START

FROM BILL BA... 0011749

INFCIRC/368
28 July 1989

GENERAL Distr.
Original: RUSSIAN

International Atomic Energy Agency

INFORMATION CIRCULAR

REPORT ON A RADIOLOGICAL ACCIDENT IN THE SOUTHERN URALS ON 29 SEPTEMBER 1957

In response to concern expressed by the international community about the possible consequences of a radiological accident which occurred in the southern Urals in 1957, Soviet specialists have prepared the attached report containing information on this event.

The report has been provided to the Agency by the Chairman of the USSR State Committee on the Utilization of Atomic Energy and is being circulated to all Agency Member States for their information.

2924Y/224Y

Official translation from Russian

ACCIDENT IN THE SOUTHERN URALS ON 29 SEPTEMBER 1957

by

B.V. Nikipelov, G.N. Romanov, L.A. Buldakov,
N.S. Babaev, Yu.B. Kholina and E.I. Mikerin

To a very great extent, the negative attitude towards nuclear power which has arisen in certain sectors of our population can be explained by the inadequate information that has been provided concerning the activities of nuclear fuel cycle facilities. This involves questions relating to the construction of new nuclear power plants, and also a comparison of their effects on the environment with those of more traditional industrial undertakings such as thermal power stations, chemical enterprises and metallurgical plants. We are concerned here, furthermore, with information on accidents that have occurred in plants belonging to the nuclear industry and the consequences of those accidents.

In the years immediately following the Second World War a military installation was set up in the southern Urals to produce a completely new type of weapon - nuclear weapons, in fact, which were needed to strengthen the defensive capacity of our country. With a truly heroic and superhuman effort on the part of the Soviet people, under extremely difficult conditions - including conditions which had a deleterious effect on the health of the staff - this nuclear shield was created. During the first few years of operation no experience was available with facilities of this kind, and problems affecting the environment and the health of personnel had not yet been studied in a scientific manner. As a consequence, certain parts of the territory surrounding the facility were contaminated during the 1950s.

Very serious radioactive contamination resulted from an accident which occurred on 29 September 1957. Owing to a fault in the cooling system used for the concrete tanks containing highly active nitrate-acetate wastes, a chemical explosion occurred in these materials and radioactive fission products were released into the atmosphere and subsequently scattered and deposited in parts of the Chelyabinsk, Sverdlovsk and Tyumensk provinces.

The radioactivity released amounted altogether to about 2 million Curies[*]. The composition of the material released is indicated in Table 1.

For the area with a ^{90}Sr contamination density of 0.1 Ci/km^2 (double the level of global fallout), the maximum length of the deposition track under the radioactive plume formed reached 300 km; for ^{90}Sr contamination density of 2 Ci/km^2 it reached 105 km, with a width of 8-9 km. The area density distribution is shown in Table 2.

[*] 1 Ci = 3.7 x 10^{10} Bq. The Chernobyl accident released 50 million Ci.

The presence of gamma emitters among the contaminating nuclides was responsible for the external irradiation of the population and the environment. During the initial period the dose rate was about 150 μR/h[*] in the area with a ^{90}Sr contamination density of 1 Ci/km^2.

Owing to radioactive decay of the short-lived nuclides, contamination levels and gamma dose rates in the area of the accident fell off fairly rapidly during the first few years after formation of the cloud track (see Table 3), and subsequently the radiation situation was governed entirely by the presence of strontium-90 and its rate of radioactive decay. The exposure of the population in the contaminated territory was due in the first instance to external irradiation from the soil and from objects in their dwellings - including their own clothing - and also to internal irradiation due to the consumption of contaminated food and drinking water and inhalation of activity at the time when the cloud was being formed. Subsequently (after half a year to a year) internal exposure from contaminated food was predominant.

The radiation protection measures adopted for the population were as follows:

- Evacuation of the population;
- Decontamination of some portions of the agricultural land;
- Monitoring of contamination levels in agricultural produce and rejection of produce with activity levels exceeding the accepted norms;
- Limitations imposed on the utilization of contaminated land;
- Reorganization of agriculture and forestry, with the creation of specialized state farms and forestry enterprises operating in accordance with the special recommendations worked out in the light of the accident.

The dynamics of the evacuation exercise for persons living in regions with a ^{90}Sr contamination density above 2 Ci/km^2 are shown in Table 4.

