Journal of Environmental Protection and Ecology 3, No 3, 698–705 (2002)

Environmental radioactivity

THE CHERNOBIL NUCLEAR DISASTER AND ITS TRACES IN BULGARIA AT PRESENT

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Abstract. Some of the effects from the disaster of the Chernobil Nuclear Power Station are considered. It is disposed at a short distance from Kiev, the capital of the Ukrainian Republic. These effects are referred to the territory of Republic of Bulgaria only. They concern mainly the soils, the foods, the hot particles and the population health. The assessment of these effects is made at present – 14-15 years after the calamity. It is established that in today's soils the radioactive deposits are fixed in the form of a layer, disposed at a definite depth. The radioactivity of the foodstuffs is in the admissible norms. The hot particles, presenting miniature pieces from the nuclear fuel of the reactor (UO_2), though having changed isotopic composition, represent a risk for the population health today, too. The illnesses number (mainly cancerous) is rised considerably. The expectations are that the maxima in the illnesses development will show themselves within the ranges of the mean life duration of one generation (50-70 years) mainly after year 2000.

Keywords: radionuclei, pollution, hot particles, illnesses, radio-phobia.

AIMS AND BACKGROUND

The Chernobil Nuclear Electric Power Station is built at about 130 km from Kiev, the capital of the Ukrainean Republic. In April 1986 4 energoblocks from the type RBMK-1000 work in it. The last, fourth energoblock, is put into operation on 31st of December of 1983.

The reactors from that type are developed about 30 years ago and are designed to provide the Soviet Military Nuclear Programme with Plutonium. The working fuel is uranium dioxide (UO_2) from the slightly enriched isotope ^{235}U, in initial quantity of about 20 kg of ^{235}U per a ton UO_2, or commonly about 3.5 tons per a full refueling of the reactor. The whole active mass is 175 t, distributed in 1700 tubes, having 18 heat-separating elements in each of them. The active zone has 7 m hight and diameter of 12 m. For management of the chain reaction and as an absorbent of the fast neutrons 211 rods of bleack-lead are used.

The nominal electric power of the reactors from the type RBMK-1000 is 1000 MW and the thermal power – 3200 MW[1].

At that type of reactors the production of electric power is attendant, for they are designed for the production of plutonium, which is obtained from worked-off nuclear fuel. At definite working regimes the reactor is unsteady, which imposes raised attention and immediate reaction to every deviation from the normal working regime.

On 25th of April of 1986, at plan stopping for repair of energoblock IV, the technical team, which is responsible for its exploitation, carry out an experiment, uncoordinated with the high authorities. During the implementation of the experiment important links from the systems for injury protection, security and signalling are shut out. Six rough operator's mistakes follows, the last of them in 1 h, 23 min and 40 s on 26th of April of 1986. Because of the positive coefficient of reactivity at low power in the reactor unmanageable, intensifying themselves processes are developed as an avalanche, which run up for seconds. The overheated water vapour breaks the reactor body by powerful explosion. Immediately after it by a second powerful explosion the accumulated in the reactor hydrogen explodes, too. The roof construction of the reactor hall of iron and concrete, which weights 800 t, jumps in the air, falls barely vertically and rest hanging on the supported walls, particularly ruined. The radioactive substances, heaped in the reactor, begin flying-off to the free atmosphere[1].

The bleack lead, used as neutron moderator in the reactors from that type, lights itself. At the developed high temperatures the overheated water vapour and the fire tongues raise the radioactive substances up to a hight of 1200 m in the atmosphere. Undertaken by the wind, they are spread away out from the reactor zone.

The radioactive emissions in the atmosphere contenue during the whole period of getting under control and liquidation of the disaster, as after 5th of May of 1986 they decrease harshly. That date is accepted for an end of the intensive emissions. Nowadays, the total amount of the released radioactive isotopes is estimated equal to 12.5×10^{18} Bq, from which $6\text{-}7\times10^{18}$ Bq are rare gases.

About 6 tons, i.e. 3-4% from the whole quantity of uranium fuel being in the reactor at the moment of the crash, are emitted in the atmosphere. 100% from the inert gases and from 20 to 60% from the soluble radionuclei are flown-off. The most considerable for the environment isotopes are emitted in quantities as follows: ^{131}I – $1.3\text{-}1.8\times10^{18}$ Bq; ^{134}Cs – 50×10^{15} Bq; ^{137}Cs – 90×10^{15} Bq or respectively 50-60% from the iodine and 20-40% from the caesium, heaped in the reactor body before the crash[1].

