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TCHERNOBYL: MISE EN PERSPECTIVE

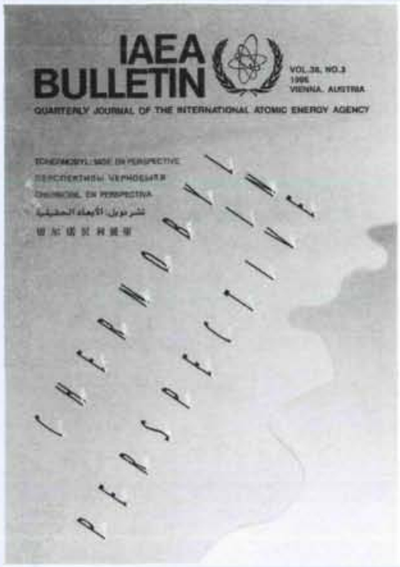
ПЕРСПЕКТИВЫ ЧЕРНОБЫЛЯ

CHERNOBIL EN PERSPECTIVA

تشرنوبل: الأبعاد الحقيقية

切尔诺贝利展望

CHERNOBYL IN PERSPECTIVE



Front Cover: Just over ten years after the world's tragic nuclear plant accident at Chernobyl, how much have we learned about its actual consequences? The scientific and technical answers are many and cover much ground and an array of complex topics. Fortunately, as the accident's long shadows recede and myths unravel, perspectives sharpen. Through global efforts, more light is being shed on the accident's true effects, and the needs of its victims. While open issues still must be resolved, a factual framework was set in April 1996 at the International Chernobyl Conference in Vienna to support decisions — especially those affecting the millions of men, women, and children living in the towns, villages, and farms most in need of assistance.
(Cover design: Hannelore Wilczek, IAEA; Stefan Brodek, Vienna.)

Facing Page: Women greet experts of the 1990 International Chernobyl Project, one of many global studies that has examined post-Chernobyl social, health, and environmental effects in parts of Belarus, Russia, and Ukraine.
(Credit: Mouchkin, Pavlicek/ IAEA).

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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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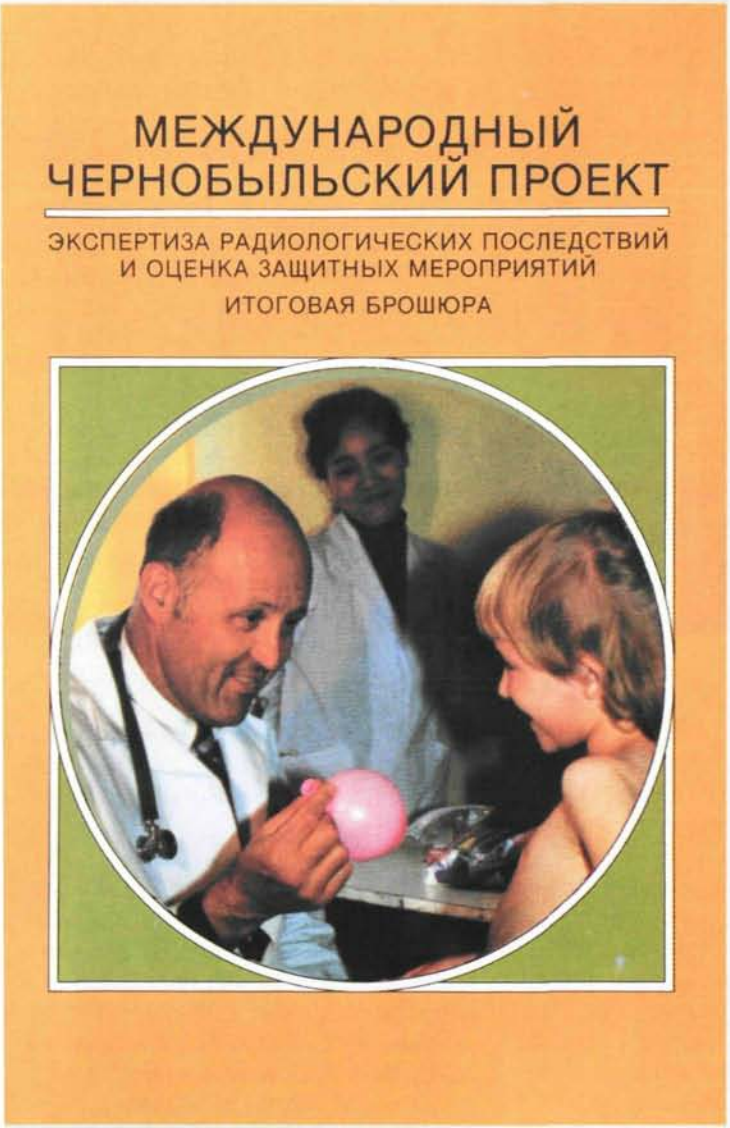
Release of radioactive material into the environment

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)*.

