Chernobyl

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Abstract

The accident at the Chernobyl nuclear power plant represents the largest release of radionuclides into the atmosphere in the history of the nuclear industry. It resulted in serious environmental and human health hazards for the territories and population of Ukraine, Belorus, and Russia. The releases contaminated about 125,000 km2 of land in Belarus, Ukraine and Russia with ^{137}Cs levels greater than 37 kBq/m2, and about 30,000 km2 with ^{90}Sr greater than 10 kBq/m2.

The accident's consequences differ from the previous nuclear accidents because of the magnitude, peculiarities, and the duration of exposure. This created a unique possibility to study the future environmental and human health impacts of radionuclides. Today, these issues remain imprecise for simple technical reasons. Because of this, the legacy of Chernobyl has become a subject of debates between those who want to minimize the consequences of the accident and those who wish to promote a catastrophic assessment.

The Accident

The Chernobyl Power Complex (Figure 3), lying about 90 km north of Kiev (Figure 1), Ukraine, consists of four nuclear reactors of the RBMK-1000 design that has significant drawbacks, making the plant potentially unstable and easily susceptible to loss of control. Because the RBMK reactor (Figure 2) produces a positive power coefficient at low power ("positive void coefficient") [17], an experiment performed on 26 April 1986 at low power with most emergency and control systems turned off led to an uncontrollable power surge. Lack of physical containment allowed the resulting two explosions to blow the off roof the power plant and emit radioactive material.

The reactor block and adjacent structure were fully destroyed by the initial explosion (Figure 4). On the roof of the destroyed reactor building, radiation levels reached a frightening 100,000 roentgens an hour. Nearby buildings were ignited by burning graphite projectiles. Radioactive particles swept across the Ukraine, Belarus, the western portion of Russia and eventually spread across Europe and the whole Northern Hemisphere (Figures 5, 6, 7).

The graphite fires continued to burn for several days despite the fact that thousands of tons of boron carbide, lead, sand and clay were dumped over the core reactor by helicopter. The fire eventually extinguished itself when the core melted, flowed into the lower part of the building and then solidified, sealing off the entry.

About 71% of the radioactive fuel in the core (about 135 metric tons) remained uncovered for about 10 days until cooling and solidification took place. One hundred and thirty five thousand people were evacuated from a 30-km radius exclusion zone.

According to different sources, the number of people involved in clean up ranges between 200,000 and 800,000 [17].

The radioactivity releases was estimated to be about two hundred times that of the combined releases in the bombing of Hiroshima and Nagasaki. Millions of people were exposed to the radiation in varying doses.

Release, Dispersion and Deposition of Radionuclides

Different analyses vary in their estimation of the releases resulting from the accident. The total release of radionuclides to the environment has been approximated as 1900 PBq of activity in the Report to the U.S. Department of Energy (Office of Health and Environmental Research) [1] and 12 EBq in assessment of the OECD Nuclear Power Agency. The latest available estimate of radionuclide releases during the Chernobyl accident is summarized in Table 1 [17].

Table 1. Current estimate of radionuclide releases during the Chernobyl accident [17]

Core inventory on 26 April 1986			Total release during the accident	
Nuclide	Half-life	Activity (PBq)	Percent of inventory	Activity (PBq)
^{33}Xe	5.3 d	6 500	100	6500
^{131}I	8.0 d	3 200	50 - 60	~1760
^{134}Cs	2.0 y	180	20 - 40	~54
^{137}Cs	30.0 y	280	20 - 40	~85
^{132}Te	78.0 h	2 700	25 - 60	~1150
^{89}Sr	52.0 d	2 300	4 - 6	~115
^{90}Sr	28.0 y	200	4 - 6	~10
^{140}Ba	12.8 d	4 800	4 - 6	~240
^{95}Zr	1.4 h	5 600	3.5	196
^{99}Mo	67.0 h	4 800	>3.5	>168
^{103}Ru	39.6 d	4 800	>3.5	>168
^{106}Ru	1.0 y	2 100	>3.5	>73
^{141}Ce	33.0 d	5 600	3.5	196
^{144}Ce	285.0 d	3 300	3.5	~116
^{239}Np	2.4 d	27 000	3.5	~95
^{238}Pu	86.0 y	1	3.5	0.035
^{239}Pu	24 400.0 y	0.85	3.5	0.03
^{240}Pu	6 580.0 y	1.2	3.5	0.042
^{241}Pu	13.2 y	170	3.5	~6
^{242}Cm	163.0 d	26	3.5	~0.9

The release of radioactive material to the atmosphere consisted of gases, aerosols and finely fragmented fuel [17]. The composition and characteristics of the radioactive material in the plume changed during its passage due to wet and dry deposition, decay, chemical transformations, and alterations in particle size. The area affected was particularly large due to the high altitude and long duration of the release (10 days [15, 16, 17]) as well as the change of wind direction.

