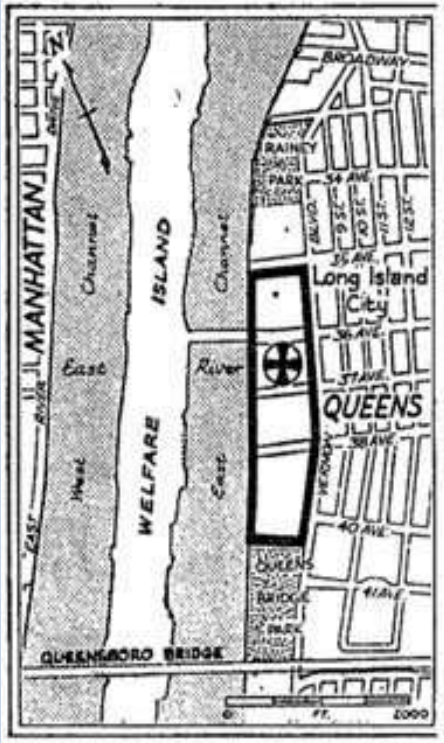
- Mounting fear of accidents
- Safety concerns
- Worries of loss of livelihoods
- The sense that NPPs destroyed the environment
- Visions of nuclear power as authoritarian

← Turkish protest camp. Fear over seismic instability. Turkey is building four Russian 1200 MWe VVERs at Akkuyu

A New York City-based reactor? Ravenswood, Queens, 1962

An early protest centered on the efforts of the utility Consolidated Edison in 1962 to build a nuclear power station in Queens on the East River just 2 km from the United Nations. This provoked extensive local opposition and the plant was killed.

But ConEd built the Indian Point NPP on the Hudson River only 40 km from the city that gained the reputation as the worst-run reactor in the US – and which contributed to fish kills and other damage to river ecosystems.



The New York Times May 10, 1963
Ravenswood generating station of Con Edison (heavy line) and site of proposed nuclear power plant (cross).

Bodega Bay, California

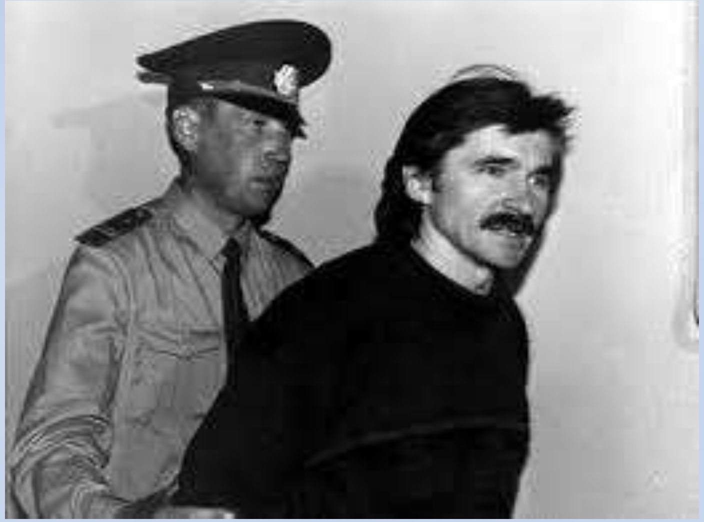
Another early protest of the 1960s involved the determination of the utility PG&E to build a 350 MWe reactor 100 km north of San Francisco on Bodega Bay, a shallow, rocky inlet of the Pacific Ocean that attracts gray whales, harbor seals and over 300 bird species including ospreys. Construction began on the reactor pit, but was abandoned in the face of citizen action – and recognition that the NPP would be built near an active part of the San Andreas fault. The AEC forced PG&E to abandon the foolish plan. The Northern California Association to Preserve Bodega Head and Harbor was instrumental in the battle. Photo: Sonoma County Museum

Protest in authoritarian states is restricted. Of the nuclear states these include China, Russia, Turkey and increasingly India.

In Russia if, after the collapse of the USSR, some opening of political institutions occurred, the succeeding security and military apparatus tried to keep embarrassing information about the nuclear enterprise in a no-longer-existing state as a state secret.

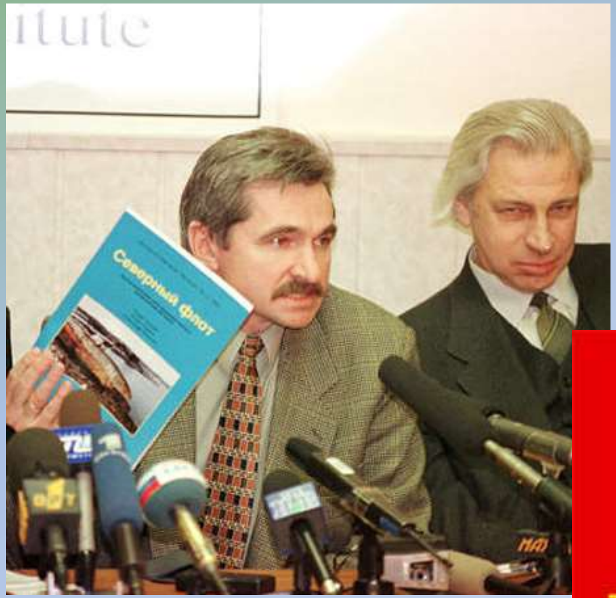
In the nuclear world in the 1990s, Chernobyl led to moratorium in reactor construction, and citizens learned more and more about past pollution and safety problems in the industry. In this environment, Aleksandr Nikitin, a former naval military officer who cooperated with the Norwegian NGO Bellona in gathering information on military waste dumps in the Arctic from open sources.

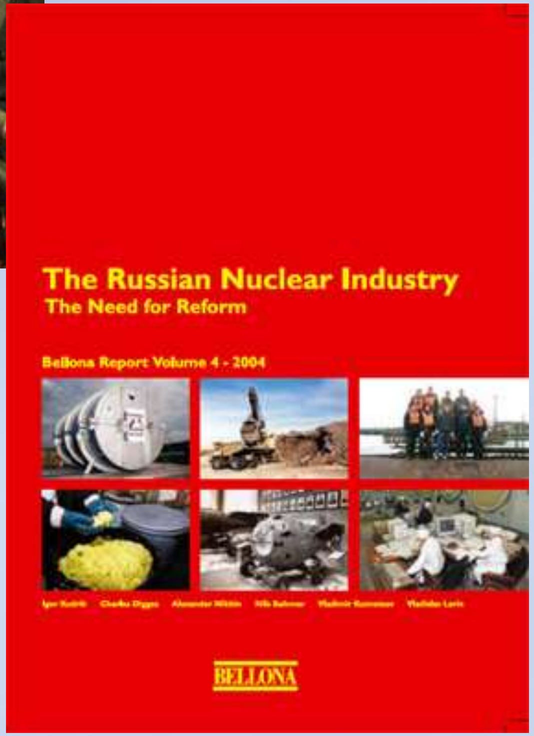
The FSB (Federal Security Agency), which had monitored Nikitin and Bellona, raided his home and the Bellona office in Petersburg, arrested him and confiscated his work and papers in 1996.



