RADIOACTIVE RESIDUES OF THE COLD WAR PERIOD:

A RADIOLOGICAL LEGACY

BY ABEL J. GONZÁLEZ

A dominating feature of the historical period known as the Cold War was the large-scale production and testing of nuclear weapons. These military activities brought with them an unprecedented generation of radioactive substances. A fraction of these "Cold War residues" ended up in the atmosphere and were dispersed throughout the world. Some remained in relatively isolated states in underground geological environments at the production or test site. Others have contaminated areas at times accessible to humans.

Augmenting this picture are other scenes of a Cold War legacy. Large amounts of radioactive waste and by-products are in storage from the production of weapons material. At some point, they are expected to be converted to peaceful applications or sent for final disposal.

Moreover, production facilities for military nuclear materials, nuclear test sites, and nuclear-powered military vessels all will be decommissioned at some stage — at the Kola Peninsula alone, a hundred out-of-service nuclear submarines are awaiting final decommissioning. The process will add to the accumulation of radioactive residues.

It would now seem that the Cold War has become just another chapter in history. The Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water marked the end of nuclear-weapon testing in the open environment and the Comprehensive Nuclear-Test-Ban Treaty may end nuclear-weapons testing altogether. Further treaties will constrain, and hopefully ban, the production of weapons material.

All this is good news. Yet the Cold War's radioactive residues remain for our generation to deal with, and they are demanding effective responses.

Over the past decade, the IAEA has been asked to play a greater role in helping countries address this Cold War legacy. A number of scientific assessments of radiological situations created by the Cold War have been carried out by experts convened by the IAEA — at nuclear test sites, nuclear production facilities, and waste dumping sites.

This edition of the IAEA Bulletin highlights these cooperative activities in the context of international developments and concerns.

Photo: Checking coconuts for radioactive contamination at Mururoa Atoll during an IAEA study.

ASSESSING COLD WAR RESIDUES

The IAEA has a unique responsibility within the UN system: it is the only organization specifically authorized by Statute to establish international standards for the protection of health (against ionizing radiation) and to provide for their application at a State's request.

Some years ago, the IAEA — jointly with five other international organizations — established new international standards of radiation safety. *(See the IAEA Bulletin, Vol. 40, No. 2, June 1998).* They are mainly intended for the control of radiation exposure arising from peaceful activities. Importantly, however, their underlying principles can be used for the retrospective evaluation of radiological situations created by unregulated military activities such as nuclear-weapon testing.

In recent years, a number of States have asked the IAEA to assess, against its international radiation safety standards, radiological situations arising from activities of the Cold War era. The objective has been to protect public health and eventually restore the affected environment for human use.

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Studies resulting from such requests have become the Agency's response to the radiological legacy of the Cold War. *(See box and graph, pages 4 and 5.)* Assessments have been requested by Kazakhstan for the Semipalatinsk site; by the Marshall Islands for Bikini; and more recently by France for Mururoa and Fangataufa in French Polynesia. At these sites "nuclear experiments" were conducted during the Cold War period. They involved nuclear-weapon tests of both fission and fusion devices and nuclear-weapon safety trials, and they were conducted in the open atmosphere and underground. *(See boxes, pages 6, 8, and 9.)* One test site studied was a large continental polygon; three others were *atolls. (See box, page 7.)* Another site studied was the Kara Sea in the Arctic where large amounts of radioactive residues were dumped.

DIMENSIONS OF THE PROBLEM

However comprehensive these IAEA studies might seem, they represent only an incomplete and small catalogue of the Cold War's radiological legacy.

Since the atomic bombing of Hiroshima and Nagasaki in Japan up to the recent tests carried out by India and Pakistan, more than 2400 nuclear-weapon experiments have taken place worldwide. In addition, large amounts of nuclear materials for military purposes have been produced. All these activities have generated huge amounts of radioactive residues. Their levels and effects have been studied by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and reported regularly to the United Nations General Assembly.

NUCLEAR-WEAPON TESTING

According to UNSCEAR — in addition to the sites studied by the IAEA — there are a number of other areas where weapon-testing experiments were carried out and where radioactive residues may remain.

They include sites in Algeria (Reggane and In-Ekker); Australia (Monte Bello, Emu and Maralinga); China (Lop Nor); Marshall Islands (Enewetak Atoll); Russian Federation (Novaya Zemlya, Totsk, and Kapustin Yar); USA (Nevada and Amchitka, Alaska)); various locations in the Pacific and Atlantic Oceans including the Malden, Christmas and Johnston Islands, as well as the sites in India and Pakistan where testing was recently done.

The Nevada test site was the location for 84 atmospheric nuclear tests; 81 tests were conducted during 1951-58, and three further tests were done in 1962. More than 900 underground tests took place between 1951 and 1992, thirty-two of which were reported to have led to residues as a result of venting. The largest underground test in the United States took place in 1971 in Amchitka, Alaska.

At Novaya Zemlya, a large and remote Arctic area, an extensive atmospheric test programme was carried out. There were several high-altitude tests, at least one land-surface test, two water-surface tests, three underwater tests and several underground tests.

Tests in the Pacific at Malden and Christmas Islands in 1957 and 1958 were air bursts over the ocean or explosions of devices suspended by balloons over land. Twelve tests, mainly surface tests, also were conducted during 1952-57 at three sites in Australia: Monte Bello Islands, Emu and Maralinga. A number of safety trials were conducted at the Maralinga and Emu sites, resulting in the dispersal of plutonium over large areas.

