The International Chernobyl Project

Multinational teams of experts assess the Chernobyl accident's radiological consequences in three Soviet Republics

Beginning in the spring of 1990 and lasting into 1991, multinational teams of specialists in radiation protection, medicine, agriculture, and other fields critically studied the radiological and health situation in selected areas of Byelorussia, Russia, and the Ukraine. Approximately 825 000 people live in 2225 settlements there that were heavily affected by the Chernobyl accident in 1986 — about 25 000 km^2 of land are contaminated with excess levels of radioactive caesium-137, a long-lived radionuclide released by the accident.

The teams were part of the International Chernobyl Project, which was initiated in late 1989 at the request of the Soviet Government. Over the course of a year, more than 200 experts from 25 countries and seven international organizations surveyed thousands of people in selected settlements and reviewed extensive data available from governmental health and radiological authorities. Altogether, they took part in nearly 50 technical missions.

In May 1991, the results of this scientific effort were reported by the project's 21-member International Advisory Committee at an international conference at the IAEA in Vienna. This article selectively highlights the Committee's official report entitled *The International Chernobyl Project: An Overview*, which has been published by the IAEA.*

Environmental contamination

It was clear from the outset that this international assessment could not expect to duplicate the four-year efforts of local experts to assess the environmental contamination of such a vast land mass. Project experts sought to examine the official assessments through a three part approach.

Firstly, they reviewed official data and the practices used for data collection and reporting. Secondly, the Project teams visited 20 governmental institutes and laboratories to review their practices and facilities for sampling and analysing environmental materials and food.

Finally, the Project teams used independent methods and equipment for surveying the radioactivity on the ground, and in the soil, sediments, air, water, vegetation, milk, and food. Given the large number of settlements affected and the limited resources available to the Project, only grab sampling and spot measurements were undertaken. The environmental and food samples collected were analysed for radioactivity at laboratories in six countries.

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

See the *Keep Abreast* section for ordering information. In addition to the Committee's Overview report, the IAEA is publishing the full technical report of the project for issuance later this year.

Nearly 50 technical missions were carried out by Project teams during 1990 to obtain data and to independently assess the radiological situation in selected villages and towns. Work included surveys of radioactivity in soil, air, water, vegetation, milk, and food, and measurements of radiation exposures for thousands of residents. (Credits: Pavlicek/ Mouchkin, IAEA)

The Project's Scope

The International Chernobyl Project had two overriding objectives: to examine assessments of the radiological and health situation in areas of the USSR affected by the Chernobyl accident and to evaluate measures to protect the population. It focused on the approximately 25 000 square kilometres in the Ukrainian Soviet Socialist Republic (UkrSSR), the Byelorussian Soviet Socialist Republic (BSSR), and the Russian Soviet Federated Socialist Republic (RSFSR) officially reported to have a caesium surface contamination level in excess of 185 kBq/m^2 (5 Ci/km^2) and particularly on those areas with a level greater than 1480 kBq/m^2 (40 Ci/km^2). About 825 000 people live in 2225 settlements in these areas. The Project selected for study 28 contaminated settlements, and seven "control" settlements outside the contaminated areas.

Prof. Shigematsu. (Credit: Pavlicek, IAEA)

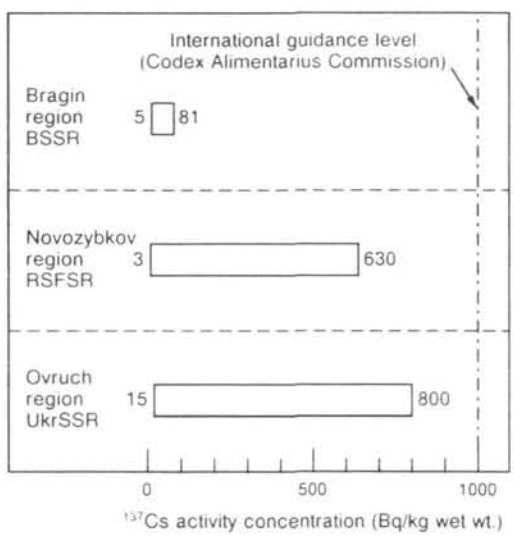
The Project did not have the resources or intention to conduct a comprehensive or elaborate long-term research study. Nor could it even remotely intend to duplicate the voluminous assessments of the environmental contamination, the radiation exposures of the population, and possible health effects due to exposures resulting from the accident. Outside the Project's scope, for example, were people who had lived in contaminated areas but had since moved elsewhere, and emergency workers and others involved in recovery and cleanup operations (often referred to as "liquidators") at the Chernobyl site. The assessment further excluded the 30-kilometre prohibited zone around the Chernobyl reactor.

