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MEASURES TO STRENGTHEN INTERNATIONAL CO-OPERATION IN MATTERS RELATING TO NUCLEAR SAFETY AND RADIOLOGICAL PROTECTION

(a) IMPLEMENTATION OF RESOLUTIONS GC(XXXIV)/RES/529 AND GC(XXXIII)/RES/508

The International Chernobyl Project: Assessment of Radiological Consequences and Evaluation of Protective Measures

1. Early in 1990, the Agency, responding to a request made by the USSR Government in October 1989, initiated an international project (the International Chernobyl Project) aimed at evaluating radiological consequences in the USSR of the Chernobyl accident for human health and the environment and determining the requirements for safe living in contaminated areas of the USSR.[1/]

2. The project involved the corroboration of radiological data, assessment of the health situation in the affected areas and evaluation of the efficacy of the measures already taken and still being taken by the Soviet authorities to protect the population and the environment in the affected areas — which are located in the Byelorussian Soviet Socialist Republic (Byel. SSR), the Russian Soviet Federative Socialist Republic (RSFSR) and the Ukrainian Soviet Socialist Republic (Ukr. SSR) and where there are some 2700 settlements with a combined population of about one million people.

1/ Specifically, the USSR Government requested the Agency to co-ordinate the organization and implementation of an assessment by international experts of "the concept which the USSR has evolved to enable the population to live safely in areas affected by radioactive contamination following the Chernobyl accident, and an evaluation of the effectiveness of the steps taken in these areas to safeguard the health of the population".

3. Following receipt of the request from the USSR Government, a project planning meeting was held in Moscow early in February 1990. Towards the end of March 1990, a ten-member international team of experts carried out a preparatory mission to the affected areas in the three Soviet republics. The team included specialists in medicine, psychology, nutrition and radiation protection from four Agency Member States and four organizations.[2/] It reviewed information provided by Soviet scientific organizations, hospitals, clinics and agricultural centres located in these areas and in Minsk, Moscow and Kiev. Also, in order to introduce the project to the local population and learn at first hand about people's concerns, the team met with villagers, with political representatives and with the representatives of a number of non-governmental organizations. On the basis of its findings, the team defined the project's goals and drafted a tentative work plan.

4. A 19-member International Advisory Committee was then set up to approve a work plan, monitor the project and prepare the final project report; it was chaired by Dr. Itsuzo Shigematsu, Director of the Radiation Effects Research Foundation in Hiroshima, Japan. The Committee met for the first time (in Minsk and Kiev) towards the end of April 1990, at which time it approved the tentative work plan after some revision. At its first meeting it was composed of scientists from ten Agency Member States and five organizations[3/], the members' expertise encompassing - inter alia - medicine, radiopathology, radiation protection, nutrition, radioepidemiology, radiology and psychology.

2/ Austria, Japan, the United Kingdom, the United States of America, the Commission of the European Communities (CEC), FAO, WHO and the Agency.

3/ Austria, the Byelorussian Soviet Socialist Republic, Canada, Finland, France, Japan, the United Kingdom, the Ukrainian Soviet Socialist Republic, the United States of America, the Union of Soviet Socialist Republics, CEC, FAO, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), WHO and the Agency.

5. Project implementation, which began in May 1990, involved some 50 technical missions to the USSR by about 200 independent experts from 24 Member States and seven organizations[4/]. A temporary Agency office in Gomel, Byel. SSR, which operated during the period of maximum activity, facilitated implementation of the project.

6. The project involved five major tasks:

Task 1: Historical Portrayal of Events Leading to the Current Radiological Situation

Project teams visited some three dozen Soviet institutions that participated in the immediate post-accident response and in subsequent efforts. On the basis of the information collected and of a review of the international literature, they prepared a historical account of the major events leading to the current radiological situation. The matters addressed included the accident itself and its immediate impact on emergency personnel, the measures (such as evacuation, decontamination and radioactive waste management) taken for the protection of public health and the environment, and the socio-economic and political factors contributing to the current situation. The historical account provided the background necessary for understanding the analytical findings of the project.

4/ Argentina, Austria, Australia, Belgium, the Byelorussian Soviet Socialist Republic, Canada, Cuba, Denmark, Finland, France, the Federal Republic of Germany, the German Democratic Republic, Hungary, Israel, Italy, Japan, the Netherlands, Norway, Sweden, the Ukrainian Soviet Socialist Republic, the United Kingdom, the United States of America, the Union of Soviet Socialist Republics, Yugoslavia, CEC, FAO, ILO, UNSCEAR, WHO, the World Meteorological Organization (WMO) and the Agency.

Task 2: Corroboration of Environmental Contamination Assessments

Project teams corroborating the Soviet assessments of the environmental contamination in the affected areas reviewed the official environmental contamination data for caesium, strontium and plutonium and evaluated the field sampling techniques, analytical methods and laboratory instrumentation used in making the assessments.

