Chernobyl — Ten years after

Global experts clarify the facts about the 1986 accident and its effects

by
Abel J. González

On 26 April 1986, a catastrophic explosion at Unit 4 of the Chernobyl nuclear power plant in the Ukrainian Republic — close to the point marking the three-way border with the Republics of Belarus and Russia — sent a very large amount of radioactive material into the atmosphere. The event was to become one of the most protracted and controversial themes of the modern technological era. The Chernobyl accident caused widespread concern over its radiological consequences, and also focused attention on nuclear safety generally. The accident's aftermath evolved together with the unfolding of glasnost and perestroika in the former USSR and soon became bound up with many misunderstandings and apprehensions about the radioactive release and its real or perceived effects.

There was initial secrecy and confusion about the accident — candidly reported in Prof. Leonid Ilyin's book, *Chernobyl: Myths and Reality*. The people living in the affected areas learned about the event mainly from hearsay rather than from authoritative reporting. The first evidence of the accident outside the USSR resulted from measurements in Nordic countries showing an unexpected increase in environmental radioactivity. This initial lack of transparency had an impact on public confidence, and subsequently so did the confusing and at times contradictory nature of the information released. Perceptions of the catastrophe ranged from those who believed that Chernobyl had been one of the world's worst ever disasters to those who saw it as a relatively limited health problem despite the tragic circumstances.

A decade later, in April 1996, more than 800 experts from 71 countries and 20 organizations — observed by over 200 journalists — met to review the Chernobyl accident's actual and possible future consequences, and to put these into proper perspective. They came together at the international conference on *One Decade after Chernobyl: Summing up the Consequences of the Accident*, held at the Austria Center in Vienna. The Chernobyl Conference was a model of international co-operation: six organizations of the UN family, including the IAEA, and two important regional agencies were involved in its organization. *(See boxes on pages 8 and 17.)*

Between the accident in 1986 and this Chernobyl conference, the IAEA participated in a range of scientific endeavours which sought to quantify the actual consequences. *(See boxes on pages 5,6,7 and 8).*

The aim of the Chernobyl Conference was to consolidate "an international consensus on the accident's consequences, to agree on proven scientific facts, and to clarify information and prognoses in order to dispel confusion". The results of the Conference speak for themselves. *(See the following article for Highlights of the Chernobyl Conference: Summary of Results).* Some important issues have been summarised here and are separately analysed in reports featured in this edition of the *IAEA Bulletin*.

Radioactive fallout. Although even today there is no complete consensus on the amount of radioactive material released by the Chernobyl accident, the best estimates — which are of the magnitude of 10^{19} international units of activity, called *becquerels* — are illustrative of the catastrophic nature of the accident. Two chemical elements in the radioactive plume formed by the materials released dominated the radiological consequences: iodine and caesium. There is a family of mainly short-lived radioactive isotopes of iodine: a significant one is iodine-131, whose activity falls by half every eight days. Radioiodines were mainly responsible for irradiation of the thyroid gland of the people living in nearby regions shortly after the accident. Of the radioactive caesiums, the most significant is caesium-137, a long-lived nuclide whose activity falls by half every 30 years. Caesium-137 was transported through the atmosphere for long dis-

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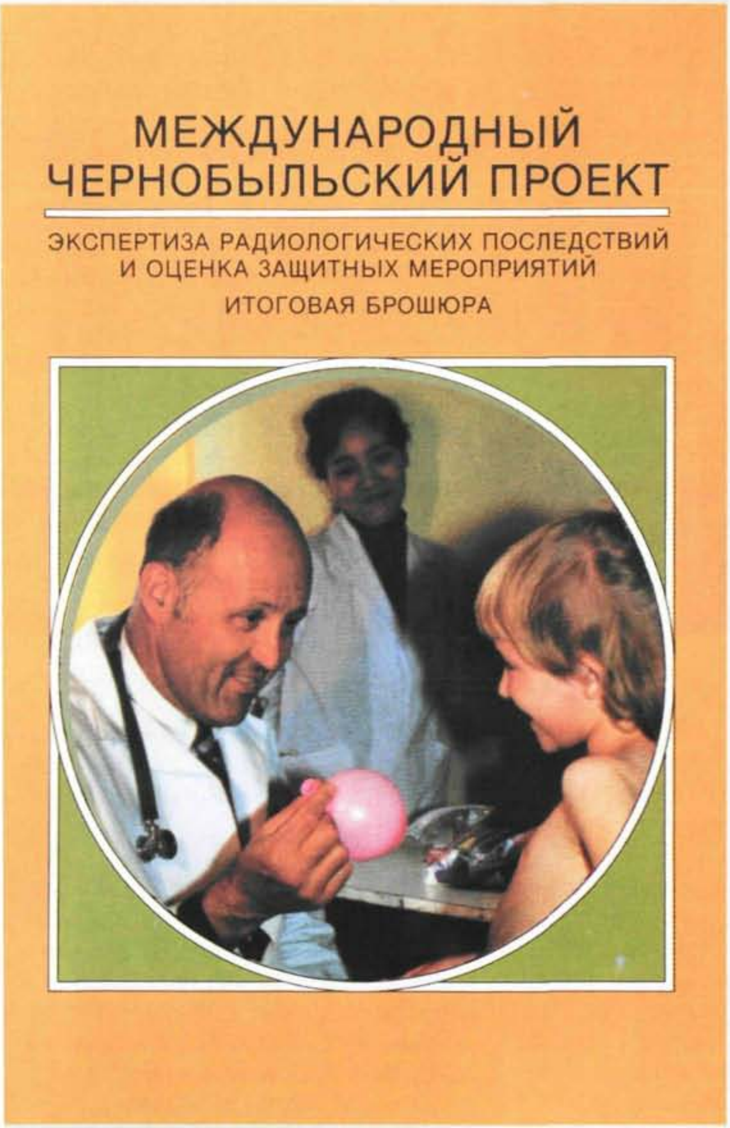
Release of radioactive material into the environment

The destroyed reactor released a very large amount of radioactive material into the environment: 10^{19} international units of activity, termed becquerels. Although the discharge included many radioactive chemical elements, just two of them — iodine (in the short term) and caesium (in the long term) — were particularly significant from a radiological point of view.