However, the pattern of deposition was very irregular, and significant deposition of radionuclides occurred where the passage of the plume coincided with rainfall.

During the important releases of radioactivity meteorological conditions changed frequently, causing significant variations in release direction and dispersion parameters. The largest particles, which were primarily fuel particles, were deposited essentially by sedimentation within 100 km of the reactor. Small particles were carried by the wind to large distances and were deposited primarily with rainfall. ^{137}Cs was selected to characterize the magnitude of the ground deposition because it is easily measurable, and it was the main contributor to the radiation doses [17] received by the population once the short-lived ^{131}I had decayed. Moreover, it is considered a biological significant radionuclide (a combination of high decay energy, biogeochemical availability, efficient energy transfer to biological systems, and ubiquitous production during nuclear accidents and from industries [4]).

The three main spots of contamination resulting from the Chernobyl accident have been called the Central, Bryansk-Belarus, and Kaluga-Tula-Orel spots (Figure 2). Ground depositions of ^{137}Cs over 40 kBq/m^2 covered large areas of the Northern part of Ukraine and of the Southern part of Belarus. The most highly contaminated area was the 30-km zone surrounding the reactor, where ^{137}Cs ground depositions generally exceeded 1,500 kBq/m^2. The ground deposition of ^{137}Cs in the most highly contaminated areas reached 5,000 kBq/m^2 in some villages of Belarus.

In addition, outside the three main hot spots in the greater part of the European territory of the former Soviet Union, there were many areas of radioactive contamination with ^{137}Cs levels in the range 40 to 200 kBq/m^2. Overall, the territory of the former Soviet Union initially contained approximately 3,100 km^2 contaminated by ^{137}Cs with deposition levels exceeding 1,500 kBq/m^2; 7,200 km^2 with levels of 600 to 1,500 kBq/m^2; and 103,000 km^2 with levels of 40 to 200 kBq/m^2.

The plume Initially moved in northwest direction to Scandinavia, the Netherlands, Belgium, and Great Britain (Figure 3) exposing the public to levels up to 100 times the normal background radiation. Later it shifted to the South and much of Central Europe, as well as the Northern Mediterranean and the Balkans.

Only trace quantities of actinides were detected in most European countries, and a very small number were found in quantities that were considered radiologically significant. The most radiologically important radionuclides detected outside the Soviet Union were ^{131}I, $^{132}Te/I$, ^{137}Cs and ^{134}Cs. A very serious concern posed the contamination of grain and dairy products from fallout.

Dose Estimates

A large number of people received substantial doses because of the Chernobyl accident. The amount is a subject of speculation and debates. The Soviet authorities and the nuclear power agencies were suspected of underestimating the results. Moreover, for the average Ukrainian it is clear that the Soviet Health and Nuclear Energy bodies were unable to provide an accurate registration of the doses received. The OECD Nuclear Power Agency provided the following data [17]:

- Liquidators - amounted up to 800,000 who were involved in clean-up operations. The average doses to liquidators are reported to have ranged between 170 mSv in 1986 and 15 mSv in 1989. The most exposed received the doses of several grays.

- (The global annual average radiation dose from natural background is 2.4 mSv, with considerable geographical variation. Hence, in a lifetime an individual accrues on average 2.4 x 70 = ~170 mSv from natural sources. Doses to specific organs are usually given in grays (Gy); but for the type of radiation involved here; one gray to the thyroid is equal to the equivalent dose of one sievert to the thyroid [16]).

- Evacuees - More than 100,000 persons were evacuated during the first few weeks following the accident who were exposed to internal irradiation arising from inhalation of radioiodines, especially ^{131}I, and to external irradiation from radioactivity present in the cloud and deposited on the ground. Thyroid doses are estimated to have been, on average, about 1 Sv for small children under 3 years of age and about 70 mSv for adults. Whole-body doses received from external irradiation prior to evacuation from the Ukrainian part of the 30-km zone showed a large range of variation with an average value of 15 mSv.

- People living in contaminated areas of the former Soviet Union - About 270,000 people live in contaminated areas with ^{137}Cs deposition levels in excess of 555 kBq/m2. Thyroid doses were received during the first few weeks after the accident; children in the Gomel region of Belarus appear to have received the highest thyroid doses with a range from negligible levels up to 40 Sv and an average close to 1 Sv for children aged 0 to 7. The whole-body doses for the 1986-1989 time period are estimated to range from 5 to 250 mSv with an average of 40 mSv. According to the estimations of the United Nations Scientific

Committee on the Effects of Atomic Radiation (UNSCEAR), the highest committed doses for the 70 years from 1986 to 2056 for people living in the most contaminated territories will reach 160 mSv.