Field work in selected villages supplemented these efforts, some 2000 measurements of external gamma dose rates at indoor and outdoor locations being taken and over 1000 samples of the soil-grass ecosystem and of milk from private and collective farms being collected. The Agency's Laboratories at Seibersdorf, Austria, were heavily involved in sample analysis, and analyses were also carried out at laboratories in other countries.

Task 3: Corroboration of Individual and Collective Dose Assessments

Project teams corroborated Soviet assessments of the individual and collective radiation doses to the affected population. Given the time and resource constraints, it would have been impossible for them to evaluate the individual doses received by all inhabitants of the affected areas. Thus, a key element of the task was a review of the criteria, methods and input parameters applied in the Soviet calculations of past, present and future radiation doses to the inhabitants of the affected areas resulting from the accident.

In parallel, project teams monitored the external and internal exposures of nearly 21 000 inhabitants of the affected areas, using equipment provided by France's Service Central de Protection contre les Rayonnements Ionisants (SCPRI); nearly 12 000 radiation dosimeters were distributed to inhabitants of selected villages in both affected and non-affected areas and later read in France; over a ten-week period,

project teams used a SCPRI mobile laboratory equipped with four whole-body counters to measure the internal caesium contamination in some 9000 inhabitants of nine villages in the three Soviet republics; the results of the individual measurements were validated at the Agency's Laboratories. An intercalibration exercise involving Soviet and other whole-body counting systems was also carried out.

Task 4: Clinical Health Effects from Radiation Exposure and Evaluation of the General Health Situation

The initial work centered on clarifying the general health situation of the population in the affected areas and on learning about endemic problems that the Soviet medical authorities had identified prior to the Chernobyl accident.

An understanding of these problems was important because there had been media reports attributing certain observed illnesses and malformations to radiation exposure resulting from the accident and because the reported observations did not correlate with the available radioepidemiological data (such as those from the 40-year follow-up studies of the atomic bomb survivors in Japan). Thus, a project team met with physicians and inhabitants in the affected areas and reviewed officially recorded patient data for blood diseases, immune system disorders, thyroid diseases, cataracts and other ailments that might or might not be radiation-induced. As medical data from before 1986 (the year of the Chernobyl accident) were sparse, the team compared the health status of inhabitants of the affected areas with that of the inhabitants of non-affected areas.

Nutrition studies were conducted in several villages so as to gain an insight into lifestyles and dietary habits and how they might affect the health of the population. Project teams surveyed dietary habits, alcohol and cigarette consumption, and other health-related factors, collecting biological and diet samples from selected families in the

affected areas. Sample analyses for radioactivity, trace elements and heavy metals were carried out at the Agency's Laboratories and at laboratories in other countries.

Medical examinations of 1356 inhabitants of seven contaminated and six non-contaminated villages were carried out (with clinical analyses of biological samples) by three project teams whose members were specialized in such areas as thyroid diseases, pediatrics, oncology, haematology, psychiatry and radiology, children being of primary interest with regard to concerns such as malignancies, thyroid disorders, anaemia, disorders of the immune and the blood clotting system, anxiety and stress and other psychological effects.

Task 5: **Evaluation of Protective Measures**

The project teams evaluating the efficacy of the measures already taken and still being taken to protect the population and the environment examined the criteria applied in enforcing such severe and life-disruptive measures as the evacuation of people and the confiscation of contaminated food; they also considered the radioactive contamination and radiation dose levels that triggered such measures. Specifically, the Soviet authorities' concept of a "lifetime (70-year) dose limit" for population exposures due to the accident was examined from the perspective of proposed alternative concepts relevant to future protective measures.

In related work, project teams concentrated on promoting a better understanding of the complex issues involved in taking policy decisions about future protective measures. CEC experts facilitated discussions among Soviet officials at five "decision-aiding" conferences - one in each of the three Soviet republics (in Minsk, Moscow and Kiev) with the participation of local officials, one in Moscow with the participation of All-Union officials and a final one in Moscow - at which the findings of the first four conferences were evaluated - with the participation of

both local and All-Union officials. The officials were introduced to quantitative techniques for decision-making. Their discussions with international experts covered not only radiological consequences for health and the environment but also socio-economic and political factors relevant to future decisions on protective measures.