About 10^{18} becquerels of iodine-131 were released by the accident. Iodine is mainly absorbed by a person's thyroid gland after inhalation or after consumption of contaminated foodstuffs such as milk products; its short range beta particles irradiate the gland from the inside. Uptake of iodine by the thyroid is very easy to prevent, for example by banning consumption of contaminated food for a few weeks until the iodine-131 decays sufficiently or by administering small amounts of non-radioactive iodine prophylactically to block the thyroid gland.



About 10^{17} becquerels of radioactive caesiums were released, and precipitated over a vast area *(see map on page 5)*. Exposure to caesium is difficult to prevent. Once it is deposited in the soil, its long range gamma rays can expose anybody in the area. To clean the surfaces is difficult and, if the concentration of caesium is high, often the only feasible countermeasure is to evacuate the inhabitants. Caesium in the soil can also be transferred into agricultural products and grazing animals.

For iodine-131, there is no clear information on where the release went, who was exposed to it and to which levels, or whether iodine uptake was effectively prevented. Indirect estimations gave firm indication that very high thyroid doses were incurred by some population groups. Children, who are particularly sensitive because of their normally high ingestion of milk products and their small thyroids, received higher doses.

In 1990 the International Chernobyl Project *(see box, page 7)* had predicted that, with high doses, a significant increase in the incidence of the relatively rare cancer of the thyroid would occur in affected children after a few years.

The cover of the Russian edition of a booklet describing the International Chernobyl Project, which was conducted by teams of international scientists in 1990 and 1991.

tances, deposited variably over vast areas, mainly in Europe and — to a minor but measurable extent — elsewhere over the whole northern hemisphere. The deposited caesium became the main cause of whole body radiation exposure in the long term. *(See box above and map on page 5).*

Radiation doses. The release of radioactive material was expected to have severe direct consequences for people and ecosystems in and near the Chernobyl plant site. Radiation damage correlates with the radiation dose incurred by people and biota. *Dose* is a quantity related to the amount of radiation energy absorbed by the mass of biological matter. The dose incurred by people is expressed in *sieverts* and, most commonly, in the submultiple *millisieverts* — one

Direct effects of radiation on the natural environment

In the first few weeks following the accident, lethal doses were reached in local biota, notably for coniferous trees and voles (small mice) in the area within a few kilometers of the reactor. By autumn 1986, dose rates had fallen by a factor of 100, and by 1989, these local ecosystems had begun to recover. No sustained severe impacts on animal populations or ecosystems have been observed. Possible long-term genetic impacts and their significance remain to be studied.

millisievert being a thousandth of a sievert (for comparison purposes, people receive on average an annual dose of 2.4 millisieverts from natural background radiation). Many of the plant workers and many people who helped to deal with the accident's aftermath — who were called '*liquidators*' — received high doses, some of thousands of millisieverts, and suffered clinical radiation syndromes. Twenty-eight people died as a consequence of their radiation injuries. Over 100,000 members of the public who were evacuated from the contaminated areas, and also those who remained living in the less affected regions, received, or are committed to receiving, relatively low whole body doses: over their lifetimes, these will be comparable with or lower than doses they would receive in a lifetime from natural sources of radiation. *(See box on page 11)*. Doses to the thyroid gland — particularly of children — were a notable exception and are presumed to have been very high. Another exception was doses in local ecosystems.

Environmental damage. Lethal radiation doses were reached in some radiosensitive local ecosystems, within a few kilometres of the accident, notably in coniferous trees and for voles. Doses fell sharply within a few months and the ecosystems eventually recovered. No sustained severe impacts on the environment have been observed so far. *(See box on the left)*. A report by M. Dreicer and R. Alexakhin addresses the environmental consequences of the accident in more detail. *(Page 24)*.

A by-product of the environmental contamination was the contamination of foodstuffs produced in the affected areas. Although for some time after the accident key foodstuffs showed activity levels exceeding the maximum levels permitted by the Codex Alimentarius,* no food now produced by collective farms exceeds these levels. Exceptionally, wild food products — such as mushrooms, berries and game — from forests in the more affected areas as well as fish from some European lakes remain above Codex levels. An important aspect in controlling the contamination of the human habitat was the agricultural countermeasures undertaken in the affected areas; these are examined by J. Richards and R. Hance in a related report. *(Page 38)*.

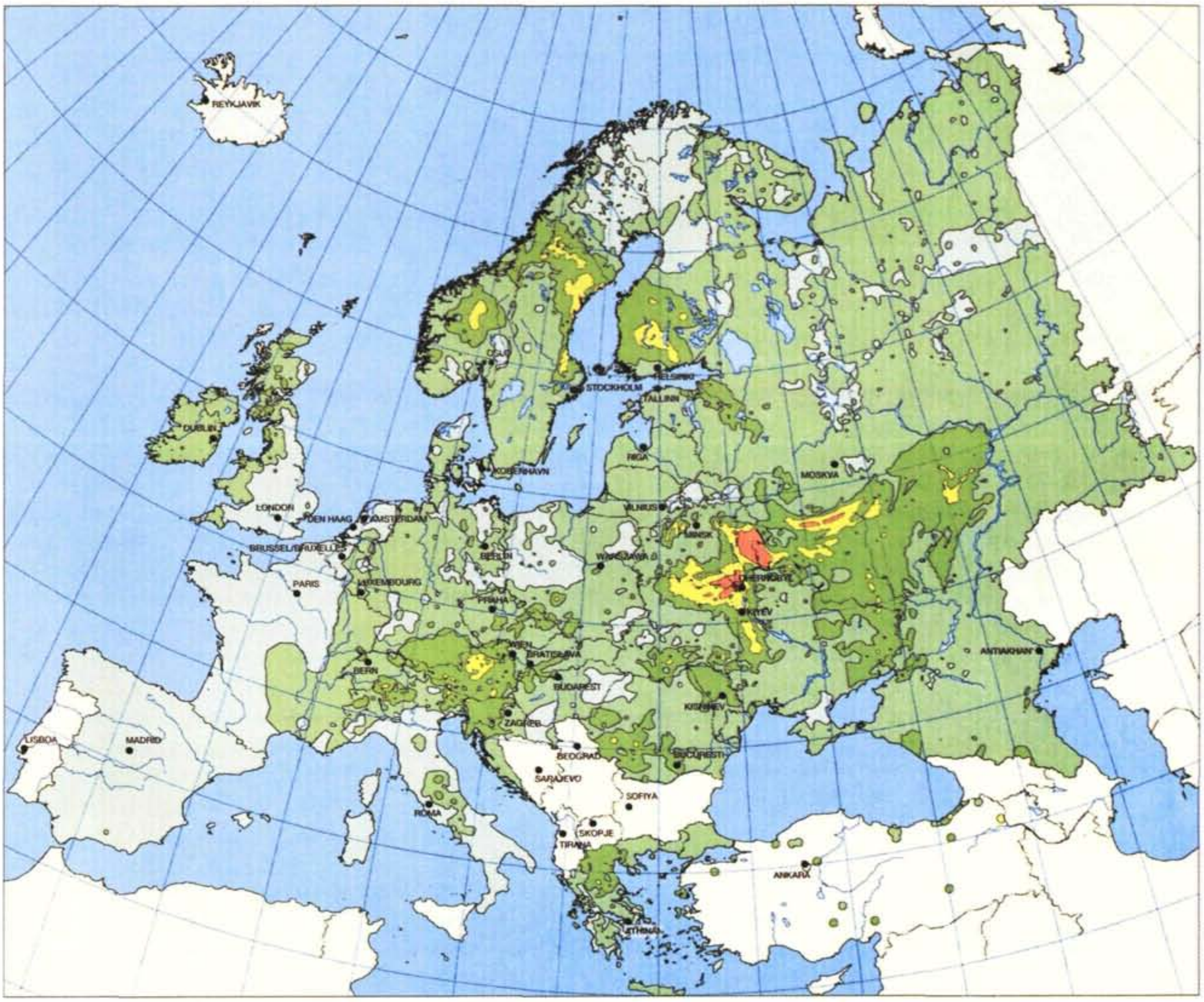
Health effects. Health effects attributed to the accident have commanded the most concern on the part of the public, decision-makers and political authorities, and the Chernobyl Conference devoted a great deal of time to the topic. *Clinically observed (and individually attributable) effects* were discussed separately from *long-term effects* which can only be attributed to radiation after long studies of a statistical epidemiological nature of large populations.** *(See box on page 10)*. Among the latter, *thyroid effects* is a special case that was treated separately from other *longer term health effects*.