Thomas Nilsen, Igor Kudrik and Alexandr Nikitin, *The Russian Northern Fleet: Sources of Radioactive Contamination*, Bellona Report vol. 2 (1996), at http://spb.org.ru/bellona/ehome/russia/nfl/index.htm. For a detailed report on the Nikitin case, including a collection of legal documentation, press releases and press articles see: Aleksandr Nikitin, Nina Katerli, *Delo Nikitina: Stretegiia pobedy* (Saint-Petersburg: Zvezda, 2001); Iurii Shmidt (ed.), *Delo Nikitina: Strategiia pobedy. Sbornik* protsessual'nykh dokumentov zashchity (Saint-Petersburg: Zvezda, 2001).

Worldwide, NGOs became active in ensuring public knowledge about the costs, benefits and risks of nuclear power.





- E. g. the Bellona Foundation, Norway and Russia in the 1990s
- Nikitin spent 10 months in pre-trial detention in St. Petersburg in 1996, was ordered to be released, and then faced several other trials, each time was acquitted, and each time the government tried to prosecute him again and again in 1998, 1999, and 2000. The Supreme Court eventually rejected further prosecution and Nikitin was finally fully acquitted.

Jon Gausllaa, "Nikitin Application Admissible," *Bellona* (November 23, 2003), at http://bellona.org/news/russian-human-rights-issues/nikitin-case/2003-11-nikitin-application-admissible.

Russian national protest against the import of SNF

- In 2000-01 Russian activists mobilized the public against notorious legislation to allow the import of foreign SNF for money. The parliament adopted the new law in spite of a massive public campaign which over 90% of Russians opposed. Within 3 months roughly 1,000 activists had collected almost 2.5 million signatures in support of the referendum.
- Yet the Central Election Commission arbitrarily invalidated more than 600,000 signatures to prevent the referendum from meeting the limit. The law soon passed, 120 tons of Bulgarian nuclear waste arrived, and other countries followed with the government permitting import through 13 Russian ports.

- Photos: https://storm100.livejournal.com/8355466.html?replyto=20449674; and https://v-tagile.ru/novosti-nizhnego-tagila/obshchestvo/syr-iz-evropy-vvozit-nelzya-a-uranovye-otkhody-mozhno-tagilchane-piketiruyut-protiv-vvoza-uranovykh-khvostov-iz-germanii

The Russian NGO “Ekozashchita” (Environmental Defense)

- Ekozashchita, which dates to 1989, (https://ecodefense.ru/ehistory/) was among the first three Russian NGOs designated by Russian Ministry of Justice as a “foreign agent” according to a new Russian law which is largely seen as a means of repression of political discontent by an Russian authoritarian State. Ekozashchita’s major activities concern nuclear power.
- The Ekozashchita pushed November 25, 2003, demonstrations to mobilize against the law, proclaiming that Russia should never be a “nuclear garbage dump.” Thirty other organizations including Greenpeace Russia and "Keepers of the Rainbow" urged the deputies to repeal the law, gathering in more than 20 cities.
- Import continues, and the state has neutralized protest.

Photo: https://moi-goda.ru/chto-sluchilos/peterburzhtsi-vishli-na-piket-protiv-vvoza-v-rossiiu-uranovich-chvostov

German Protests in Gorleben

German protesters opposed what they saw as the inherent authoritarianism of nuclear power.

Gorleben, Germany, is the site of a controversial interim intermediate radioactive waste storage facility initially planned to serve with the nearby salt dome as a final future deep repository. (The site was finally rejected in 2020 for geological reasons.). The first shipments of SNF arrived in April 1995, and included spent fuel from several French and German facilities. An anti-nuclear protest of 4,000 people met the trains of waste -- and 7,600 police; the protests escalated in number and violence over the years, with the broader public finding the government's response disproportionate and inappropriate.

(In 1974, at Wyhl, West Germany, 28,000 people occupied the site of a proposed nuclear station to stop its construction in a nature preserve. People remained on site until the project was abandoned.)

Photos: WIkiwand

The California “Abalone Alliance” protest against the destruction of “pristine” nature – and vs. Diablo Canyon NPP

"Circling up" at a Diablo Canyon protest, 1979.
Photo: Jessica Collett

- One of the first public protests against nuclear power gelled around the Diablo Canyon station. The Abalone Alliance (1977-1985) took its name from the multitudinous red abalone massacred in Diablo Canyon in 1974 when the utility carried out a hot flush of the reactor unit’s plumbing. The Alliance, “a loose coalition of 60 anti-nuke organizations,” staged blockades and occupations at the reactor site.
- In June 1979, 30,000 people attended an anti-nuclear rally headlined by singer Bonnie Rait.
- Nearly two thousand people were arrested during a two-week blockade in 1981, including singer Jackson Browne, making this the largest number arrested at an anti-nuclear protest in the United States. Perhaps as many as 30,000 protestors descended on the site. *Newsweek* headlined, “Diablo Canyon: The Assault That Failed.”
- The Alliance sought not only demonstrations, but resistance to ensure that Diablo Canyon never operated. Opposition here – and to the Bodega Bay plant north of San Francisco (not built) – and at Seabrook – required that protestors become technologically sophisticated in identifying risk factors and in understanding the law and administrative procedures needed to pursue opposition.