7. In addition to the activities comprising the five major tasks, there were three activities aimed at providing help to and furthering the knowledge of the scientific and technical community as regards some pressing issues:

Medical seminars (to provide the medical community in the three Soviet republics with a better understanding of the medical problems related to radiation)

In July 1990 an international team of physicians held a series of three-day medical seminars in three towns in the affected areas (Gomel, Byel. SSR; Novozybkov, RSFSR; Ovruch, Ukr. SSR), in order to broaden the local medical community's understanding of the medical problems reported in those areas. The seminars, which addressed radiation protection principles, the diagnosis, prognosis and treatment of radiation-induced illnesses, and related topics, were attended by over 1200 local physicians and public health administrators, including hospital doctors, general practicioners and professional staff of epidemiological centres and local health centres both from affected and from adjacent areas.

Agricultural seminars and other agricultural activities (to try to alleviate a pressing problem - the transfer of caesium from the soil into agricultural products)

In August 1990 an FAO/Agency team visited the affected areas in order to assess the problems of managing contaminated agricultural land. One of the team's recommendations was that consideration be given to the use of caesium binders for reducing the uptake of radiocaesium into grazing animals, and six Soviet scientists and administrators visited the Norwegian Institute of Radiation Hygiene in order to familiarize themselves with relevant techniques. Experiments using caesium binders conducted in the three Soviet republics showed promising results. Subsequently, a series of theoretical and practical seminars were organized on the management of contaminated agricultural environments and in particular the use of caesium binders: a two-day theoretical seminar - held in Gomel - was attended by approximately 250 people, including scientists from the three Soviet republics, scientists working at the All-Union level, administrators and managers; three identical practical seminars - held consecutively in Gomel, Novozybkov and Korosten (Ukr. SSR) - were attended by a total of some 1300 people, including collective farmers, public health service representatives and veterinarians.

Seminar on radioecology (to achieve a better understanding of radioecological problems in the contaminated areas)

In January 1991, a one-week seminar entitled "Systematic Assessment of Doses to Man following Radionuclide Release into the Environment" was held at the University of Kiev. The topics covered in the lectures were sources of environmental radioactivity, exposure pathways, dosimetric concepts, the effects of radiation, environmental measurements, dose assessment modelling, sample collection and processing, quality assurance, parameter determination, reliability of models, sensitivity/uncertainty analysis, validation of models, presentation of results, decision-making, and case studies of dose assessments in practice. The seminar was attended by approximately 200 people, with backgrounds in fields such as radiobiology, biology, radioecology, environmental science and public health.

8. The conclusions and recommendations of the International Chernobyl Project were approved in March 1991 by the International Advisory Committee.

9. From 21 to 24 May 1991 an "International Conference on the International Chernobyl Project: Assessment of Radiological Consequences and Evaluation of Protective Measures" was held in Vienna. The Conference scrutinized the assessments made under the Project and also the Project conclusions and recommendations.

10. In June 1991, the Board of Governors agreed that the Project conclusions and recommendations should be submitted to the General Conference pursuant to resolution GC(XXXIV)/RES/529 adopted by the General Conference last year.[5/] They are contained in the Annex to this document.

11. The detailed project findings are being published in a Technical Report of which an Overview has already been published and made available to Member States.

5/ In operative paragraph 8 of resolution GC(XXXIV)/RES/529, the General Conference welcomed and endorsed "the project to assess comprehensively the radiological consequences of the Chernobyl accident in the USSR".

The International Chernobyl Project

Assessment of Radiological Consequences and Evaluation of Protective Measures

C O N C L U S I O N S A N D R E C O M M E N D A T I O N S

of the Report by the International Advisory Committee

1. Introduction

The conclusions and recommendations of the International Chernobyl Project were approved by the International Advisory Committee (IAC) at its meeting in Vienna from 18 to 22 March 1991 and they are based upon the radiological and health assessments carried out by the Project. The technical details of these assessments are to be found in the extensive Technical Report, to which reference should be made for further information.

The conclusions and recommendations are subject to the constraints and limitations of the Project design. These constraints and limitations should be recognized so that the conclusions and recommendations are not interpreted to be more or less than is warranted by the Project.

Ideally, the Project teams would have had sufficient time and resources to examine exhaustively and verify independently all the information available to them as well as to carry out more extensive independent analyses. Such comprehensive efforts were not feasible nor were they altogether warranted. More limited objectives were necessary and were adopted for a number of reasons: the time available to complete the Project was limited; the data provided to the Project teams were not always adequate; the evaluation of the radiological situation immediately after the accident could no longer be independently assessed because of the time that had elapsed and the consequent decay of short lived radioisotopes; the number of available independent experts as well as their time were limited; the thousands of square kilometres that were contaminated could not be thoroughly monitored or systematically surveyed for 'hot spots' of contamination; and the hundreds of thousands of people living in these areas could not be individually examined. Finally, the Project survey was concerned principally with human problems and relevant environmental considerations such as agricultural contamination; consequences of the accident for other species were not specifically considered.

