International Conference

Twenty Years after the Chernobyl Accident:

Future Outlook

Kyiv, Ukraine, April 24-26, 2006.

CONCLUSIONS AND RECOMMENDATIONS

CONFERENCE ORGANIZERS

Government of Ukraine in co-operation with:

Government of the Republic of Belarus

Government of the Russian Federation

European Commission

International Atomic Energy Agency

World Health Organization

United Nation Development Programme

Council of Europe

European Centre of Technological Safety

International Charitable Fund "Ukraine 3000"

Institute of Radiation Protection and Nuclear Safety, France

Society for Technical and Nuclear Safety GRS, Germany

CONTENT

1. INTRODUCTION

This report presents the Conclusions and Recommendations of the International Conference "Twenty Years after the Chernobyl Accident: Future Outlook", held in Kiev on April 24-26, 2006. It is based on material presented during the Conference, in particular the national reports of Belarus, the Russian Federation and Ukraine. In addition, due account has been taken of the main findings of the following relevant documents:

- Conclusions and reports of the Chernobyl Forum (2003-2005), and International Conference "Chernobyl: Looking Back to Go Forwards", September 6-7, 2005, Vienna, Austria;

- Conclusions of the International Conference "Chernobyl 20 years later. Strategy of recovery and sustainable development of suffered regions", Minsk – Gomel (Belarus), April 19-21, 2006;

- Conclusions of the International Conference "Chernobyl 20 years later: Local and regional authorities facing catastrophes", Slavutych (Ukraine), March 2 – 4, 2006;

- Conclusions of the International Conference "Radioactivity after Nuclear Explosions and Accidents", Moscow, (Russia), December 5-6, 2005;

- Executive Summary of the International Conference "Fifteen years of Chernobyl catastrophe. Lessons Learned ", Kyiv (Ukraine), April, 2001.

The Conference was held to mark the 20th anniversary of the Chernobyl accident. The accident had major social, political, economic, health and environmental impacts, both in the immediately affected countries and beyond. Despite the two decades that have passed, considerable resources continue to be allocated to mitigate the consequences of the accident, in particular to the continuing management and socio-economic restoration of affected settlements and ensuring the long-term safety of the damaged reactor and its surroundings. On a more positive note, the accident has acted as a stimulus for the further improvement of nuclear safety and radiation protection globally, in particular in the area of emergency preparedness and response.

The purpose of the Conference was to review, consolidate and share the vast experience gained over the past two decades in responding to and managing the diverse and continuing impact of the Chernobyl accident. A further objective was to look forward and identify what still needs to be done to mitigate current and future impacts of the accident and determine whether new policy initiatives are warranted, regionally or internationally.

A common understanding has been developed of the causes of the accident, its consequences and how they have been subsequently managed. Many lessons have been learned as a result of this unfortunate experience but, if properly heeded, the risk of any future accident will be extremely low and even should an accident occur, its radiological impact will be effectively managed.

The main conclusions and recommendations emerging from this common understanding are presented in the following sections.

2. BACKGROUND

On 26 April 1986, the most serious accident in the history of the nuclear industry occurred at Unit 4 of the Chernobyl nuclear power plant in the former Ukrainian Republic of the Union of Soviet Socialist Republics, near the common borders of Belarus, the Russian Federation and Ukraine.

The Chernobyl accident was the result of an inherently unsafe reactor design combined with serious deficiencies in "safety culture". Additionally, the operators were not informed of design weaknesses and did not comply with all operational procedures. The combination of these factors provoked the worst nuclear accident in which the reactor was totally destroyed within a few seconds.

Major releases of radionuclides from the Chernobyl reactor continued for ten days following the explosion on April 26. These included radioactive gases, condensed aerosols and fuel particles. The total release of radioactive material was about 14 EBq [1], including 1.8 EBq of ^{131}I, 0.085 EBq of ^{137}Cs, 0.01 EBq of ^{90}Sr and 0.003 EBq of plutonium isotopes. Radioactive noble gases contributed about 50% of the total activity released.

More than 200,000 square kilometers of Europe was contaminated with levels of ^{137}Cs above 37 kBq/m^2. Much of this area was within the three most affected countries, Belarus, Russia and Ukraine. The level of deposition was extremely varied and was enhanced in areas where it was raining while the contaminated air masses passed. Most of the strontium and plutonium was deposited within 100 km of the destroyed reactor due to their larger particle sizes.

Many of the more significant radionuclides had short physical half-lives. Thus, most of the radionuclides released in the accident have long since decayed away. The releases of radioactive iodine caused greatest concern immediately after the accident. After the first year the main radiological impact has been determined by the deposition of caesium isotopes and this will continue for decades to come; deposits of ^{90}Sr are also of longer term concern but of much less significance than caesium isotopes. Over the longer term (hundreds to thousands of years) the plutonium isotopes and americium-241 will remain, although at levels not radiologically significant outside of 30 km zone.

The deposition in urban areas in the nearest (about 3 km) city of Pripyat and surrounding settlements could have given rise to substantial external exposure. However, this was, to a large extent, averted by the evacuation of residents. The deposition of radioactive material in other inhabited areas has resulted in the continuing exposure of the population, albeit at much reduced levels compared to the immediate aftermath of the accident.

In most settlements outside the 30 km zone the dose rate has essentially returned to the background level before the accident. The territories contaminated as a result of the accident have been intensively monitored and studied for two decades and the behavior of the main residual contaminants, ^{137}Cs and ^{90}Sr, is well understood.

A wide range of effective countermeasures has been established and implemented by the respective Governments to maintain radiation exposures and contamination levels below national standards.