In Algeria, nuclear testing included low-yield tests at the sites of Reggane and In-Ekker in the Algerian Sahara in 1960-61.

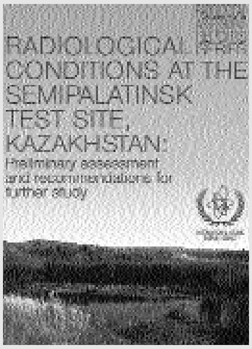
Tests at the Lop Nor site in the western China included 22 atmospheric tests that were conducted between 1964 and 1980, while underground testing continued until 1996. Also in the Asian region, a nuclear device was tested in India in 1974, and testing took place in May 1998 in both India and Pakistan.

In summary, 2408 nuclear experiments have been reported to UNSCEAR. Of these, 541 were atmospheric and 1867 were underground. The total yield* of all tests was 530 megatons. Of this total, 440 megatons were from atmospheric tests and 90 megatons from underground tests. The yield is the amount of energy generated by the nuclear explosion. The knowledge of yields and other testing characteristics allows scientists to establish the

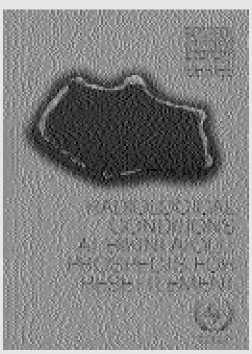
**Yield is usually expressed in kilotons or megatons, with one kiloton equivalent to 1000 tons of trinitrotoluene (TNT) and one megaton equivalent to one million tons TNT. Precisely in order to avoid ambiguity, it has been agreed that a kiloton is exactly equivalent to the release of 10^{12} calories of explosive energy.*

ASSESSING A COLD WAR LEGACY: THE IAEA RESPONSE

Over the past decade, countries have turned to the IAEA for assistance in assessing the radiological effects of past nuclear testing and dumping practices. The assessments include:

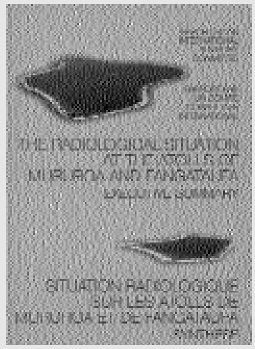


Semipalatinsk, Kazakhstan. In 1993, the Government of Kazakhstan informed the IAEA of its concern about the radiological situation in Semipalatinsk, where nuclear-weapons testing was carried out from 1949 to 1989. It requested assistance, and a preliminary radiological evaluation of Semipalatinsk was subsequently done. *(See article, page 12.)* More than 450 atmospheric and underground tests were conducted at the site. Although the IAEA preliminary study could offer reasonable assurances of safety to the permanent resident population of the region, it found very high levels of radioactive residues in large areas of the site itself: radiation doses of up to 140 mSv per year would be incurred if the site area was permanently inhabited. These findings do not take into account the potential radiological consequences of underground testing at Semipalatinsk, which the IAEA study did not assess.



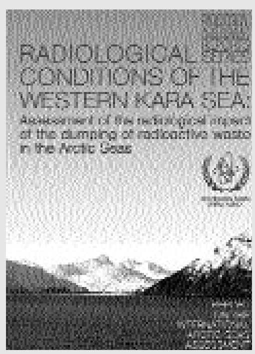
Bikini Atoll, Marshall Islands. In 1994, the Government of the Republic of the Marshall Islands — a Pacific Ocean archipelago of around thirty atolls and a few reef islands — requested assistance from the IAEA. The request was to conduct an independent international review of the radiological conditions at Bikini Atoll and to consider and recommend strategies for the eventual rehabilitation of the Atoll by the Bikinians. An extensive testing programme was conducted at this location. Before the testing started, the Bikinians had been evacuated far away from their residential location at Bikini Atoll — the Bikini Island — and they were now anxious to return to their homeland.

The IAEA Study, which has recently been published, concluded that Bikini Island should not be permanently resettled under present radiological conditions because individual radiation doses there could reach levels as high as 15 mSv per year and a number of relatively simple remedial measures, such as soil fertilization, could easily reduce the doses. If these measures are undertaken, the Study concluded, Bikini Island could be safely resettled. *(See article, page 15.)*



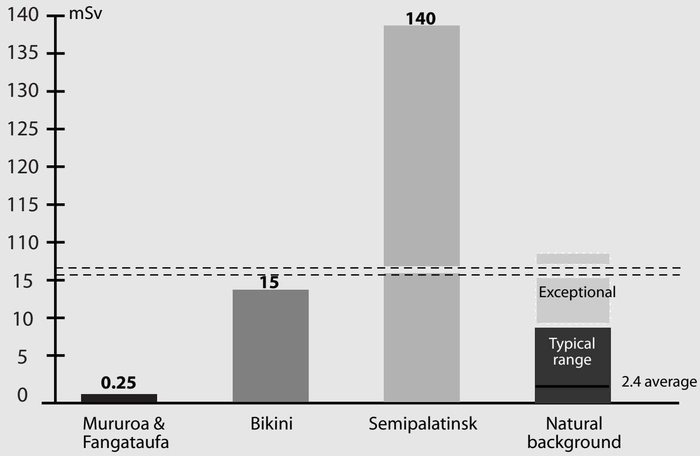
Mururoa and Fangataufa, French Polynesia. In August 1995, France became the first nuclear-weapon State to ask the IAEA to evaluate a nuclear test site, namely the radiological conditions at the Atolls of Mururoa and Fangataufa in French Polynesia. France had conducted 193 nuclear experiments at these atolls. Following the French request, the IAEA organized the Study of the Radiological Situation at the Atolls of Mururoa and Fangataufa — it was to become one of the largest radiological assessments ever carried out within the UN system. *(See articles on pages 21, 24, 30, 34, 38.)* The Study has recently been finalized and published by the IAEA in eight volumes. *(See box, page 23.)*