Different amounts from other radionuclei are emitted too, besides ^{131}I and caesium. More important are: ^{90}Sr, ^{95}Zr, ^{95}Nb, ^{103}Ru, ^{106}Ru ^{110}Ag, ^{125}Sn, ^{132}I, ^{132}Te, ^{140}Ba, ^{141}Ce, ^{144}Ce and many others. In the atmosphere these isotopes fall in various forms – from free and chemical-active ionic form till insoluble and incombustible ceramic compounds.

Radionuclei, having a decay period less than 1 month, present in general about 85% from the emission; 13% of it have a decay period of several months; at 1% of it that period is of about 30 years and at 0.001% of it – about 50 years.

A part of the radioactive substances leave the reactor under the form of miniature particles of pulverized uranium fuel, having especially high specific activity, others of them very shortly connect with particles of dust or water droplets from the air. These two types of radioactive aerosols form the group of "the hot particles"[1].

The radioactive isotopes, raised by the fire, are taken by the wind and together with the atmosphere flows are carried towards north. They reach Sweden. During the following days the wind direction changes continuously. The radioactive isotopes in the atmosphere, under the effect of their gravity, deposit themselves downwards continuously, and as a result the whole air layer is turned out a source of radioactive pollution. The radioactive substances, partially settled upon the earth surface, are carried off by the surface wind secondarily towards still unpolluted regions.

The precipitation is a very important factor for the surface radioactive pollution. It washes the radioactivity from the clouds and from the underlying air and deposits it upon the earth. The frontal cloudiness is prevailing cumulus, composed by separate, more or less developed, clouds, from which showers and heavy showers fall. In result on the earth surface the radioactive pollution is heterogeneous and depends on the amount of the fallen precipitation. A "spotted" radioactive pollution has occurred, as on places, distanced several hundreds meters, the activity differs in dozens and hundreds times – the local "hot spots" form, having high radioactivity and comparatively weakly polluted areas.

On the earth the radionuclei take their migration road by different ecological chains. Part of them rest on the vegetable cover. Other part is kept in the surface soil layer and the soluble mobile fraction goes inside the soil, towards the roots of the plants, the ground waters, the rivers, the lakes and the seas. So the long-term radioecological consequences start[1].

RESULTS AND DISCUSSION

On 1st of May 1986 the radioactive cloud has reached the Bulgarian territory. Its passing is accompanied by passing of an atmospheric front. The same day, about midday, the sensors of department "Measurement" in the National Institute of Meteorology and Hydrology at the Bulgarian Academy of Sciences, Sofia, register increasing of the radioactivity many times (of the order of tens thousands times), accompanying the weak rain fallen then. "Hot particles" from the nuclear fuel, thrown out during the reactor explosion, are found. Heavy radioactive pollution, characterised by a complex γ-spectrum, has come. It is observed at the earth surface, the subjects on it and in the rainfall sewage waters[2].

The fallen frontal rainfalls have spotted distribution. In result the specific summary activity of the rainfalls in the different areas changes from 18 Bq/l up to above 5700 Bq/l, as, depending on the total precipitation amount upon the earth surface, summary activity between 20 Bq/m^2 and 23 600 Bq/m^2 per 24 h is settled during the period of peak pollution. Average about 90% from that activity are due to ^{131}I, and the proportion ^{137}Cs: ^{90}Sr is about 3:1.

In its first days the Chernobil radioactive pollution exceeds many times the levels, reached during the period of intensive nuclear experiments before 1963 and creates complex configuration of the settled upon the earth surface activities, having clearly expressed influence of the altitude. The Southern Bulgaria pollution exceeds on average 2.2 times that in northern Bulgaria and is characterised by underlined heterogeneous distribution. At a distance of several kilometers the values measured differ between ten and more times. Aerogamma-spectrometer measurements show a presence of considerable, by gender, cise and specific activity "hot spots", having characteristic areas of several hundreds square meters. They are typical for the mountain areas and are comparatively more weakly expressed in the plains. The rainfalls since the beginning of May, having different intensity and prevailing spotted character, contribute to creating a pollution with complex configuration upon the earth surface.

In Bulgaria after the Chernobil disaster the radioactive pollution of the surface air and atmospheric deposits is the most large-scaled transboundary technogeneous radioactive pollution, come on the country territory for its whole history. Between the affected European countries Bulgaria comes on 11th place by pollution of its territory with ^{131}I and on 4th place – by ^{137}Cs (Ref. 1).