Clinically observed effects. The number of people who suffered clinically observed health effects individually attributable to radiation exposure due to the Chernobyl accident was relatively modest, given the accident's dimensions. A total of 237 persons, all of them workers dealing with the accident, were suspected of suffer-

continued on page 9

*The Codex Alimentarius — which is established by FAO and WHO — sets the maximum permitted level of radioactivity for foodstuffs moving in international trade.

**See "Biological effects of low doses of ionizing radiation: A fuller picture", by the author in the *IAEA Bulletin*, Vol. 36, No. 4 (December 1994).



Projection: Lambert Azimuthal

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Total caesium-137 deposition normalised to 10 May 1986.

2 — 10 — 40 — 185 — 1480 kBq/m²

0.054 — 0.27 — 1.08 — 5 — 40 Ки/км²

Data not available

Preliminary version of the total Caesium-137 deposition map taken from the "Atlas of Caesium deposition on Europe after the Chernobyl accident," EUR report 16733, EC Office of Publication, Luxembourg, 1996.

Cumulative Deposition of Caesium Across Europe

The radioactive materials released by the Chernobyl accident fell out over vast areas and the deposited activity was easily measurable. The deposits were shown in so-called "contamination" maps such as this one showing cumulative deposition of caesium across Europe which was presented at the Conference. For the scientific community, the maps clearly provided a pictorial view of measurable activity. However, in the minds of the public at large the maps showed areas regarded as "contaminated" and — therefore — "unsafe." Using sensitive radiation measuring devices, scientists were able to draw maps down to very low levels of activity and up to very large distances. Negligible levels were shown and presented as "contamination" in maps of the former USSR. When the maps were made available — some years after the accident — people became concerned even though the radiation doses caused by these deposits in much of the thousands of square kilometers so "contaminated" were lower than natural background radiation levels in many parts of the world.

Assessing the Chernobyl Consequences

During the past decade, many international activities have helped assess the Chernobyl accident's consequences. These activities can be divided into two periods: those carried out before the 1990 International Chernobyl Project which gave a fuller account of the accident, and those activities which follow up the Project to the time of the International Chernobyl Conference in April 1996.

1986-89: The Initial Picture — Piecing Together the Facts

August 1986: The Post-Accident Review Meeting. A widely attended international gathering was organized by the IAEA a few months after the accident: the "Post-Accident Review Meeting". The outcome was reported on by the then recently created International Nuclear Safety Advisory Group, INSAG.[1]

The INSAG report examined the causes of the accident and presented the preliminary Soviet assessment of the amount of radioactive materials released from the damaged reactor. It also contained a limited but significant early account of the radiological consequences:

- *Of the on-site personnel, about 300 had to be hospitalized for radiation injuries and burns.*
- *135,000 people were evacuated: their collective dose from external radiation was estimated to be $1.6x10^4$ man-sievert (man Sv).*
- *Doses to thyroids were estimated to be mostly below 300 millisieverts (mSv), although some children may have received thyroid doses as high as 2500 mSv.*
- *The long-term collective dose to the population was pessimistically estimated at $2x10^6$ man Sv with a realistic estimate at $2x10^5$ man Sv.*

Some calculations on the potential long-term health effects were also made and the chances of epidemiological detection of these effects were judged to be limited: *only in the cohorts with substantially high doses could some effects possibly be discovered, e.g. benign and malignant thyroid neoplasms.*

May 1988: The Kiev Conference. Two years later, the international scientific community had the second opportunity to review the radiological consequences during the International Scientific Conference on the Medical Aspects of the Accident at the Chernobyl Nuclear Power Plant held by the Soviet authorities in co-operation with the IAEA in Kiev in May 1988. (An unedited version of the Conference proceedings was issued by the IAEA as an unpriced publication and a report summarizing the information also was published.)[2]

Information presented at the Conference covered various topics:

- *The actual number of clinically diagnosed radiation injuries was precisely reported: 238 occupationally exposed persons had declared signs of radiation syndromal sickness (eventually a lower number was positively diagnosed); of these 28 had died. Two other people were killed by the reactor explosion (another died of coronary thrombosis).*
- *Releases of radioactive materials produced wide surface contamination with spots of up to 30 x 10^5 Bq/m^2 (80 Ci/km^2) and contamination of milk with specific activity of up to 20,000 Bq/L.*
- *The collective dose commitment inside the former USSR was estimated at 226,000 man-Sv of which 30% was committed in the first year, with whole body doses up to 50 mSv in the first year*
- *Doses to the thyroids were confirmed to be up to 2500 mSv.*