In the immediate aftermath of the accident - that is, within 7 to 10 days - six hundred persons were evacuated from the settlements in the most severely affected area; and about ten thousand persons were evacuated in the 18 months following the accident. Altogether 10 180 persons were evacuated. Maximum average exposure doses preceding evacuation reached 17 rem in external exposure and 52 rem in effective dose equivalent (150 rem to the gastrointestinal tract).

Decontamination consisted mainly in ploughing under the surface layers of agricultural land. In 1958 and 1959 about 20 000 hectares of land at the head end of the cloud track were ploughed under in the usual way and

[*] 1 R = 2.58×10^{-4} coulomb/kg.

in 1960-1961 deep ploughing was carried out on 6200 hectares of land, in the course of which the contaminated surface layers were turned under to a depth of more than 50 cm.

A regime for limiting the use of contaminated areas and the access of the population to such areas was introduced immediately after the accident at the head end of the cloud track, and after completion of the evacuation in 1959 this regime was extended to the entire region with a ^{90}Sr contamination density in excess of 2 Ci/km^2; this region was then subjected to special sanitary protection regulations. Subsequently, in 1962, this zone was reduced to 220 km^2, with a maximum ^{90}Sr contamination density of 100 Ci/km^2 at the far end. The rest of the territory was returned to agricultural use.

In 1958, 59 000 ha were removed from agricultural use in Chelyabinsk province and 47 000 ha in Sverdlovsk province. Beginning in 1961, these lands were gradually returned to agriculture.

In Chelyabinsk six special state farms were set up, and in the Sverdlovsk region three such farms; in the latter region, agricultural production was restored in 1961. In Chelyabinsk province the restoration of lands to agricultural use was virtually completed by 1978, and by now 40 000 ha out of a total of 59 000 have been returned to agriculture.

The work of the specialized state farms is carried out in accordance with special scientific and practical regulations developed for the purpose[*] and is concentrated primarily on the production of meat as a product with minimum ^{90}Sr levels by comparison with other foodstuffs. For economic reasons the specialized state farms do yield other products as well, but where contaminated lands amount to 10-15% of the total agricultural land available to the farms, this land is used exclusively for the production of cattle and pig fodder. Levels of contamination of meat and milk on the specialized state farms of Chelyabinsk province are shown in Table 5. The effectiveness of this agricultural system, evaluated on the basis of the reduction in ^{90}Sr levels brought about in the produce of the specialized state farms by comparison with the levels in "unregulated" agricultural produce, amounts to factors of 2-7 for meat production and 3-4 for milk. However, these figures cannot be applied to the produce of individual farms.

Non-evacuated population continued to live in areas with an average maximum ^{90}Sr contamination density of around 1 Ci/km^2. The main exposure pathway for these people after the initial period following the accident was ingestion of strontium-90 with food, in particular milk (as much as 60-80%); strontium-90 is deposited in the skeleton, with consequent irradiation of bone and red bone marrow. After thirty years, the daily intake of strontium-90

[*] The relevant recommendations were formulated by experts of the Experimental Station set up by the USSR Ministry of Medium Mechanical Engineering in 1958 to study the consequences of the accident. This work was carried out in co-operation with the local branch of the Institute of Biophysics of the USSR Ministry of Health.

with food by these members of the population had dropped by a factor of 1300 in comparison with the initial period of the accident, and by a factor of 200 compared with 1958. This was due to the fact that strontium-90 concentrations in milk and other products fell off more quickly than would be expected from the isotope's decay rate (by factors of as much as 110 over thirty years) owing to physico-chemical processes which transformed the strontium in the soil, as well as other natural processes. The annual limit on intake of strontium-90 for a limited sector of the public, namely 0.32 μCi/year under NRB-76/87 [the 1987 radiation safety standards] was exceeded at a contamination density of 1 Ci/km^2 over the first four years following the accident. At present the annual strontium-90 intake for members of the population living in areas with a contamination density of 1 Ci/km^2 averages 3% of the permissible annual intake, the largest value being 12% in one settlement.

After thirty years in areas with a maximum average ^{90}Sr contamination density of 1 Ci/km^2, the effective dose equivalent was 1.2 rem, of which about 2.5 rem affected the red bone marrow and about 8 rem the bone. If we take a dose limit of 0.5 rem per year for exposure of the red bone marrow, the aggregate exposure over thirty years was 2.5: (0.5 x 30) = 0.17 of the permissible limit under NRB-76/87. This evaluation could well be increased by a factor of two, however, in view of the uncertainties in the formation of irradiation pathways.