- Populations outside the former Soviet Union - The radioactive materials of a volatile nature (such as iodine and cesium) that were released during the accident spread throughout the entire Northern Hemisphere. The doses received by populations outside the former Soviet Union were relatively low, and showed large differences from one country to another depending mainly upon whether rainfall occurred during the passage of the radioactive cloud. According to [5] the average dose to a person in Eastern Europe was 0.001mSv/hr, after three weeks of exposure, the total dose per person was 0.5Sv. In some areas of Poland, initial exposure levels were observed to be as high as 0.01mSv/hr. The values given do not include an exposure due to ingestion. Dose estimates made on a sample of eastern European people showed that this exposure measured no more than 1 Gy localized in the thyroid gland. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) estimated the average doses outside the former USSR as follows: the highest national average first year dose was 0.8 mSv; the highest European regional average committed dose over the 70 years to 2056 will reach 1.2 mSv.

Exposure pathways

According to WHO, "Six... pathways are possible by which exposure may occur following a nuclear accident..." [14]. External exposure includes ground shine, cloud shine, and deposition on skin and clothing. Internal exposure consists of ingestion, inhalation, and absorption from the skin. The main pathways to man resulting from the accident are “from external irradiation from the activities deposited on the ground and internal irradiation from the contamination of foodstuffs” [16].

"Direct exposure from deposited radionuclides together with the ingestion pathway was estimated to be three orders of magnitude greater than that from inhalation or exposure to airborne radionuclides (cloud shine)."

The OECD Nuclear Energy Agency stated [17] that the exposure of the population as a result of the accident resulted in two main pathways of exposure. The first is the radiation dose to the thyroid because of the concentration of ^{131}I and similar radionuclides in the gland. The second is the whole-body dose caused largely by external irradiation mainly from ^{137}Cs.

The absorbed dose to the whole body is thought to be about 20 times more deleterious, in terms of late health effects incidence, than the same dose to the thyroid [17]. Cesium is absorbed almost completely in the bloodstream of humans from the intestinal tract, and accumulates in muscles and parenchymal organs (liver, kidney, etc.) [11,12]. The main route of absorption for strontium is from the intestinal tract to the bloodstream. Eventually, it accumulates in bones [11,12].

Plutonium inhaled by humans is absorbed in the lungs. Then, depending on the chemical form, which can have a half-life of 1 –3 years, the plutonium isotopes are dissolve in body liquids and are transported to liver and bones, remaining there for a long time [11,12].

Radiation Effects

Different forms of ionizing radiation produce different biological effects [14]. In case of directly ionizing particles, the ion density along the path of low-energy radiation is greater than that along the path of high-energy radiation. Low energy radiation moves slower and has more time to interact. The total pathway of low-energy radiation is usually shorter, so the total number of interactions may well be less, compared to high-energy radiation. The ion density toward the end of the radiation path is greater than at the beginning, because the velocity of the radiation is less, and the probability of interaction is greater. As a result, ∀- particles are capable to produce the highest specific ionization (i.e. the greatest number of ion pairs per unit length of path, followed in order by ∃- particles and electrons. ϶-radiation interacts with the matter by transferring the energy to electrons.

As ionizing radiation passes through the body, it interacts with the tissues transferring energy to cellular and other constituents by ionization of their atoms [17]. This phenomenon has been extensively studied in the critical genetic material, DNA, which controls the functions of the cells. If the damage to DNA is slight and the rate of damage production is not rapid, i.e. at low dose rate, the cell may be able to repair most of the damage. If the damage is irreparable and severe enough to interfere with cellular function, the cell may die either immediately or after several divisions.

At low doses, cell death can be accommodated by the normal mechanisms that regulate cellular regeneration. However, at high doses and dose rates, repair and regeneration may be inadequate, so that a large number of cells may be destroyed leading to impaired organ function. This rapid, uncompensatable cell death at high doses leads to early deleterious radiation effects which become evident within days or weeks of exposure, and are known as "deterministic effects". These deterministic effects can be life threatening in the short term if the dose is high enough, and were responsible for most of the early deaths in the Chernobyl accident.