For the secrecy reason the country population is deprived of information about the event and measures are not taken for its current information. Measures for its most elementary radiation protection are not organised, too. In the same time such measures are undertaken towards the army and the high ranks of the authority. An aerogammaphoto is made of the government residence.

From 4th to 11th of May of 1986 mass athletic long distance races are carried out instead of providing information about the danger and announcement of measures for the population protection. On 19th of May of 1986 mass marathon, in which 41 000 children and youths take part, is carried out, too. In result of the inhaled radioactive aerosols, the content of radioactive iodium in the Bulgarian children's thyroid gland is on the first place in Europe. The same concerns the radioactive ^{137}Cs in the body of the Bulgarians. By these sinister records we retreated of the most polluted areas in Ukraine and Belarus only[3].

In 3-4 months the degree of radioactive pollution of the main foods decreased meanly 5 to 8 times in comparison with the beginning of the event. Because of lack of sufficient food and uncomprehension of the gravity of the problem during the season autumn–winter of 1986/1987 the domestic animals are fed on forages from the first mowing of the spring of 1986. Because of that, a "second radiation peak" came.

Other peculiarity of the radioactive cloud, that has been above the Bulgaria territory, was that it contained big amount of "hot particles". Part of them are monolith and the rests are porous. In result of the high temperature affect deep fissures are observed inside them. Their distribution by activities is logarithmic-normal (Fig.1).

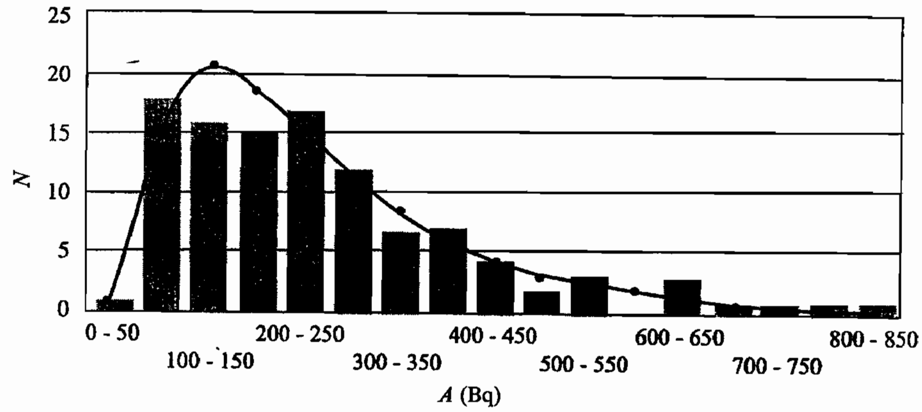

Fig.1. Density of distribution by activities of 109 "standard" high active "hot particles"[1]
N – number of the particles; *A* – Bq

"Hot particles", having changed isotopic composition, called "monoelemental", in which one or two radionuclei give the most or practically the whole radioactivity, are found, too. Towards 6th of May of 1986, between 3 and 5% of the activity of the "standard hot particles", settled in Bulgaria, are due to ^{90}Sr. Mean 13% from the whole settled in Bulgaria radioactivity are caused by the "hot particles". For the different areas of the country this part varies from 6 to 23%, as it is bigger for Northern Bulgaria than for Southern. Above 11% of the total radioactivity, inhaled by the "mean Bulgarian" during the period 2nd-7th of May of 1986, are caused by "hot particles". In result the risk of cancerous illnesses among the Bulgarian population is up to 6 times higher than the risk of the same activity, distributed homogeneously in the lung[1].

After the Chernobil disaster, the Bulgarian population irradiation is defined by a few basic sources: radioactive pollution of soils, surfaces, subjects etc., which causes raising of the γ-background and outer overbackground radiation of the human body; radioactive pollutions of the atmospheric air and of the drinking water, in result of which the radionuclei fall in the human body and cause inner radiation; radioactive pollution of the skin and the hair cover of the human being, so as of the clothes, which brings to contact radiation of foods and foodstuffs by radionuclei, which through the nutritive chains (plant–human being or plant–animal–human being) fall in the body and lead to inner radiation. It is assumed that the relative share of the first two sources is neglectibly little. 95% from the inner radiation of the Bulgarians are caused by ^{131}I, ^{134}Cs, ^{137}Cs and ^{90}Sr. It follows to account the fact, too, that the radioactive pollution in Bulgaria has clearly expressed heterogeneity (Table 1)[1].