In addition to studying matters of health and safety and the ecological situation that had arisen in the areas affected by the radioactive cloud, special medical brigades performed therapeutic and diagnostic tasks among the local population and carried out a public information campaign aimed at ensuring the best possible approach to radiation hygiene. This latter campaign consisted largely in propaganda for personal hygiene aimed at preventing the uptake of radionuclides in human beings, confiscation of foodstuffs contaminated beyond acceptable levels and in the replacement of those foodstuffs by pure uncontaminated products. In the first stage of the accident an effort was made to interrupt the food chain at the fodder-growing and stock-raising level: this was during the autumn and winter. Interruption of the food chain at the soil-fodder-crop-growing level was carried out in a second stage, during the spring and summer of the following year when radionuclides were reaching living organisms with the new harvest. The main steps taken at this stage were deep ploughing of the radionuclides and careful monitoring of fodder and of food for human consumption. Deep ploughing-under of the soil was started in the late autumn of 1957, but was carried out to a large extent in the summer of 1958. This was a measure which reduced the gamma dose by a factor of ten.

These should not be considered as radical measures. Although they made it possible to reduce the uptake of radioactive materials by human beings by a factor of more than ten, the radiation burden to internal organs was reduced by no more than a factor of two. This was due to the composition of the radionuclide mixture in the fallout from the accident.

Other clean-up measures also proved to be inadequately effective, especially as decontamination, owing to the special geographical characteristics of the region, produced comparatively poor results.

Medical surveillance of the population was carried out in the following manner. The zone affected by radioactive contamination was mapped out and the population living in that zone was transferred, stage by stage, to localities free of radioactive contamination (see Table 4). In all the inhabitants of the region - those who were resettled and also those who lived on the boundary of the resettlement zone, i.e. the region with contamination levels lower than 1 Ci/km^2 (^{90}Sr), and persons living further from the boundary of the contaminated zone - a number of health indicators were studied: these included general physical state, blood formation (haemopoiesis), neurological status, the development of children, the condition of new-born infants and their physical development, the development of allergies, the condition of the gastrointestinal tract, the incidence of infectious illnesses, and infant mortality. During the first three years after the accident these studies were carried out once a year and in the subsequent period once every ten years. The investigations are continuing at the present time with a view to finding any malignant tumours that have developed as well as other similar afflictions, and to establishing the causes of death among persons who spent a short time in either the contaminated region or in control areas.

These dynamic population studies have revealed the following. During the first three years the resettled population and groups living in the area with ^{90}Sr contamination levels above 2 Ci/km^2 (see Table 6) exhibited no excess over control groups of specific symptoms such as radiation sickness in any of its forms, nor were there any instances of bone marrow depression or any organic neurological changes or cases of allergy development. There was, further, no manifestation of any increased frequency of vegetative-vascular disorders, myocardial infarction, hypertonic states or any similar disorders. Furthermore, although in 21% of the persons investigated - out of a total of more than 5000 individuals at certain times - a reduction in the leukocyte count in the peripheral blood was found on one occasion, there was rarely any reduction in the thrombocyte count and equally rarely any functional neurological disorders. The external gamma dose among this group of people amounted to anywhere from 0.7 to 17 rem, and the effective dose equivalent to 2.3-52 rem. The main dose, for example, was three to four times greater than the permissible effective dose equivalent to the gastrointestinal tract during the first year owing to the presence of "non-absorbable" radionuclides in the fallout mixture.

Special attention has been given to what is the most strongly indicative and most sensitive criterion of both the health and safety situation and the ecological state of the environment, a criterion which reacts rapidly to radiation - namely infant mortality, i.e. deaths among children aged less than one year. The investigations were conducted among the inhabitants of areas affected by the cloud, among persons living in areas with a ^{90}Sr soil contamination density of less than 1 Ci/km^2 (control group number 1) and among persons living in regions remote from the boundaries of the cloud track (control group number 2).

As can be seen from Table 7, even against the background of very high infant mortality in those years, it was not possible to detect any aggravating influence of enhanced radiation levels on this indicator. A certain excess of infant mortality in the second control group was due to high frequencies of pneumonia and disease of the newborn.