Lower doses and dose rates do not produce these acute early effects, because the available cellular repair mechanisms are able to compensate for the damage. However, this repair may be incomplete or defective, in which case the cell may be altered so that it may develop into a cancerous cell, perhaps many years into the future, or its transformation may lead to hereditable defects in the long term. These late effects, cancer induction and hereditary defects, are known as "stochastic effects" and are those effects whose frequency, not severity, is dose dependent. Moreover, they are not radiation-specific and, therefore, cannot be directly attributed to a given radiation exposure.

For this reason, low dose health effects in humans cannot be measured and, therefore, risk projections of the future health impact of low-dose ionizing radiation exposure have to be extrapolated from measured high-dose effects. The assumption was made that no dose of ionizing radiation was without potential harm and that the frequency of stochastic effects at low doses would be proportional to that occurring at high doses. This prudent assumption was adopted to assist in the planning of radiation protection provisions when considering the introduction of practices involving ionizing radiation. The ICRP has estimated the risk of fatal cancer to the general population from whole-body exposure to be 5 per cent per sievert.

The health impact of the Chernobyl accident can be classified in terms of acute health effects (deterministic effects) and of late health effects (stochastic effects); moreover there are also psychological effects, which can influence the health.

Acute effects

Immediate effects were limited to reactor the plant personnel and “liquidators”. Two people died during the accident. Over 400 people were at the site and were exposed to large amounts of radiation. About 237 (figures differ in different sources) were admitted to hospitals and 134 were diagnosed with acute radiation sickness. 28 of these people died within 3 months. Gastrointestinal damage was a serious concern, causing early and lethal changes in intestinal function among 11 patients who had received doses greater than 10 Gy. The deaths of 26 of the 28 patients who died were associated with skin lesions that affected over 50% of the total body surface area. After the acute phase, 14 additional patients have died over the past ten years. Of those who recovered, most continued with emotional or sleep disorders. 30% suffered from various medical disorders that reduced their ability to work. No clinical symptoms of acute radiation syndrome were seen in the people evacuated from the 30-km evacuation zone or in residents of affected areas, according to [17].

Long-Term Effects

The only consensus reached so far concerning the long-term effects is that Chernobyl have caused significant increases of childhood thyroid cancer in the region around the plant [16], [17]. Thyroid cancer is due to the inhalation of radioactive iodine or ingestion from drinking milk from cows that ate grass contaminated with radioactive particles. ^{131}I is absorbed and bioconcentrated in milk. The ^{131}I becomes incorporated almost exclusively in the thyroid gland. This is particularly true for children in the contaminated regions in Belarus, northern Ukraine and the Bryansk and Kaluga regions of the Russian Federation. The minimum latency period between exposure and the diagnosis of thyroid cancer seems to be about 4 years.

The report includes the following table of data showing the increase in thyroid cancer rates.

Number of Cases Per Year

Country	1986	1987	1988	1989	1990	1991	1992	1993	1994
Total									
Belarus	2	4	5	7	29	59	79	82	333
Russian Federation	0	1	0	0	2	4	6	11	24
Ukraine	8	7	8	11	26	22	47	42	208*

Incidence per Million Children

Country	1986	1987	1988	1989	1990	1991	1992	1993	1994
Belarus	0.9	1.7	2.2	3.0	13	26	28	34	36
Russian Federation	0.0	2.0	0.0	0.0	4.0	0.0	8.0	12	22
Ukraine	0.7	0.6	0.7	0.9	2.2	1.8	3.9	3.5	3.1*

*Incomplete number

The rate of thyroid cancer in children up to the age of 15 has increased 200 fold in Gomel Oblast, Belarus since the accident.

The histology of the cancers has shown that nearly all (95% of the cases) were papillary carcinomata (Ni94) and that they were particularly aggressive, often with prominent local invasion and distant metastases, usually to the lungs.

Usually, the thyroid can be successfully removed so most of the victims are expected to recover. The cancer rate tends to increase [17]. According to [16], the extent of the future incidence of thyroid cancers as a result of the Chernobyl accident is very difficult to predict. Because of the uncertainties in dose estimates and, the present increase in the incidence would probably persist for several decades. Other thyroid diseases, such as autoimmune thryroiditis, nodular goiter, and hypothyroidism have been intensely studied, but show no reliable signs of increase.

As stated in the Assessment of the NEA Committee on Radiation Protection and Public Health [17], “there has been no increase in leukemia, congenital abnormalities, adverse pregnancy outcomes or any other radiation induced disease in the general population either in the contaminated regions or in Western Europe, which can be attributed to this exposure. It is unlikely that surveillance of the general population will reveal any significant increase in the incidence of cancer.” The statement is at odds with Ukrainian and Belorussian other observations

Several studies report a large increase in a number of specific diseases involving the endocrine, nervous, digestive, and genitourinary systems, referring to psychological effects. The studies also report increases in the incidence of mental retardation, behavioral, and emotional problems in exposed children.