In the early months after the accident, the levels of radioactive material in plants and animals were dominated by surface deposits of radionuclides. The deposition of radioiodine caused the most immediate concern, but the problem was confined to the first months after the accident because of rapid decay of the most important isotope ^{131}I. Radioiodine was rapidly taken up into milk leading to large thyroid doses to those (especially children) consuming milk, in particular in

[1] 1 EBq = 10^{18} Bq (Becquerel).

areas where food restrictions were not imposed. In the rest of Europe increased levels of radioiodine in milk were observed in those areas where dairy animals were already outdoors.

Subsequently, uptake of deposited radionuclides through plant roots from soil became increasingly important. Radioisotopes of caesium (^{137}Cs and ^{134}Cs) were the nuclides which led to the largest problems and, even after decay of ^{134}Cs (half-life of 2.1 years) by the mid-1990s, the levels of longer-lived ^{137}Cs in agricultural products from highly affected areas still required control in many areas. In addition, ^{90}Sr remains of potential concern in areas close to the reactor, but at greater distances its deposition levels were low. Other radionuclides, such as plutonium isotopes and ^{241}Am had no significant impact on agriculture.

In general, there was a substantial reduction in the transfer of radionuclides to vegetation and animals in intensive agricultural systems in the first few years after the accident, as would be expected due to weathering, physical decay, and migration of radionuclides down the soil, reductions in bioavailability in soil and due to countermeasures.

The radiocaesium content in foodstuffs is influenced not only by the level of deposition but also by the type of ecosystem and soil and agricultural management practice. Much greater transfer to foodstuffs occurs in areas with barren (sand or peat) soil, where animals graze unimproved pastures that are not ploughed or fertilized. This particularly affects rural residents, who are commonly subsistence farmers with privately owned dairy cows.

Currently, ^{137}Cs activity concentrations in agricultural food products produced in areas affected by the Chernobyl fallout are generally below action levels. However, in some limited areas with high radionuclide contamination and areas with high transfer of radionuclides from soil to plant, milk may still be produced with ^{137}Cs concentrations that exceed action levels. In these areas, countermeasures and environmental remediation may still be warranted.

Following the accident, vegetation and animals in forests and mountain areas have shown particularly high uptake of radiocaesium in non-cultivated food products. Particularly high ^{137}Cs concentrations have been found in mushrooms, berries and game, and these high levels have persisted for about two decades. This is due to the recycling of radiocaesium particularly in forest ecosystems.

In the future ^{137}Cs in milk and meat and, to a lesser extent, ^{137}Cs in plant foods and crops remain the most important contributors to human internal dose. But in some areas of Belarus, Russia and Ukraine, consumption of non-cultivated foods with ^{137}Cs makes a major contribution to exposure and this can be expected to continue for several decades.

The high transfer of radiocaesium in the pathway lichen-to-reindeer meat-to-humans has been demonstrated again after the Chernobyl accident in the Arctic and sub-Arctic areas of Europe. The Chernobyl accident led to high levels of ^{137}Cs of reindeer meat in Finland, Norway, Russia and Sweden and caused problems for local population.

Radioactive material from Chernobyl contaminated surface water systems in areas close to the reactor site and in many other parts of Europe. The initial levels were due primarily to direct deposition of radionuclides on the surface of rivers and lakes, dominated by short-lived radionuclides (primarily ^{131}I). In the first few weeks after the accident, high concentrations of radionuclides in drinking water from the Kyiv Reservoir were of particular concern. Levels in water bodies fell rapidly during the weeks after fallout through dilution, physical decay and absorption of radionuclides in the catchments areas of the water bodies. Bed sediments are an important long-term sink for radioactive materials, which are subsequently covered by layers of “clean” sediments.

In general, ^{137}Cs and ^{90}Sr levels in water and fish of rivers, open lakes and reservoirs are now low. However, in some “closed” lakes with no outflowing streams in Belarus, Russia and Ukraine, both water and fish will remain contaminated at significant levels with ^{137}Cs for decades to come.

Owing to the large distance of the Black and Baltic Seas from Chernobyl, and the dilution in these systems, radionuclides concentrations in seawater were much lower than in freshwater. Because of these low levels and the low bio-accumulation of caesium in marine biota, the levels of ^{137}Cs levels in marine fish are of no concern.

The Governments of the Soviet Union, and later – Belarus, Russia and Ukraine - introduced a wide range of short- and long-term countermeasures to mitigate the accident's negative consequences.

The most effective agricultural countermeasures in the early phase were exclusion of contaminated pasture from animal diets and rejection of milk based on radiation monitoring data. Feeding animals with "clean" fodder was effectively performed in some countries. However, these countermeasures were only partially effective in reducing radioiodine intake via milk because of the lack of timely information about the accident and necessary responses, particularly for private farmers in the three most affected countries.

The greatest long-term problem has been caesium contamination of milk and meat. In the USSR and later in the Belarus, Russia and Ukraine, this has been addressed by the treatment of land used for fodder crops, clean feeding and application of caesium-binders, such as Prussian blue, to animals. This enabled most farming practices to continue in affected areas and resulted in a large reductions in contamination and consequently in the exposure of people.

Acute effects of radiation in plants and animals were evident in those areas (within 30 km zone) with high levels of contamination with significant variation between type of plant and animal depending on their radio sensitivity. Genetic changes of somatic and germinal cells were observed and different cytogenetic anomalies revealed. In the flora and fauna of the Exclusion Zone radiation-induced effects were observed both at the individual and population levels.

The recovery of affected flora and fauna in the Chernobyl Exclusion Zone is a complex process. On one hand, there is the continuing influence of radiation on local populations of animals and plants; on the other hand, there is active migration from less affected territories and restitution of local populations due to a lessening of the anthropogenic pressure on the nature of Exclusion Zone (people resettlement, cessation of farming etc.).