As we know, the theoretical assumption that anomalies may occur in the offspring of irradiated parents has given rise to a great deal of apprehension. Investigations aimed at clarifying this effect were carried out in the period 1980–1987, i.e. at a time when the radiation doses received as a result of the accident were bound to have had their full effect not only on the first but on the second generation of persons subject to the action of radiation. The resultant data are presented in Table 8.

This information, based as it is on a large volume of data, appears to confirm that the radiation levels we have been discussing have no effect on the appearance of congenital defects, or on mortality from such defects, in individuals irradiated in the first and second generations following an accidental release of radioactive fission products.

Investigators all over the world have been particularly interested in the development of malignant tumours as a result of exposure to ionizing radiation at any and all doses. The idea that such tumour formation is possible relies on the hypothesis of a linear development of cancerous growths which has no threshold. However, an analysis of the incidence of such disease, and of the causes and levels of mortality from malignant neoplasms, carried out over decades, has indicated no significant difference between irradiated and unirradiated populations as far as the incidence of such illness and the structure and level of mortality are concerned (see Table 9).

Table 9 encompasses mortality levels from all types of cancer. It will be seen, in the first place, that there are no differences in mortality depending on the place of residence of the persons concerned. Secondly, with time, in the USSR as in the world as a whole, and also in areas affected by the radioactive cloud, mortality from malignant tumours is increasing - the consequence of a general worsening of the ecological situation in the world. The role of radioactive contamination and doses of ionizing radiation against the generally unfavourable background is so small as to be scarcely detectable. The radiation levels built up following the events of 1957 are well below the limit which, in the light of all the realistic factual evidence available to us, could be considered as significant - in other words below a dose of 50 rem. Even this level, in terms of effective dose equivalent, was received by only a limited number of people (see Table 4), and in this population no meaningful deviations in the structure of illness have been detected up till now.

The scientific investigations which have been carried out since 1957 on the territory affected by the radioactive cloud in the Urals have yielded data of fundamental theoretical and practical importance:

- Information relating to the spatial and temporal distribution of radionuclides in terrestrial and aqueous ecosystems, and to the behaviour of radionuclides in the food chains of land and water animals;

- Information relating to the dynamics of formation of the radioactive cloud, the time required for the plume to become established, the stability of the plume, its redistribution in space and time, and so on;

- The paths by which dose burdens to man, natural organisms and communities were formed in the acute period and in the longer term;

- Biochemical and biophysical turnover of radionuclides;

- The biological effects of radiation observed in natural organisms and in members of the population;

- Forecasts of root and non-root uptake of radionuclides in crops and livestock, and measures to reduce the levels of radioactive contamination; and

- Organization of safe and rational methods applicable to agriculture, forestry, water bodies, and fish and game culture in the areas affected by radioactive contamination. Possibilities for the reorientation of public and individual farm production. Arrangements permitting agricultural production without the necessity of any special agrotechnical or zootechnical measures in areas with the following degrees of radioactive contamination: 5 Ci/km^2 - grain, hay, natural grasses; up to 10 Ci/km^2 - milk, seed grasses, silage crops; up to 25 Ci/km^2 - beef, root plants; up to 50 Ci/km^2 - fodder grain crops; and up to 100 Ci/km^2 - pork, potatoes, fodder grain crops for processing, seed grasses, seed grains.

The scientific investigations carried out from 1957 onwards made it possible to establish a reliable long-term prognosis for the development of the radiation situation following the Chernobyl accident, to predict the biological effects of the accident on various elements of the environment, to develop practical recommendations for reducing the negative consequences of the Chernobyl accident on agriculture, forestry, and on land- and water-based wildlife in the parts of the Ukraine affected by radiation and also in parts of the Gomel' and Mogilev provinces of the Byelorussian SSR. The work of the radioecologists in the Urals is being continued in this direction.

The experience obtained in managing the radioecological and radiation-hygiene consequences of the Chelyabinsk and Chernobyl accidents has been used in the preparation of a "Guide to the planning and implementation of measures designed to reduce the negative radiological and radioecological consequences of accidents going beyond the design basis accident and involving releases of radioactivity to the environment", which, once it has been approved by the state regulatory bodies, will be used when necessary by undertakings in the nuclear and nuclear power industries.