At the same time, Vladimir Bebeshko, the Director of the Institute of Clinical Radiology, Ukraine, [15] published the health effects of the Chernobyl Accident on

- The 237 people who suffered from acute radiation syndrome (ARS),
- The 15 000 people who lost their ability to work owing to disease,
- The 12 000 children who received large doses to the thyroid gland,
- The 9 000 children who were irradiated in utero

  (No exposure doses were provided).

The main health disorders observed have been:

- Gastrointestinal which were inflammatory in the years immediately following the accident and ulcerative in later years;
- Immunological, the homeostasis (natural balance) of which
- was genetically determined;
- Metabolic, with disorders appearing 5-6 years after the accident;
- Respiratory, primarily chronic obstructive bronchitis;
- Haemopoietic, blood disorders characterized by an increase or decrease in the number of white blood cells.
- Neuropathologies, in some cases a reduced mental capacity.
- Cardiovascular

There are no documented cases of cancer in patients with confirmed ARS, though study groups of irradiated children have shown incidences of thyroid cancer.

[15]. However, a few former USSR republics, especially Belarus, reported a rise in leukemia, a condition that would have been expected to increase.

According to the Ministry of Emergencies of Belarus' the incidences of birth defects have increased in heavily contaminated areas. A condition known as "minisatellite mutation" in the Mogilev district of Belarus is "unusually high".

Most genetic mutations resulting from exposure to radiation are recessive and are not likely to be expressed until the individuals affected have grandchildren. As some individuals continue to be exposed. As a result, many effects of radiation on an exposed individual may not be manifested for years to come.

It is possible that the actual rise in incidents of the diseases is masked by the mass resettlement into other unaffected areas after the accident. This may have resulted in skewed results since any increase in the rate of cancer would be averaged over a larger population of individuals, many of who had not been exposed.

Environmental and Agricultural Impacts

All soils throughout the world contain radionuclides to a greater or lesser extent (for instance ^{137}Cs as a result of nuclear testing). Typical natural soil constituents – ^{40}K, ^{137}Cs, ^{90}Sr - are then taken up by crops and transferred to food, leading to a concentration in food and feed of between 50 and 150 Bq/kg [17].

The most significant radionuclide contaminants in agriculture are those which are relatively highly taken up by crops, have high rates of transfer to animal products, and have relatively long radiological half-lives. At the same time, the ecological pathways leading to crop contamination and the radioecological behavior of the radionuclides are affected not only by the physical and chemical properties of the radionuclides but also by the soil types, pH, cropping systems (including tillage), climate, seasons and, where relevant, biological half-lives within animals.

The major radionuclides of concern in agriculture following a large reactor accident are ^{131}I, ^{137}Cs, ^{134}Cs, and ^{90}Sr. Their uptake by plants is the major source of contamination of agricultural produce.

Cesium is transported most intensively by diffusion within peat and sandy soils [12]. The most intensive transfer of 137Cs in vegetation characterizes these soils. In contrast, in clay-rich soils ^{137}Cs is fixed strongly and transported slowly along the biological chain. WHO [13] states that "... root uptake of cesium will be substantially higher for acid soils with a low clay and a high organic matter content and may continue for many years in some soil conditions." The transfer coefficients for ^{137}Cs depend mainly on the soil type. Considerably less ^{137}Cs is transported from dry land to water compared to ^{90}Sr. Considerable quantities of ^{137}Cs concentrate in foodstuffs of forest origin such as mushrooms, berries, and in fish of living in sediments and in mineral low content waters.

Strontium migrates in soils by diffusion. It enters plants slowly by through the roots and via secondary surface contamination caused by wind. Plants in sandy soils are accumulated easier compared to those with high clay and humus content. There is a 10-50 fold difference among the ^{90}Sr transfer factors of plants in different soils. About 0.1% of ^{90}Sr is absorbed by cows during a day and transferred to a liter of milk.

Because of their low solubility, the isotopes of plutonium migrate through the soil and water by the mechanical transport. Their transfer to plants and along the food chain to human is insignificant. Inhalation is the major pathway for plutonium.

The releases during the Chernobyl accident contaminated about 125,000 km2 of land in Belarus, Ukraine and Russia with ^{137}Cs levels greater than 37 kBq/m2, and about 30,000 km2 with ^{90}Sr greater than 10 kBq/m2. The reduction is reported to be slow. Cesium concentrates mainly in the upper 10-cm soil layer.