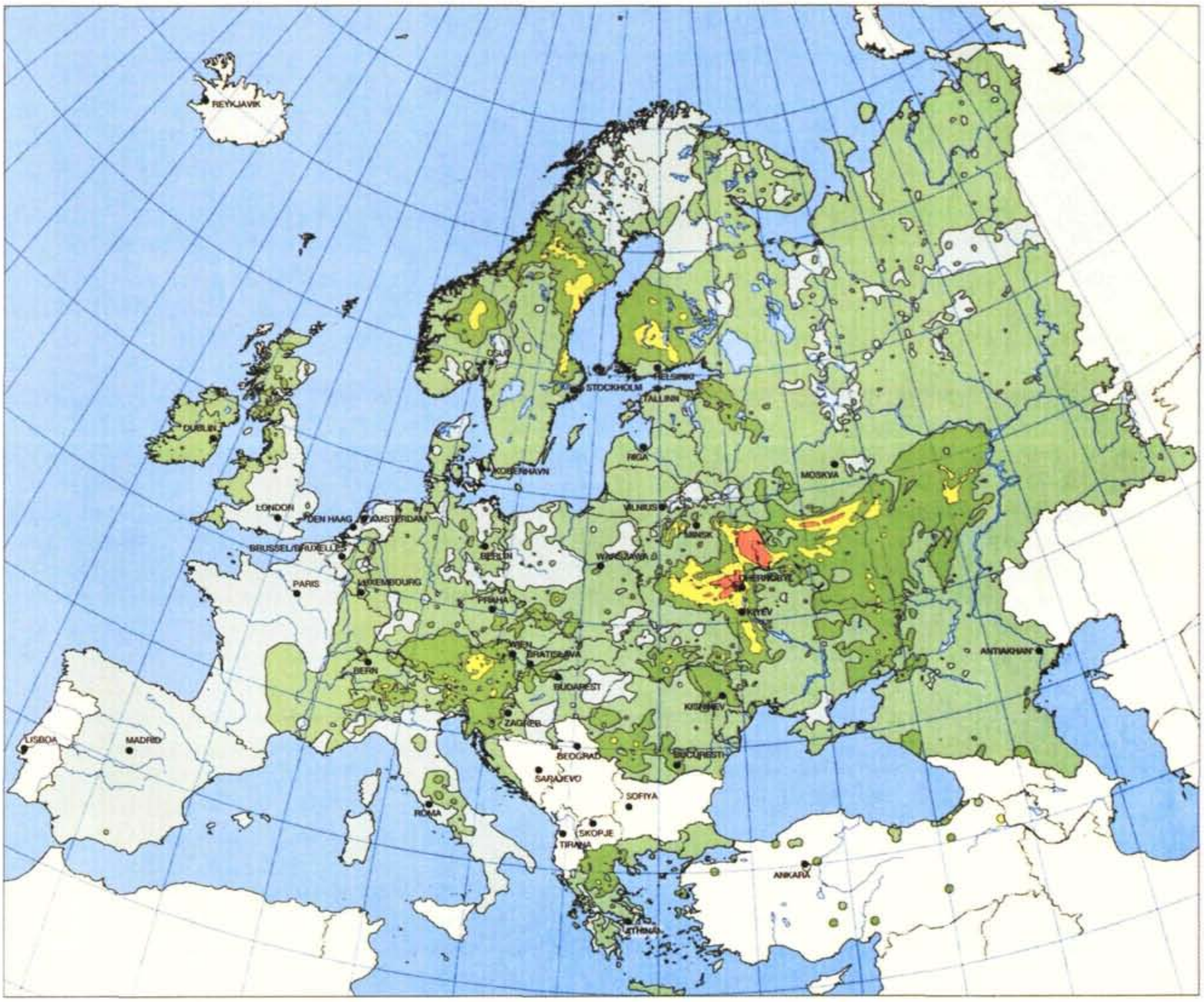
Health effects. Health effects attributed to the accident have commanded the most concern on the part of the public, decision-makers and political authorities, and the Chernobyl Conference devoted a great deal of time to the topic. *Clinically observed (and individually attributable) effects* were discussed 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 10^5 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.

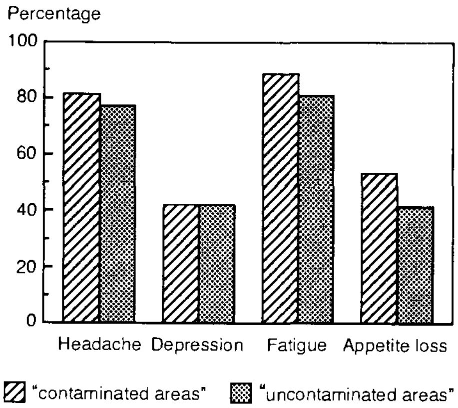
April 1996: the International Conference on One Decade After Chernobyl — Summing up the Accident's Consequences. The main organizations involved in assessing the Chernobyl accident's consequences, namely the IAEA, WHO and EC, united their efforts in co-sponsoring the recent Chernobyl Conference. They 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.

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.

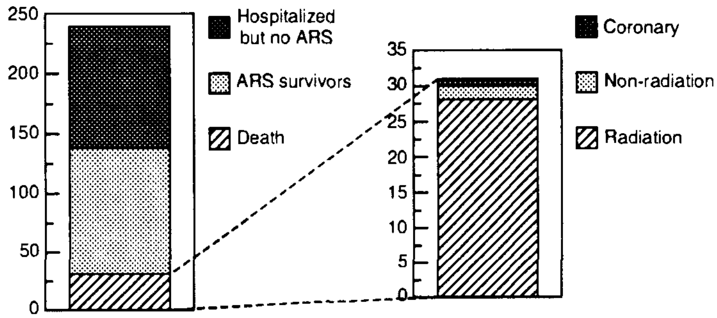
* Rolevich, I.V.; Kenik, I.A.; Babosov, E.M; and Lych, G.M.; Voznyak, U.V; Kholosha, V.I.; Koval'skij, N.G.; and Babich, A.A. Background paper 6 on the Social, Economic, and Institutional Impact, in the Proceedings of the Chernobyl Conference being published by the IAEA.

