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# RADIOLOGICAL CONSEQUENCES OF THE CHERNOBYL ACCIDENT

by

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# ABSTRACT

Radiological consequences of the Chernobyl accident were discussed mainly based on the results obtained from the International Chernobyl Project organized by the IAEA in 1990. The Project was developed in response to the request raised by the government of the Soviet Union to the IAEA for the conduct of an objective evaluation of the situation involving the Chernobyl casualties and the measures that had been taken by the Soviet Government.

Field investigations were carried out by the five teams consisting of approximately 200 experts from 7 international organizations and 25 nations. The results of this Project revealed that various health problems certainly had occurred among residents in the surrounding areas in association with the Chernobyl accident, and this was particularly notable among the so-called liquidators and evacuees from the contaminated areas. The question is, however, to what extent are such health problems related to radiation exposure. The estimation of individual radiation doses is indispensable for the solution of this question, and maximum efforts should be devoted to extending cooperation to such studies.

Too much information seems to have become available on the Chernobyl accident. That is, what we need is reliable information that includes the factors of when, where, what, who, and how. Information lacking these elements can not be evaluated or compared with other data. It should be noted that the report of the International Chernobyl Project in 1991 clearly indicates these factors.

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# RADIOLOGICAL CONSEQUENCES OF THE CHERNOBYL ACCIDENT

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## Introduction

On 26 April 1986, an accident involving Reactor No. 4 occurred at the Chernobyl Nuclear Power Plant located 130 km northwest of Kiev, the capital of the Ukrainian Republic. This accident took place during a test of shutdown of the reactor. A rapid rise of reactor power was followed by an explosion and fire, and large amounts of radioactive substances were released into the environment. It is said that the accident was due to inadequacies in the safety design coupled with operational mistakes.

The world first learned of this accident from the detection of abnormal levels of atmospheric radioactivity in Sweden. Only very limited information was available from the Soviet Union in the first two to three months after the accident. At the end of August 1986, a delegate of scientists from the Soviet Union made a detailed report on the circumstances of the accident to the International Atomic Energy Agency (IAEA) in Vienna. This information was subsequently transmitted throughout the world. Up to that time, the only channel of communication between the Soviet Union and the world concerning this accident had been the late Dr. Armand Hammer, President of the Occidental Petroleum Corporation, Los Angeles, California.

It is well known that arrangements made by Dr. Hammer made possible the visit to Moscow by Dr. Robert Peter Gale shortly after the accident to conduct bone marrow transplants to victims of the Chernobyl radiation. In early July 1986, Dr. Hammer invited radiation specialists, not only from the United States but also from other nations, including an IAEA representative and me, to a meeting in Los Angeles. The conference was chaired by Dr. Gale, and a set of recommendations to the Soviet Government was prepared on how to deal with the health effects of the Chernobyl accident.

These recommendations were transmitted to the Soviet Union by Dr. Gale. Because the recommendations emphasized the experience in Hiroshima and Nagasaki, there subsequently have been frequent exchanges between various parties related to the Chernobyl accident in the Soviet Union and my group in Japan. Since then, a state of excessive information has developed because of the perestroika and glasnost' that have taken place in the Soviet Union, no doubt, in part due to the competition in news reporting among members of the mass information media. This greater availability of information, however, has caused increased anxiety among residents of areas affected by radiation.

The government of the Soviet Union as well as the three Republics of Ukraine, Byelorussia (now called "Belarus"), and Russia have made great efforts to deal with the radiological consequences of the Chernobyl accident. In addition, they have sought assistance and cooperation in the health care and studies of the health effects in the victims of the Chernobyl accident from Japan, the United States, Canada, and several European nations, as well as international organizations such as IAEA, WHO (World Health Organization), and the League of Red Cross and Red Crescent Societies. Because the anxiety among the residents was manifested in various ways, in October 1989 the government of the Soviet Union requested the IAEA to conduct an objective evaluation of the situation involving the Chernobyl casualties and the measures that had been taken by the Soviet Government.