Efforts were therefore directed to the assessment of data, techniques and methodologies employed to estimate contamination levels, doses[1] and

health effects, and to the evaluation of radiological protection policies. Sufficient data were obtained independently to enable the Project teams to formulate independent judgements.

In order to assist the authorities of the USSR, the BSSR, the RSFSR and the UkrSSR, major efforts were devoted to the urgent need to provide guidance with respect to radiological protection measures (including the 'safe living concept') and the associated radiological protection practices and policies. The radiological considerations influencing a policy such as relocation (for example, the radiation doses and risks averted by relocating populations) had to be evaluated within the context of the resulting psychological, social and economic factors.

An assessment was made of the health of persons who had been residing in settlements in the contaminated areas of concern since the time of the accident. This was done by examining the population for potential health effects due directly to radiation as well as health effects that may have occurred as a result of factors related to the accident but not due to radiation exposure. Since there were few baseline data for these populations from the time before the accident, it was necessary to compare results for these people with those for other people living in the region but outside the contaminated areas of concern.

As the Project was directed at those currently living in the contaminated areas, the radiological health effects to the more than 100 000 people evacuated from the prohibited zone around the Chernobyl site were considered only for those currently living in the areas under review. Nor did the Project address health effects for the large number of emergency personnel (the so-called 'liquidators') who were brought into the region temporarily for accident management and recovery work. The health of this occupationally exposed population is reportedly being monitored at medical centres throughout the USSR.

Some issues received comparatively little attention, owing primarily to the unavailability of necessary and sufficient data. For example, it was not possible to corroborate the early contamination of land and the exposures of the public due to iodine isotopes. Nor were the early remedial protective actions undertaken (e.g. thyroid blocking by iodine prophylaxis and evacuation) subject to thorough evaluation.

Despite the limitations of time and financial and human resources, the International Advisory Committee is of the opinion that the Project represents a much needed international humanitarian and scientific response to the needs of the authorities and the people of the USSR who were affected by the Chernobyl accident.

The International Advisory Committee acknowledges the many problems in a study of such breadth. Nonetheless, the work has involved leading and eminent international scientific investigators and medical specialists who endorse its adequacy and its results. It is a significant step in the evaluation of the consequences of the accident.

2. Environmental contamination

General Conclusions

Measurements and assessments carried out under the Project provided general corroboration of the levels of surface contamination for caesium 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.

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.

Detailed Conclusions

CAPABILITIES OF SOVIET LABORATORIES

The analytical capabilities of Soviet laboratories appeared to be adequate. There is an extensive infrastructure for the analysis of environmental and food samples. The range of performance of the Soviet laboratories that participated in the intercomparison exercise was broad, but similar to that found in previous international comparison exercises. The few problems identified, including the tendency to overestimate strontium, did not significantly affect the use of data for conservative dose assessment purposes.

The field studies which were assessed, even though they excluded 'hot spots', appeared to give adequate results for the average values characterizing surface deposition in a region. In accordance with the methodology that reportedly had been used, 'hot spots' that had been identified were systematically excluded in the reported estimation of

average surface deposition for a given region and were not listed in the detailed data provided to the Project teams.

The extensive surface water sampling programmes are adequate. Certain problems during sampling and/or analytical procedures could lead to possible overestimation of the concentrations of radionuclides in water.

Insufficient information was available to evaluate air sampling equipment and procedures. Although the relative contributions from airborne resuspension of radioactive materials to dose are believed to be minor, it should be noted that the occurrence of airborne resuspension, particularly during agricultural activities or dry periods, cannot be excluded.

Rapid screening and sophisticated techniques used locally for monitoring commercially available food from production to consumption appeared to be satisfactory. The relevant instrument calibration techniques could not be evaluated sufficiently by the Project owing to the lack of detailed technical information.

INDEPENDENT PROJECT SURVEYS

A variety of surveillance methods were used in the surveyed contaminated settlements and the surveyed control settlements to estimate surface contamination. The ranges of average values of surface contamination due to the deposition of caesium on the ground given in the official maps made available to the Project were corroborated. On the basis of the limited number of soil samples independently analysed for plutonium and strontium, the results for plutonium were found to correspond to the reported estimates, whereas a potential for overestimation in the reported data for strontium was identified.

The radioactive contamination of drinking water resources that were sampled in the surveyed contaminated settlements was found by the Project team to be significantly lower than the intervention levels established by the authorities.

The radioactive contamination of food samples was found to be in most cases below the intervention levels established by the responsible authorities in the settlements surveyed. In some settlements, milk from

individual farms and food collected in natural areas in contravention of official recommendations could be contaminated above these levels.

Recommendations

Local laboratories should, as is customary, be confidentially notified of the Project findings of relevance for them and should take appropriate remedial actions where needed. Local laboratories which have participated in the intercomparison exercise should be informed confidentially of their performance so that they can rectify problems where necessary.