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).*

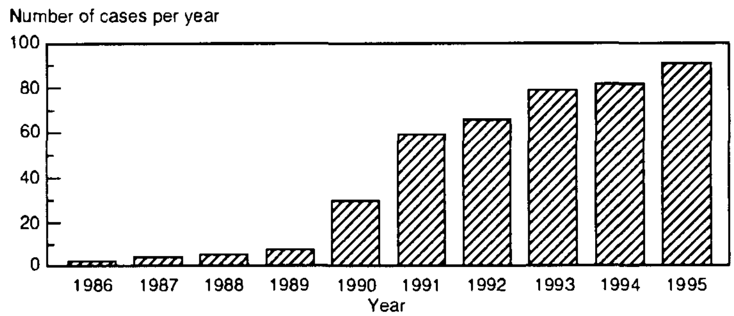
Clinically observed effects among liquidators

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.

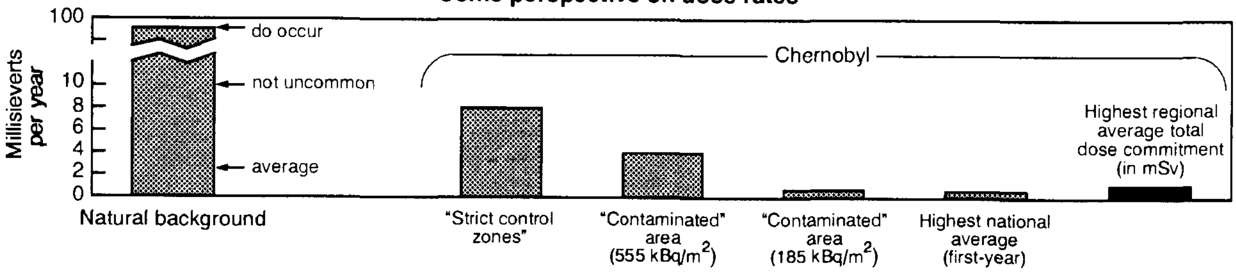
Longer term health effects. There is no evidence to date of any increase in the incidence of any malignancies other than thyroid carcinoma or of any hereditary effects attributable to radiation exposure caused by the Chernobyl accident. This conclusion, surprising for some observers, is in accordance 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

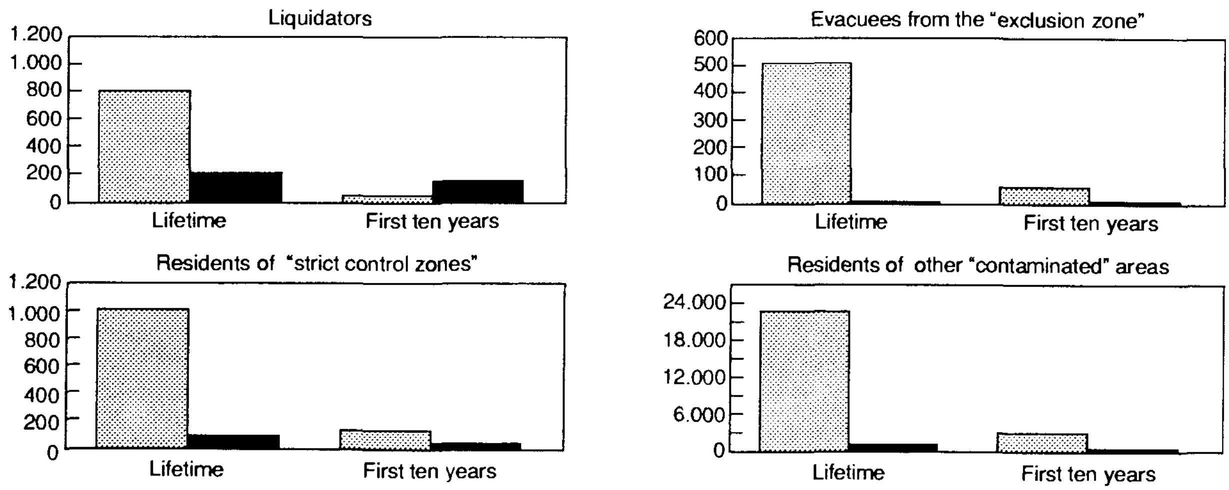
For predicting the long-term effects in a population exposed to radiation, it is important to estimate the radiation doses to be incurred by people during their lifetime. Except for the liquidators, the levels of whole body doses were relatively low. Of the 116,000 people that were evacuated for radiation 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

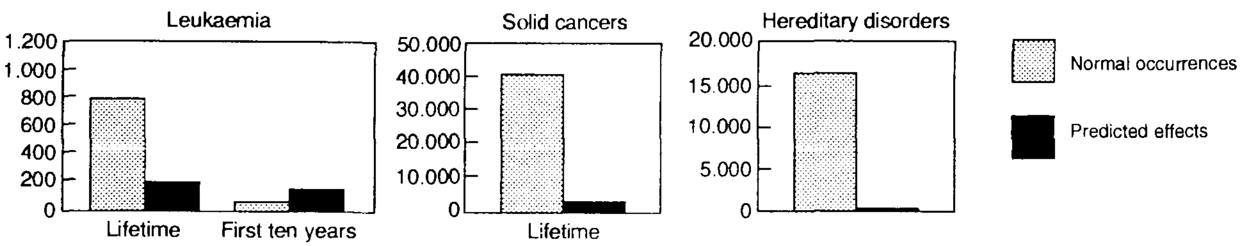


The graphs show the predictions of radiation induced long-term effects versus the cases of these effects expected to occur normally among the same population. The first set presents cases of leukaemia in four population groups, namely: the "liquidators"; the evacuees from the "exclusion zone"; the residents 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. ❐