In response to this request the IAEA developed an International Chernobyl Project, and, following a pilot study in March 1990, the International Advisory Committee (chaired by this author) was established with the cooperation of WHO, FAO (Food and Agriculture Organization), CEC (Commission of European Communities), and other international agencies. This Committee was given responsibility for conducting the evaluation requested by the Soviet Government. For this purpose, five teams were organized to study five topics related to the Chernobyl radiation accident, i.e., historical portrayal, environmental contamination, radiation exposure, health impact, and protective measures.

Field investigations were carried out by these five teams from May 1990 to January 1991. Approximately 200 experts from 7 international organizations and 25 nations participated in these 5 teams, and a total of 50 investigations in various areas was conducted. The results were released in May 1991. Although the studies were limited by the available time, manpower, and funds, they are considered to be the most-objective, comprehensive evaluation of the consequences of the Chernobyl accident to date.

This discussion of the radiological consequences of the Chernobyl accident will refer primarily to the results of those studies (Ref. 1), although, if available, more-recent information from other sources will be added.

## Historical Portrayal

The IAEA Project's goal on this topic was to compile a historical portrayal of events leading to the current radiological situation. For this purpose, the Project collected published material on the Chernobyl accident and interviewed people living in the affected areas, as well as governmental officials and scientists.

The Project reviewed various issues such as emergency actions at the site, evacuation of the prohibited zone, securing the site, radiation release and transport, protection of rivers and the Kiev reservoir, decontamination, intervention measures, and Soviet requests for assistance. A brief chronology of some relevant events up to the inception of the IAEA Project is shown here in the Table.

The following events may be worthwhile to add to the Table:

(1) The WHO Scientific Advisory Committee meeting was held in October 1990 at the Radiation Effects Research Foundation (RERF) in Hiroshima to review the basic proposals of the International Program on the Health Effects of the Chernobyl Accident (IPHECA) and the establishment of an International Center on Radiation Health Issues (ICRHI). These proposals were based on the April 1990 memorandum of understanding between the Ministry of Health of the Soviet Union and the WHO.

At this meeting, the RERF research program was discussed, and recommendations were developed involving six areas: epidemiology, dosimetry, mitigation of psychological effects, clinical follow-up, education and training, and data-base management. Protocols for four pilot projects have now been prepared by WHO. These include epidemiological registry, thyroid, hematology, and in utero brain damage.

The Japanese Government provided approximately 20 million U.S. dollars to the WHO in February 1991 to make medical equipment and supplies available through the WHO ICRHI mentioned above to be established in Obninsk. However, the WHO IPHECA itself is now under readjustment due to the independency of each Republic, i.e., Ukraine, Belarus, and Russia.

(2) The IAEA entered into an agreement with the Soviet Union in September 1990 for the establishment of the Chernobyl Centre for International Research (CHECIR) in a suburb of Kiev. The purpose of this Centre is to conduct studies and research on the consequences of the accident within a radius of 30 km of the Chernobyl nuclear power plant. Each nation to participate in these research projects is expected to enter into a bilateral agreements with the Soviet Union through the IAEA. The research projects currently proposed under this agreement can be classified into the following three groups: (1) decontamination, environmental restoration, and management of the resulting waste; (2) epidemiology, cytogenetics, and dosimetry; (3) radioecology.

This agreement will also be readjusted because of the independence of each Republic.

(3) The Sasakawa Foundation in Japan is well known as the leading voluntary financial contributor to the WHO Smallpox Eradication Program and has many other accomplishments in overseas medical cooperation. At the beginning of 1990, the Soviet Union asked the Sasakawa Foundation for direct assistance to the exposed residents since most of the international and binational agreements related to the Chernobyl accident primarily involved studies and research.

In response to this request, the Foundation sent experts to the areas affected by the Chernobyl accident to determine the method of cooperation it could extend. Consequently, the Foundation decided to provide 40 million U.S. dollars over a five-year period beginning from April 1991 to extend the following kinds of assistance to the Republics of Ukraine, Byelorussia, and Russia.

- Donation of five mobile examination units (with ultrasound equipment for the examination of the thyroid, hemoanalysis equipment, whole body counter, etc.) and five buses for transportation of the residents.
- Provision of medical equipment and supplies
- Provision of medical drugs and reagents
- Dispatch of experts
- Acceptance of trainees
- Conduct of educational activities for residents of the affected areas

At the beginning of June 1992, a symposium was held in Mogilev, Belarus, to review the results of one year's activities which include the examination of 13,500 children in the five affected areas of the three Republics.