The Study's results have been encouraging: the Atolls, which have never been permanently inhabited, could be safely settled in the future because the highest radiation doses will fall below the negligible amount of 0.25 mSv per year in the more extreme hypothetical conditions of habitation.



Arctic Seas, Russian Federation. In 1993, the Office of the President of the Russian Federation reported on the former Soviet Union's dumping of radioactive waste in the Kara Sea. The amount of radioactive material subsequently estimated to have been dumped was huge: about 37 petabecquerels. The Russian announcement created great concern, not least among Contracting Parties to the Convention on Prevention of Marine Pollution by Dumping of Wastes and other Matters to which the IAEA has specific technical obligations. Consequently, an international evaluation project was undertaken and recently finalized. *(See article, page 18.)* Although the amount of radioactive material dumped is large, the project results were not alarming for public health and safety. Mainly because of the enormous dispersion capability of ocean waters and to the remoteness of the Kara Sea, the potential radiation doses to humans would be minute, the Study found. Only military personnel patrolling the fjords near the dumping sites could be expected to incur doses above natural background levels.

MAXIMUM ANNUAL RADIATION DOSES FROM COLD WAR RESIDUES



The graphs show maximum annual radiation doses that would be incurred by hypothetical individuals inhabiting the sites studied by the IAEA. It should be noted that unqualified comparisons of the results of these studies can be misleading due to different characteristics of the tests and of the sites where they took place and due to variations in the hypothesis used.

For reference purposes, annual natural background doses per year also are shown. Doses are expressed in millisievert as explained below.

*The **dose of radiation** is the energy absorbed from radiation per unit mass of matter, which for radiation protection purposes is weighted by two factors. One factor takes into account the effectiveness of a given type of radiation to induce health effects. The other factor takes account of the differing sensitivities of different organs of the body to radiation. The **unit of dose** is the joule per kilogram, but the term sievert (Sv) is used for the unit of the weighted dose. This graph uses the millisievert (mSv), which is equal to a thousandth of a sievert. The global average dose for individuals from natural background radiation is 2.4 mSv per year.*

activity* and isotopic composition of the radioactive residues generated by the test.

The 440-megaton yield exploded in the atmosphere has released into the environment the impressive amount of thousands of exabecquerel of radioactivity. *(See table, page 6.)* It has been dispersed and deposited as fallout, part locally and part globally. *(See box, page 9.)*

The radioactive residues from the 90 megatons exploded beneath the Earth are basically contained in the geological media. But they may move over the centuries through the geosphere and eventually reach the environment. *(See box, page 8.)*

The radiological legacy from nuclear testing is a multi-faceted picture. It is mainly due to the residual radioactive materials from nuclear-weapons safety trials, as well as from the local fallout caused by atmospheric tests. In addition, the legacy encompasses the potential migration of radioactive residues and venting associated with the underground tests that were conducted.

PRODUCTION OF WEAPONS MATERIALS

The production of nuclear weapons involves securing quantities of enriched uranium or plutonium for fission devices and of tritium and deuterium for fusion devices. The fuel cycle for military purposes is similar to that for the peaceful programmes for nuclear electrical energy generation: uranium mining and milling, uranium enrichment, fuel fabrication, operation of material-production reactors and fuel reprocessing mainly for the separation of plutonium. A main difference, however, is that peaceful nuclear programmes have generally been under the supervision and scrutiny of independent regulatory bodies, whereas military programmes usually were not.

Radionuclides have been released at various stages of the cycle for producing nuclear-weapons materials, but particularly during fuel reprocessing and plutonium separation.

In the USA, nuclear-weapons materials production plants include Fernald in Ohio (materials processing), Oak Ridge in Tennessee (enrichment, separations,

**The activity (or radioactivity) of a radioactive substance expresses the rate of nuclear transformation of radionuclides emitting radiation. It is the number of transformations occurring within that material per unit of time. The unit of activity is the reciprocal second, termed the becquerel (Bq). Since one Bq expresses a very small activity, the following multiples are used: 1000 Bq or kilobecquerel (kBq); one million Bq or megabecquerel (MBq); 1 x 10^9 Bq or gigabecquerel (GBq); 1 x 10^{12} Bq or terabecquerel (TBq); 1 x 10^{15} Bq or petabecquerel (PBq); 1 x 10^{18} Bq or exabecquerel (EBq). In order to grasp the magnitude of the becquerel, it should be noted that the Codex Alimentarius recommends that radioactivity in food should not exceed around 1000 becquerels of caesium, or one becquerel of plutonium, per kilogram of foodstuff.*

THE "NUCLEAR EXPERIMENTS"

Nuclear experiments were of two types: ***nuclear tests*** and ***safety trials.***

■ **In a nuclear test,** a nuclear device is exploded with large releases of energy. The explosion is caused by nuclear fission, by nuclear fusion, or a combination of both.