One decade after Chernobyl: The basis for decisions

A major international conference sums up the scientific understanding of the Chernobyl accident's major consequences

Highlights of results

*Although much has been learned about the tragic Chernobyl accident of 26 April 1986 over the past 10 years, important issues remain to be resolved. In efforts to set the factual framework for the international community's ongoing assistance, the IAEA, European Commission (EC), and World Health Organization (WHO) jointly convened a major international conference in April 1996 to sum up the scientific understanding of the accident's consequences. (See box.) At its conclusion, the Conference issued a Summary of Results which was formulated on the basis of Conference reports and keynote presentations; background papers prepared by expert panels and Conference discussions of them; and the conclusions of each technical session. The Joint Secretariat of the Conference recommended that the Summary be used as the basis for decisions concerning future work and collaboration with the aim of alleviating the consequences of the Chernobyl accident. Featured here are selected highlights from the Summary of the Conference Results.**

Initial response to the accident

Emergency measures had to be taken to bring the release of radioactive material under control, to deal with the debris from the reactor, and subsequently to construct a confinement structure, the so-called "sarcophagus", which was completed in November 1986, to contain the remains of the reactor core.

The response to the accident was carried out by a large number of ad hoc workers, including operators of the plant, emergency volunteers such as fire-fighters and military personnel, as well as many non-professional personnel. All these people became known by the Russian term *likvidator*. About 200,000 "liquidators" worked in the Chernobyl region between 1986-87, when radiation exposures were the highest. They were among some 600,000 to 800,000 persons who were registered as involved in activities relating to alleviating the consequences of the accident. This includes persons who participated in the clean-up after the accident (including cleaning up around the reactor, construction of the sarcophagus, decontamination, road building, and destruction and burial of contaminated buildings, forests and equipment), as well as many other general personnel who worked in the territories designated as "contaminated" and who generally received low doses.

Between 27 April and mid-August 1986, about 116,000 inhabitants were evacuated from their homes in the region around the Chernobyl plant, the intention being to protect them from radiation exposure. A so-called "exclusion zone" was established, which included territories with the highest dose rates, to which public access was prohibited. This exclusion was continued in the independent successor countries of Belarus and Ukraine after the dissolution of the

*The full summary is included in the Proceedings of the Conference being published by the IAEA.

The far-reaching dimensions of the Chernobyl accident go far beyond its radiological effects, though they frequently receive the most attention. Many of the problems still facing people in the villages and towns most heavily affected by the accident are related to other factors, and they require further study and greater resources to solve.

Facing page: The fence surrounding the restricted 30-km zone. *This page, clockwise from top left:* Medical doctors checking children in Ukraine; a farm inside the 30-km zone, where some people who were evacuated have chosen to return to their homes; villagers in Belarus learning how to measure radiation levels in homes; aerial view of the Chernobyl plant, with the sarcophagus at right; farmers receiving information about radiation assessments.

(Credits: Mouchkin/IAEA; Pavlicek/IAEA; Government of Belarus; Eric Voice)

Soviet Union. The exclusion zone covers in total 4300 km^2.

Releases and deposition of radioactive material

The total activity of all the radioactive material released in the accident is today estimated to have been around 12 x 10^{18} Bq, including some 6-7 x 10^{18} Bq due to noble gases.* About 3% to 4% of the used fuel in the reactor at the time of the accident as well as up to 100% of noble gases and 20% to 60% of the volatile radionuclides were released. This current estimate of radioactivity is higher than the estimate of 1986. The 1986 estimate was made by authorities of the former USSR on the basis of summing the activity of the material deposited within the countries of the former USSR. However, this reassessment of the source term does not alter the estimations of individual doses.

The radionuclide composition of the material released in the accident was complex. The radioactive isotopes of iodine and caesium are of the greatest radiological significance: the iodines, with their short radioactive half-lives, had the greater radiological impact in the short term; the caesiums, with half-lives of the order of tens of years, have the greater radiological impact in the long term. The estimates for the activity of the amounts of the key radionuclides released are as follows: iodine-131: ~1.3 - 1.8 x 10^{18} Bq; caesium-134: ~0.05 x 10^{18} Bq; caesium-137: ~0.09 x 10^{18} Bq. These values correspond to about 50% to 60% of the iodine-131 in the reactor core at the time of the accident and about 20% to 40% of the two radiocaesiums.

Deposition of material. Material released to the atmosphere was widely dispersed and eventually deposited onto the surface of the earth. It was measurable over practically the entire northern hemisphere.

Most of the material was deposited in the region around the plant site, with wide variations in deposition density. The areas of the surrounding territories of Belarus, the Russian Federation, and Ukraine in which activity levels of caesium-137 in excess of 185 kBq/m^2 were measured were estimated at 16,500 km^2, 4600 km^2, and 8100 km^2, respectively.

*The amount of a given radionuclide is expressed in terms of the quantity "activity", which corresponds to the number of spontaneous nuclear transformations releasing radiation per unit time. Its unit is the reciprocal second (s^{-1}), termed becquerel.