December 1988: Global Assessment by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). UNSCEAR did a thorough assessment of the impact outside the USSR. In its 1988 report to the UN General Assembly, UNSCEAR estimated that:

- *The highest national average first-year dose was 0.7 mSv (or one third of the global average natural background exposure).*
- *The highest regional average total dose commitment was 1.2 mSv (or 1/30 of the average lifetime dose from natural sources).*
- *The total global impact of the Chernobyl accident was 600,000 man Sv, equivalent on average to 21 additional days of world exposure to natural background radiation.*

May 1989: The Extent of Consequences Crystallizes —The IAEA "Ad Hoc Meeting". Three years after the accident, scientists obtained a more comprehensive insight into the magnitude of the accident's consequences at an informal ad hoc meeting which was organized by the IAEA Secretariat in May 1989 at the time of the 38th session of UNSCEAR. It was attended by over 100 scientists from 20 countries and reported at a subsequent symposium on recovery operations after accidents[3]. The information provided by Soviet experts attending the meeting gave a more detailed account of the long-term situation:

- *Contamination maps of the affected territories, open to international scrutiny, showed 10,000 km^2 of territories with radioactive contamination in excess of $5.5x10^5$ Bq/m^2 (15Ci/km^2).*
- *786 settlements with 272,800 people were in "areas of strict control" where — up to January 1990 — a collective dose of 13,900 man Sv was expected to be incurred, with a few members of the public being expected to exceed 170 mSv.*
- *The international community was advised of the intervention criterion for countermeasures and protective actions established by the Soviet authorities, which would eventually become very controversial. 350 mSv of lifetime dose.*

continued on the next two pages

1990-91: A Fuller Account — The International Chernobyl Project

March 1990 - May 1991: Expert assessments on site — More facts emerge. In October 1989, the USSR formally requested the IAEA to co-ordinate "an international experts' assessment" of the concept which the USSR had evolved to enable the population to live safely in areas affected by radioactive contamination following the Chernobyl accident, and an evaluation of the effectiveness of the steps taken in these areas to safeguard the health of the population.

As a result, *the International Chernobyl Project (ICP)* was launched in early 1990.[4] It focused on four key issues of concern to the population and policy makers: the extent of the existing contamination in the inhabited areas; the projected radiation exposure of the population; the current and potential health effects; and the adequacy of measures being taken at the time of the Project to protect the public. Conclusions and recommendations were approved by the ICP *International Advisory Committee* on 22 March 1991 and presented for scrutiny to an international conference in Vienna 21-24 May 1991. They were published by the IAEA and can be summarized as follows:

- *The surface contamination levels reported in the "contamination" maps available at the time were generally corroborated: 25,000 km² were defined as affected areas with ground concentration levels of caesium-137 in excess of 1.85 x 10⁵ Bq/m² (5 Ci/km²); of this total, approximately 14,600 km² are located in Belarus, 8,100 km² in Russia and 2,100 km² in the Ukraine.*
- *The whole body radiation doses to be incurred over a lifetime were estimated to be below 160 mSv or two to three times lower than originally thought; however, it was impossible to corroborate the level of thyroid doses actually incurred.*
- *Significant but non-radiation related health disorders and psychological disturbances such as stress and anxiety were found in the population, but — outside the group of heavily exposed workers — no health disorders were detected which could be directly attributed to radiation exposure. As expected, at the time of the Project no increase in the incidence of leukaemia or cancers could be substantiated and potential future increases in malignancies other than thyroid cancer were expected to be difficult to discern.*
- *The general conclusions on the health situation were followed by a number of detailed conclusions. Some were related to neoplasms, in particular to the increases in cancer reported at the time and to the potential future cancer increase, as follows:*
  - *Soviet data indicated that reported cancer incidence had been rising for the last decade and had continued to rise at the same rate since the accident. However, the Project considered that there had been incomplete reporting in the past and could not assess whether the rise was due to increased incidence, methodological differences, better detection and diagnosis, or other causes.*
  - *On the basis of estimated Project doses and currently accepted radiation risk estimates, future increases over the natural incidence of cancers and hereditary effects would be difficult to discern, even with large and well designed long term epidemiological studies; however, reported estimates of absorbed thyroid dose in children were such that it was anticipated that there might be a statistically detectable increase in the incidence of thyroid tumours in the future.*
- *Protective measures being taken at the time of the Project or planned for the long term, such as some relocations and foodstuff restrictions, were found to exceed those which would be necessary on radiation protection grounds.*

The ICP also recommended a number of follow-up actions including continuing epidemiological evaluations and fostering health care, concentrating on "*selected high risk populations*."

Notes to pages 6 and 7.

[1]International Nuclear Safety Advisory Group, *Summary Report on the Post-Accident Review Meeting on the Chernobyl Accident,* Safety Series No. 75-INSAG-1; IAEA; Vienna (1986).

[2] See *Proceedings of the All-Union Conference on the Medical Aspects of the Chernobyl Accident,* IAEA-TECDOC 516, and Konstantinov, L.V. and González, A.J., "The Radiological Consequences of the Chernobyl Accident", *Nuclear Safety,* Vol. 30, No. 1 (January-March 1989).

[3]Gonzalez, A.J ; "Recovery operations after the Chernobyl Accident: The intervention criteria of the USSR's National Commission on Radiation Protection"; IAEA-SM-316/57, in the *Proceedings of International Symposium on Recovery Operations in the Event on a Nuclear Accident or Radiological Emergency,* IAEA-SM-316/57, page 313.

[4]The ICP was sponsored by the European Commission, the Food and Agriculture Organization of the United Nations, the International Labour Organisation, the World Health Organization, the World Meteorological Organization, the IAEA, and UNSCEAR. An independent "International Advisory Committee" of 19 members was set up under the chairmanship of Dr. Itsuzo Shigematsu, the Director of the Radiation Effects Research Foundation in Hiroshima, which, ever since 1950, has monitored and analysed the health of atomic bomb survivors in Japan, the largest population ever exposed to high doses of radiation. The other scientists on the Committee came from ten countries and five international organizations. The expertise encompassed, among other disciplines, medicine, radiopathology, radiation protection, radioepidemiology and psychology. The most active phase of the project ran from May 1990 until the end of that year. About 200 experts from 23 countries and 7 international organizations participated, and 50 scientific missions visited the USSR Laboratories in several countries, including Austria, France and the USA, helped to analyse and evaluate collected material.