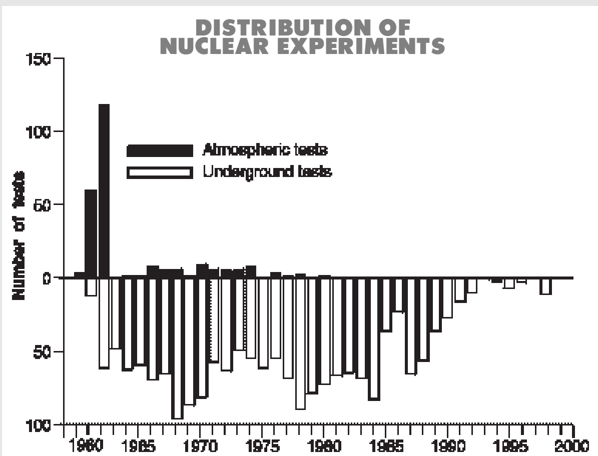
—***In a fission device,*** two subcritical masses of fissile material, such as uranium-235 and plutonium-239, are brought together to produce a supercritical mass. The heavy nucleus is spliced into two parts (the fission products), which subsequently emit neutrons, releasing energy equivalent to the difference between the rest mass of the original nucleus and the rest mass of the fission products and the neutrons.

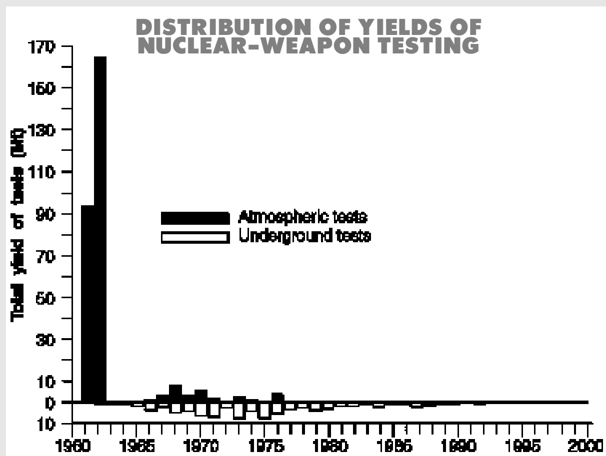
—***In a fusion device,*** atomic nuclei of low atomic number fuse to form a heavier nucleus with the release of large amounts of energy. The reaction becomes self-sustaining at very high temperatures, which are achieved with the help of an inner fission device surrounded by light hydrogenous material, such as deuterium and lithium deuteride.

■ **In a safety trial,** more or less fully developed nuclear devices are subject to simulated accident conditions. During them, the nuclear weapon core is destroyed by conventional explosives with no or, in some instances, very small releases of fission energy. While the radioactive residues of a nuclear test are the fission and fusion products, the radioactive residue of a safety trial is the fissionable material itself.

Both nuclear tests and safety trials were carried out in the atmosphere and underground.

The table and graphs present data from nuclear tests that have been conducted since 1960. The table covers the activity of nineteen radionuclides produced, released to the atmosphere, and globally dispersed in atmospheric nuclear tests. The data indicate the normalized release for fission and fusion devices, and the total activity released from worldwide testing.