Radiation doses

The 200,000 persons who participated in 1986-87 in the "liquidation" of the consequences of the accident received average doses of the order of 100 mSv.** Around 10% of them received doses of the order of 250 mSv; a few per cent received doses greater than 500 mSv; while perhaps several tens of the people who responded initially to the accident received potentially lethal doses of a few thousands of millisieverts.

The 116,000 people evacuated from the exclusion zone in 1986 were already exposed to radiation. Fewer than 10% had received doses of more than 50 mSv and fewer than 5% had received doses of more than 100 mSv.

The radioiodines released delivered radiation doses to the thyroid gland.*** Iodine was absorbed into the bloodstream, generally by ingestion in foodstuffs, mainly contaminated milk, and also by inhalation from the initial radioactive cloud, and accumulated in the thyroid gland. Doses to the thyroid were anticipated to be particularly high compared with those to other body organs, especially for children.

The long-term doses to the populations in various countries of the northern hemisphere as a result of the accident, including average doses in various countries, have been assessed by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). UNSCEAR estimated that individual doses outside the former USSR as a result of the accident were as follows: the highest national average first year dose was 0.8 mSv; the highest European regional average committed dose over

**The quantity radiation dose is a measure of the energy absorbed by tissues per unit tissue mass, weighted by the effectiveness of the radiation type and the radiosensitivity of the various tissues in the body. Its unit is the sievert (Sv), with a subunit of millisieverts (mSv), or thousandths of a sievert. For perspective, the global annual average radiation dose due to natural background radiation is 2.4 mSv, with considerable geographic variation. Hence over a standard lifetime of 70 years, an individual accrues an average dose of 2.4 mSv x 70 = 170mSv due to natural background radiation.

***Doses to specific organs are usually expressed in grays (Gy). For the type of radiation of concern here, a dose of 1 Gy to the thyroid corresponds to a (weighted) equivalent thyroid dose of 1 Sv.

The International Conference One Decade After Chernobyl: Summing up the Consequences of the Accident

by Malcolm Crick

Germany's Environmental Minister, Dr. Merkel, who served as Conference President, confers with a colleague at the heavily attended International Chernobyl Conference in Vienna.
(Credit: Pavlicek/IAEA)

From 8-12 April 1996 at the Vienna International Centre, the IAEA, European Commission (EC), and the World Health Organization (WHO) jointly sponsored an International Conference to recapitulate the scientific understanding of the major social, health, and environmental consequences of the Chernobyl accident. The Conference was organized in co-operation with the UN through its Department of Humanitarian Affairs (UNDHA), the UN Educational, Scientific and Cultural Organization (UNESCO), the UN Environment Programme (UNEP), the UN Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the Food and Agriculture Organization (FAO) of the UN, and the Organization for the Economic Co-operation and Development through its Nuclear Energy Agency (OECD/NEA).

Some 800 scientists and government officials in fields of nuclear energy, radiation safety, and health care attended the meeting, as well as more than 200 representatives of the media. Participants included high-level governmental representatives from the accident's three most heavily affected countries — Belarus, the Russian Federation, and Ukraine — and delegates from almost 90 States and intergovernmental organizations.

The Conference President was Dr. Angela Merkel, Minister for Environment, Nature Conservation and Nuclear Safety of Germany, assisted by a Bureau of senior scientists. An Advisory Committee of senior experts from Belarus, Russia, and Ukraine monitored the Conference's organization and development.

The Conference featured a range of sessions at which experts reviewed the findings of work carried out to date, including the outcome of two major international conferences, one hosted in November 1995 by WHO and the other in March 1996 under EC auspices in Minsk. It also considered the outcome of an IAEA/UNDHA International Forum on Nuclear Safety Aspects held in Vienna the week before the Conference. Opening addresses were made by IAEA Director General Hans Blix; WHO Director General Hiroshi Nakajima; H.Tent, EC Director General for Science, Research and Development; and M. Griffiths, UNHDA Director. The Conference further featured national statements by Alyaksandr Lukashenko, President of Belarus; A. Shoigu, Minister for Emergencies, Russia; and Yevgeni Marchuk, Prime Minister of Ukraine.

In a Briefing Seminar, seven keynote presentations were given by representatives of UNESCO; UNSCEAR; FAO; OECD/NEA and of organizations in Germany, Japan, and the United States on the results of major bilateral post-Chernobyl assistance projects.

The technical symposium featured eight separate topical sessions on a range of social, health, and environmental subjects. Topics included clinically observed health effects; thyroid effects; longer term health effects; other health-related effects including psychological effects, stress and anxiety; consequences for the environment; the social, economic, institutional and political impact; nuclear safety remedial measures; the consequences in perspective, and a prognosis for the future. For each session, Background Papers had been prepared in advance by committees of senior experts, including experts from Belarus, Russia, and Ukraine, nominated by the Advisory Committee. At each Topical Session, the Rapporteur introduced the relevant Background Paper and any related scientific papers presented at a Poster Session. A following open discussion proved extremely stimulating and lively. The conclusions of each session were reported to the Bureau of the President and summarized at the Final Session of the Technical Symposium. In addition to the plenary discussions, some 181 individual scientific posters were displayed as well as 12 technical exhibits of key projects. On the last day, a rather provocative panel discussion took place with representatives of the media, science and government, which further explored the public's perception of the Chernobyl accident consequences and tried to address why it differed from that of experts.