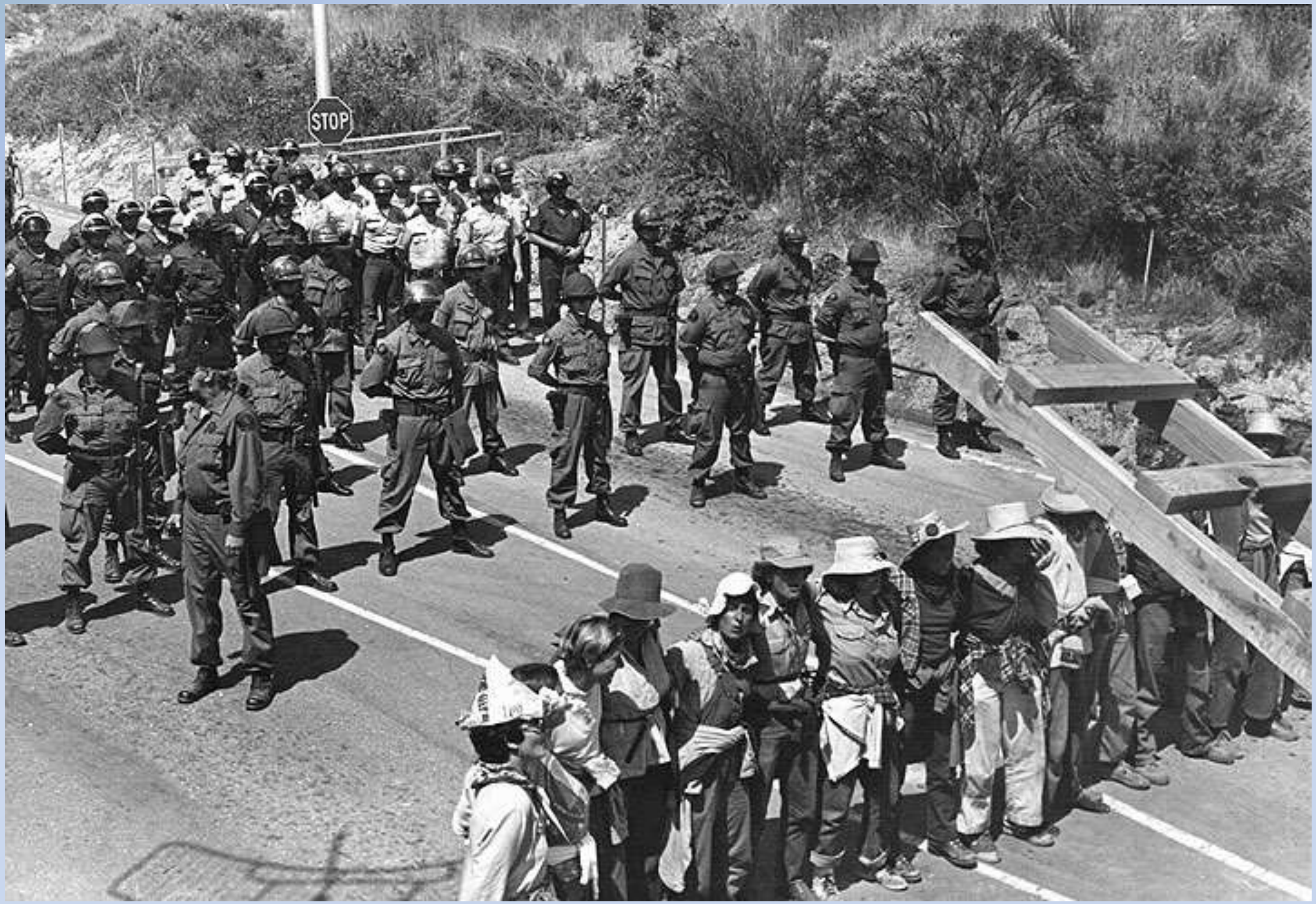
Diablo Canyon NPP Demonstration, view of the Pacific Ocean

Photo: Found SF Digital Archive

Abalone Alliance, September 1981

The Mother Bear Brigade meets the Sheriff's Department inside the main gate.

Photo: Steve Stallone at Found SF Digital Archive



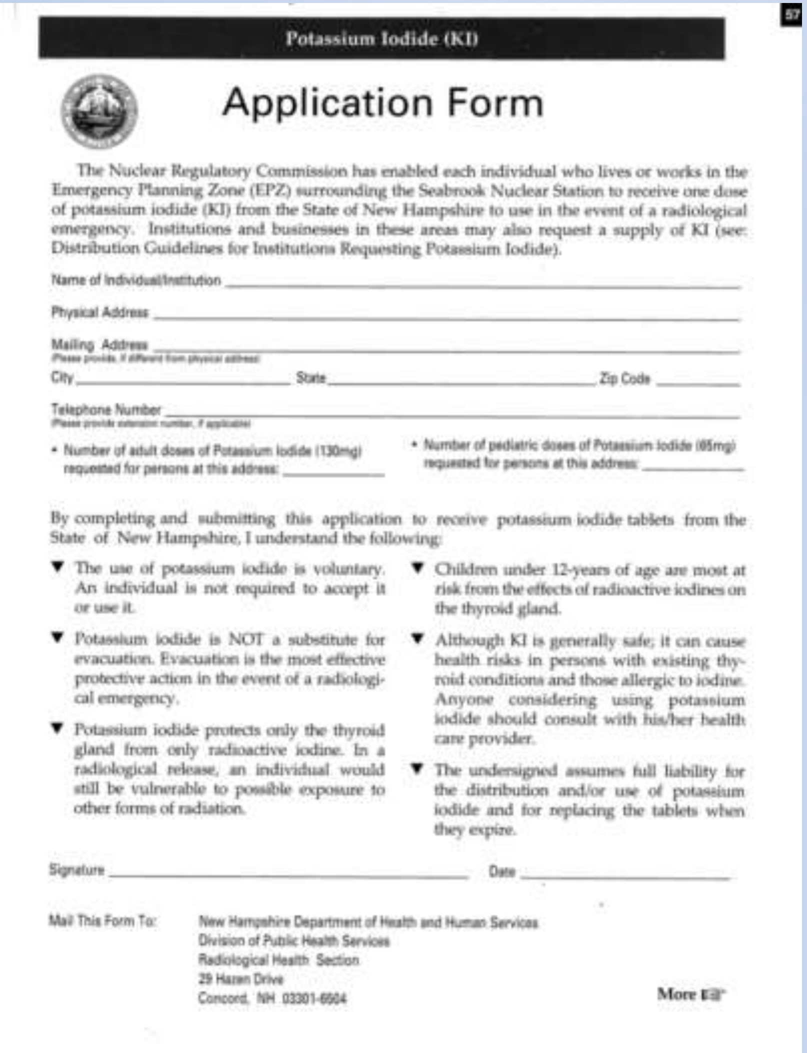
Seabrook, NH, USA NPP: The Clamshell Alliance

- In response to safety and environmental concerns, activists on the East Coast organized the “Clamshell Alliance” to work against Seabrook NPP.
- During the heyday of nuclear power projects, in May 1968 the Public Service Company of New Hampshire (PSNH) announced plans to build a nuclear plant in Newington, NH, on the Great Bay (the site now of multitudinous shopping malls). A year later, in the face of local opposition and higher costs, PSHN gave up this plan. In 1972 the company proposed instead to build two reactors on the Hampton-Seabrook estuary, of salt marshes and critical habitat for birds and other fauna, along the Atlantic Ocean in Seabrook, NH, the first to come online by 1979, the second in 1981, with a total cost of less than $1 billion. Meeting safety and other requirements, the total cost was eventually $16 billion that bankrupted PSNH.
- To alleviate public grievances, the government of New Hampshire negotiated the opportunity for the Clamshell Alliance to hold pro-solar power and music festival at the Seabrook site. The aim of the governor was to avoid bad publicity and the cost of law enforcement. Twenty thousand people attended.
- Yet protests snowballed. Hundreds of demonstrators descended on the plant when PSNH began the first power tests in June 1985, with 627 arrested for trespassing. The protesters included children and handicapped people. The plans generated extensive public opposition, protest, and occupation of the construction site by the Clamshell Alliance. Protests continued into the 1990s.

Photo Credit: Boston Globe via Getty Images.

In case of an accident, is evacuation possible?
Against the Chance of Iodine-131 exposure: Potassium Iodide tables

- 170,000 people live in the Seabrook evacuation region. How long would it take safely to evacuate them?
- According to the CDCs, Iodine-131 is the most important harmful radioactive isotope fallout. It exposes the thyroid gland for about 2 months after each nuclear test, and exposed individuals, especially children, have an increased risk of thyroid disease including thyroid cancer. (See also www.cancer.gov/i131/).
- Yet the US Nuclear Regulatory Commission does not require that NPPs to provide potassium iodide tables that protect the thyroid gland against internal uptake of radioiodines in the event of a nuclear reactor accident. Leaving it up to individual states. The Seabrook NPP in New Hampshire does provide tablets, but only on request.
- In 1997 local authorities in France began distributing potassium iodide tablets to everyone living within 10 kilometers of 24 nuclear installations. This decision “sparked considerable interest among radiation scientists in other countries, particularly the United States.”