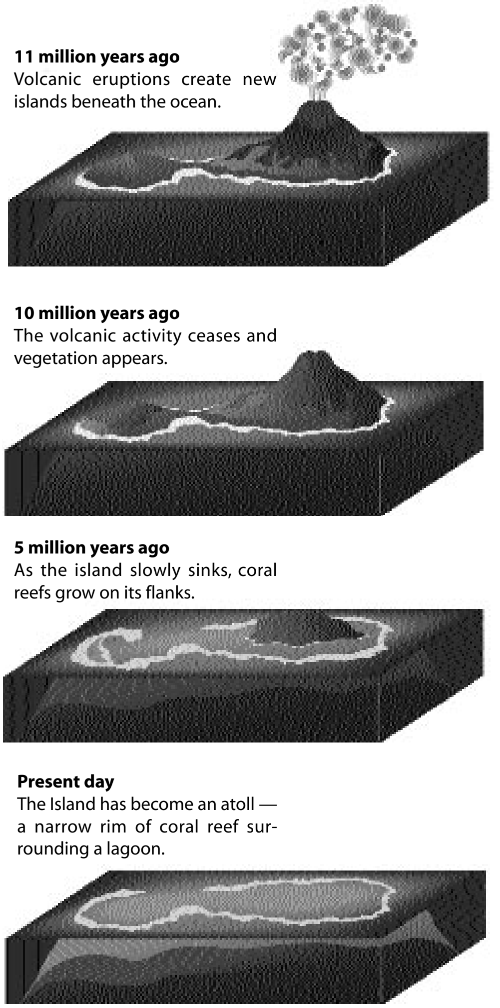


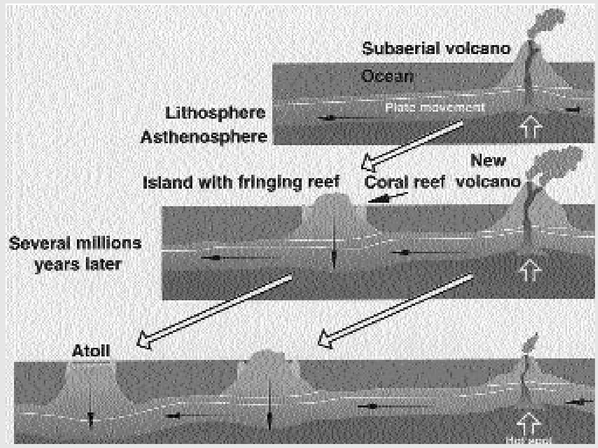
ACTIVITY OF RADIONUCLIDES PRODUCED IN ATMOSPHERIC NUCLEAR EXPLOSIONS

Radionuclide/half-life		Estimated activity (excluding local fallout)		
		Normalized release (Pbq/megaton)		*Total activity from worldwide testing (EBq)*
		Fission	***Fusion***	
Tritium	12.32 years	0.026	740	240
Carbon-14	5730 years		0.67	0.22
Manganese-54	312.5 days	-	15.9	5.2
Iron-55	2.74 years	-	6.1	2
Strontium-89	50.55 days	590	-	91.4
Strontium-90	28.6 years	3.90	-	0.604
Yttrium-91	58.51 days	748	-	116
Zirconium-95	64.03 days	922	-	143
Ruthenium-103	39.25 days	1540	-	238
Ruthenium-106	371.6 days	76.4	-	11.8

Radionuclide/half-life		Estimated activity (excluding local fallout)		
		Normalized release (Pbq/megaton)		*Total activity from worldwide testing (EBq)*
		Fission	***Fusion***	
Antimony-125	2.73 years	3.38	-	0.524
Iodine-131	8.02 days	4200	-	651
Caesium-137	30.14 years	5.89	-	0.912
Barium-140	12.75 days	4730	-	732
Cerium-141	32.50 days	1640	-	254
Cerium-144	284.90 days	191	-	29.6
Plutonium-239	24,100 years	-	-	0.00652
Plutonium-240	6560 years	-	-	0.00435
Plutonium-241	14.40 years	-	-	0.142

Notes: For simplicity it is assumed that all carbon-14 is due to fusion. ***Source:*** UNSCEAR.





NUCLEAR EXPERIMENTS AT ATOLLS

Many nuclear experiments assessed by the IAEA were conducted at *atolls* — ring- shaped coral reefs enclosing a lagoon. The reef is a narrow rim that juts a few meters above the ocean. In many places, irregular channels, called "hoas" were cut by ocean waters, creating a string of islets called "motus". Atolls evolved from volcanoes that millions of years ago erupted under the sea, creating islands that slowly subsided over time. Rims were formed by deposits of dead coral built up around the island as it subsided beneath the sea. Despite its volcanic origin, an atoll carries no risk of volcanic eruption. This is because the original island, as it subsided, was moved away from the original volcano"hot spot" by the drift of the Earth's geotechtonic plates.

laboratories), Rocky Flats in Colorado (manufacture of weapons parts), Hanford in Washington (plutonium production) and Savannah River in South Carolina (plutonium production). In the Russian Federation, the facilities include Chelyabinsk, Krasnoyarsk and Tomsk. In the United Kingdom, sites include Springfield (uranium processing and fuel fabrication), Capenhurst (enrichment), Sellafield (production reactors and reprocessing), Aldermaston (weapons fabrication) and Harwell (research). Plutonium production reactors were operated at Sellafield (two graphite-moderated, gas-cooled reactors known as the Windscale piles) and later at Calder Hall on the Sellafield site and Chapelcross in Scotland. A well-known fire in one of the Windscale reactors in 1957 resulted in the release of radionuclides. In France, the first experimental reactor, named EL1 or Zoé, went critical in 1948, and a pilot reprocessing plant began operation in 1954. A second experimental reactor, EL2, was constructed at the Saclay centre. From 1956-59, three larger production reactors began operation at the Marcoule complex on the Rhône River. These gas-cooled, graphite-moderated reactors, operated until 1968, 1980 and 1984 respectively. A full-scale reprocessing plant was also built and operated at the Marcoule site from 1958. Two further reprocessing plants were built at La Hague in the north of France.

In China, the first experimental reactor was constructed in Beijing, and a uranium enrichment plant was built in Lanzhou in Gansu Province. The production

UNDERGROUND NUCLEAR-WEAPON TESTING

Underground nuclear weapons testing began in 1951. After 1963, when the limited nuclear test ban treaty banned atmospheric tests, extensive underground test programmes were done. The Comprehensive Nuclear-Test-Ban Treaty, while not yet ratified by all countries, may effectively cease the practice of underground weapons testing.

The total number of underground tests has greatly exceeded that of atmospheric tests, although their total yield has been much less. Most underground tests were of lower yield, particularly where containment of nuclear debris was sought. In the short term, only with venting or diffusion of gases following these tests, as has happened on occasions, could contamination of the environment occur.

Several tests involved simultaneous detonation of nuclear charges, either in the same or separate boreholes or tunnels. These so-called “salvo” tests were done for reasons of efficiency or economy. They also deterred detection from distant seismic measurements.