There is no agreement concerning the mobility of ^{137}Cs in soils. The OECD Nuclear Energy Agency [17] considers it relatively low while [6, 7, 8, 9, 10] estimate it as pretty high leading to still high concentration of ^{137}Cs in vegetation, fish, and sheep in Britain and Scandinavian countries. According to Sanchez A.L., et al, [8] “the plant to soil concentration ^{137}Cs ratio varied from 0.06 to 44.” They ascertained that the ratios are 4 – 7 times higher for the plants growing on highly organic soils compare to mineral soils. Smith J. T., et al, pointed out that the effective biological half-life in young fish, water and terrestrial vegetation has increased from 1 – 4 years during the first five years after Chernobyl to 6 – 30 years in the 1990th.

On the whole, it is not possible to predict the rate of radionuclide reduction and plant uptake, and the restrictions on the use of land are still necessary in the more contaminated regions in Belarus, Ukraine and Russia, and partially in Europe.

Because of the high filtering characteristics of trees, deposition was often higher in forests than in agricultural areas. When contaminated, the specific ecological pathways in forests often result in enhanced retention of radionuclides. The high organic content and stability of the forest floor soil increases the soil-to-plant transfer of radionuclides. As a result, berries, mosses, and mushrooms often exhibit high concentrations of radionuclides. This became evident in Scandinavia where reindeer meat had to be controlled. In other areas, mushrooms became severely contaminated with ^{137}Cs.

Radionuclides contaminate water sources from deposition from the air, discharge as effluent, and by washout from the catchment basin. Radionuclides contaminating are quickly redistributed in water and tend to accumulate in bottom sediments, benthos, aquatic plants and fish. The main pathways of potential human exposure may be directly through contamination of drinking water, or indirectly from the use of water for irrigation and the consumption of contaminated fish. There is no agreement regarding the contamination level of the river ecosystems.

Outside the former Soviet Union, direct and indirect contamination of lakes has caused and is still causing many problems, because the fish in the lakes are contaminated above the levels accepted for sale in the open market. In Sweden, for instance, about 14,000 lakes (i.e., about 15% of the Swedish total) had fish with radiocaesium concentrations above 1,500 Bq/kg (the Swedish guideline for selling lake fish) during 1987.

Potential residual risks

The destroyed reactor was entombed in a 300,000-tonne concrete and steel structure known as the "Sarcophagus". The construction was completed in November 1986. Currently, the design raises concerns for its stability and long-term resistance and represents a standing potential risk. Some supports for the enclosure are the original

Unit 4 building structures, which may be in poor condition following the explosions and fire, and their failure could cause the roof to collapse. This situation is aggravated by the corrosion of internal metallic structures due to the high humidity of the Sarcophagus atmosphere provoked by the penetration of large quantities of rain water through the numerous cracks which were present on the roof and were only recently repaired [17].

A technical solution leading to the elimination of the above sources of residual risk has been discussed. Unfortunately, the participating parties have not come to an agreement for financial reasons.

Figure 1. The site.