Potassium Iodide (KI)

Application Form

The Nuclear Regulatory Commission has enabled each individual who lives or works in the Emergency Planning Zone (EPZ) surrounding the Seabrook Nuclear Station to receive one dose of potassium iodide (KI) from the State of New Hampshire to use in the event of a radiological emergency. Institutions and businesses in these areas may also request a supply of KI (see: Distribution Guidelines for Institutions Requesting Potassium Iodide).

Name of Individual/Institution ____________

Physical Address ____________

Mailing Address ____________
(Please provide, if different from physical address)

City ____________ State ____________ Zip Code ____________

Telephone Number ____________
(Please provide extension number, if applicable)

- Number of adult doses of Potassium Iodide (130mg) requested for persons at this address: ____________
- Number of pediatric doses of Potassium Iodide (65mg) requested for persons at this address: ____________

By completing and submitting this application to receive potassium iodide tablets from the State of New Hampshire, I understand the following:

- The use of potassium iodide is voluntary. An individual is not required to accept it or use it.
- Potassium iodide is NOT a substitute for evacuation. Evacuation is the most effective protective action in the event of a radiological emergency.
- Potassium iodide protects only the thyroid gland from only radioactive iodine. In a radiological release, an individual would still be vulnerable to possible exposure to other forms of radiation.
- Children under 12-years of age are most at risk from the effects of radioactive iodines on the thyroid gland.
- Although KI is generally safe; it can cause health risks in persons with existing thyroid conditions and those allergic to iodine. Anyone considering using potassium iodide should consult with his/her health care provider.
- The undersigned assumes full liability for the distribution and/or use of potassium iodide and for replacing the tablets when they expire.

Signature ____________ Date ____________

Mail This Form To: New Hampshire Department of Health and Human Services
Division of Public Health Services
Radiological Health Section
29 Hazen Drive
Concord, NH 03301-6504

More

See Michael Balter, “France Distributes Iodine Near Reactors,” *Science*, vol. 275, no. 5308 (March 28, 1997), pp. 18710-1872.

Shoreham demonstrations, June 1979

Event: Shoreham Nuclear Power Plant, No Nukes Protest
Brookhaven, New York
June 3, 1979

- On June 3, 1979, over 15,000 people protested outside the unfinished plant; this was a reaction to a partial meltdown and radiation leaks from TMI. This was a huge number of people in a town of 600 inhabitants, and perhaps the largest in Long Island history. Despite rain, anti-nuclear protestors of all ages came together to make a statement against the plant. More than 600 people were arrested.
- The demonstration reflected growing anti-nuclear sentiment in the United States, and throughout the world, in the 1970s. Additional safety concerns regarding the Shoreham plant contributed to further delays. There was worry that in the event of a meltdown, residents would not be able to evacuate. In early 1983, the state agreed that safe evacuation was indeed not feasible.

Photo: https://www.swarthmore.edu/library/peace/Exhibits/Dorothy%20Marder/MarderExhibit3_files/MarderExhibit3.html

Protest at the Kudankulam (KKNPP) Station

Protests against nuclear power – and big hydro projects – have been ongoing in India for the past 40 years. Regarding KKNPP, industry efforts to run a mock evacuation drill -- telling people to cover their nose and mouth and run for their lives -- led to massive demonstrations on August 11, 2011, followed in September by mass hunger strikes, fasting, and blocking state roads. Hunger strikes resumed in mid-October when talks failed, and the strikers "laid siege in front of the KKNPP on October 13-16, 2011 when the KKNPP authorities did not halt work at the site as per the Tamil Nadu state cabinet resolution." On September 10, 2012, 1000s of people gathered on the Idinthakarai beaches to protest against fuel loading at the station. The protestors, mostly women, were tear gassed and fired upon. One person was killed. Sixty were arrested, several of them on charges of sedition.

Fishers' communities at risk from KKNPP

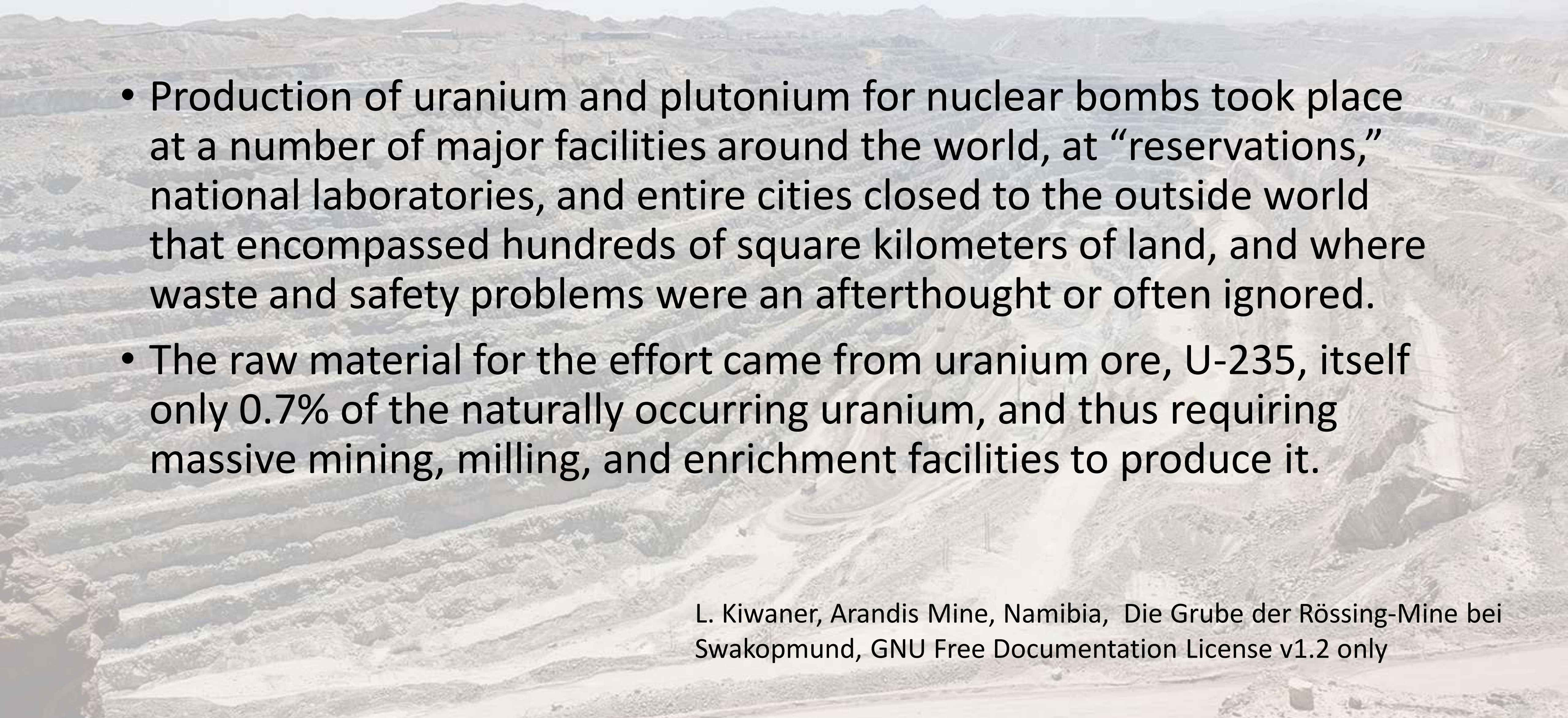
Protestors claimed that the plant's effluent, discharged into the sea, releases toxins and impacts the quality of fish. They claim that said that since the plant has been operational, the quantity, variety and quality of fish has been reduced.