The UNSCEAR record of the total number of all underground tests by all countries is 1867. The yields of individual tests are not fully available but the total yield is estimated to be 90 megatons. It would be desirable to have more complete data of those tests in which venting occurred, with estimates of the amounts of radioactive materials thereby dispersed in the environment.

Underground tests were usually conducted in geologically appropriate basements at depths several hundred meters below the Earth, though some were done at inappropriate locations.

Each explosion generates intense heat and high pressure:

Within tens of microseconds, the nuclear reactions are completed. Radiation energy vaporizes rock, leading to high pressure buildup and generation of an intense shock wave.

Within hundreds of microseconds, the shock wave transforms the surrounding rock and the heat generated vaporizes and melts surrounding soil and other material.

Within tens of milliseconds, the cavity stabilizes and molten lava collects at the bottom, in a lens-shaped pool — termed “meniscus” —trapping most refractory radionuclides.

Within minutes to hours, the molten rock solidifies and the roof of the cavity collapses, forming a roughly cylindrical cavity. Upon cooling, the molten soil solidifies as a glass-like lava. The cavity filled with rubble in turn eventually fills with water infiltrating from the surrounding soil.

Much residual radioactive material associated with underground nuclear testing is trapped in the lava. But some radionuclides are deposited on the rubble and are available for exchange with water in the cavity.

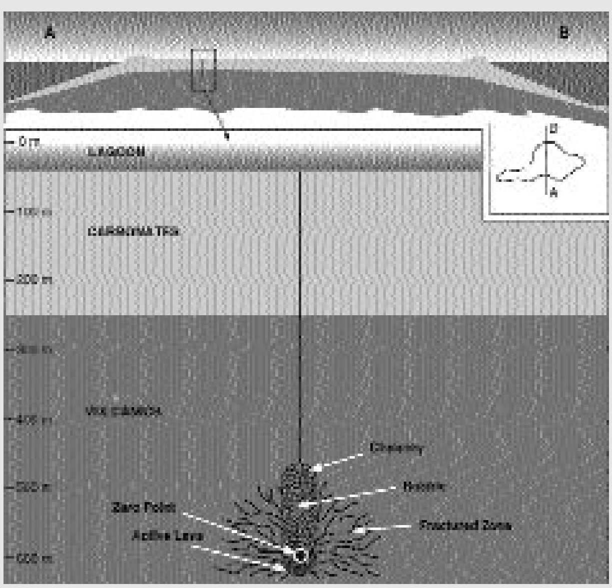
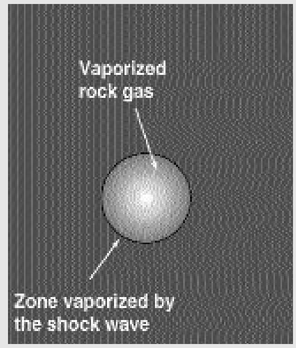
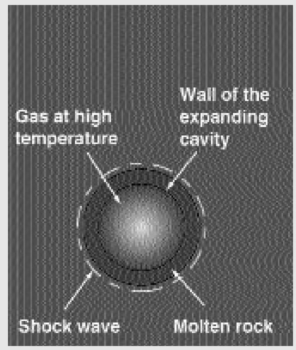


Figure: Underground Test at an atoll.