(4) The Chernobyl Pledging Conference sponsored by the United Nations was held in September 1991 in New York. At this Conference, the Soviet Union proposed 131 projects and sought external contributions totaling 650 million U.S. dollars. Statements of support were given by representatives of 30 nations, but I believe that speeches made by the U.S. delegate Mr. Edward Marks and by the Japanese delegate Mr. Katsumi Sezaki deserve to be quoted here.

Mr. Marks said that his government had co-sponsored the General Assembly resolution on the Chernobyl accident with the understanding that the results of an expert assessment on the radiological consequences of the accident would be taken into consideration. He added that the United States had no current plans to contribute to the new, extra-budgetary fund established to support the large-scale resettlement and recovery projects proposed by the Soviet Union.

Mr. Sezaki said that earlier this year, Japan had extended some 20 million U.S. dollars to the WHO for its activities in the region. He also stated that the international community should be guided by the report prepared by the International Advisory Committee of the IAEA, which report should be regarded as the basis for future international cooperation on the Chernobyl question.

## Environmental Contamination

Release of radioactive substances into the environment continued for ten days from 26 April 1986, when the accident occurred, to 6 May 1986. One-tenth of the approximately one billion curie (37 exabecquerel) of radioactive material that had been contained in the reactor core, or about 100 million curie (3.7 exabecquerel) of radioactive substances, was released into the environment. This formed a plume that spread over the entire northern hemisphere. However, 66% of the iodine 131 and 44% of the cesium 137 were deposited within the Soviet Union.

The conclusion of the IAEA Project on this topic was as follows:

1. Measurements and assessments carried out under the Project provided general corroboration of the levels of surface contamination for cesium as reported in the official maps that were made available to the Project. Analytical results from a limited set of soil samples obtained by the Project teams corresponded to the surface contamination estimates for plutonium but were lower than those for strontium.

2. The concentrations of radionuclides measured in drinking water and, in most cases, in food from the areas investigated were significantly below guideline levels for radionuclide contamination of food moving in international trade and, in many cases, were below the limit of detection (see Fig. 1).

The IAEA Project team also made the following recommendations on this problem:

1. A program should be established to assess the significance of "hot spots." Research programs on the characteristics of hot particles and their occurrence in the envient are warranted and should be continued.

2. Water sampling and analytical techniques should be improved to comply with established procedures. The potential for long-term contamination of water bodies, possibly leading to contamination of the aquatic food chain, should be investigated. Research should be planned on radionuclide behavior in ecosystems and on the desorption of strontium from sediments in surface-water bodies and its impact on agriculture through irrigation practices.

3. A program should be implemented to derive more-detailed official large-scale contamination maps. A collaborative program of air sampling and analysis should be established between the local laboratories and the network of international laboratories set up by the IAEA Laboratory at Seibersdorf obtain more-definitive information on the relevance of the resuspension and inhalation pathways.

These recommendations are not yet fully realized. International cooperation should be encouraged to facilitate their implementation.

## Radiation Exposure

The exposure to humans by the Chernobyl accident can be separated into the following four routes:

1. External exposure from the plume.
2. Inhalation of atmospheric radioactive substances.
3. External exposure by radioactive substances deposited on the ground.
4. Internal exposure by intake of contaminated food.

In the first year following the accident, route 4 was the greatest contributor and accounted for 60-80% of the dose received by residents in the surrounding areas. Thereafter, the contribution of route 3 increased and accounted for the majority of the dose.

External exposure was measured independently under the auspices of the IAEA for the Project. Eight thousand film-badge dosimeters were distributed to residents of seven settlements. Ninety percent of the results were below the detection limit of 0.2 mSv for a 2-month exposure period. This result agrees with what would be expected on the basis of calculational models (see Fig. 2).

Whole-body counting of cesium was carried out under the auspices of the IAEA for the Project and included more than 9000 people in nine settlements. The results indicated generally lower body contents of cesium than would be predicted on the basis of most models of environmental transfer, dietary intake, and metabolism. Similar results for whole-body counting of cesium have been reported in other countries. The latest data for whole-body counting of 13,500 children during 1991-92 conducted by the Sasakawa Project also indicated lower levels of cesium.