1991-96: Follow-up Co-operative Studies — Toward Clearer Perspectives

Many international initiatives followed the International Chernobyl Project, including those highlighted here.

Follow-up initiatives by the IAEA. An agricultural countermeasures project was sponsored by FAO and IAEA[5] and a new environmental assessment was organized by IAEA and supported by the Institut de protection et de sûreté nucléaire (IPSN, France)[6].

The WHO International Programme on the Health Effects of the Chernobyl Accident (IPHECA). The results of the IPHECA project were recently published and discussed at the WHO International Conference on the Health Consequences of the Chernobyl and other Radiological Accidents, held in Geneva, 20-23 November 1995. IPHECA generally confirmed the conclusions of the ICP and provided additional information on the increase in child thyroid cancer incidence foreseen by the ICP.

The IPHECA conclusions can be summarized as follows:

- *Psychosocial effects, believed to be unrelated to radiation exposure, resulted from the lack of information immediately after the accident, the stress and trauma of compulsory relocation to less contaminated areas, the breaking of social ties, and the fear that radiation exposure could cause health damage in the future.*
- *A sharp increase in thyroid cancer was reported, especially among children living in the affected areas. By end-1994, 565 children aged 0-14 years were diagnosed as having thyroid cancer (333 in Belarus, 24 in the Russian Federation, 208 in Ukraine).*
- *There was no significant increase in the incidence of leukaemia or other blood disorders.*
- *Some evidence was found to suggest retarded mental development and deviations in behavioural and emotional reactions in a small number of children exposed to radiation in utero; however, the extent to which radiation might have contributed to such mental changes cannot be determined because of the absence of individual dosimetry data.*
- *The types and distribution of oral diseases observed in the residents of "contaminated" areas were the same as those of the residents of "uncontaminated" areas.*

Projects supported by the European Commission (EC). The EC supported many scientific research projects on Chernobyl's consequences. The results were summarized at the First International Conference of the European Union, Belarus, the Russian Federation and the Ukraine on the Consequences of the Chernobyl Accident, held in Minsk, on 18-22 March 1996. The projects produced valuable information that can be used for future emergency planning, dose assessment and environmental remediation, as well as in the treatment of highly exposed individuals and in screening for thyroid cancer in children.

Other initiatives. These include several UNESCO supported studies, mainly on psychological consequences; special reports from UNSCEAR and the Nuclear Energy Agency of the OECD; and individual studies in the affected States and in other countries, e.g. a comprehensive monitoring of the affected people carried out by Germany, an extensive study sponsored by Japan's Sasakawa foundation, a major USA project and a large Cuban assessment on the intake of caesium-137, covering about 15,000 children.

April 1996: the International Conference on One Decade After Chernobyl — Summing up the Accident's Consequences. The main organizations involved in assessing the Chernobyl accident's consequences, namely the IAEA, WHO and EC, united their efforts in co-sponsoring the recent Chernobyl Conference. They organized the event in co-operation with the UN itself (through its Department of Humanitarian Affairs), UNESCO, UNSCEAR, FAO and the Nuclear Energy Agency of OECD. The Chernobyl Conference was attended by 845 scientists from 71 countries and 20 organizations and covered by 280 journalists. It was presided over by Germany's Federal Minister for the Environment, Nature Conservation and Nuclear Safety and attended by high-level officials and members of government, including the President of Belarus, the Prime Minister of Ukraine, and the Russian Federation's Minister for Civil Defence, Emergencies and Elimination of Consequences of Natural Disasters, as well as by France's Minister for the Environment. Three national reports, 4 addresses by intergovernmental organizations, 11 keynote presentations, 8 background papers, 181 detailed poster papers and 12 technical exhibits provided the basis for this summing up of the Chernobyl accident's consequences.

[5]The "Prussian Blue (PB) Project" aimed to reduce contamination in milk and meat using a technique involving the use of the PB chemical compound in ruminants' foodstuffs. It was mainly funded by the IAEA and Norway whose specialists developed the technique. With time this project would prove to be the most cost effective of all post-ICP follow up projects. A US $50,000 annual investment by Belarus saved US $30m of lost milk/meat production annually.

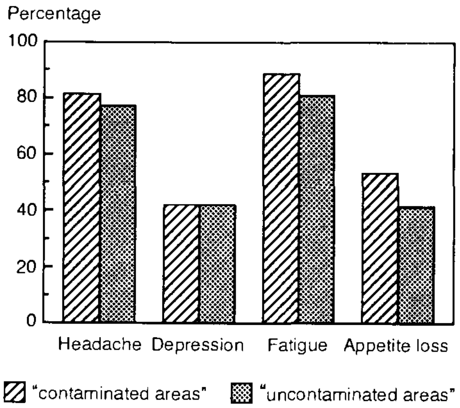
[6]Following a specific request of Belarus at the 1994 IAEA General Conference, the IAEA engaged in a mainly environmental project on "prospects for the contaminated area". The project has been financed mostly by IPSN, which was heavily involved in its technical implementation together with scientists of the affected regions. Some conclusions arose that extend beyond the general conclusions of the ICP to cover the general environment. Referring to the forested biocoenosis — the environmental system that had reportedly suffered most from the Chernobyl accident — the project concluded that the radioactive contamination was not on a massive scale and affected mainly pine forests: the death of the pine plantations, although severe in the immediate vicinity of the plant, amounted to less than 0.5% of the forested area of the exclusion zone.

ing clinical syndromes of radiation exposure and were hospitalized, and 134 of them were diagnosed with *acute radiation syndrome.* Of these, 28 died of the consequences of radiation injuries (three other persons died at the time of the accident: two due to non-radiation blast injuries and one due to a coronary thrombosis). *(See graph on page 10).* Some years after the accident, 14 additional persons in this group died; however, their deaths were found to be not necessarily attributable to radiation exposure. A following report in this edition by Dr. G. Wagemaker et al. describes the clinically observed effects in more detail. *(Page 29).*