Quality assurance programmes to assure consistently reliable results should be in place in local laboratories. These laboratories should participate regularly in international intercomparison programmes and international intercalibration exercises.

A programme should be established to assess the significance of 'hot spots'. Research programmes on the characteristics of hot particles and their occurrence in the environment are warranted and should be continued.

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 to study radionuclide behaviour in ecosystems, and desorption of strontium from sediments in surface water bodies and its impact on agriculture through irrigation practices.

It may be advantageous to consider the future use in the USSR of validated models to predict radionuclide levels in food. The use of these models could be cost effective in the long term and reduce the need for extensive sample analysis.

All data from the BSSR, the RSFSR and the UkrSSR related to radiological contamination should be shared with the USSR Central Data Bank in Obninsk so as to be made available to all Republics. All such information should also be made available to relevant institutes and institutions.

A programme should be implemented to derive more detailed official large scale contamination maps.

A collaborative programme 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 in order to obtain more definitive information on the relevance of the resuspension and inhalation pathways.

3. Radiation Exposure of the Population

General Conclusions

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 caesium 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[2].

Detailed Conclusions

EXTERNAL EXPOSURE

The external exposure due to deposited radionuclides is, in most areas, the most significant contributor to dose, especially in those areas where food restrictions have been applied. The reported methodology for calculations of external dose is being confirmed by local measurements using thermoluminescence dosimetry.

Independent measurements of external exposure were carried out under the auspices of the IAEA for the Project. Eight thousand film badge dosimeters were distributed to residents of seven settlements. Ninety per cent of the results were below the detection limit of 0.2 mSv for a two month exposure period. This result is in agreement with what would be expected on the basis of calculational models.

INTERNAL EXPOSURE

Doses from incorporation of caesium in the first four years after the accident were estimated by the authorities on the basis of measurements of

incorporated caesium, including both ^{134}Cs and ^{137}Cs. The procedure for estimating doses from these measurements is in accordance with that used in the independent evaluations made under the Project.

Official estimates of projected doses due to the intake of caesium are based on a number of influencing factors, including an assumed half-time of 14 years for ^{137}Cs in the environment. This assumption is designed to ensure that doses are not underestimated and is prudent.

Official estimates of doses due to the intake of strontium in the first four years after the accident were based on a metabolic model and measurements of strontium in foods, or on an assumed ratio of strontium to caesium in foods if no data on strontium were available.

Official estimates of projected doses due to the intake of ^{90}Sr in the diet were made on the assumption of an environmental half-time of 10 years; this assumption was not referenced, but is stated to be derived from experience gained after the accident at a nuclear materials production plant in Kyshtym in the USSR in 1957.

On the basis of the results of an intercomparison programme with the participation of local laboratories and the IAEA Laboratory using standardized phantoms, it can be concluded that the accuracy obtained in local whole body measurements for caesium is adequate for radiological protection purposes.

Whole body counting of caesium was carried out under the auspices of the IAEA for the Project and covered more than 9000 people in nine settlements. The results indicated generally lower body contents of caesium than would be predicted on the basis of most models of environmental transfer, dietary intake and metabolism. Similar results for whole body counting of caesium have been reported in other countries.

Absorbed thyroid doses due to iodine were officially reported on the basis of thyroid measurements made in the early stages 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.[3]

However, since the iodine had completely decayed by the time of the Project, no independent verification of the reported absorbed thyroid doses was possible.

DOSE ESTIMATE COMPARISON

Independent estimates of doses were made for the surveyed contaminated settlements on the basis of average deposition results. It could not be assumed that such generalized dose estimation assumptions or environmental modelling calculations would accurately reflect the local soil conditions, agricultural practices and living habits in the surveyed contaminated settlements but the results could be expected to provide a general basis for comparisons.

The ranges in the estimates of 70 year (1986-2056) doses were as follows:

Independent estimates for the surveyed contaminated settlements:

External dose:	60-130 mSv
Internal dose (caesium):	20- 30 mSv
Total (including strontium):	**80-160 mSv**

Officially reported estimates for the same settlements:

External dose:	80-160 mSv
Internal dose (caesium):	60-230 mSv
Total (including strontium):	**150-400 mSv**

Independent Project estimates for the surveyed contaminated settlements were lower than the officially reported dose estimates. Overall, there is agreement to within a factor of 2-3 between the independent estimates and the officially reported estimates[4].

Recommendations

The official procedures for dose assessment reported to the Project use deterministic models that are designed not to underestimate doses. Probabilistic dose assessment methods should be developed so that more realistic estimates of dose are eventually available and uncertainties in the calculation are fully assessed.

Over the next few decades it should be possible to extend scientific knowledge of environmental transfer factors by studies in the contaminated areas of concern. Measurement of external exposure rate, caesium body burden and the caesium and strontium content of foodstuffs should be continued.