People exposed to radiation from the Chernobyl accident can be divided into the following categories:

- emergency workers participating in recovery operations at the Chernobyl NPP and in the Exclusion zone after the accident;
- evacuees from the most contaminated areas; and
- populations of less contaminated areas, who have not been evacuated.

During 1986-1987 initially about 350 000 people (servicemen, NPP staff members, firemen, medical and other workers) were involved in clean-up operations after the accident. Among them about 240 000 participated in this work at the NPP and in 30-km zone. Later, the number of registered "liquidators" grew to 600 000.

In spring and summer of 1986, 116 000 people were evacuated from the most contaminated settlements. Later, about 220 000 more people were resettled.

At present approximately five million inhabitants of Belarus, Russia and Ukraine are living in territories contaminated at levels greater than 37 kBq/m^2 of ^{137}Cs (normalized to levels in 1986). Of these, about 200 000 are residing in territories contaminated at levels greater than 555 kBq/m^2. of ^{137}Cs.

The exposure of these different groups varied over a wide range, from levels, that could cause death (one or tenths of a Gray in a few hours) to levels comparable with natural background radiation or lower (below 0.001 Gray per year). Currently in the majority of settlements, annual doses do not exceed 1 mSv, the dose limit for members of the public. Those continuing to live in contaminated areas since 1986 have already received about 80% or more of the total dose from the accident.

Large-scale measures to prevent early medical consequences of accident (e.g., medical aid for those with acute radiation injuries, iodine prophylaxis, medical surveys) required the mobilization of considerable public health and medical resources.

In spite of initial underestimates of the scale of the accident, lack of government information and a significant number of liquidators receiving high radiation exposures, actions taken by the medical services were, in general, correct. However, failure to control the production and consumption of contaminated foodstuffs in some areas and delayed and insufficient iodine prophylaxis, resulted in a large number of thyroid cancers especially among those, who were children or teenagers at the time of accident. The frequency of some forms of solid tumors and leukemia appears to be increasing among clean-up workers but this needs to be confirmed by further investigations.

Non-radiation factors of accident (lack of information about possible health effects, fear and uncertainty about the future, changes of social conditions and way of life, stress etc.) also had a major influence on the health of the population that was initially not recognized and underestimated.

The Chernobyl accident and efforts to overcome its consequences were very expensive for the Soviet Union and subsequently for Belarus, Russia and Ukraine. Direct expenses (building of “Shelter” object, creation of the Exclusion zone, evacuation and resettlement, greatly increased health care, radiological monitoring of food, etc.) amounted to tens of billions of dollars, and indirect expenses (e.g., lost industrial potential) are estimated to be hundreds of billions of dollars. The financial burden on governments to assist in resettling the affected population to new locations, as well as the health care and social assistance for several million people soon exceeded capabilities of the states.

Measures imposed to ensure radiation safety led to major economic losses, especially in agriculture. Large areas of agricultural land were withdrawn from use; much food and wood production stopped. Economic instability following the break-up of the Soviet Union aggravated the situation. Unemployment in the affected regions increased substantially, mainly because of the loss of jobs as production declined. The level of poverty in the affected territories is higher than the average in the three countries. The demographic structure of population has also been distorted, with a large and increasing number of the elderly and a decline in the number of young people and qualified professionals; this is having a major negative impact on economic recovery. The low investment in these areas partially reflects negative perceptions of contaminated land. Partially as a result of the secrecy surrounding the accident in the early stages, myths and misperception of the dangers of radiation were typical both for affected territories and far beyond. Provision of unbiased and comprehensible information remains a problem. The feeling of helplessness continues among affected people making self-sufficiency more difficult to achieve. This remains a key challenge for all those involved in minimization the consequences of the accident.

Destruction of unit 4 of Chernobyl NPP led to the production of tremendous quantities of radioactive wastes, at the power plant and in its vicinity. Construction of the “Shelter” or “Sarcophagus” from May to November 1986 isolated the damaged reactor and led to a decrease in radiation levels as well as preventing further spread of radionuclides into the environment.

The “Shelter” was built rapidly in high levels of radiation. This resulted in design faults as well as a lack of information about its stability. The basic concern with the “Shelter” is the possible destruction of the building and discharge of radioactive dust into the environment.

To avoid the possible destruction of the “Shelter”, measures to strengthen unstable components and the creation of new safe confinement (NSC), which should serve at least 100 years, are being performed. Construction of the NSC will permit the dismantling of the existing “Shelter”, allow the removal of highly active fuel containing materials (FCM) and convert the “Shelter” into an ecologically safe system.

Transformation of the Shelter into an ecologically safe system is being carried out in close collaboration with the EC and other countries. A Shelter Implementation Plan (SIP) has been developed with the following aims:

- to decrease the probability of collapse of the Shelter by stabilizing its components;
- to decrease the consequences of an accident during the collapse of “Shelter”;
- to increase nuclear safety of the “Shelter”;
- to increase the safety of workers and the environment;
- to determine a long-term strategy for transformation of the “Shelter” into an ecologically safe system.

The Government of Ukraine has an agreement with G7 countries and the European Commission to collaborate on the transformation of the “Shelter” into an ecologically safe system. To implement the SIP the International Chernobyl Foundation was created under the administration of the European Bank of Reconstruction and Development. Realization of the SIP will increase the safety of Chernobyl NPP 4th unit and reduce the anxiety about possible collapse of the existing Shelter.