Thyroid effects. The situation in relation to thyroid effects is serious. Up to the end of 1995, there were more than 800 cases of thyroid cancer reported in children, mainly in Belarus. *(See graph on page 10).* Thyroid cancer may be induced by causes other than radiation, but all these cases seem to be likely associated with radiation exposure due to the accident. They represent a dramatic increase in the normal incidence of this rare type of cancer and the increase seems not to persist among children born after 1986. Thyroid cancer is usually non-fatal with early diagnosis, treatment and attention. At the time of the Chernobyl Conference, three of the affected children had already died. The prospects cannot be precisely predicted: the high incidence is expected to continue for some time and the number of reported cases may be in the thousands; the mortality will depend very much on the quality and intensity of the treatment given to the affected children. Prof. E.D. Williams et al. reviewed the thyroid effects in a separate report. *(Page 31).*

Symptoms unrelated to radiation

A population survey on non-radiation related symptoms was carried out in areas directly affected by the accident (so-called "contaminated areas") and control areas in the "uncontaminated" regions. Results presented at the International Conference show on the one hand a surprisingly high incidence of these symptoms and on the other hand that the incidence is not clearly related to whether people are living in "contaminated" or "uncontaminated" areas. These effects could be attributed to the accident itself or to economic hardship and social disruption in the region.



Social, economic, institutional and political impacts

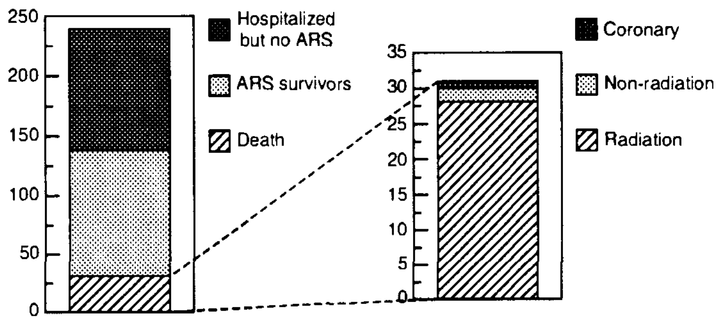
A background paper on Chernobyl's socio-economic, institutional, and political impact was prepared by high-level officials of Belarus, Russia, and Ukraine and discussed at the International Conference*. The various countermeasures taken by the authorities, some of them to address radiation hazards, created many social and economic problems. Some problems identified in the paper follow:

- Immediately after the accident 116,000 people had to be evacuated. Further, between 1990 and the end of 1995, almost 210,000 additional people were resettled. A new town, Slavutich, was built for the personnel of the Chernobyl plant to replace Pripyat, which had to be evacuated.
- Complete villages had to be decontaminated and major work on infrastructure, such as gas and water supply networks and sewage systems was carried out. The loss of Chernobyl Unit 4 together with the halt on construction of new reactors, hampered electricity supplies.
- There was major disruption to normal life and economic activity in the affected areas. In particular, agricultural and forestry production was severely disturbed and large production losses were incurred. Compensation was granted to agricultural enterprises, co-operatives and the population at large for losses of crops, animals and possessions. Moreover, monetary payments were made to different sectors of the population — for example, to purchase imported foodstuffs to replace home-grown produce.
- The control measures limited industrial and commercial activities. It was difficult to sell or export products, leading to a fall in local incomes. Also, the perception of an "unsafe" life in the affected areas and of the unavailability of "clean" products have held back industrial and commercial investment.
- Restrictions on customary activities made everyday life difficult and unsettling. Anxiety, distress, fatalistic attitudes and a kind of "victim" mentality grew among the population and are still prevalent in the affected areas.
- Significant demographic changes in the region due to emigration — particularly among young people — and the subsequent shift in the birth rate have led to shortages of young skilled workers and professionals.
- After the accident, a transformation from a centrally planned to a market economy started in the affected countries. This difficult transformation was complicated by the need to deal with the consequences of the accident.

* Rolevich, I.V.; Kenik, I.A.; Babosov, E.M; and Lych, G.M.; Voznyak, U.V; Kholosha, V.I.; Koval'skij, N.G.; and Babich, A.A. Background paper 6 on the Social, Economic, and Institutional Impact, in the Proceedings of the Chernobyl Conference being published by the IAEA.

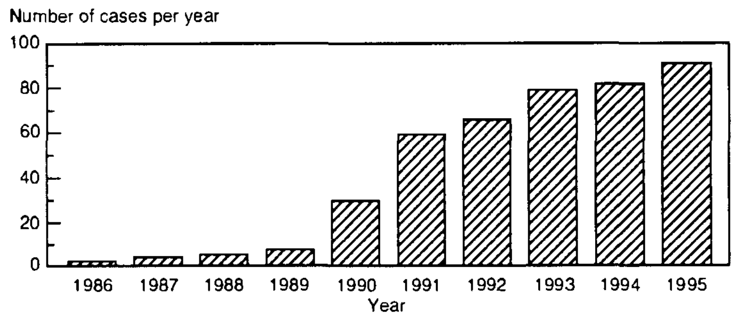
Clinically observed effects among liquidators

The figure shows the total number of people hospitalized after the accident, among them those who have been clinically diagnosed as having acute radiation syndrome (ARS), and those who died either by radiation related causes or by other causes.



Number of thyroid cancer cases among children in Belarus

The increase in the incidence of thyroid cancers in children has been notable. The graph shows the number of cases in children in Belarus aged below 15 at the time of treatment. The total number of cases reported so far is 800. The high incidence is expected to continue for some time and the total number of excess cases reported will probably be in the thousands.



Health effects attributable to radiation exposure

There are two types of health effects that can be attributable to the radiation exposure due to the Chernobyl accident.

The first are *early syndromes* that can be clinically observed in the exposed individuals — i.e. they can be diagnosed by a specialized practitioner who can unequivocally attribute the type and severity of the effect to the amount of the individual's radiation exposure. They only occur at relatively high radiation doses, above a threshold dose, and present a distinctive pathology affecting specific organs and tissues. With large doses they affect the whole body and are diagnosed as *acute radiation syndrome* (ARS). At Chernobyl, these effects were suffered by a number of fire fighters and other emergency workers only.

The second are potential *long-term radiation induced malignancies* and — plausibly — *hereditary effects*, which are difficult or sometimes impossible to discern from the usually high normal incidence of these types of effects in the population. These long-term effects cannot be directly attributed to radiation from the results of individual clinical examinations but only indirectly through long epidemiological studies in large population groups. They became evident as an increase in the statistical incidence of the effects in the population. However, if the radiation dose is very small or the number of people affected is small, the effects become undetectable against the normal incidence. At Chernobyl, such effects have become evident only as an increase in the incidence of thyroid malignances in children.