Absorbed thyroid doses due to iodine were officially reported on the basis of thyroid measurements made soon after the accident and assumptions concerning intake. Mean absorbed thyroid doses for children from birth to seven years old were officially reported to vary from less than 0.2 Gy to 3.2 Gy for seven surveyed contaminated settlements. (The maximum reconstructed absorbed thyroid dose, in Bragin, was officially reported as 30-40 Gy.) However, since the iodine had completely decayed by the time of the Project, no independent verification of the reported absorbed thyroid doses was possible.

The conclusion of the IAEA Project was as follows:

> The official procedures for estimating doses were scientifically sound. The methodologies that were used were intended to provide results that would not underestimate the doses. Independent measurements in individual residents monitored for external and for internal exposure from cesium incorporated into the body yielded results that would be predicted on the basis of calculational models. Independent Project estimates for the surveyed contaminated settlements were lower than the officially reported dose estimates.

## Health Impact

As soon as the accident occurred, 237 workers fought the fire that broke out in Reactor No. 4. They all received heavy doses of radiation and developed symptoms of acute radiation sickness within one hour after the accident, and 31 have died (two of the deaths were due to the explosion and burns).

Late health effects due to radiation usually are nonspecific, and epidemiologic methods must be employed to make any estimate of whether a certain disorder of health is attributable to radiation. "Epidemiologic methods" means that the study population (denominator) is defined, and then the health abnormalities (nominator) are examined by whether exposed or not, or by radiation dose. Most of the previous reports on the health effects due to the Chernobyl accident had not been based on such methods, and it was not possible to say whether there is any relation to radiation exposure.

This point was taken into consideration by the IAEA Project teams when they carried out their studies. The children who were examined were found to be generally healthy. Field studies indicated that there were a significant number of adults in both surveyed contaminated and surveyed control settlements with substantial medical problems, with 10% to 15% (excluding hypertensive adults) requiring medical care (see Fig. 3). Reported adverse health effects attributed to radiation have not been substantiated either by those local studies that were adequately performed or by the studies under the Project.

Many of the local clinical investigations of health effects had been done poorly, producing confusing, often contradictory, results. The reasons for these failures included: lack of supplies and well-maintained equipment, poor information through lack of documentation and lack of access to scientific literature, and shortages of well-trained specialists. Nevertheless, despite these obstacles, several local clinical studies were carefully and competently performed, and the Project team was able to corroborate the results in most cases.

The conclusions obtained by the IAEA Project teams are as follows:

1. There were significant non-radiation-related health disorders in the populations of both surveyed contaminated and surveyed control settlements studied under the Project, but no health disorders that could be attributed directly to radiation

exposure. The accident had substantial negative psychological consequences in terms of anxiety and stress due to the continuing high levels of uncertainty, the occurrence of which extended beyond the contaminated areas of concern. These were compounded by socioeconomic and political changes occurring in the Soviet Union.

2. The official data that were examined did not indicate a marked increase in the incidence of leukemia or cancers. However, the data were not detailed enough to exclude the possibility of an increase in the incidence of some tumor types. Reported absorbed thyroid dose estimates in children are such that there may be a statistically detectable future increase in the incidence of thyroid tumors.

3. On the basis of the doses estimated by the Project and currently accepted radiation risk estimates, future increases over the natural incidence of cancers or hereditary effects would be difficult to discern, even with large and well-designed long-term epidemiological studies.

It should, however, be noted that the study was limited to the population continuing to be exposed to radiation from the accident, namely those who remained in the surveyed contaminated settlements. It would not have been possible to search out and conduct medical examinations on those who had left, such as evacuees from the contaminated areas and liquidators who engaged in decontamination works.

The IAEA Project teams recommend that consideration should be given to the introduction of programs to alleviate psychological effects. These might include informational programs for the public. There should also be educational programs set up for teachers and local physicians in general preventive health care and radiation health effects. It is also recommended that the adverse health consequences of relocation should be considered before any further relocation takes place.

It should be added here that the result of thyroid examinations conducted by the Sasakawa Project for 13,500 children in the five affected areas during 1991-92 revealed no unusual prevalence of abnormalities. This is consistent with the result of the IAEA Project as well as with the conclusion obtained at the "Symposium on the Effects on the Thyroid of Exposed Population Following the Chernobyl Accident" held in Chernikov, Republic of Ukraine, in December 1990 under the sponsorship of the WHO/Regional Office for Europe.