To decrease radiation levels and ensure safer working conditions at the destroyed reactor and in its vicinity, temporary depositories of radioactive wastes were created during 1986 -1987 in the Exclusion Zone at a distance of 0.5 - 15 km from the reactor. These facilities were created without appropriate project documentation and do not comply with modern standards for radioactive waste disposal. This situation needs to be evaluated and a permanent technical solution found. There is a need for an appropriate state strategy for management of highly radioactive long-lived waste in the territory of the Exclusion Zone. In future years, owing to construction of NSC, possible dismantling of the “Shelter”, removal of FCM and construction of an ecologically safe system, additional radioactive wastes will accumulate and need to be disposed of.

Creation of the Chernobyl Exclusion Zone (about 30-km zone) was a defensible measure, not only because of the need to evacuate people from the most contaminated territory, but also for subsequent tasks aimed at minimizing the consequences of accident. The Exclusion Zone is the most contaminated territory and the largest source of radiation exposure, but it provides now and in future, an important protective function against radionuclides spreading beyond of its limits.

3. ENVIRONMENT

Compared with April-May, 1986, the levels of radiation in the environment have decreased several hundreds of times because of natural processes (physical decay, migration of radionuclides) as well as through the application of countermeasures. Therefore, much of the land that was initially contaminated can now be used with little or no restrictions or remedial measures. However, the Chernobyl Exclusion Zone, as well as some territories of Belarus, Russia and Ukraine, are still significantly contaminated and some limitations on land using will be needed for decades to come.

Recommendations for Environmental Monitoring and Research

1. There is a need to continue targeted monitoring of radiation levels in the contaminated territories, especially for ^{137}Cs, as well as ^{90}Sr, and in some places for isotopes of plutonium and ^{241}Am, especially in the Chernobyl Exclusion Zone

2. Monitoring is needed to:

- assess the efficiency of different counter-measures;
- inform the population about levels of radionuclide content in foodstuffs;
- estimate current and future doses to populations living in the contaminated territories.

3. Monitoring should be concentrated in the those territories with high levels of contamination in foodstuffs and/or where exposures are significantly higher than normal,

Recommendations for Remediation

General

4. There is a need to periodically evaluate and revise countermeasures to ensure that they remain appropriate and are implemented where they will be most effective.

5. Authorities and affected populations should be better informed about the risks of radiation at levels typical of those to which they are exposed. They should also be more involved in decision making related to the long-term management and development of the contaminated territories.

6. A strategy for rehabilitation and the long-term management of the contaminated territories should be developed.

Agriculture

7. Countermeasures have resulted in a significant decrease of the contamination of foodstuff and in the exposure of the population.

8. The most effective agricultural countermeasures were: providing livestock with uncontaminated fodder, determination of the content of radionuclides in animals; addition of Prussian blue in forage of cattle and the use of large quantities of mineral fertilizers when growing crops. These measures and the drainage of wet peaty soils resulted in major reductions in the content of radionuclides in pastures and meadows.

9. Production and use of uncontaminated forage for animals was a priority and resulted in major reductions in the levels of contamination in milk.

10. For territories with barren soil (sandy or peat), where high levels of cesium transfer into plants occurs, the application of agricultural counter-measures must continue, in some cases for long periods.

11. More attention should be paid to controlling milk production on farms where radionuclides concentrations still exceed permitted levels.

12. Given the declining levels of radiation over time, periodic reviews should be made of settlements categorized as “affected” and therefore subject to remedial measures with a view to making best use of limited resources.

Forests, aquatic environments and natural goods

13. Large-scale application of technological countermeasures to change the levels, distribution or transfer of cesium is practically impossible in forestry.

14. Collection of natural food products (mushrooms and berries), fishing from “closed lakes” and the hunting of wild animals will need to be restricted, in some cases for several decades, in those areas where the levels of contamination exceed permissible standards.

15. Guidance on food preparation to decrease internal exposures should continue to be promulgated and the degree to which it is being followed, monitored

Recommendations for the Chernobyl Exclusion Zone

16. There is a need for an integrated strategy, capable of finding broad international support, for the long term management and rehabilitation of the Exclusion Zone, that takes account of the following:

- management of radioactive waste in the Exclusion Zone;
- return of land in the Exclusion Zone to use in the national economy while ensuring radiological and ecological safety and addressing existing social-economical constraints;
- assessment and enhancement of the barrier function of the Exclusion Zone to limit the transfer of radionuclides beyond its boundary;
- improved monitoring of the Exclusion Zone and the “Shelter”;
- establishing an “early notification” system to detect any increased levels of radiation and to signal an emergency situation;
- increase the ecological safety of the Exclusion Zone and minimize any negative ecological influence on adjacent territories.

17. The Chernobyl Exclusion Zone has considerable research potential for: improving models of radionuclide transfer in the environment, development of new approaches to remediation of contaminated territories and to environmental protection. The development of a strategy for the effective use of this Zone as a unique infrastructure for radioecological research should be encouraged, both for use nationally and internationally.

4. HEALTH

The Conference acknowledged the outstanding efforts of the health professionals who provided medical care to the emergency workers during the early days after the accident. The contribution of the international medical and scientific community was also acknowledged for their long-term commitment and support.

The health consequences of the Chernobyl accident are of a multifaceted nature and are related to both direct radiation exposure and to a combination of many non-radiation factors. The nature and magnitude of the health consequences remains the subject of continuing debate among the scientific community, the public, policy makers, non-governmental organizations and within the media. This debate will inevitably continue but, increasingly, a common understanding is emerging on the effects of the accident.

The conclusions are presented in two separate sections: firstly, those which are based on existing international consensus; and, secondly, those for which the scientific basis is not yet fully established and which will need confirmation or otherwise by further research.