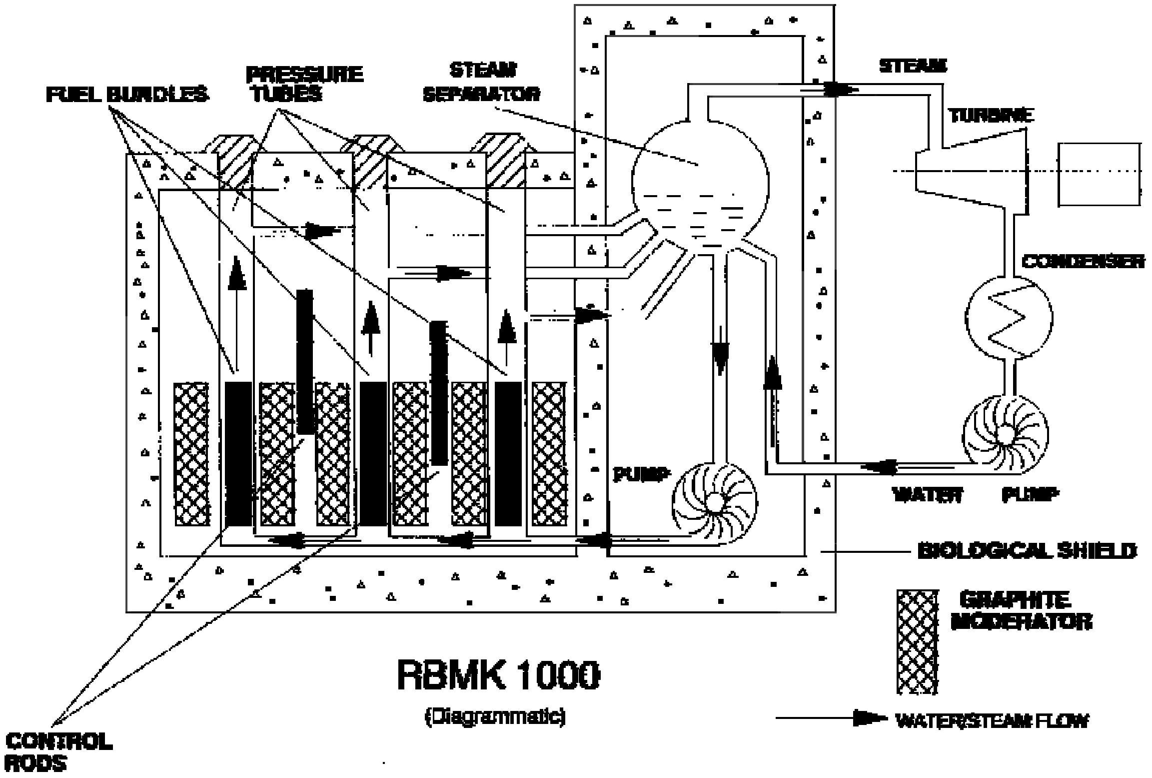


Figure 2. The RBMK reactor

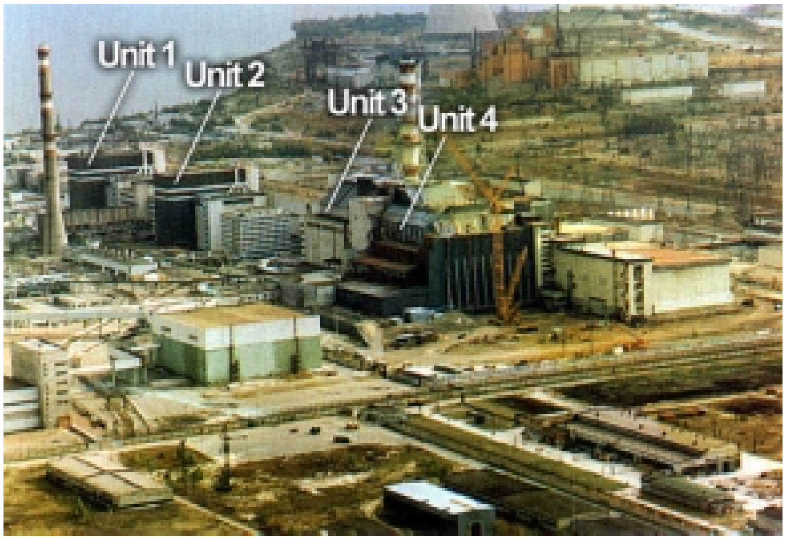


Figure 3. Arial view of Chernobyl Nuclear Power Plant (current)

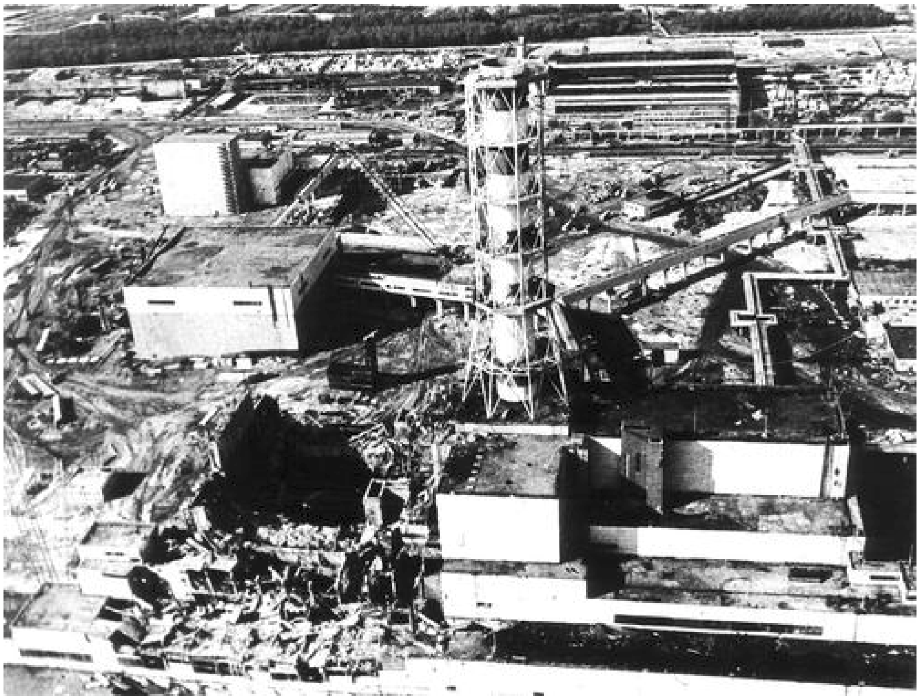


Figure 4. The aerial view of the plant after the accident.