More than 200 experts from research institutes, universities, and government agencies in 25 countries, and seven international organizations, took part in studies. The work plan was approved and directed by a 21-member International Advisory Committee under the Chairmanship of Prof. Itsuzo Shigematsu of the Radiation Effects Research Council in Hiroshima, Japan. Members included scientists from the World Health Organization (WHO), Food and Agriculture Organization (FAO), United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), International Labour Office (ILO), Commission of the European Communities (CEC), and the IAEA.

Despite the limitations, the Committee's final report describes the Project as 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", and a "significant step" in the evaluation of the accident's consequences.

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.



trade and in many cases were below the limit of detection. *(See graph.)*

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.

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 resuspen-

sion, 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.

RECOMMENDATIONS. 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.

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.

Radiation exposure of the population

As with the environmental contamination evaluation, Project experts did not duplicate the past efforts, but sought to assess the official exposures through a three part approach.

Firstly, there was a review of official information on radiation doses to people living in seven settlements selected for study. Each of these settlements has a ^{137}Cs ground contamination greater than 555 kBq/m^2 (15 Ci/km^2) and in each instance non-contaminated food is provided commercially and there is a ban on the consumption of locally produced food. The Project teams visited over 20 institutes and government ministries in the BSSR, RSFSR, and the UkrSSr, where they examined and discussed dose calculation methodology. Attempts were made to reconstruct the dose estimates using the official information provided and direct discussions with local experts. However, this work was hampered by gaps in information, particularly in regard to the methods used to estimate ^{131}I thyroid doses and past levels of caesium contamination in food.

Secondly, the Project teams assessed the radiation exposure of the selected population using internationally recognized methods and their own independently compiled database obtained through extensive fieldwork in mid-1990. They measured external radiation exposures for some 8000 residents and performed whole body monitoring of 9000 individuals for internal contamination. The whole body measurements were validated in French and Austrian laboratories and in the IAEA Laboratory at Seibersdorf.

Finally, the independent Project estimates were compared with the official dose values. While there are shortcomings in extrapolating exposures from the Project's relatively small population samples, the information is adequate for a valid assessment of the overall population radiation exposure.

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.

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 percent of the results were below the detection limit of 0.2 mSv for a 2-month exposure period. This result is in agreement with what would be expected on the basis of calculational models. *(See graph.)*

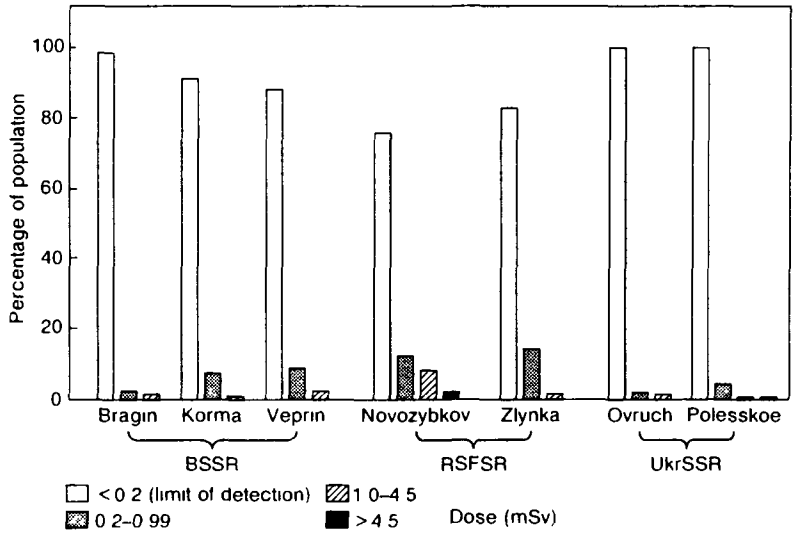
Internal exposure. Doses from incorporation of caesium in the first 4 years after the accident were estimated by the authorities on the basis of measurements of incorporated caesium, including both ^{134}Cs and ^{137}Cs. The procedure for estimating doses from these measurements is in accordance with that used in the independent evaluations made under the Project.

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. (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.

Project measurements of external dose to the population in selected settlements



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.

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.

Health impact

In an attempt to assess the reported increases in illness attributed to the Chernobyl accident and to deal with the concerns, a two step approach was used in the Project. The first step was to review official data at key medical centres and institutes. The next step was to examine people in both surveyed contaminated and surveyed control settlements and to compare the results. Because medical data before 1986 are sparse, the health of inhabitants from the surveyed contaminated settlements had to be compared with that of a similar population living in surveyed control settlements where contamination levels are lower but socio-economic conditions are similar. The examination results were reviewed by Project teams of doctors and epidemiologists, who employed a limited version of a commonly used epidemiological approach to determine the health risk. Additionally, a nutrition expert reviewed data in Moscow and the three Republics, and a field team visited 13 settlements to conduct total diet studies.

Any health effects study inititated 4 years after the accident was bound to have weaknesses and limitations and this one was no exception. To begin with, the study was limited to the population continuing to be exposed to radiation from the accident, namely those who remained in the surveyed contaminated settle-

ments. It would not have been possible to search out and conduct medical examinations on those who had left.