Consensus-based Conclusions on Health Effects

Acute Effects

1. Acute radiation syndrome (ARS) was diagnosed in 134 emergency workers exposed from 1 to 16 Gy of whole-body irradiation. Twenty eight patients died within three months after exposure. During the following years, nineteen more ARS survivors died due to various causes; however their deaths were not necessarily directly attributable to radiation exposure. Among the general population exposed to the Chernobyl radioactive fallout, however, the radiation doses were much lower than among the emergency workers, and ARS and associated fatalities did not occur.

Long-term Effects

2. Radiation-induced cataract has been reported in emergency workers exposed to relatively high doses. However, some epidemiological studies suggest an increased cataract risk in those exposed to doses as low as 0.25 Gy.

3. Thyroid cancer in those exposed to ^{131}I at a young age is recognized as a major health effect of the accident confirmed by findings of many national and international studies.

4. Over the past 20 years nearly 5000 cases of thyroid cancer have been diagnosed in persons exposed at the age of 0-18 in Belarus, Russia and Ukraine. A large proportion of these cancers can be attributed to Chernobyl radiation and the risk was highest for those younger than age 6 at the time of exposure.

5. As a response to the increased thyroid cancer incidence, an effective system of monitoring for early diagnosis, treatment and rehabilitation of such patients was set up in the three affected countries.

6. Treatment of thyroid cancer patients is usually very successful; however, the quality of life of these patients remains affected by factors such as life-long monitoring and the need to use thyroid hormone-supplements.

7. Recent studies suggest a two-fold increase in the incidence of leukaemia between 1986 and 1996 in Russian and Ukrainian emergency and recovery operation workers exposed to more than 150 mGy (external dose). Ongoing studies of the workers may provide additional information on the possible increased risk of leukaemia. However, according to the findings of studies in other populations, including atomic bombing survivors, patients treated with radiotherapy and those occupationally exposed in medicine and the nuclear industry, the radiation-induced leukemia risk decreases after some 10-15 years following exposure. Therefore, it is unlikely that the risk of leukaemia will be increasing in the following decades.

8. At present, there is no convincing evidence that the incidence of leukaemia or cancer (other than of the thyroid) increased in children or adults in the general affected population. Additionally, because of the low doses received by the general population, such studies are likely to lack statistical power to identify any increase in risk. Many studies of leukaemia and cancer morbidity in the general population of the affected countries had methodological limitations and were lacking reliable individual dose estimates.

9. Radiation-induced solid cancer normally occurs only after a minimum latency of about 15 years. Therefore, it may be too early to evaluate the full impact of the accident on solid cancer mortality. There appears to be some evidence of increased solid cancer mortality among emergency workers and specific groups of the general population (e.g. breast cancer in women exposed to higher doses at a young age). However, these findings should be interpreted with caution and further monitoring and research should improve our understanding of this effect.

10. The absence of a demonstrated increase in cancer risk – apart from thyroid cancer – is not proof that no increase has occurred. Such an increase, however, is difficult to identify against

the background of cancer mortality in the affected populations. Additionally, given the large number of individuals exposed, even small differences in the models used to assess risks at low doses can greatly affect cancer risk estimates. Therefore, cancer incidence and mortality projections to quantify the potential long-term impact of Chernobyl continue to suffer from major uncertainties.

11. Cardiovascular disease morbidity and mortality increases have been noted among those Russian and Ukrainian emergency and recovery operation workers who were exposed to doses above 150 mSv. These findings should be interpreted with special caution because of the possible influence of confounding factors, such as stress and lifestyle. These findings also need confirmation in further well-designed studies.

12. Psychological effects are recognized as the important health consequences of the accident. Any traumatic experience causes stress, depression, anxiety (including post-traumatic stress symptoms), and medically unexplained physical symptoms. Such effects have also been reported in Chernobyl-exposed populations. Several studies found higher anxiety levels among exposed vs. controls, as well as more frequently reported multiple unexplained physical symptoms and subjective poor health. However, the context in which the Chernobyl accident occurred adds to the difficulty in interpreting these findings because of the complicated series of socio-economic traumatic events unleashed by the accident, aggravating an already stressful situation.

13. Changes in the immune system of exposed people have been described in some national studies. The results were mainly expressed as changes in peripheral blood lymphocytes and in serum immunoglobulins. Study results have been inconsistent, and many other factors, such as stress, chronic infection, exposure to chemical substances, etc. may also affect immune system reactions.

Tentative conclusions on health effects requiring further validation

14. There was a report suggesting a possible increase in thyroid cancer risk among Russian and Ukrainian clean-up workers. However, these findings need further investigation to clarify this observation.

15. According to national statistical reports from Ukraine and Russia, the general morbidity among emergency workers, evacuees and residents of the most contaminated territories is progressively increasing. Since 1993-1994 morbidity has been exceeding average national levels, most notably with regard to the prevalence of non-tumor somatic and psycho-somatic disorders. However, no association with radiation dose has been established for such diseases, nor has a similar effect ever been reported in studies on other populations exposed to ionizing radiation.

16. Reports from national studies on the results of medical surveillance of the affected populations suggest there may be an increased prevalence of benign thyroid nodules and thyroid dysfunctions. Such findings should be interpreted with caution, as region-specific iodine deficiency resulting in high prevalence of endemic goiter, plus a thyroid screening effect, may lead to considerable confounding.

17. National reports from Ukraine suggested a higher prevalence of different forms of mental disorders among emergency workers, residents of the contaminated territories, and those exposed *in-utero*. However, no association between mental health and exposure was established. These findings need careful further investigation, as they are not consistent with findings of other studies on populations exposed to even higher doses of radiation.