Sources: See S. P. Udayakumar, "Why Are We Fighting in Koodankulam: S P Udayakumar," *Dianuke*, December 19, 2012, at https://www.dianuke.org/why-koodankulam-udayakumar/

Waste Handling and Disposal

Weapons Grade Nuclear Fuel Production

- Production of uranium and plutonium for nuclear bombs took place at a number of major facilities around the world, at “reservations,” national laboratories, and entire cities closed to the outside world that encompassed hundreds of square kilometers of land, and where waste and safety problems were an afterthought or often ignored.
- The raw material for the effort came from uranium ore, U-235, itself only 0.7% of the naturally occurring uranium, and thus requiring massive mining, milling, and enrichment facilities to produce it.



L. Kiwaner, Arandis Mine, Namibia, Die Grube der Rössing-Mine bei Swakopmund, GNU Free Documentation License v1.2 only

The intractable problem of radioactive waste

- The most intractable problem of the nuclear age is how to manage the vast quantities of radioactive waste that have accumulated over the past nearly 80 years. Depending on the kind of waste a number of temporary measures were adopted over the course of this period (buried drums, tanks and buried tanks, tanks with double hulls, dumping at the sea, pushing tailings to the side, pouring it into lakes and rivers and so on). But a long-term, effective way to handle the most dangerous waste, for example, deep geologic depository from 200 to 1,000 m beneath the surface, has yet to open anywhere.
- Scientists have even talked about loading some of it onto rockets and sending it into space, or using a peaceful nuclear explosion (PNE) to build an underground cavern to take it. And suggestions to use a so-called closed cycle to burn spent nuclear fuel in a hybrid mixture ("MOX") will not reduce the waste, since it too must be processed to extract the fissile material in it. This inevitably leaves behind volatile, toxic wastes.
- The following photographs and images explore the history and challenges of dealing with the four kinds of radioactive waste: 1) Low level; 2) Medium level; 3(High level; 4) and "Legacy" waste, by far the largest amount, the most dangerous, and the least secure.

Low-level Radioactive Waste (LLW)

- By volume 90%, by radioactivity 1% of all waste
- Hospitals, industry, nuclear fuel cycle
- Paper, rags, tools
- Compacted and incinerated

- Source: IAEA →

Waste Handling and Disposal During Reactor Decommissioning

Removal of 1500 cubic yards of soil contaminated with extremely low levels of nuclear waste from the former Fort Greely Nuclear Power Plant.

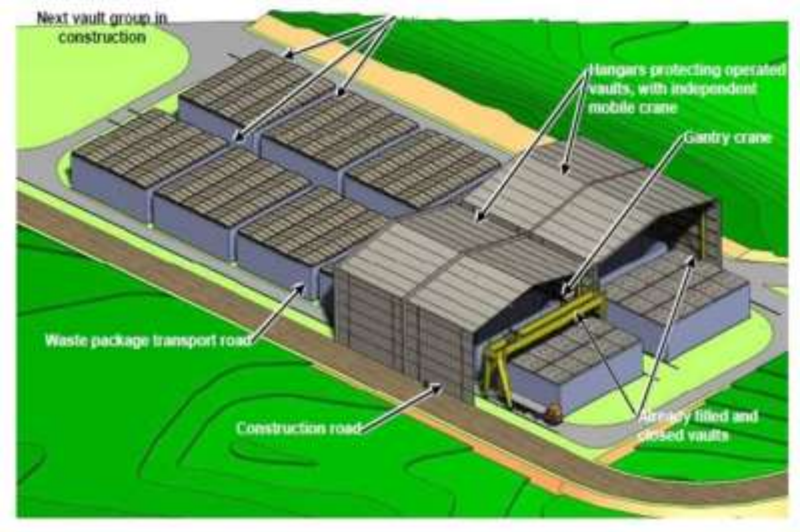
Fort Greely, Alaska. By US Army Corps of Engineers - images.usace.army.mil, Public Domain, https://commons.wikimedia.org/w/index.php?curid=1298601

LLW in several countries

- UK – LLW Repository at Drigg in Cumbria operated by UK Nuclear Waste Management (a consortium led by Washington Group International with Studsvik UK, Serco, and Areva) on behalf of the Nuclear Decommissioning Authority.
- Spain – El Cabril LLW and ILW disposal facility operated by ENRESA.
- France – Centre de l'Aube and Morvilliers operated by ANDRA.
- Sweden – SFR at Forsmark operated by SKB.
- Finland – Olkiluoto and Loviisa, operated by TVO and Fortum.
- South Korea – Wolseong, operated by KORAD.
- Japan – LLW Disposal Center at Rokkasho-Mura operated by Japan Nuclear Fuel Limited.