The study concentrated on small to moderate size rural villages and towns since these were located in areas of higher contamination than the larger cities. The type of settlements and the population groups studied cannot be taken as entirely representative of the situation in the larger cities of the affected areas. Nutritional differences due to variations in food availability and consumption would undoubtedly contribute to differences in health status.

There were serious limitations in the data officially provided. Internal correlation of the diverse data as well as correlation with the Project data were extremely difficult because of deficiencies in the equipment and methodology that had been used.

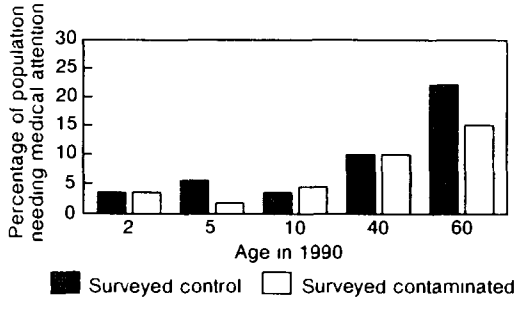
CONCLUSIONS. There were significant non-radiation-related health disorders in the populations of both surveyed contaminated and survey control settlements studied under the Project, but no health disorders that could be attributed directly to radiation exposure. The accident had substantial negative 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.

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.



Project assessment of the general health of the population in selected settlements

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 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% of adults in surveyed control settlements wanted to relocate, the adults in the surveyed contaminated settlements were so concerned that 72% wanted to relocate. The percentages of the population who think that the Government should relocate the whole population are higher: 20% and 83%, 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. *(See graph.)*

• *Cardiovascular disorders.* There were many hypertensive adults; however, the statis-

Checking radiation levels in a house in the village of Babovichi in the republic of Russia (Credit: Pavlicek, IAEA)

tics 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 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 the 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. 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.

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.

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.

Protective measures

Project experts primarily examined those protective measures taken or proposed from 1990 onwards by the authorities. This was a central issue in the USSR request for an international study. A more limited evaluation was also made of measures taken prior to 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.

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.

Food restrictions. 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 established by the authorities were based on consideration of the most exposed persons, i.e. the critical group, as opposed to the average individual in the affected group.

With allowance made for the differences in formulation between the respective criteria, the intervention levels established by the authorities are at the lower bound of the range recommended internationally. In view of the scale of the accident, the extent over which restrictions were needed and the shortcomings in food supply and distribution in the areas concerned, higher values of intervention levels would have been justifiable.

Doses actually received due to the ingestion of contaminated foodstuffs were substantially lower than the prescribed intervention levels of dose, typically by a factor of 2–4, and as a consequence foodstuffs may have been restricted unnecessarily.

The social consequences, including costs, of banning the consumption of foodstuffs were in many cases disproportionate to the doses averted.

Relaxation of the criteria for foodstuffs should be considered as a preferable alternative to relocation when overall health, social and economic effects are taken into account. Continuing restrictions on the consumption of domestically produced food in the contaminated areas of concern imply for some people a serious deterioration in the quality of life which may only be remedied by relocation to areas where previous lifestyles can be resumed. The relatively low intervention levels adopted for foodstuff restrictions may have exacerbated these problems.

An immense and largely successful effort has been made by the authorities to contain the agricultural consequences of the Chernobyl accident. Great efforts have also been made to reduce radiation risks to the population as a whole and to agricultural workers and their families in particular. The negative social effects of agricultural countermeasures could be further reduced by employing certain types of caesium binder.

Relocation. The bases on which the criteria for relocation were derived by the authorities are not wholly consistent with the principles currently recommended internationally; this, however, does not necessarily imply that the quantitative criteria adopted are inappropriate.

In establishing relocation criteria, there were various conceptual misunderstandings and terminological problems among the parties concerned (including central and local authorities) that contributed to many of the present problems:

- The use of imprecise terminology and the misunderstanding and/or misrepresentation of some fundamental radiological protection concepts and principles, on the part of both the scientific community and others, have been a source of much needless confusion and disagreement in the USSR. This, taken together with the considerable delays in developing policy and effectively communicating it, has been largely responsible for the failure to reach a broad consensus on relocation policy. Moreover, it has contributed to a loss of confidence on the part of the affected population in the measures being taken in their interest.
- One of the more important misunderstandings or misrepresentations has been confusion over, and lack of recognition of, the very different origins and purposes of the dose limits recommended internationally for controlling planned increases in radiation exposure and those of the dose levels at which intervention is prompted to reduce existing radiation exposures. Dose limits *per se* are not the appropriate levels at which to intervene following an accident. The dose averted by relocation is the relevant quantity for judging the radiological benefits of relocation and, where practicable, quantitative criteria should be expressed in terms of this quantity.

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.

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 5 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. 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.