Although the potential relative contributions from resuspension to dose are believed to be minor, even for outdoor workers, doses should be assessed for critical groups such as agricultural workers.

Local scientists should participate more actively in international dose assessment validation studies. Such activities include intercomparisons of environmental transfer models and internal and external dosimetry intercomparisons.

Local scientists should participate more actively in international programmes on both the formal level (for example, through attendance at seminars, symposia and conferences) and the informal level to provide an exchange of information on technology that can be applied to the effective solution of dosimetric problems. Support should be given for specialists to gain experience working in foreign laboratories.

4. Health Impact

General Conclusions

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 and 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 USSR.

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

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.

Detailed Conclusions

CURRENT HEALTH EFFECTS ATTRIBUTED TO RADIATION

Reported adverse health effects attributed to radiation have not been substantiated either by those local studies which 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 well maintained equipment and supplies; poor information through lack of documentation and lack of access to scientific literature; and shortages of well trained specialists. Nevertheless, despite these obstacles, a number of the local clinical studies were carefully and competently performed and the Project team was able to corroborate the results in most cases.

SPECIFIC RESULTS OF PROJECT FIELD STUDIES

Field studies were undertaken of continuous residents of rural surveyed contaminated settlements (with surface contamination higher than 555 kBq/m^2 (15 Ci/km^2) due to caesium) and surveyed control settlements of 2000 to 50 000 persons, using an age matched study design. The studies were performed in the second half of 1990 and relate to the health status at that time. The strategy of the study, to elucidate major health problems identified by general clinical examinations and sophisticated laboratory tests, was adequate to answer most concerns of the population. There was no exhaustive testing of each individual, and the study did not resolve all questions relating to potential health effects.

Psychological Disorders

There were many important psychological problems of anxiety and stress related to the Chernobyl accident and in the areas studied under the Project these were wholly disproportionate to the biological significance of the radioactive contamination. These problems are prevalent even in the surveyed control settlements. The consequences of the accident are inextricably linked with the many socioeconomic and political developments that were occurring in the USSR.

A large proportion of the population have serious concerns; these people are not acting in an irrational way that could be termed radiophobic. The vast majority of adults examined in both the surveyed contaminated settlements and the surveyed control settlements visited either believed or suspected they had an illness due to radiation. Most adults in both surveyed contaminated and surveyed control settlements were native to the local area and virtually all have stated that they have lived in the

settlements since birth and therefore relocation is a major concern. While only about 8 per cent of adults in surveyed control settlements wanted to relocate, the adults in the surveyed contaminated settlements were so concerned that 72 per cent wanted to relocate. The percentages of the population who think that the Government should relocate the whole population are higher: 20 per cent and 83 per cent, respectively.

General Health

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 per cent to 15 per cent (excluding hypertensive adults) requiring medical care.

Cardiovascular Disorders

There were many hypertensive adults; however, the statistics related to both systolic and diastolic blood pressure were similar for both surveyed contaminated and surveyed control settlements, and both were comparable with published values for Moscow and Leningrad.

Nutrition

Diet appeared to be limited in range but adequate. No significant differences in reported eating habits were found between surveyed contaminated and surveyed control settlements. No detrimental effects on growth due to voluntary or official dietary restrictions imposed as a result of the accident were found. There were no significant differences between the growth rates of children in surveyed contaminated and surveyed control settlements, and the rates for both groups are well within published USSR and international norms. Adults were generally overweight by international standards in all areas studied. Intake and excretion of iodine were found to be at the low end of the acceptable range. Most other dietary constituents and components were found to be adequate; however, vitamin intake was not examined. Dietary intakes of toxic elements (lead, cadmium, mercury) were low in comparison with those reported for many other countries and were well below the maximum tolerable intake levels specified by international organizations. Blood lead levels were also investigated and were found to be well within the normal range.

Thyroid Gland Disorders

No abnormalities in either thyroid stimulating hormone (TSH) or thyroid stimulating hormone (TSH) or thyroid hormone (free T4) were found in children examined. No statistically significant difference was found between surveyed contaminated and surveyed control settlements for any age group.

Mean thyroid sizes and size distributions were the same for populations of surveyed contaminated and surveyed control settlements. Thyroid nodules were extremely rare in children; they occurred in up to 15 percent of adults in both surveyed contaminated and surveyed control settlements. Project results are similar to those reported for populations in other countries.

Haematology

Some young children with low haemoglobin levels and low red cell counts were identified. However, there were no statistically significant differences between values for any age group of the population in surveyed contaminated and surveyed control settlements. No difference was found between the populations when leucocytes and platelets were examined. Immune systems (as judged from the lymphocyte level and the prevalence of other diseases) do not appear to have been significantly affected by the accident.