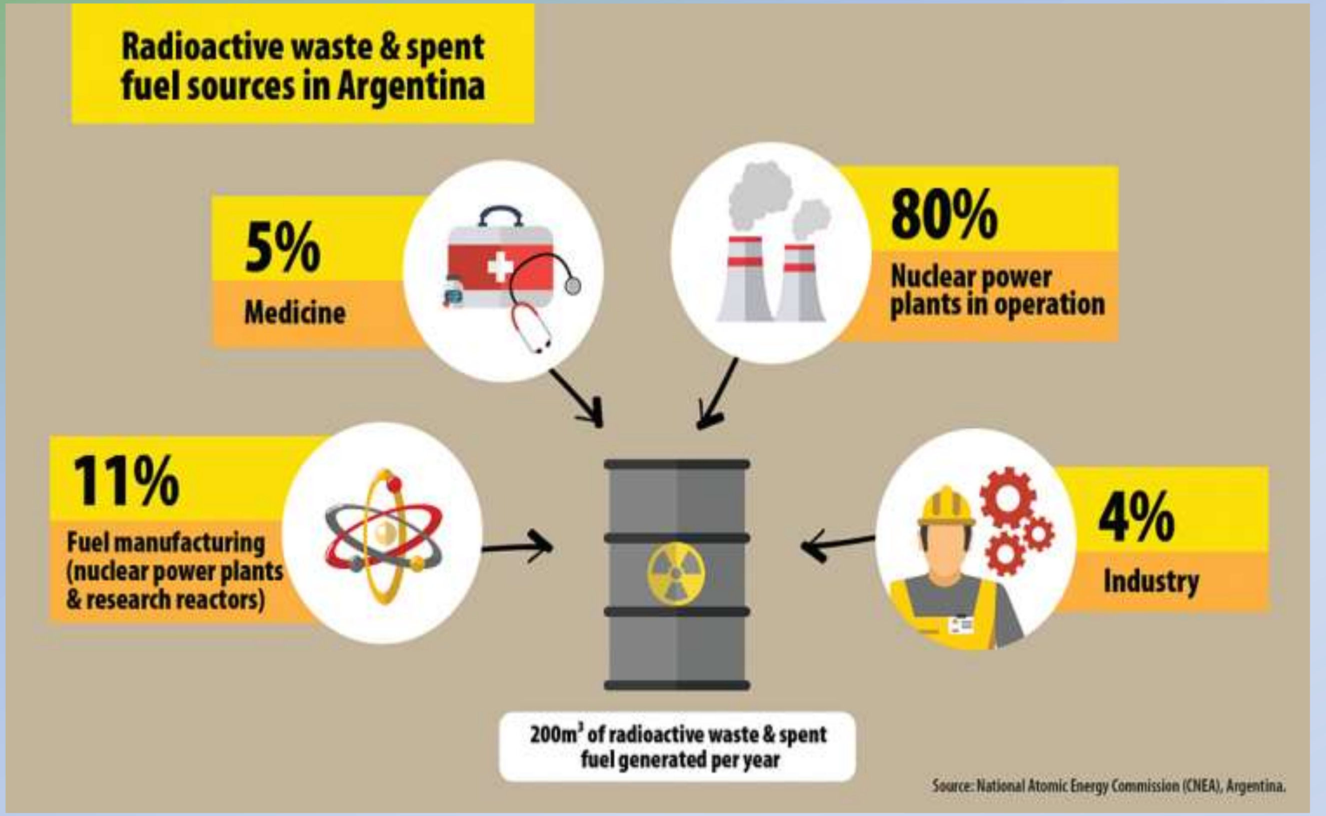
Intermediate-level waste

- Requires shielding
- Resins, chemical sludge, metal cladding
- Materials from reactor decommissioning (99% of their radioactivity is in fuel itself)
- Often solidified in concrete or bitumen
- 7% of the volume, 4% of the radioactivity of all waste



Near Surface Repository For Low And Intermediate Level Short-Lived Radioactive Waste (Design) - Project B25-1. At shutdown Ignalina NPP (2 @ 1500 MWe RBMKs). Source: Ignalina NPP

High-level waste (HLW) and SNF



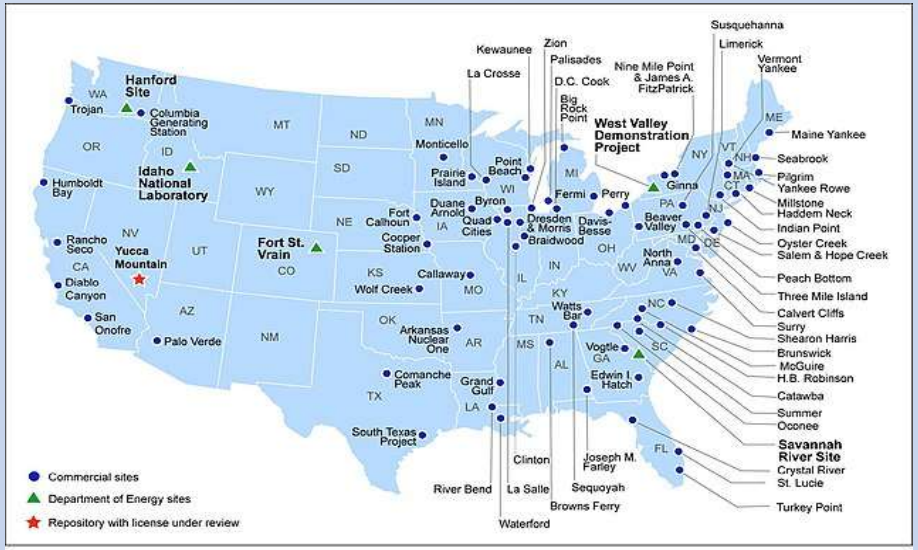
- This waste is 3% of the volume, but 95% of all radioactivity.
- Comes from burning U in a reactor
  - Used fuel designated as waste
  - Separated waste from reprocessing used fuel
- Fission products and transuranic elements
- It requires cooling and shielding
- A "technical incentive" to wait 40-50 years after removal to store it permanently when there is less heat and the radioactivity as declined 99%

← Source: IAEA

Spent Nuclear Fuel

- 250,000 tons worldwide of SNF, mostly in storage ponds, increasingly in dry casks
- Initially stored in cooling pools until cooled for dry storage
- The amount is growing by at least 10,000 tons annually
- In the US alone, there are scores of HLW temporary storage sites

Source: World Nuclear Association ↑



Source: Department of Energy. | GAO-17-174

Source: US GAO at www.gao.gov/products/GAO-17-174 →

According to the Nuclear Energy Institute, a typical nuclear power plant in a year generates 20 metric tons of used nuclear fuel. The nuclear industry generates a total of about 2,300 metric tons of used fuel per year. Over the past four decades, the entire industry has produced about 62,500 metric tons of used nuclear fuel. If used fuel assemblies were stacked end-to-end and side-by-side, this would cover a football field about seven yards deep. When cooled they can be stored above ground in concrete casks ("dry cask storage") that must be protected by armed guards around the clock to ensure against terrorist attack.

Secure dry cask storage at Maine Yankee NPP, 8 km from Wiscasset, the self-proclaimed "prettiest village in Maine."
Source: Maine Yankee. →

Is it possible to reprocess SNF to extract the remaining energy content?

- Any SNF will have some U235 and Pu in it. Reprocessing allows Pu to be recovered, used in fuel, and unavailable for bomb manufacture. It is then mixed with depleted uranium oxide in a MOX fabrication plant to make fresh fuel. This process allows some 25-30% more energy to be extracted
- ← The US MOX facility at Savannah, South Carolina, was five times over cost at $8 billion and 10 years late when closed. Construction on the plant began in 2007 to implement a U.S.-Russian agreement for each nation to dispose of 34 metric tons of plutonium deemed unneeded by their nuclear weapons programs.
- Hundreds of thousands of tons of this material stored throughout the globe represent a major, ongoing threat to environment and safety.

Photo: Arms Control Organization

One possibility may be deep geologic storage. No facility has yet opened, and most are over cost or mired in controversy.

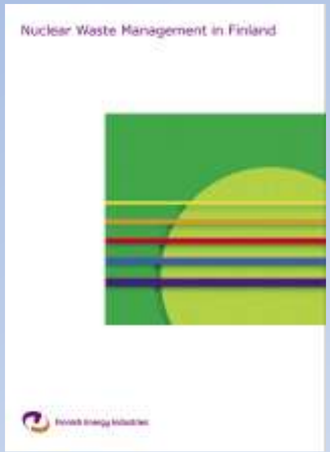
CLAB – the Central Interim Storage Facility for Spent Nuclear Fuel is located at Simpevarp about 25 kilometer north of Oskarshamn. This is where all the spent nuclear fuel from Swedish nuclear power plants is kept while waiting for the final repository to begin operating.