Table 1. Division by areas of the territory of Bulgaria by level of surface radioactive pollutions and estimation of the mean doses[1]

Group	Area	Total effective dose (mSv)
I. Highest	Kurdjaly, Stara Zagora, settlements, having altitude above 800 m	1.7
II. High	Yambol	1.3
III. Mean	Sofia – town and county, Pernik, Russe, Silistra, Shumen, Haskovo, Razgrad, Pazardjik, Vidin, Targovishte, Gabrovo, Sliven	1.0
IV. Low	Burgas, Blagoevgrad, Varna, V.Tarnovo, Pleven, Dobrich, Kyustendil, Lovech, Montana, Plovdiv	0.8
V.Lowest	Vratsa	0.6

A few years after the disaster the generalised effective doses of the irradiation, accepted for the country population, are: for children – 1.03 and for the adults – 0.79 mSv. The maximum equivalent dose of thyroid gland radiation is about 200 mSv. It is expected the Bulgarian population to be charged with: fatal cancer (with lethal exit) – 363 cases, having different localisation; unfatal cancer – 107 cases or in general 470 cases. It is expected the serious genetic effects to reach 80 cases.

It is expected these illnesses maximum, except the cancer of thyroid gland and marrow, to express themselves in the frames of the mean life duration of one generation – 50-70 years. In every rest localisations the prognoses are, that they will be observed after 2000 (Table 2). The question arises – could these cases be "saved" to Bulgarians? (Ref. 1).

Table 2. Prognosticated cases of cancer illnesses in Bulgaria in consequence of Chernobil pollution[1]

Organ or tissue	Cases of fatal cancer	Period of manifestation
Bladder	18	after 2000
Marrow	31	about 1991
Bones surface	3	after 2000
Lacteal glands	12	about 2000
Large intestine	52	after 2000
Liver	9	after 2000
Lung	52	about 2000
Gullet	18	after 2000
Ovaries	6	after 2000
Skin	1(2)	about 2000
Stomach	63	after 2000
Thyroid gland	44	about 1995
Others	30	
By pre-natal radiation	20	
Total	363 cases	

At dynamics tracing of the illnesses of malignant newly-formations after 1986 it is established that they increase slowly every year. After 1993 the tendency is towards steeper increasing of the curve, describing standardised cases of sickening by some kinds of cancer, at the men as well as at the women. At the men the cases of the large intestine cancer and the rectum, the prostatic gland and the bladder become more frequent. At the women – of the lacteal gland, the cervix and the uterus, the ovaries and the large intestine. At sexes both, still from 1992-1993, the cases of sickening by skin cancer gradually increase. During 1996 at the men 1.9 per 100 000 people and at the women 2.5 per 100 000 people are sickened by skin cancer, as the mean number is 2.3 per 100 000 people.

During the first year after the disaster, because of the lack of official communications and explanations about the necessary radiation-protective measures, together with the circumstance, that a manipulated information for the radioecological status and the radiation danger is given, in the population a feeling of unsertainty, depression, defencelessness and a sense for own impotence are formed. The fragmentary, unsystematic and uncoordinated measures contribute to that, too. In result – radiophobia appeared and embraced the most of Bulgarians.

The radiophobia in our country brought to a psycho-social mass stress by Chernobil. That stress manifested itself mainly in the period 1986-1987 and after 1989. It caused arising of series stressogeneous illnesses, the most extended from which are: the artery hypertonia, the miocarditis ischaemia, the aterosclerosis, the diabetes, the asthma, the ulcer illness, etc.

In spite of the 15-years prescription of the crash, nowaday the country population has a sharpen sensitivity towards the radiation pollutions, towards the nuclear electric power stations as a whole and suspicion towards the responsible institutions of the government[1].

The economic consquences of the disaster come from: confiscation of the leafy vegetables from the market during May 1986; decreasing of the milk quantity, intended for direct consumption by the population, during the spring of 1987; prohibition of considerable amounts of meat for the internal market; scrapping and burial as a radioactive waste of medicinal plants from yield 1986; technological changes, made in order to utilise a maximum part from the radioactive-polluted products, having animal origin, and many others.

CONCLUSIONS

The total amount of damages by the Chernobil disaster, officially stated, runs up to 2 672 018 leva. By the rate of exchange of that time they are equal to about 3 millions $US. According to others, unofficial, but significantly more precise estimations, these losses run up to the huge sum of 186 500 000 of $US.

The preference of conjectural-political and subjective considerations before radiation-hygienic, social and commercial-economic arguments brought to one of the lowest coefficient of protectiveness so as to important financial losses for the country, which could be escaped at an adequate and professional active position of the autorities[1].

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Received 27 October 2001
Revised 15 June 2002