18. Results of selective cytogenetic monitoring of exposed people in Ukraine indicated an increased chromosomal aberration frequency in peripheral-blood lymphocytes and signs consistent with genetic instability in offspring of exposed individuals. However, the health implications of these findings are still unclear and further research is needed to investigate these effects.

Recommendations for health care and research

19. Persons who suffered from acute radiation syndrome remain a priority group for follow-up and health care.

20. The emergency workers, evacuees from Pripyat city and the population of the 30-km zone as well as *in utero* exposed children who received high radiation exposure are also priority groups for follow-up and health care.

21. Further ophthalmologic examinations among those exposed to high levels of radiation from the Chernobyl accident might be useful to further assess cataract risk and improve the prognosis of cataract patients.

22. High-quality registries of health outcomes, including cancer-registries should be maintained in the future. They will be useful not only for epidemiological studies but also as a source of reliable information for decision-making and education of the population.

23. Continuous attention to psychological health consequences among Chernobyl-affected populations should be a priority. However, given the complex nature of psychological stressors in these populations, this attention should be within the framework of a general public mental health policy.

24. Persons exposed to Chernobyl radiation as children and teenagers have entered into reproductive age. Reproductive health programs including risk-communication and education tools would be helpful for informed decision making in family planning.

25. Risk communication efforts should be improved, providing the community and decision-makers with appropriate and scientifically sound information about the health consequences of the accident.

26. The system of medical monitoring of highly exposed workers should continue. Yearly medical surveillance of exposed persons with lower doses is ongoing, but the cost-effectiveness or benefit to individuals is unlikely. Better targeted programs to address specific population health concerns (e.g., infant health, prevention of chronic diseases) are needed.

27. Cancer screening programs of populations living in the affected countries (including emergency workers) should be implemented on the basis of good evidence of effectiveness and efficiency of such programs.

28. When population-based breast cancer screening programs are implemented, special care should be taken to include all female clean-up workers in these programs.

29. Further investigations of possible associations between radiation dose and non-cancer diseases, in particular cardiovascular system diseases, should be conducted for better risk quantification.

30. Emerging evidence on associations between radiation dose and chronic diseases among populations exposed to the accident (i.e. leukemia and solid cancer among recovery workers) should continue to be subjected to broad international review for scientific validation.

5. RECOVERY AND DEVELOPMENT

Social-economical recovery is the most significant problem of regions affected by the Chernobyl catastrophe. Life of for this population could improve, if economic conditions improve and they can be self-sufficient. These changes depend on good policy at the national level, including improvement of conditions for business and investments. There is a need to provide help to individual farmers and family businesses in the contaminated territories. There is considerable worldwide experience on such economical development.

Efforts at self-sufficiency and economic development must aim at returning of the regions to “normal life”. Residents should be informed that using simple precautionary measures in relation to radiation exposure will provide safety at home and at work and that they can have children without fear.

Management and State Policy

1. The reaction of national authorities to the accident was on an unprecedented scale. However mistakes were made such as: untimely evacuation of populations, ineffective use of iodine prophylaxis, calling on large groups of people to mitigate the accident who were unprepared to carrying out dangerous work in high levels of radiation. In addition, inadequate information was provided to affected people about the effects of the accident, and the failure to stop the consumption of contaminated milk had a negative health impact.

2. Lack of reliable information led to mistrust of authorities generally and, in particular, in official statements on radiation levels. This greatly hindered effective communication with the public, and the recovery process itself. Successful minimization of Chernobyl accident consequences is being possible only with adequate integrated scientific maintenance of all accomplished works. Research and monitoring should continue. The role of science remains important for territory rehabilitation and providing protection of the population from radiation.

3. Persistent social and economic difficulties in many of the contaminated settlements are a direct result of earlier failings and exemplify the importance of extensive public participation in preparation of and making decisions on protection measures, as well as using transparent and open access to information. These considerations are equally important for the management of any future accident resulting in environmental contamination, nuclear or otherwise.

Government Programmes and Spending

4. Evacuation and resettlement of more than a hundred thousand people caused psychological stress, however this was justified on the grounds of radiation safety. Later resettlement of people from low contaminated areas was unjustified. This experience has implications for responding to any future accident, nuclear or otherwise.

5. Because of the natural recovery processes along with protection measures the radiation levels have significantly reduced. This allows for a revision of the number of settlements considered to belong to radioactively contaminated zones. Areas with low levels of contamination would become suitable for normal dwelling. Zones with higher levels of contamination require a different strategy including monitoring, provision of health and social services, and other assistance.

6. Government programmes need to be streamlined and budgets refocused, particularly in light of limited financial resources. It is necessary to develop programmes, supporting local initiatives, strengthening confidence of people in self-dependent responsibility for their future. Reorganization of Chernobyl social programmes should aim at:

- targeting benefits and resources to assist the most needy people;
- reducing resettlement programmes; families who still have a legal right to relocation (e.g. in Ukraine), with their consent, could be provided with financial compensation instead of resettlement;
- strengthening primary health care, including promotion of healthy lifestyles and reproductive health, and psychological support where needed;

- ensuring safe food production; constant efforts are needed to encourage the cultivation of radiologically safe crops, especially on the family farms.

Social and Economic Development

7. Anxiety about health consequences of radiation exposure has not abated over time. In affected areas some inhabitants are in a state of helplessness, passivity and are unable to make decisions about their future. Innovative approaches are needed to involve affected populations on measures to improve their living conditions on the contaminated territories There is a need to present information to certain groups of persons, who can use it and give helpful advice to the affected population, using an integrated approach to healthy lifestyle, not only about radiation dangers.

8. Economical development and community self-sufficiency is a key to improvement of living conditions. There should be a basic strategy of economic and social rehabilitation of people living in contaminated territories. People and communities should themselves organize their own future; be economically effective and overcome the psychological and social consequences of the accident.