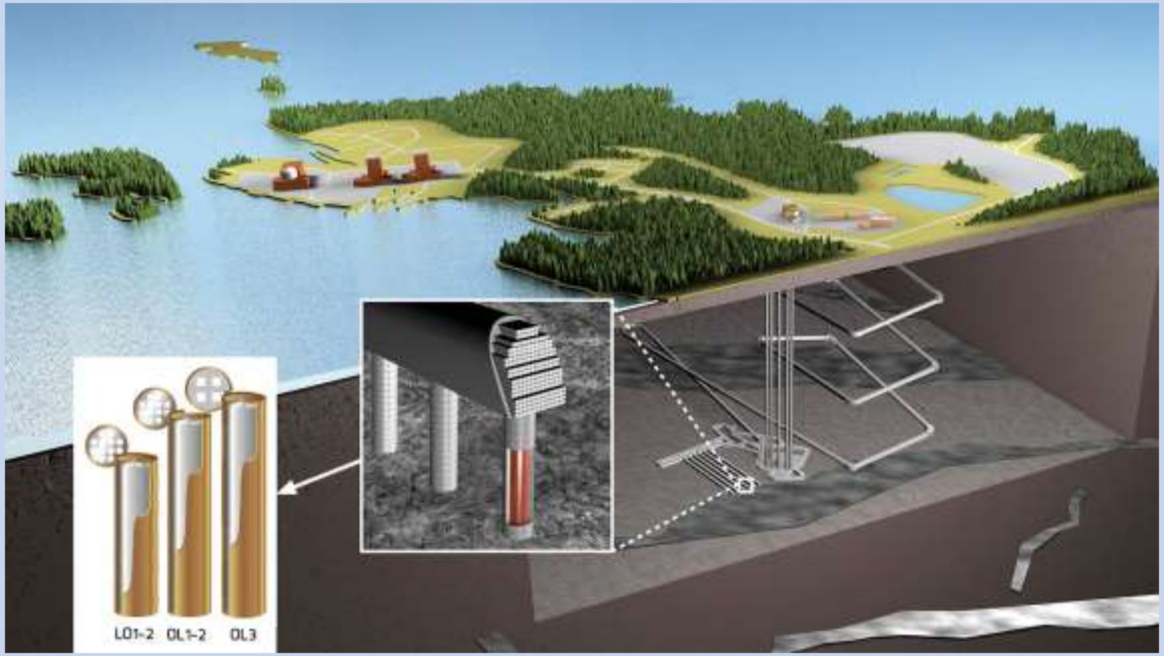
https://www.skb.com/our-operations/clab/

Deep Geological HLW Storage

- The Onkalo, Finland, facility, scheduled to open 2023. It is eight km from Olkiluoto NPP (with 2 BWRs). (At Olkiluoto a third reactor has been under construction for 17 years, Framatome ANP's 1600 MWe European Pressurized Water Reactor (EPR), and at $8 billion, three times over cost.).

- Illustration: NEA OECD

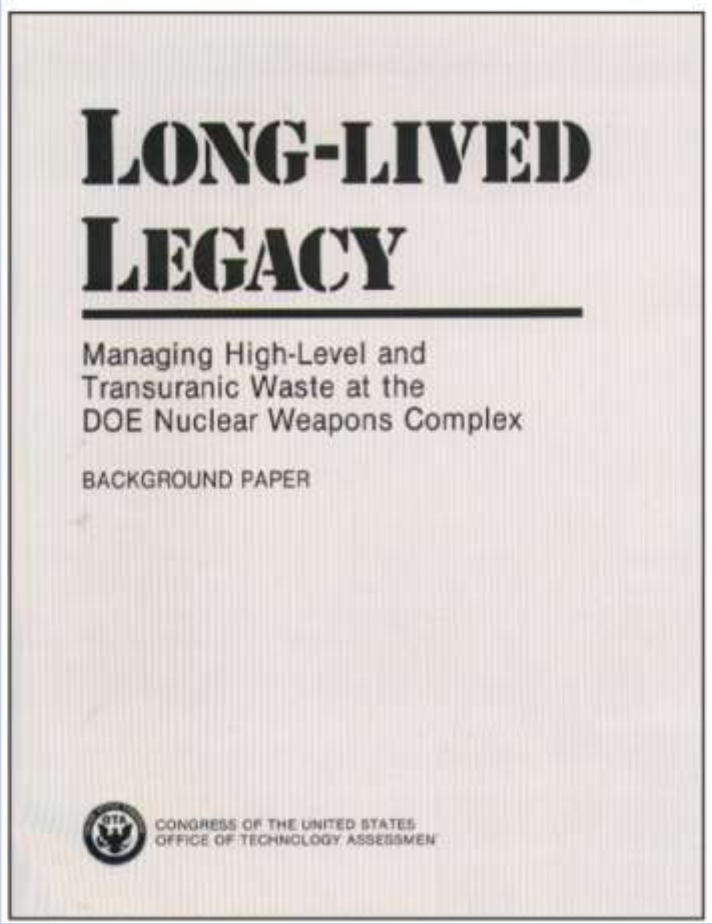




Legacy Waste

- The most important, yet considered separately and to this day poorly handled
- Cold War production of weapons grade fuel for military purposes
- Already from the 1970s specialists referred, quite vaguely, to the “legacy of radioactive waste.” In the US.
- In the late 1980s with a determination to clean up weapons production facilities, especially at Hanford, Washington, the designation of “legacy waste” as a special category became standard.
- An Office of Technology Assessment study from 1991, for example, refers to the legacy of waste. A US Nuclear Regulatory Commission Report of 2000 called this waste precisely “legacy waste” nine years later.
- Lag in definition of problem perhaps in the efforts of the Department of Energy to avoid environmental regulations, as ought to have been required by the US National Environmental Protection Act (NEPA, 1971) and the EPA (Environmental Protection Agency).

See: OTA, *Complex Cleanup: The Environmental Legacy of Nuclear Weapons Production* (Washington: OTA, 1991); National Research Council, *Long-Term Institutional Management of U.S. Department of Energy Legacy Waste Sites* (Washington: National Academy Press, 2000); Michael Veiluva, “Federal Responsibilities and Realities: An Alternative View of the Cleanup of The Nuclear Weapons Complex,” *Social Justice*, Vol. 22, No. 4 (62), Public Health in the 1990s: In the Shadow of Global Transformation & Militarism (Winter 1995), pp. 126-139.



LONG-LIVED LEGACY

Managing High-Level and Transuranic Waste at the DOE Nuclear Weapons Complex

BACKGROUND PAPER

CONGRESS OF THE UNITED STATES
OFFICE OF TECHNOLOGY ASSESSMEN

US legacy waste (US Department of Energy [DOE])

- The US has millions of m^3 of radioactive waste, thousands of tons of spent nuclear fuel and material, and huge quantities of contaminated soil and water. The Fernald, Ohio, site has 14 million kg of uranium product, 1.1 billion kg of waste, 2.5 million m^3 of contaminated soil and debris, and a 90 ha portion of the underlying Great Miami Aquifer had uranium levels above drinking standards.
- The United States has at least 108 sites designated as areas that are contaminated and unusable, sometimes many thousands of acres.
- At ORNL alone there have been at least 167 known contaminant release sites.
- The legacy of Hanford plutonium production alone consists of 8 nuclear reactors, 5 large plutonium processing complexes, 60,000 weapons, 200,000 m^3 of high-level radioactive waste in 177 storage tanks, plus 710,000 m^3 of solid radioactive waste, and contaminated groundwater over a reservation of 200 square miles (520 km^2).