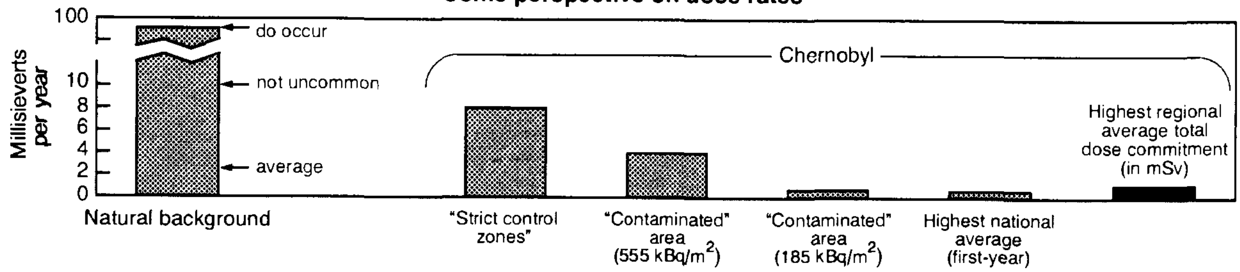
Longer term health effects. There is no evidence to date of any increase in the incidence of any malignancies other than thyroid carcinoma or of any hereditary effects attributable to radiation exposure caused by the Chernobyl accident. This conclusion, surprising for some observers, is in accordance with the relatively small whole body doses incurred by the populations exposed to the radioactive material released. The lifetime doses expected to be incurred by these populations are also small. In fact, the risks of radiation induced malignancies and hereditary effects are extremely small at low radiation doses and, as the normal incidences of these effects in people are relatively high, it is not surprising that no effects could be detected. *(See box, page 11).*

An exception to the lack of evidence of long-term effects might have occurred in the group of liquidators: taking into account the relatively high doses reported in this group, an increase in the incidence of leukaemia might have been detected. For all other malignancies and hereditary effects, the theoretically predicted number of cases due to radiation exposure from the accident are so small in comparison with the background incidence as to be impossible to confirm statistically.

Estimating long-term effects

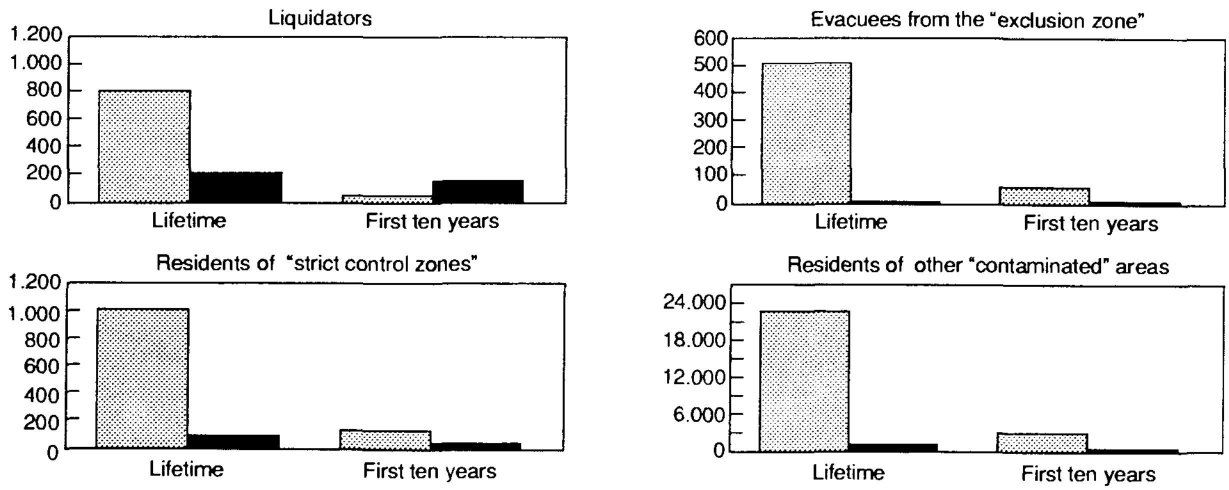
For predicting the long-term effects in a population exposed to radiation, it is important to estimate the radiation doses to be incurred by people during their lifetime. Except for the liquidators, the levels of whole body doses were relatively low. Of the 116,000 people that were evacuated for radiation protection reasons, fewer than 10% received doses of more than 50 mSv, a dose that can be incurred in a few years of living in an area of high natural levels of background radiation. Even for people who continued to live in the highest contamination areas, the doses they have committed for life will be in the same order of magnitude; the maximum accumulated dose — which was predicted by the ICP in 1990 to be around 160 mSv — is now estimated to be around 120 mSv. Outside the most affected areas the doses are even smaller: the highest European regional average dose committed over 70 years was estimated by UNSCEAR to be 1.2 mSv, or half the average dose that will be incurred in just one year of exposure to average background radiation, as shown below.

Some perspective on dose rates

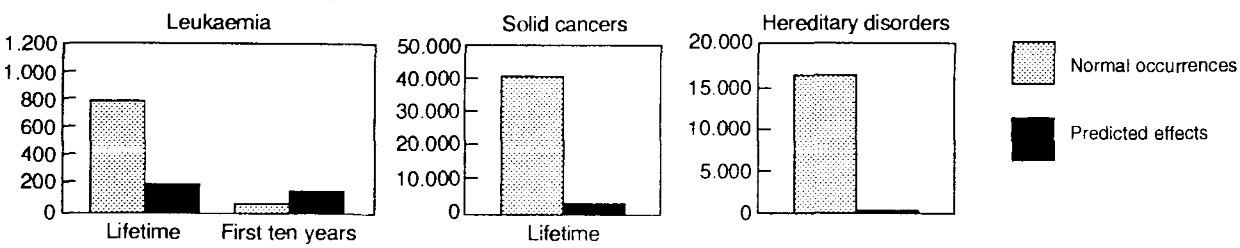


The graphs show the predictions of radiation induced long-term effects versus the cases of these effects expected to occur normally among the same population. The first set presents cases of leukaemia in four population groups, namely: the "liquidators"; the evacuees from the "exclusion zone"; the residents of "strict control zones"; and the residents of the so-called "contaminated" areas. The second set expands on the comparison for the liquidators between radiation-induced and normal cases for leukaemia, solid cancers and hereditary disorders. Except for leukaemia in the liquidators (and thyroid cancers in children), the number of theoretically predicted radiation induced effects is statistically not significant when compared with the normal occurrences. However, the detection of increase in leukaemia in liquidators is elusive and no long-term effects attributable to the Chernobyl accident — other than thyroid carcinomas — have been found.