The conclusion of the above symposium states as follows:

There are many conflicting and anecdotal reports of some of the adverse health effects attributable to the Chernobyl accident, in particular, thyroid disorders. Both the public and some members of the medical profession believe that there is a general increase in morbidity, but there are insufficient reliable health data to make an objective assessment of the situation. This uncertainty will tend to increase the anxiety of the population.

## Protective Measures

The IAEA Project teams examined primarily those protective measures taken or proposed by the authorities from 1990 on. This was a central issue in the Soviet Union request for an international study. A more-limited evaluation was also made of measures taken before 1990 to understand how past actions may have influenced or constrained future options. These measures were compared with international recommendations and evaluated for their appropriateness. The conclusions obtained are as follows:

1. The unprecedented nature and scale of the Chernobyl accident obliged the responsible authorities to respond to a situation that had not been planned for and was not expected. Thus, many early actions had to be improvised. The Project teams were not able to investigate in detail many actions taken by the authorities owing to the complexity of the events. In those cases in which the Project teams were able to assess these actions, it was found that the general response of the authorities had been broadly reasonable and consistent with internationally established guidelines prevailing at the time of the accident. Some measures could doubtless have been better or taken in a more timely manner, but these need to be viewed in the context of the overall response.

2. The protective measures taken or planned for the longer term, albeit well intentioned, generally exceed what would have been strictly necessary from a radiological protection viewpoint. The relocation and foodstuff restrictions should have been less extensive. These measures are not justified on radiological-protection grounds; however, any relaxation of the current policy would almost certainly be counter productive in view of the present high levels of stress and anxiety amongst inhabitants of the contaminated areas of concern and people's present expectations. It is recognized, however, that there are many social and political factors to be taken into consideration, and the final decision must rest with the responsible authorities. At any rate, no modification introduced should lead to more restrictive criteria.

The IAEA Project teams recommend the following points:

1. Protective measures  Arrangements should be made in the future for the compilation of a comprehensive and agreed database containing all relevant information on the implementation and the efficacy of the protective measures taken and this should be processed into a coherent framework.

A complete and detailed evaluation should be made of the protective measures taken (or planned to be taken) in order to validate the conclusions of the Project study. This should cover all aspects related to radiological protection, i.e. the doses, the costs and the efficacy of the protective measures.

Agricultural measures that may have a less adverse impact on traditional agricultural practices should be investigated.

2. Public information  Factors that may influence the acceptability to the local population of continued habitation of settlements in the contaminated areas of concern should be further identified and analysed.

More realistic and comprehensive information should be provided to the public on the levels of dose and risk consequent upon their remaining in the contaminated areas of concern. These risks should be compared with risks experienced in everyday life and with risks from other environmental contaminants, e.g. radon and industrial emissions.

3. Resource allocation  A comparison should be made between the effectiveness of resources allocated to the mitigation of the consequences of the accident and those allocated elsewhere to other programs for public health improvement.

An assessment should be undertaken of the cost and effectiveness of relocation for a number of individual settlements, chosen to encompass the range of different characteristics encountered, in order to confirm the validity of the conclusions reached for average settlements.

## Conclusion

Various health problems certainly had occurred among residents in the surrounding areas in association with the Chernobyl accident, and this was particularly notable among the so-called liquidators and evacuees from the contaminated areas. The question is to what extent are such health problems related to radiation exposure. Although there may be various constraints and limitations, the estimation of individual radiation doses is indispensable for the solution of this question, and maximum efforts should be devoted to extending cooperation to such studies.

This is the point that I repeatedly emphasized at the IAEA meeting organized in Vienna in May 1991 to present a report on the results of the International Chernobyl Project. Without such efforts, reports on the occurrence of health abnormalities and the assessment of such risks may be meaningless. It is our belief from our experience that the emphasis of cooperation to the Chernobyl health problems should be on health surveys together with dosimetry studies.