Figure 4. The “Sarcophagus”

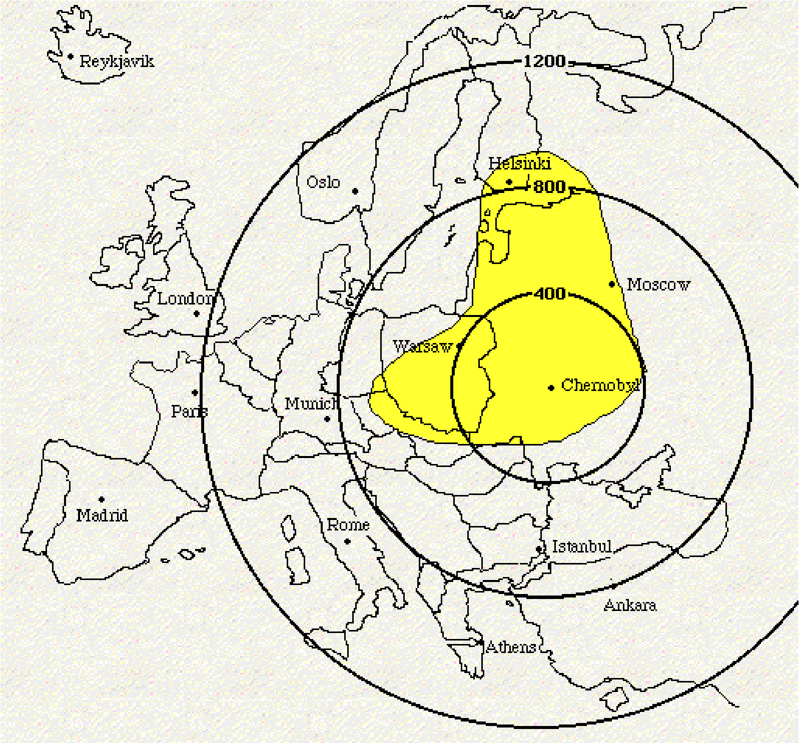
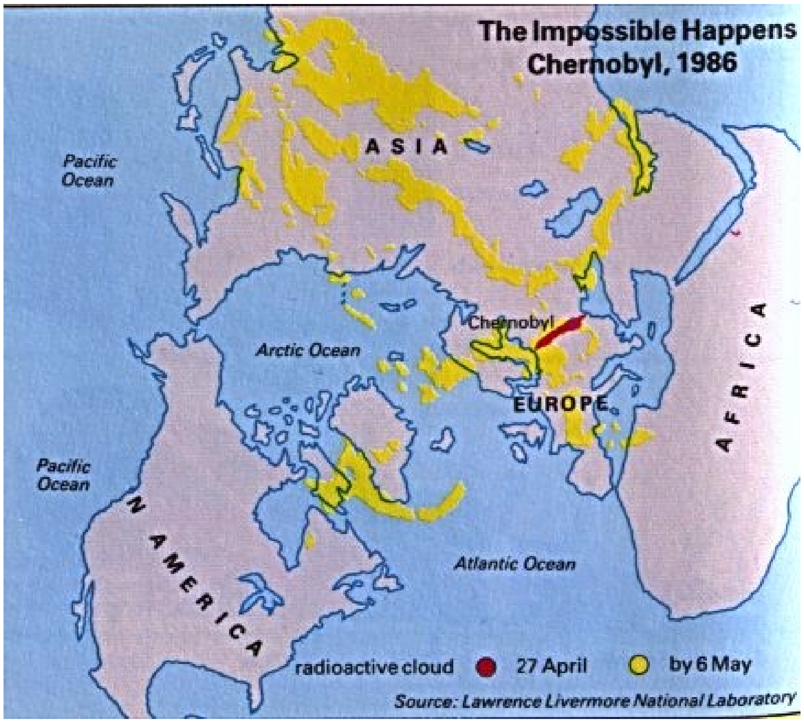


Figure 5. The movement of the plume toward Western Europe.



radioactive cloud 🟥 27 April 🟨 by 6 May

Source: Lawrence Livermore National Laboratory

Figure 6. Contamination areas as of 27 April 1986 and 6 May 1986

Figure 7. Contamination areas. (37 mCi/km^2 = 1 Bq/m^2).

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