Neoplasms

Review of USSR data indicated that reported cancer incidence had been rising for the last decade (starting before the Chernobyl accident occurred) and has continued to rise at the same rate since the accident. The Project team considered that there had been incomplete reporting in the past and could not assess whether the rise is due to increased incidence, methodological differences, better detection and diagnosis or other causes. The data did not reveal a marked increase in leukaemia or thyroid tumours since the accident. However, owing to the classification scheme used and other factors, the possibility of a slight increase in the incidence of these tumours cannot be excluded. Only hearsay information relating to such tumours was available.

Radiation Induced Cataracts

There was no evidence of radiation induced cataracts in the general population.

Biological Dosimetry

Chromosomal and somatic cell mutation assays are still being completed on adults who had worked outdoors, since their exposures were assumed to be the highest. So far, no significant difference has been found between adults living in surveyed contaminated and surveyed control settlements. The data obtained were consistent with the Project dose estimates.

Foetal and Genetic Anomalies

Review of USSR data for settlements in contaminated areas of concern as well as for the Republics as a whole indicated relatively high infant and perinatal mortality levels. These levels prevailed before the accident and appear to be decreasing. No statistically significant evidence was found of an increase in incidence of foetal anomalies as a result of radiation exposure.

POTENTIAL DELAYED HEALTH EFFECTS

Available data reviewed do not provide an adequate basis for determining whether there has been an increase in leukaemia or thyroid cancers as a consequence of the accident. The data were not detailed enough to exclude the possibility of an increase in the incidence of some tumour types. On the basis of the doses estimated by the Project and currently accepted radiation risk estimates, future increases over the natural incidence of all cancers or hereditary effects would be difficult to discern, even with large and well designed long term epidemiological studies. Reported estimates of absorbed thyroid dose in children are such that there may be a statistically detectable increase in the incidence of thyroid tumours in the future.

Recommendations

GENERAL HEALTH AND POTENTIAL ACCIDENT CONSEQUENCES

The adverse health consequences of relocation should be considered before any further relocation takes place.

Consideration should be given to the introduction of programmes to alleviate psychological effects. These might include informational programmes for the public. There should also be educational programmes set up for teachers and local physicians in general preventive health care and radiation health effects.

The current policy of annual physical examinations is conceptually adequate for the health needs of the general population in the contaminated areas of concern. However, certain high risk groups (such as children with high absorbed thyroid doses) will need specific medical programmes based on their potential risks.

Energetic action should be taken to improve the standard of medical, diagnostic and research equipment and the availability of medical supplies, manuals and spare parts.

Clinical and research investigations should emphasize the use of appropriate control groups, standards and quality control procedures.

Improvements should be made in the statistical, data collection and registry systems used by local scientists by the adoption and application of internationally accepted standards and methods.

There should be increased opportunities for information exchange and greater availability of scientific literature for local health professionals.

POTENTIAL DELAYED HEALTH EFFECTS

In view of the limited resources available, the concept of the WHO Scientific Advisory Group on the Health Effects of Chernobyl, namely to concentrate on prospective cohort studies of selected high risk populations, should be endorsed. It is impractical, owing to the extreme difficulty and

cost, to conduct long term studies or to evaluate all persons who live in the affected Republics.

GENERAL PUBLIC HEALTH ISSUES IN THE AFFECTED REPUBLICS

Action should be taken on adult hypertension and dental hygiene as major health issues. The need for continuing programmes for iodization of salt should be re-evaluated; if these are found to be necessary, the effectiveness of the chemical process should be assessed.

5. Protective Measures

General Conclusions

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.

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 counterproductive 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.

Detailed Conclusions

EVACUATION AND THYROID BLOCKING

The intervention levels of dose for evacuation established by the authorities were consistent with international guidance at the time of the accident.

The general policy for administration of stable iodine established by the authorities was in compliance with the international guidance at the time of the accident. The numerical values of the intervention levels, however, were not in full agreement with those recommended internationally.

The resources required to evaluate the practical implementation of these two protective measures were far in excess of those available within the Project. Consequently, only a superficial analysis was made of these aspects, on which no further conclusions can be made.

SURFACE DECONTAMINATION

Efforts were made after the Chernobyl accident over a period of several months to reduce external exposure due to radioactive materials that were released in the accident and deposited on surfaces. The wide range of measures taken included: the removal of soil to a depth of 10-15 cm; asphalting and covering soil with gravel, broken stones, sand or clean soil; daily mechanized washing; surface washing; demolition of structures; and burial of waste. These measures are reported to have been moderately effective; however, the Project teams did not specifically investigate these reports.