Large areas were affected by the Chrnobyl accident, and even simply from a geographical standpoint, follow-up studies of the exposed population would not be as easy as in Hiroshima or Nagasaki. In addition, it will be essential to have a well-developed health and medical care system as the background for follow-up studies. However, most important is to obtain the cooperation of members of the exposed population. It is hoped that those concerned with Chernobyl studies will learn how the cooperation of the atomic bomb survivors in Hiroshima and Nagasaki had been maintained over these many years.

Too much information seems to have become available on the Chernobyl accident. That is, what we need is reliable information that includes the factors of when, where, what, who, and how. Information lacking these elements can not be evaluated or compared with other data. It should be noted that the report of the International Chernobyl Project in 1991 clearly indicates these factors.

## References


1. International Advisory Committee 1991. The International Chernobyl Project: Technical Report, IAEA
2. International Advisory Committee 1991. The International Chernobyl Project: An Overview, IAEA
3. The International Chernobyl Project 1991. IAEA Bulletin 33(2):4-13.

Table

## CHRONOLOGY OF MAJOR EVENTS

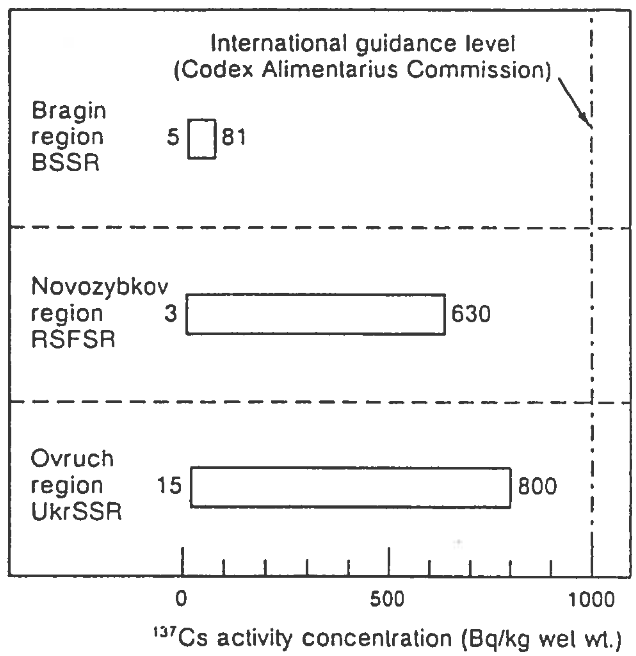
| | |
|---|---|
| 26 April 1986 | Accident occurs 01:23. Governmental Commission formed |
| 27 April 1986 | Evacuation of Pripyat takes place |
| 6 May 1986 | End of 10 days of atmospheric release of radioactive material from the core |
| 6 May 1986 | Introduction of 'temporary permissible levels' for drinking water and foodstuffs |
| 6 May 1986 | Evacuation of the population within the prohibited zone completed |
| 31 May 1986 | Revision of 'temporary permissible levels' |
| May 1986 | 'Temporary dose limits' for the population set at 100 mSv (internal and external) annual total dose |
| July 1986 | First summarized contamination map (not published until 1989) |
| November 1986 | Completion of the 'sarcophagus' construction |
| — 1987 — | 'Temporary dose limits' for the population reduced to 30 mSv annual total dose (subsequently lowered to 25 mSv for 1988) |
| April 1987 | Completion of the work begun in May 1986 for protecting the water system |
| December 1987 | Revision of the 'temporary permissible levels' established 31 May 1986 |
| — 1988 — | 'Temporary dose limits' for the population reduced to 25 mSv annual total dose |
| September 1988 | Council of Ministers of USSR adopts the 350 mSv lifetime dose for relocation to be implemented as of 1 January 1990 |
| March 1989 | Contamination maps officially published in the three Republics |
| April 1989 | BSSR Academy of Sciences registers disagreement with the 350 mSv lifetime dose concept and makes new proposals |
| October 1989 | USSR requests the IAEA to organize an international assessment of the consequences of the accident and the protective measures taken |

Source : Ref. 2

Fig. 1

**Project measurements of caesium concentration in total diet samples from surveyed settlements**

Project analyses of a limited number of total diet samples (e.g. bread, potatoes, vegetables) collected from residents of 11 settlements indicated a relatively large variation in the measured levels of caesium contamination.




Source : Ref. 3