Conference proceedings, including a Summary of Results, are being published by the IAEA. Information also is available through the IAEA's World Atom Internet Services at *http://www.iaea.or.at/worldatom/thisweek/preview/chernobyl.*

Mr. Crick, a staff member of the IAEA Department of Nuclear Safety, served as Scientific Secretary of the Conference.

the 70 years to 2056 was estimated to be 1.2 mSv. In the International Chernobyl Project, it was estimated that the highest committed doses for the 70 years from 1986 to 2056 for people living in the most contaminated territories were of the order of 160 mSv. Recent, more detailed, studies have produced similar results.

Health effects

Clinically observed effects. A total of 237 occupationally exposed individuals were suggested to be suffering from clinical syndromes attributable to radiation exposure and were admitted to hospital. Acute radiation syndrome (ARS) was diagnosed in 134 cases. Of these 134 patients, 28 died as a consequence of radiation injuries, all within the first three months. Two more persons had died at Unit 4 from injuries unrelated to radiation (and one additional death was thought to have been due to a coronary thrombosis).

Gastrointestinal damage was a serious concern, causing early and lethal changes in intestinal function among 11 patients who had received doses greater than 10 Gy. The deaths of 26 of the 28 patients who died were associated with skin lesions that affected over 50% of the total body surface area. After the acute phase, 14 additional patients have died over the past ten years; however, their deaths do not correlate with the original severity of ARS and are therefore not necessarily — and in some cases are certainly not — directly attributable to radiation exposure.

There is little doubt that the patients received the best possible treatment in line with the state of knowledge at the time, in the most experienced centre available. However, the therapy of bone marrow transplantation recommended at the time was of little benefit. With today's knowledge, this is readily understandable in view of the inherent immunological risks of the procedure, the heterogeneous exposure characteristics and the other complicating injuries due to radiation, such as unmanageable gastrointestinal damage or skin lesions. Bone marrow damage can best be managed in future by the prompt administration of haemopoietic growth factors. The most optimal combination and dose scheduling for these still need to be determined, however. For other radiation damage also, new diagnostic tools have become available which may contribute to a more accurate prognosis and more individually tailored treatment.

At present, the more severely affected patients suffer from multiple ailments, including effects of mental stress, and are in need of up-to-date treatment and preventive measures against secondary effects. Health care should be ensured for these patients, and their state of health should be monitored over the forthcoming two to three decades. Among the disease patterns encountered, it will be important to distinguish between those that are attributable to radiation exposure and those due to confounding factors intrinsic to the populations affected by the accident.

Thyroid effects. A highly significant increase in the incidence of thyroid cancer among those persons in the affected areas who were children in 1986 is the only clear evidence to date of a public health impact of radiation exposure caused by the Chernobyl accident. (In 1991, the report on the International Chernobyl Project had stated that "it is expected that there will be a radiogenic excess of thyroid cancer cases in the decades to come. This risk relates to thyroid doses received in the first months after the accident..." *.) This increase in incidence has been observed in Belarus and to a lesser extent in Ukraine and in the Russian Federation. The number of reported cases up to the end of 1995 is about 800 in children under 15 years old at the time of diagnosis; more than 400 of these cases were in Belarus. In most cases the diagnoses have been confirmed by international experts.

The increase has been observed in children who were born before or within six months of the accident. The incidence of thyroid cancer in children born more than six months after the accident drops dramatically to the low levels expected in unexposed populations. Moreover, most of the cases of thyroid cancer are concentrated in areas thought to have been contaminated by radioiodines as a result of the accident. Thus both temporal and geographical distributions clearly indicate a relationship of the increase in thyroid cancer to radiation exposure. Furthermore, since the thyroid gland concentrates iodine, one or more radioactive isotopes of iodine are presumed to be the causative agents of the increase in incidence of thyroid cancer in children.

Analyses of exposure by age confirmed the hypothesis that very young children were at the greatest risk. It is now considered that the increase in the incidence of thyroid cancer in those exposed as young children may persist.

This could increase the prevalence of thyroid cancer in the affected group in the future, requiring adequate resources for dealing with it.

In the present case, the minimum latency period between exposure and diagnosis of thyroid cancer seems to be about four years. This latency period is somewhat shorter than expected on the basis of previous experience related to acute exposure to external radiation.

To date, only three children in the cohort of diagnosed cases have died of thyroid cancer. These post-Chernobyl papillary thyroid cancers in children, in spite of their aggressiveness, appear to respond favorably to standard therapeutic procedures if appropriately applied; however, only short term follow-up data are available as yet. There is thus a need for complete and continuing follow-up of the affected children in order to establish the optimal therapy. Life-long administration of L-thyroxine to children is mandatory after thyroidectomy.

The extent of the future incidence of thyroid cancers as a result of the Chernobyl accident is very difficult to predict. There remain uncertainties in dose estimates and, although it is not certain that the present increase in the incidence will be sustained in the future, it will most probably persist for several decades. If the current high relative risk is sustained, there would be a large increase over the coming decades in the incidence of thyroid carcinoma in adults who received high radiation doses as children.

In the event of any future accident, recognized measures should be taken under strictly defined conditions to protect populations at risk from exposure of the thyroid to radioiodine, such as prevention of the consumption of contaminated food and iodine prophylaxis through the distribution of pharmacological doses of stable iodine. The populations living around the Chernobyl plant have historically been subject to iodine deficiency, and remedy of this deficiency through the consumption of iodized salt in food is in any case recommended.