FOOD RESTRICTIONS

Criteria

The basis on which the intervention levels for food restrictions established by the authorities were derived was broadly consistent with international guidance prevailing at the time of the accident. There was, however, considerable ambiguity in the international guidance. Furthermore, the derived levels of radionuclide concentrations for various foodstuffs

used in the USSR, each having merits and disadvantages. In particular, surface contamination is not generally applicable for dose estimates because there is a strong dependence of dose estimates on local soil conditions, food consumption habits and lifestyle.

Social Impact

It appears that due account has not been taken by the authorities of the many negative aspects of relocation in formulating the relocation policy. There are indications from studies in other areas that the mass relocation of people leads to a reduction in average life expectancy (through increased stress and changes of lifestyle) and a reduced quality of life in a new habitat.

In applying a lifetime dose criterion for relocation, it is inappropriate to take account of past doses. Intervention may reduce the risk of adverse health effects in proportion to the dose averted but it can have no influence on doses already received before the intervention. For dose ranges below the threshold for deterministic effects, it is conceptually unsound and in contradiction to the principles for intervention to take past doses into account. There are, however, circumstances in which the total, past and projected, doses received may be the relevant quantity, for example in judging the need for and extent of any long term medical follow-up or care of those exposed as a result of the accident.

The cautious approach adopted (i.e. overestimates) in the estimation of doses to people living in the contaminated areas of concern, on the grounds that this was in their best interest, was inappropriate in principle and contradictory to the fundamental objectives of intervention. It had two important negative consequences: firstly, the radiological consequences of continuing to live in contaminated areas were overstated and this contributed to additional and unnecessary fear and anxiety in the population; secondly, and more importantly, some people will be relocated needlessly.

The average levels of individual lifetime dose that could potentially be averted by relocation, prompted by either the 350 mSv (35 rem) or the 40 Ci/km^2 (1480 kBq/m^2) criterion, are of the same order as or less than the doses due to average natural background radiation.

It is not clear that the modest nature of the doses that could be averted by relocation, and their assumed risks, are fully appreciated by either the population of the contaminated areas of concern or many of those people advocating a more stringent regime. The extra incremental risk to which an individual remaining in a contaminated area would be exposed would be marginal in comparison with risks experienced in everyday life and in itself would not justify such a radical measure as relocation.

Policy Reappraisal

On strictly radiological protection grounds, there can be little if any justification for the adoption of more restrictive relocation criteria than those currently adopted in the All-Union programme (i.e. 40 Ci/km^2, or 1480 kBq/m^2). Indeed, a reasonable case could be made for a relaxation in the policy, i.e. for an increase of the intervention levels.

A much larger number of people than those living in settlements with contamination levels in excess of 40 Ci/km^2 (1480 kBq/m^2) are to be relocated; the doses averted by the relocation of these people will be significantly less than the modest values already indicated. The implications of this are that more restrictive criteria are being adopted in practice.

Many factors, other than those of a strictly radiological protection nature, have had an important and possibly overriding influence on relocation policy. The need to restore public confidence, which has been seriously eroded for many reasons over the past five years, to reduce anxiety and to gain broad acceptance for the policy was identified to be particularly important. In ongoing reappraisals by the authorities of the relocation policy, these factors are being assigned much greater weight than factors of a strictly radiological protection nature. The relative importance to be attached to the various factors is, however, a matter for the relevant authorities.

Future changes in relocation policy will inevitably be constrained by past actions. Notwithstanding the merits of and technical justification for a change in policy, acceptance of major changes would be difficult to achieve, particularly where these involved a relaxation in the criterion previously adopted. A relaxation in the current relocation policy (i.e. a

higher intervention level) would, however, almost certainly be counterproductive given the very difficult social conditions in the contaminated areas of concern. There can be no justification on radiological protection grounds for the adoption of a more restrictive policy. This should be strongly resisted unless there are overriding considerations of a social nature.

Recommendations

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.

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.

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 programmes 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.

FOOTNOTES

1 The word 'dose', unless otherwise specified, is generally used to mean 'effective dose', i.e. the total absorbed dose appropriately weighted for the harmfulness of the radiation type and the susceptibility to harm of human tissues.

2 The Project selected, in co-operation with local authorities, a number of settlements in the contaminated areas of concern in order to perform the necessary surveys. Some of the settlements were located in areas of relatively high soil surface contamination while others were located in areas of relatively low soil surface contamination but with the potential for high radiation doses to people. In this text, these settlements are called "surveyed contaminated settlements". Settlements were also selected outside the contaminated areas of concern to serve as references for comparative purposes. These settlements are called "surveyed control settlements".

3 These estimates were derived on the basis of doses due to ^{137}Cs and ^{90}Sr; where appropriate, shorter lived isotopes of caesium and strontium were also taken into account.

4 The maximum reconstructed absorbed thyroid dose (in Bragin) was officially reported as 30--40 Gy.