Predictions of radiation-induced leukaemia compared with normal occurrences



Predictions of radiation-induced effects among liquidators compared with normal occurrences



More than 800 experts from over 70 countries and organizations attended the International Chernobyl Conference.
(Credit: Pavlicek/IAEA)

The reason why the theoretically expected increase in the incidence of leukaemia in the liquidators has not become evident requires further investigation. It could be that the dose was lower than reported, or that the epidemiological studies of this group are somehow inadequate. Less plausibly, the risk factors for radiation induced leukaemia could be lower than the currently estimated cases of leukaemia in the 200,000 registered liquidators who worked in 1986-87, which was of the order of 200 over a lifetime as compared to a spontaneous number of around 800. *(See graph on page 11)*. Dr. E. Cardis et al. go into greater detail in their report on the long-term health effects. *(Page 36)*.

A retrospective look at the findings of the International Chernobyl Project in 1990 in relation to health effects is provided by Dr. Fred Mettler. *(Page 33)*.

Social and other impacts. The Chernobyl Conference found that social, economic, institutional and political impacts were also important consequences of the Chernobyl accident. A background paper prepared jointly by officials of Belarus, Russia and Ukraine described the catastrophe in terms of economic and social disruption. *(See box on page 9)*. Large economic losses attributed to the accident were reported in this official document and also in the national statements delivered at the Chernobyl Conference. For the period 1986-91, the total direct losses and outlays in the former USSR were stated as exceeding 23,000 million roubles. The expenditures were accounted for — inter alia — by: losses of capital assets and in production; population resettlement, including construction of dwellings and other facilities; forest protection, water conservation, and soil decontamination and treatment; and, various compensations and payments of allowances to the population. The President of Belarus, reported that, "According to our most modest estimates, the economic damage incurred following the Chernobyl accident is equal to 32 annual budgets of the Republic, i.e. US $ 235,000 millions. For these purposes we allocate annually 20-25% of the State budget." The Russian Federation Minister for Civil Defence, Emergencies and Elimination of Consequences of Natural Disasters reported that, "Over the past years, trillions of roubles have been made available for the rehabilitation of the parts of Russia affected by the accident." For the Ukraine, its Prime Minister reported that, "The total expenditure in eliminating the consequences of the accident over the period 1992 to 1996 alone, paid out of the Ukrainian national budget, exceeds US $ 3,000 millions."

Certainly, a major social problem lies in the significant psychological symptoms detected among the population, such as anxiety, depression and various psychosomatic disorders attributable to mental distress. It has been found that it is extremely difficult to discern whether these effects are attributable solely to the Chernobyl accident or to economic hardships and other social problems in the region: the levels of these disorders in the areas concerned seem to be surprisingly high whether people were directly affected by the accident or not. *(See graph on page 9)*. In a separate report, Dr. Britt-Marie Drottz-Sjoeberg et al. look at social and psychological effects in more detail. *(Page 27)*.

Nuclear safety issues. For the public as well as for the responsible authorities, the Chernobyl accident prompts the question: Are Chernobyl-type reactors now safe? Experts say that the possibility of a repeat of the accident has virtually

Nuclear safety

An International Forum on Chernobyl's Nuclear Safety Aspects was held in Vienna from 1 to 3 April 1996 under the sponsorship of the IAEA and the UN Department of Humanitarian Affairs. The Forum results were reported at the Chernobyl Conference.

Some highlights follow:

Causes of the Accident: The available detailed information is sufficient to identify the causes of the accident and to take effective measures to prevent the repetition of such an event. It was confirmed that:

- there were significant deficiencies in the design of the reactor — in particular of its shutdown system — and operating procedures were severely violated at the time of the accident;
- there was a lack of safety culture in the organizations responsible for operation and for control: important safety weaknesses had been recognized long before the accident occurred but were not remedied.

Safety of RBMKs. Between 1987 and 1991, a first stage of safety upgrading was performed on all RBMK units of the Chernobyl type, which addressed the most serious problems identified, as follows:

- void reactivity effect has been reduced;
- the efficiency of the scram system has been increased;
- the operational organization has strengthened.

Issues beyond the scope of this first stage of upgradings still require more detailed attention entailing varying requirements corresponding to the different generations of RBMK reactors.

The Sarcophagus. Broad agreement was reached that there is a risk of partial or total collapse of the sarcophagus during its design lifetime (approximately 30 years). While even in the worst case of a complete collapse widespread effects would not be expected, the stabilization of the sarcophagus is a high priority safety issue.

The sarcophagus is currently safe from the point of view of criticality. However, configurations of fuel masses exist inside it which could reach a critical state when in contact with water. Although this potential criticality could not lead to large off-site releases, water entering the sarcophagus is a further significant safety issue.

Potential safety implications of the proximity of the sarcophagus to the remaining operating unit of Chernobyl need further investigation.

been ruled out because of safety improvements that have been made at plants of this type. Other safety improvement issues at the remaining Chernobyl units and reactors of the same RBMK type require attention. In addition, there is the separate issue of the safety of the remaining debris at Chernobyl, most of which is contained within the structure known as the *sarcophagus*. All these issues were discussed thoroughly at an international forum, *One Decade After Chernobyl: Nuclear Safety Aspects*, which preceded the Chernobyl Conference and was reported on at the Conference. *(See box above)*. More details about the forum and its conclusions are presented by Mr. L. Lederman in a following report. *(Page 44)*.

Outlook. The scientific assessments of the consequences of the Chernobyl accident have now been discussed and corroborated ten years later by a wide and representative international gathering of experts. The results provide the public at large, decision-makers and political leaders with authoritative information about these consequences. This ought to put an end to much of the misinformation that has arisen over the consequences of the accident.

The radiation levels that can still be detected in most affected areas are sufficiently low as to permit normal economic and social activity to be resumed. The health effects have not turned out to be as catastrophic as some feared and others reported. But a number of radiation effects did occur and more are expected to occur and should be dealt with. Moreover, the socio-economic impacts are very serious.

All efforts should now be concentrated on using our better understanding of the consequences to help those who have truly been affected and are still in need of help. ❒