Longer term health effects. Apart from the confirmed increase in the incidence of thyroid cancer in young people, there have been some reports of increases in the incidence of specific malignancies in some populations living in contaminated territories and in liquidators. These reports are not consistent, however, and the reported increases could reflect differences in the follow-up of exposed populations and increased ascertainment following the Chernobyl accident; they may require further investigation.

Leukaemia, a rare disease, is a major concern after radiation exposure. Few fatalities due to radiation induced leukaemia would theoretically be expected according to predictive models (based on data from the survivors of the Japanese atomic bombing and others). The total expected excess fatalities due to leukaemia would be of the order of 470 among the 7.1 million residents of "contaminated" territories and "strict control zones", which would be impossible to distinguish from the spontaneous incidence of about 25,000 fatalities. The total expected figure among the 200,000 liquidators (who worked in 1986-87) would be of the order of 200 fatalities against a spontaneous number of 800 deaths due to leukaemia. According to current models, about 150 of these 200 excess leukaemia deaths among the liquidators would have been expected to have occurred in the first ten years after exposure, for which the spontaneous incidence is 40. In summary, to date, no consistent attributable increase has been detected either in the rate of leukaemia or in the incidence of any malignancies other than thyroid carcinomas.

Among the 7.1 million residents of "contaminated territories" and "strict control zones", the number of fatal cancers due to the accident is calculated, using the predictive models, to be of the order of 6600 over the next 85 years, against a spontaneous number of 870,000 deaths due to cancer. Future increases over the natural incidence of all cancers, except for thyroid cancer, or hereditary effects among the public would be difficult to discern, even with large and well-designed long-term epidemiological studies, as had already been stated in the report on the International Chernobyl Project.

Increases in the frequency of a number of non-specific detrimental health effects other than cancer among exposed populations, and particularly among liquidators, have been reported. It is difficult to interpret these findings because exposed populations undergo a much more intensive and active follow-up of their state of health than does the general population. Any such increases, if real, might also reflect effects of stress and anxiety.

Existing population-based cancer and mortality registries should be improved or, where

*See *The International Chernobyl Project: Technical Report, Assessment of Radiological Consequences and Evaluation of Protective Measures*, Part F: Health Impact, Section 3.11.3, p. 389, published by the IAEA (1991).

appropriate, such registries should be set up. In addition, specific studies to investigate the reported increases and also the predicted increases, particularly in leukaemia among liquidators, should be carried out. This should be done using carefully designed protocols applied uniformly to analyze, and possibly to distinguish the effects of, confounding factors.

Psychological consequences. Several important studies and programmes have been conducted over the past ten years to determine social and psychological effects of the Chernobyl accident. These have confirmed earlier findings (including those of the International Chernobyl Project) that there are significant psychological health disorders and symptoms among the populations affected by the Chernobyl accident, such as anxiety, depression and various psychosomatic disorders attributable to mental distress. It is extremely difficult to distinguish the psychological effects of the Chernobyl accident from effects of economic hardship and the dissolution of the USSR.

The psychological effects of the Chernobyl accident resulted from the lack of public information, particularly immediately after the accident, the stress and trauma of relocation, the breaking of social ties, and the fear that any radiation exposure is damaging and could damage people's health and their children's health in the future. It is understandable that people who were not told the truth for several years after the accident continue to be skeptical of official statements and to believe that illnesses of all kinds that now seem more prevalent must be due to radiation. The distress caused by this misperception of radiation risks is extremely harmful to people.

The lack of consensus about the accident's consequences and the politicized way in which they have been dealt with has led to psychological effects among the populations that are extensive, serious and long lasting. Severe effects include feelings of helplessness and despair, leading to social withdrawal and loss of hope for the future. The effects are being prolonged by the protracted debate over radiation risks, countermeasures and general social policy, and also by the occurrence of thyroid cancers attributed to the early exposures.

There is an urgent need to foster trust in the personal ability to change one's life for the better; to encourage small-scale and communal projects to improve matters locally and to support organizations promoting rehabilitation of the populations concerned; to increase public knowledge of the health effects of radiation and radiation protection; and to develop, integrate and sustain existing networks of local authorities, specialists and researchers in the social and psychological field.

Environmental consequences

Concerning direct consequences for animals and plants, lethal radiation doses were reached in some radiosensitive local ecosystems, notably for coniferous trees and for some small mammals within 10 km of the reactor site, in the first few weeks after the accident. By the autumn of 1986 dose rates had fallen by a factor of 100. By 1989 the natural environment in these localities had begun to recover. No sustained severe impacts on populations or ecosystems have been observed. The possibility of long-term genetic effects and their significance remains to be studied.

For humans, the significance of the environmental contamination depends on the pathways for their exposure. The main pathways are by external irradiation from radioactive material deposited on the ground and by internal irradiation due to the contamination of foodstuffs. In the first few weeks after the accident, radioiodines were the radionuclides of the greatest radiological importance. Since 1987, most of the radiation dose received has been due to caesium-134 and caesium-137, with a minor contribution from strontium-90, while plutonium-239 has made a minimal contribution to dose.

Several items of the normal diet were contaminated by radioactive materials. Early after the accident, key foodstuffs such as milk and green vegetables had contamination levels in excess of what is today considered acceptable by the WHO/FAO Codex Alimentarius Commission, set as maximum permitted contamination levels for foodstuffs moving in international trade. (These levels are now globally established by the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources.) There are some questions about the effectiveness of the control measures that were taken in the early stages following the accident.