9. Government, regional and local authorities should collaborate with the aim of:

- improving conditions for business, encourage investments and support private sector development; national policy should stimulate economic development at the regional and local levels;
- creating a positive image to attract investment with the purpose of economic development and increase jobs, using the experience of local agencies for economical development;
- encourage the creation and growth of small and middle-sized enterprises in affected areas and in adjacent cities using the whole spectrum of methods of business support, developed and tested in other countries of the world;
- application of advanced domestically produced and foreign experience in development of community initiatives, such as creation of credit alliances, manufacturing, consumers' co-operatives and youth centers.

10. Efforts to re-establish affected regions should follow four general principles:

- identify the needs of inhabitants and communities, and necessities of society as a whole;
- help people manage their own and community life, not relying on the habit of dependency upon others to help;
- provide for effective use of resources, giving priority to the most affected people and communities, using limited budget resources effectively;
- switch from humanitarian aid to assistance in economic development of regions, by coordinating efforts between international organizations, governments, local authorities and non-governmental sector.

11. It is necessary to continue international help and collaboration to assist central government, regional and local authorities in social and economical recovery of affected communities and in appropriate public health measures.

12. Many lessons have been learned from Chernobyl both in the area of radiation safety and nuclear accidents emergency planning and mitigation of accident consequences. At the same time existing worldwide experience in the field of post-crisis administration and rehabilitation could be useful for the solution of Chernobyl problems. Therefore experience exchange should be promoted both between affected countries and in the world as a whole.

6. SAFETY MANAGEMENT AND INSTITUTIONAL DEVELOPMENT

The accident has shown the importance of strict compliance with basic safety principles for the design and operation of nuclear installations, continuous safety assessments and the timely upgrading of installations to eliminate deviations, of remaining abreast of and incorporating best world practice and experience and taking into thorough account the human factor.

Significant investment in improvements of nuclear safety and radiation protection has been initiated because of the Chernobyl catastrophe. The accident acted as a catalyst, initiating important changes at national and international levels in nuclear safety principles, legislation, technology and practice. International cooperation in the sphere of nuclear and radiation safety was broadened and fully incorporated the countries of the former Soviet block for the first time.

The accident has convincingly demonstrated that the cost of ensuring the safety of nuclear installations is considerably lower than that of dealing with accident consequences. Large-scale accidents may cause significant health and environmental impacts, as well as great social and economic damage to countries located in their area of influence. Direct and indirect damage amounting to hundreds of billions of US$ have been reported by Belarus, Russia and Ukraine as a result of the Chernobyl accident.

The accident had a major impact on public acceptance of nuclear energy worldwide; it led to the cancellation of a large number of projects for nuclear power plants and to a phase out policy in several countries. Nuclear safety remains one of the major issues for public acceptance when considering the construction of new plants.

Improvements in Nuclear Safety and Security Legislation and Regulation

1. The Chernobyl accident prompted many actions to strengthen international and national legislation on nuclear safety. Several internationally binding conventions or protocols related to nuclear safety, emergency management, spent fuel and radioactive waste management, liability, and the physical protection of nuclear material were developed and adopted.

2. As a direct response to the accident, two international Conventions were adopted in 1986. These are the “Convention on Early Notification of a Nuclear Accident” and “Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency”. Around 100 countries currently ratify both of them. Since 1986 in the IAEA an emergency centre is in function to fulfill its obligations under these two Conventions.

3. The Convention on Nuclear Safety (CNS) was adopted in 1994 and ratified by all countries with nuclear power plants and by a further 25 countries without them. An international nuclear safety regime was established under this Convention and the parties were obliged to follow nuclear safety principles based largely on the IAEA Safety Fundamentals “The Safe Operation of Nuclear Installations”. Self-assessment reports on their safety status are made nationally and are peer reviewed at the triennial meetings of the CNS.

4. The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management was adopted in 1997. This promotes an effective nuclear safety culture worldwide through enhancing the safety in spent fuel and radioactive waste management and the parties are obliged to follow the safety principles of the IAEA Safety Fundamentals “Principles of Radioactive Waste Management”.

5. A cadre of International Safety Standards, under the leadership of the IAEA, were developed and promulgated throughout the nuclear industry. These Standards have become accepted by the international community and are the basis for assessing safety acceptability in all areas (design, construction, operation, shutdown and decommissioning) and at all types of nuclear installations (nuclear power plants, research reactors, fuel cycle facilities).

6. Based on the experience of protecting the population after the Chernobyl accident, the International Commission on Radiological Protection (ICRP) recommended single level criteria of intervention (ICRP-63, 1993). Later still, partially in response to long-term Chernobyl problems, the ICRP developed recommendations on the protection of the population in conditions of prolonged exposure (ICRP-82, 1999). The ICRP recommendations are converted into IAEA safety standards.

7. Before the Chernobyl accident there were no international standards for permissible levels of radionuclides in food products. In response to the threat of internal exposure of the inhabitants of some European countries, in May 1986 in the USSR and the European Union, corresponding standards had been developed. In 1989 the Codex Alimentarius Commission established guidelines on Levels for Radionuclides in Food for Use in International Trade (CAC, 1990). These guidelines were recently updated.

8. The International Nuclear Safety Advisory Group (INSAG) emerged on the world stage as an authoritative body that could independently provide high level insights concerning issues of safety relevance at all nuclear installations. The group's report on The Chernobyl Accident (INSAG-1, updated as INSAG-7) set the precedence for providing sage counsel on all issues related to nuclear safety.