The Radioactive Reality of Hanford Reservation

According to ICAN (the International Campaign to Abolish Nuclear Weapons), Hanford has 56 million gallons of legacy radioactive waste held in underground tanks and solid waste buried throughout the site. By the site's own admission, innumerable spills and solid waste burials were not accurately recorded. The environmental and health effects have been devastating–and ignored. The same story is true in Russia.

Plutonium Stockpiles, 1999

Country of Origin	Weapon-Grade Plutonium	Commercial-Grade Plutonium
Argentina	0	6 tonnes
Belgium	0	23-31 tonnes
Brazil	0	0.6 metric tons
Britain	7.6 tonnes	98.4 tonnes (~51 t. separated)
China	1.7-2.8 tonnes	1.2 tonnes
France	6-7 tonnes	151-205 tonnes (~70 t. separated)
Germany	0	75-105 tonnes (~17 t. separated)
India	150-250 kg	6 tonnes (<1 t. separated)
Israel	300-500 kg	0
Japan	0	119-262 tonnes (~21 t. separated)
Kazakhstan	2-3 tonnes	0
North Korea	25-35 kg	0
Pakistan	0	0.5 tonnes (0 t. separated)
Russia	140-162 tonnes	65 tonnes (~30 t. separated)
United States	0	257.2 tonnes (14.5 t. separated)

Source: Robert S. Norris and William M. Arkin, "World Plutonium Inventories – 1999," Natural Resources Defense Council, from the *Bulletin of the Atomic Scientists*, September/October 1999, at http://www.ccnr.org/plute_inventory_99.html

Plutonium Stockpiles

- The US Case: The amounts of plutonium produced in production reactors, where, and current inventories was declassified in the USA only in 1993.
- The United States Government has used 14 plutonium production reactors at the Hanford and Savannah River sites to produce plutonium for the U.S. nuclear weapons stockpile and DOE research and development programs.
- The total DOE plutonium acquisitions for the period 1944 to September 30, 1994, were 111.4 metric tons. Of the 111.4 MT plutonium acquired, 104 MT were produced in Government reactors; 103.4 MT in production reactors, and 0.6 MT in nonproduction reactors. In addition, 1.7 MT were acquired from U.S. civilian industry, and 5.7 MT from foreign countries.
- See https://sgp.fas.org/othergov/doe/pu50yc.html

Another form of Cold War high level radioactive waste: Buried Submarines Reactors

Hanford, Washington, Area 200. This burial ground contains 138 trenches running north and south. Sixty one of the trenches are 370 meters (960 feet) long, thirty one of the trenches are 293 meters long, and the remaining trenches vary. Trench 94 contains defueled US Navy submarine reactor compartments. The burial ground is marked and radiologically posted.

Photo and text:
Virtual Globetrotting

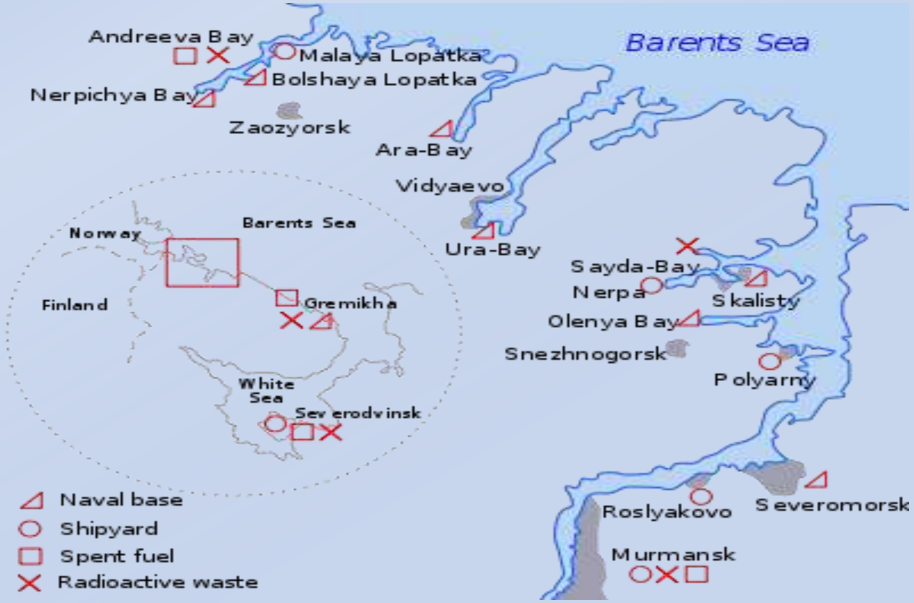
Spent nuclear reactor compartments in Trench 94, Hanford. *Photo Jurgen Hess*

The problem of legacy waste throughout the world is no better

Russia faces costly and extensive problems, not the least of which because there is no complete inventory of waste sites, their location and their contents. Since legacy waste includes fallout and PNEs, careful cleanup make take decades. The problem concerns all of Russia's ZATOs, its testing grounds, its army and navy bases in the Ural Mountains, Krasnoiarsk region, and in Kazakhstan, Uzbekistan and elsewhere.

To give some sense of the scope of the problem the following photos reveal the radioactive legacy of the Soviet Northern Fleet, based on the Kola Peninsula, Murmansk province, and SNF dumps along with reactor vessels and decommissioned submarines.

Murmansk – Andreeva Bay



Rusting submarines, fuel containers, delapidated buildings, exposed to the Arctic world.
Sources: Bezopasnot’ RAO; Safronov and Nikitin; Bellona

Severodvinsk, Russia, on the White Sea

Severodvinsk, home to several nuclear shipbuilding yards, military, and radioactive waste facilities. Sunbathers on the shore.

Source: https://www.flickr.com/photos/45111575@N00/298063091

UN Sees Nuclear Power as Environmentally Sound

- UNECE *Technology Brief: Nuclear Power* (August 2021):

  "Nuclear power is an important source of low-carbon electricity and heat that contribute to attaining carbon neutrality. They have played a major role in avoiding carbon dioxide (CO2) emissions to date. Decarbonising energy is a significant undertaking that requires the use of all available low-carbon technologies. Analyses indicate that the world's climate objectives will not be met if nuclear technologies are excluded. Beyond existing large-scale nuclear reactors, nuclear power continues to evolve with new technologies emerging including small modular reactors (SMRs) and advanced reactor technologies. These technologies will complement established large-scale reactors and open new markets, including district heating, high-temperature process heat and hydrogen production. SMRs could provide electricity for small grids or remote locations and will improve the integration of variable renewable energy sources."

Does the Chain Reaction Continue?