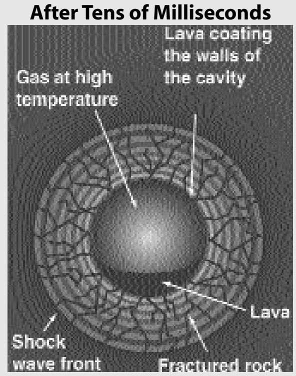
After Tens of Microseconds



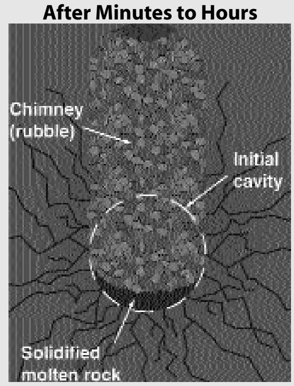
After Hundreds of Microseconds



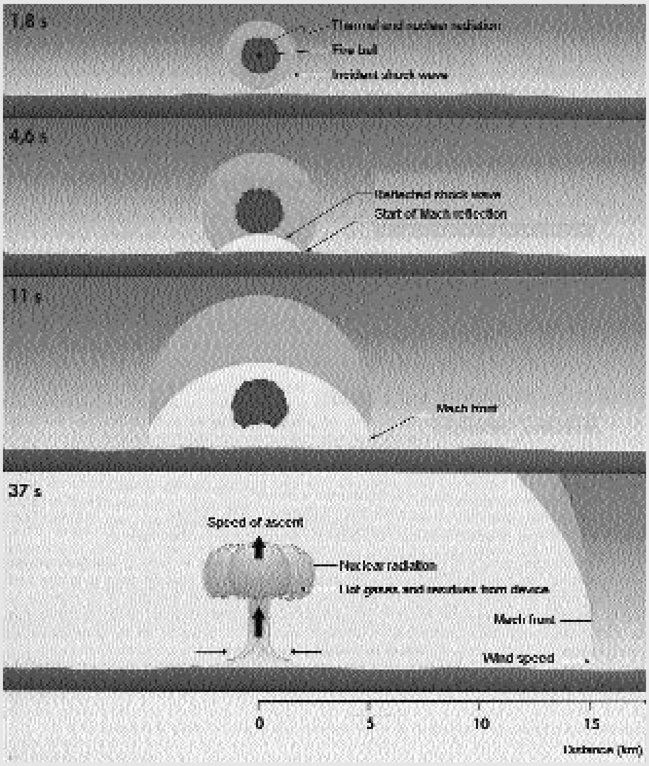
After Tens of Milliseconds



After Minutes to Hours



ATMOSPHERIC NUCLEAR-WEAPON TESTING



Atmospheric nuclear testing was conducted at various locations on and above the Earth's surface. It has included mountings on towers, place-ments on barges on the ocean surface, suspensions from balloons, drops from airplanes, and high-altitude rocket launchings.

The number of atmospheric tests peaked during 1951-58 and 1961-62. There was a moratorium in 1959, which was by and large observed in 1960. The most significant years of testing in terms of total explosive yield were 1962, 1961, 1958 and 1954.

The total number of atmospheric tests carried out by all countries was 541, and the total yield was 440 megatons. Twenty-five atmospheric tests account for nearly 66% of the total explosive yield of all tests.

Depending on the altitude of the explosion, the radioactive residues entered the local, regional or global environment. They have caused the largest collective radiation doses to humans thus far from man-made sources of radiation.

Radioactive residues. The radioactive residues from an atmospheric nuclear test are divided between local ground or water surfaces and the tropospheric and stratospheric regions of the atmosphere. Deposition depends on the type of test, location and yield.

The portion of the radioactive residues deposited locally at the site is termed *local* fallout. The remainder is widely dispersed in the atmosphere as *tropospheric* and *stratospheric* fallout.

Local fallout from surface tests can comprise as much as 50% of the production of radioactive residues and includes large radioactive aerosol particles. These particles are deposited within about 100 kilo-meters of the test site. Usually when the altitude of the deto-nation is suffi-ciently high, the fireball created by the explosion does not reach the level of the ground. This minimizes the production of local fallout. *(See figure.)*

Tropospheric fallout consists of smaller aerosols which are not carried across the tropopause after the explosion and which deposit with a mean residence time of up to a month. During this time, the debris becomes dispersed, though not well mixed, in the latitude band of injection following trajectories governed by wind patterns. From the standpoint of human exposure, tropospheric fallout is important for radionuclides with a half-life of a few days to two months.

Stratospheric fallout, which comprises a large part of the total fallout, results from particles which are carried to the stratosphere. They later give rise to global fallout, the major part of which is in the hemisphere of injection. Stratospheric fallout accounts for most of the worldwide residues of long-lived fission products.

In recent years, some further details about atmospheric nuclear testing have become available. In particular, the numbers and yields of explosions have been adjusted, and estimates have been made of the radioactive residues deposited from local fallout.

reactor began operation in 1967, and the reprocessing plant in 1968. Plutonium production and reprocessing were carried out at the Jinquan complex, also in Gansu Province, where weapons were assembled. Production and reprocessing also took place at Guangyuan in Sichun Province, where larger installations were constructed.

At some of the world's nuclear-weapons material sites, activities related to peaceful nuclear power programmes have been incorporated. At some of them, dismantling of weapons is taking place.

Relatively high releases of radioactive residues into the environment occurred during the early years of operating some of these facilities when pressures to meet production schedules were high and controls sometimes relaxed. In addition, a number of accidents have combined to enhance releases, particularly at facilities in the former USSR. *(See box, next page.)*

The amount of radioactive residues from nuclear-weapons material production is not fully known. UNSCEAR continues to collect and publish information provided by States.

OUTLOOK

Recent developments give rise to optimism about the generation and handling of Cold War residues:

- On 22 September 1995, the IAEA General Conference took up the issue of the radiological consequences of nuclear-weapon testing. In a landmark resolution, it called on all States concerned "to fulfil their responsibilities to ensure that sites where nuclear tests have been conducted are monitored scrupulously and to take appropriate steps to avoid adverse impacts on health, safety and the environment as a consequence of such nuclear testing".
- In September 1998, the IAEA General Conference — while recalling its 1995 resolution and welcoming the encouraging conclusions of the Study of Mururoa and Fangataufa — emphasized that those conclusions should not be used in justifying the development and testing of nuclear weapons, and requested the IAEA Director General to report on aposite developments in this area.
- The 1998 IAEA General Conference further urged all States to become parties to the Comprehensive Nuclear-Test-Ban Treaty. It also urged all States, especially those with the capability to produce fissile material, to support the negotiations for a treaty prohibiting the production of fissile materials for nuclear weapons or other nuclear explosive devices (FMT). The Conference on Disarmament had finally agreed to commence negotiations of the FMT.
- US and Russian representatives attending the 1998 IAEA General Conference agreed to bring commercial enterprises to ten Russian nuclear cities. By this agreement, the USA will lend its private enterprise experience to the ten Russian cities and match American private sector companies with appropriate Russian facilities for manufacturing, marketing and sales of commercial goods. A similar approach was tried in US nuclear cities such as Hanford and Oak Ridge.
- A recent agreement between Norway and Russia establishes cooperation in a number of areas. It addresses decommissioning spent nuclear fuel from nuclear-powered submarines; the commissioning of a temporary storage facility at Andreeva Bay, in Murmansk, Kola Peninsula; the commissioning of interim storage facilities of radioactive residues in Chelyabinsk, and at a shipyard in Severodvinsk, Arkhalgelsk; and the dismantling of a floating structure in Murmansk that is currently storing more than 600 hazardous damaged spent fuel elements from nuclear-powered vessels.