Table 1

Characteristics of the radionuclide mixture released in the accident

Radionuclide	Contribution to total activity of the mixture, %	Half-life	Type of radiation emitted	Nature of radiological hazard
^{89}Sr	traces	51 d	β, γ	
$^{90}Sr + {}^{90}Y$	5.4	28.6 y	β	Internal irradiation (skeleton)
$^{95}Zr + {}^{95}Nb$	24.9	65 d	β, γ	External irradiation
$^{106}Ru + {}^{106}Rh$	3.7	1 y	β, γ	External
^{137}Cs	0.036	30 y	β, γ	External and internal
$^{144}Ce + {}^{144}Pr$	66	284 d	β, γ	External
^{147}Pm	traces	2.6 y	β, γ	
^{155}Eu	traces	5 y	β, γ	
$^{239,240}Pu$	traces	–	α	

Table 2

Area and population of the contaminated region

Density of radioactive contamination, Ci/km^2 (^{90}Sr)	Area of the region, km^2	Population of the region ($\times 10^3$)
> 0.1	> 15 000	~ 270
including:		
> 2	1 000	10
> 100	120	2.1

Table 3

Dynamics of the radiation situation

Time after accident, years	Contamination density		Gamma dose rate (relative units based on initial value)
	Gross activity (relative units)	^{90}Sr, Ci/km^2	
0	1	0.027	1
1	0.34	0.026	5.6×10^{-2}
3	0.10	0.025	8.3×10^{-3}
10	0.043	0.021	9.8×10^{-4}
25	0.029	0.014	3.8×10^{-4}

Table 4

Dynamics of population evacuation and of exposure dose to the population before evacuation

Population group and size (x 10^3)	Average contamination density, Ci/km^2 (^{90}Sr)	Time required for evacuation, days	Average dose received up to evacuation, rem	
			External exposure	Effective dose eq.
I: 0.60	500	7-10	17	52
II: 0.28	65	250	14	44
III: 2.0	18	250	3.9	12
IV: 4.2	8.9	330	1.9	5.6
V: 3.1	3.3	670	0.68	2.3
Total: 10.18 [*]				

[*] Following the Chernobyl accident 115 000 persons were evacuated.

Table 5

^{90}Sr concentrations in the meat and milk of cattle during the period 1965-1988

Indicator	1965-1970	1971-1975	1976-1980	1981-1985	1986-1988
Meat (beef)					
1. Specialized state farms					
Observed concentration, pCi/kg	0.59	0.45	0.27	0.097	
Normalized (permissible) concentration, (pCi/kg)/(Ci/km^2)	12	6.8	3.7	1.8	
Milk					
Observed concentration, pCi/L		33	28	18	12
Normalized concentration, (pCi/L)/(Ci/km^2)		32	23	15	12
2. Privately held cattle					
Observed concentration, pCi/L	–	210	110	140	130
Normalized concentration, (pCi/L)/(Ci/km^2)	–	220	110	150	140

Table 6

Observed changes in the health of individuals living in areas with a contamination density of 2 Ci/km^2 (by comparison with control groups)

Syndrome	Frequency of occurrence (% of patients investigated)
Radiation sickness (all forms)	None observed
Bone marrow depression	None observed
Reduced leukocyte count in blood	21
Reduced thrombocyte count	A few cases
Functional neurological disturbances	A few cases
Organic neurological changes	None observed
Allergy development	None observed

Table 7

Mortality among infants aged < 1 year per 1000 births in areas affected by the plume

Causes of mortality	Plume track	Control No. 1	Control No. 2
All causes	27.7	31.4	38.6
Nutritional disorders	15.2	12.2	5.1
Pneumonia	1.7	3.1	16.1
Infectious, illnesses	1.6	2.3	3.0
Disease of the newborn	8.7	13.8	14.5

Table 8

Mortality of newborn infants with innate developmental defects (per 1000 live births)

In the whole of the affected zone, including the plume track	In Chelyabinsk province	In Sverdlovsk province
0.95 ± 0.08	1.0 ± 0.08	1.1 ± 0.07

Table 9

Mortality due to malignant neoplasms (per 100 000 inhabitants)

Period of research	In the whole of the affected zone, including the plume track	In Chelyabinsk province	In Sverdlovsk province
1970-1980	145.8	146.6	-
1980-1987	160.7	167.6	159.4