9. After the Chernobyl accident several immediate and continuous actions were pursued at the national level to change and improve the national nuclear legislations. Especially the NIS and CEES had to replace most of their legislations. At present in all these countries International Conventions are realized.

Improvement of International and National Instruments

10. The World Association of Nuclear Operators (WANO) was created to facilitate the exchange of experience between operating organizations. Every organization in the world that generates electricity from nuclear power plants is a voluntary member of WANO.

11. In order to facilitate communication with the public on the severity of nuclear accidents, the International Nuclear Event Scale INES was developed by the IAEA and the NEA. Its currently applied by a large number of countries.

12. The open culture of sharing lessons learned is exemplified by operational experience feedback and peer reviews. WANO's peer reviews and the IAEA's safety review projects facilitate exchange amongst nuclear power operators and other nuclear installations to spread the best safety practices worldwide.

13. Creation and strengthening of independent powerful and competent national regulatory bodies is one of the most important improvements of nuclear safety instruments.

Improvements of RBMK Reactor Safety

14. Immediately after the accident a series of technological measures started to be implemented at all RBMK reactors, aiming to address within a short term the most critical safety deficiencies of the initial design of the RBMK. The main results of this period that lasted for a few years can be summarized as follows:

- significant reduction of the Positive Reactivity Coefficient;
- improvements to the Shutdown System;
- improvement of the Reactor Cavity Overpressure Protection
- increased Reliability of Core Cooling Systems;
- improvement of the Instrumentation and Control Systems.

15. In the following period, plant specific modernization programmes were developed for each RBMK unit with a specific schedule of implementation. The aim of the plant specific modernization programmes was to substantially enhance the operation safety level of these reactors. Most of these programmes are currently still under way. Two of them, Ignalina 2 and Kursk 1, have been completely implemented. The Safety Analysis Reports of these two units after modernization have been reviewed by international experts. The conclusions underline noticeable improvements in the different areas of operating safety: reactor systems, accident analysis, operating procedures, safety culture, etc. However few important points, in particular the confinement issue, still remain open for further improvements.

16. A consequence of the Chernobyl accident was a certain number of initiatives associated with the perfection of shutdown technology and the decommissioning of RBMK reactors. In Ukraine the last operating RBMK unit at Chernobyl was permanently shut down in 2000 and in Lithuania Ignalina-1 was shut down in 2004; furthermore the Lithuanian government has committed to close the second unit by 2009.

17. A more general objective was to define the content of decommissioning plans and decommissioning projects for the so called 'first generation reactors', which includes also some models of VVERs (in Armenia, Bulgaria, Slovakia and other countries).

Chernobyl NPP Site

18. The "Shelter" constructed urgently in severe radiation conditions remains the major potential source of nuclear and radiation risk. Its stabilization and construction of new safe confinement for the destroyed Unit 4 remains first priority in order to provide for long-term isolation of fuel containing materials and the radioactive waste from the environment. A multidisciplinary construction programme known as the Shelter Implementation Plan (SIP) was established for the purpose in 1997. The Chernobyl Shelter Fund, managed by EBRD for the international community and Ukraine, was created to finance and implement the SIP.

19. Future strategic tasks aiming at conversion of the Shelter in environmentally safe system are:

- dismantling the unstable structures of the "Shelter";
- development and implementation of technologies for extraction and isolation of the fuel containing materials and long-lived radioactive waste in order to create an additional barrier for these dangerous materials;
- creation of the infrastructure and facilities for the ultimate storage of the fuel containing materials and long-lived radioactive waste.

20. Before the Chernobyl accident, there was no experience in the world on treatment of such vast amounts of radioactive materials created accidentally. Disposal of radioactive waste had been carried out under extreme conditions without proper justification of waste classification and recording of its amount and precise location, waste isolation technologies, etc.

21. Managing the radioactive waste from the Chernobyl accident is becoming a more pressing and topical problem as time goes on. Despite the established national programmes and

international projects on radioactive waste management, there is still no realistically balanced and sound unified concept for radioactive waste management, which includes all stages from collection and processing to final disposal.

22. The international community has played an important role in dealing with the consequences of the Chernobyl accident. The 1995 Memorandum of Understanding (MoU) between the Governments of the G7 countries and the European Commission and the Government of Ukraine on the Closure of the Chernobyl NPP by 2000 represents a major milestone. The MoU provided for a comprehensive programme for the closure of Chernobyl NPP, including the transformation of the Shelter into an environmentally safe system, and a commitment for financial support

23. Taking into account the Chernobyl's lessons in the field of radioactive waste management it is necessary:

- to complete an inventory of all waste repositories including creation of a national register of the radioactive waste and cadastre of repositories. In this connection the data should be obtained to substantiate decisions on the subsequent repositories utilization and, in case of need – to design techniques of radioactive waste retrieval, conditioning, storage and disposal;
- to substantiate and make decisions concerning the necessity and sequence of waste retreating out of a repository. These decisions should be made on the basis of a comprehensive analysis of the long-term safety and assessment of the repositories influence on the environment;
- to create in the ChEZ the infrastructure (the National center) for treatment, conditioning, storage and disposal of the main types of Ukrainian radioactive waste both of Chernobyl origin and those from other national nuclear power facilities. For this purpose, it is necessary: to develop and accept a national strategy of radioactive waste management, develop and accept a national program, and to create a State fund to finance activities associated with radioactive waste management;
- in view of tasks concerning the above-mentioned infrastructure it is necessary to activate the works on substantiation and construction of a geological disposal system for long-lived waste.

The Conference recommends that this Conclusions and Recommendations be used for future decision-making. We all need to be vigilant, to ensure that nuclear safety remains as our highest priority and that the lessons learned from the Chernobyl accident are never forgotten.