The IAEA continues to work within this evolving global framework, to assist countries in dealing with the radiological legacy of the Cold War. It is encouraging that non-governmental organizations concerned with environmental protection are supporting these IAEA efforts.*

At the 1998 Conference on the Study of the Radiological Situation at the Atolls of Mururoa and Fangataufa, IAEA Director General Mohamed ElBaradei summarized the Agency role: while the responsibility for safety lies primarily with national governments, he said, the IAEA plays a fundamental role through three complementary activities: "the development of legally-binding international agreements and the servicing of their implementation; the establishment of a comprehensive corpus of non-binding safety standards; and the provision of assistance in the application of those standards".

**At the IAEA Conference on the Mururoa Study in 1998, the representative of Greenpeace International stated that "the Study could serve as a model for similar studies of former nuclear test sites".*

NUCLEAR MATERIALS PRODUCTION IN THE FORMER USSR

Three sites in the former USSR were major production centres for nuclear-weapon materials.

■ The **Mayak** nuclear materials production complex is located in the Chelyabinsk region between the towns of Kyshtym and Kasli near the eastern shore of Lake Irtyash. Operation of uranium-graphite reactors for plutonium production and a reprocessing plant began in 1948. Relatively high discharges of radioactive materials to the nearby Techa River occurred during 1949-56. Controls of releases, initially absent, were introduced in the early 1960s. More than 100 PBq of fission products and plutonium isotopes were released as effluents into the atmosphere and into the Techa River during 1949-1956. In April-May 1951, a heavy river flood resulted in contamination of the flood plain used for livestock grazing and hay making. In 1956, residents of the upper reaches of the river moved to new places of residence and the most highly contaminated part of the flood plain was enclosed.For some inhabitants, however, the Techa River contamination has remained a significant source of exposure up to the present time.

On 29 September 1957, a fault in the cooling system of a storage tank containing liquid radioactive wastes led to a chemical explosion and a large release of radionuclides. The total activity dispersed off-site over the territory of the Chelyabinsk, Sverdlovak and Tyumen regions was approximately 74 PBq. Further contamination with radioactive residues associated with the operation of the Mayak complex occurred in 1967, when water receded from Lake Karachai, which had been used for waste disposal, and the wind caused re-suspension of contaminated sediments from the shoreline.

■ The **Krasnoyarsk** nuclear materials production complex is located about 40 kilometers from the city of Krasnoyarsk. The first direct-flow reactor at Krasnoyarsk was commissioned in 1958, the second in 1961 and the third closed-circuit reactor in 1964. A radiochemical plant for irradiated fuel reprocessing was put into operation in 1964. Radioactive waste discharges from the Krasnoyarsk complex enter the Yenisei River. Trace contamination can be found all the way from the city of Krasnoyarsk to the river estuary about 2000 kilometers downstream. In 1992, two of three reactors of the Krasnoyarsk complex were shut down. This reduced considerably the amount of radioactive discharges into the Yenisei River.

■ The **Tomsk** complex is located on the right bank of the Tom River 15 kilometers north of the city of Tomsk. It was commissioned in 1953 and is the largest complex for the production of plutonium, uranium and transuranic elements in the Russian Federation. The Tomsk complex includes uranium-graphite production reactors, enrichment and fuel fabrication facilities, and a reprocessing plant. Radionuclides in liquid wastes are discharged into the Tom River, which flows into the Ob River. In 1990-92, three of the reactors of the Tomsk complex were shut down, reducing considerably the amount of radioactive discharges to the Tom River.

On 6 April 1993, an accident occurred at a radiochemical plant, resulting in the release of radioactive materials. The radiological consequences of the accident were assessed by the IAEA. A narrow trace of low radioactive contamination 35 to 45 kilometers long was formed in a north-easterly direction. The village of Georgievka is the only populated place in the area of the pattern.

The IAEA's role in undertaking radiological assessments, Dr. ElBaradei said, "is to be objective and scientifically credible", and he underlined that the Agency remains prepared to respond to further requests in this area.

Epilogue: *In late 1998, the Government of Algeria filed a request with the IAEA for a technical cooperation project with the objective of "quantifying the radioactive contamination caused by nuclear explosions [in Algeria], evaluate the radiological impact on the local population and set up a plan to monitor the former nuclear test sites". The request was submitted to the IAEA Board of Governors in December 1998 and favourably considered.*

At the same time, the international community is starting to learn more about another potential radiological legacy of the Cold War: powerful radiation sources once used for military purposes that are unregulated and abandoned. The Republic of Georgia recently requested the IAEA's assistance in the wake of a radiological emergency. Two powerful radiation sources were found, one abandoned along the banks of a river, and another unshielded source in the countryside near a border town.

Over the past year, Georgian authorities report they have found more than fifty abandoned radiation sources that are probably of military origin. ❒