Countermeasures are relatively inefficient in reducing external exposures but can be very efficient in reducing the uptake of radioactive material. In the long term, the appropriate application of agricultural countermeasures can reduce the uptake of caesium into food. The effectiveness of countermeasures depends on local conditions such as soil type. For example, in some localities where the amount of caesium deposited on the ground was relatively small, the transfer to milk could nevertheless be high. In general, no food produced by collective farms now exceeds the WHO/FAO Codex Alimentarius levels, although some foods produced by private farmers do exceed these levels.

The semi-natural environment, i.e. with characteristics intermediate between those of managed agricultural land and those of natural environments, may have a predominant influence on the levels of future doses to the human population. The transfer factor for radionuclides from soil to the milk of cows grazing on meadows varies by a factor of several hundred, depending on the type of soil. Some food products derived from animals that graze in semi-natural pastures, forests and mountain areas, and wild foods (such as game, berries and mushrooms), will continue to show levels of caesium-137 that exceed the Codex Alimentarius levels — in some cases greatly — over the next decades and are likely to be a major source of internal doses in the future.

Local dose rates of radioactive material buried at the Chernobyl site can be considerable. Furthermore, for orderly management of the provisional depositories of radioactive residues from the accident, the potential contamination of the local groundwater in the long term should be considered.

Social, economic, institutional, and political impact

Between 1990 and the end of 1995, decisions were taken by the authorities to further resettle people in Ukraine (about 53,000 persons), Belarus (about 107,000 persons), and the Russian Federation (about 50,000 persons). Evacuation and resettlement has created several serious social problems, linked to the difficulties and hardships of adjusting to the new living conditions.

Demographic indicators in "contaminated" regions have worsened: the birth rate has decreased, and the work force is migrating from "contaminated" areas to "uncontaminated" areas, creating shortages of labour and professional staff.

The control measures imposed by the authorities to limit radiation exposure in "contaminated" territories have limited industrial and agricultural activities. Moreover, the attitude of the general population towards products from "contaminated" areas makes it difficult for produce to be sold or exported, leading to reductions in local incomes.

Restrictions on people's customary activities make everyday life difficult and distressing. Major rehabilitative actions have been undertaken over the past years. However, it is necessary to provide the public with more and better information on the measures taken to limit the consequences of the accident, on present radiation levels and on radionuclide concentrations measured in foodstuffs.

The social and economic conditions of people living and working in "contaminated" territories are heavily dependent on public subsidies. If the compensation system in force were to be reconsidered, some funds could be redirected to new industrial and agricultural projects.

The consequences of the Chernobyl accident and the measures taken in response, exacerbated by the political, economic and social changes of the past few years, have led to a worsening in the quality of life and of public health as well as to unfavorable effects on social activity. The situation was further complicated in the years after the accident by incomplete and inaccurate public information on the accident's consequences and on measures for their alleviation.

Nuclear safety and the sarcophagus

The main cause of the Chernobyl accident lay in the coincidence of severe deficiencies in the design of the reactor and of the shutdown system, and the violation of procedures. The lack of "safety culture" in the responsible organizations of the Soviet Union resulted in an inability to remedy such design weaknesses, even though they had been known before the accident.

In addition to those features of direct relevance to the causes of the accident, the original design of plants with RBMK reactors (Soviet light water cooled, graphite moderated reactors) had further deficiencies. In particular, the original design of the first generation of RBMK reactors falls short of present safety objectives. Remaining deficiencies, such as the partial containment, require further attention.

In accordance with a dynamic approach to safety, all nuclear power plants that do not meet an internationally acceptable level of safety need appropriate upgrading or should be shut down. In September 1991, the IAEA Conference on The Safety of Nuclear Power: Strategy for the Future expressed a consensus that the safety standards of older operating plants should be reasonably compliant with current safety objectives. Active commitment to this objective remains of prime importance for ensuring an acceptable level of safety for nuclear installations and for enhancing public confidence in nuclear energy.

A significant number of remedial measures to enhance nuclear safety have been taken over the past decade at existing plants with RBMK reactors: technical and organizational measures were taken immediately after the Chernobyl accident, as well as safety upgrades performed between 1987 and 1991 which essentially remedied the design deficiencies that contributed to the accident. Progress has also been achieved in areas such as plant management, training of personnel, non-destructive testing and safety analysis. As a result, a repetition of the same accident scenario seems no longer practically possible. However, the possibility of other accidents leading to substantial releases cannot be excluded.

For all RBMK plants, there are plans for further safety improvements to remedy those design deficiencies of RBMK reactors that are not directly related to the Chernobyl accident. The implementation of these plans is lagging behind what is needed because the countries concerned lack the necessary resources.

Expedited implementation of what has been agreed to be necessary and has already been planned is a top priority for the national nuclear programmes as well as for international cooperation: necessary safety improvements must be carried out independently from consideration of early decommissioning of the plants; more resources must be made available for enhancing the safety of the RBMK plants that are currently operated; the status of national regulatory authorities and their support organizations must be strengthened.

Similar backfits as for other RBMK units were also performed at the Chernobyl plant. However, safety concerns with RBMK units are not only related to the generic design deficiencies, but also to the quality of equipment.

The decision of the Ukrainian authorities to close down the remaining units at Chernobyl is not a reason for neglecting the need for safety measures and backfits during the remaining time of operation.

The sarcophagus. The sarcophagus that was constructed around the destroyed reactor presently contains about 200 tones of irradiated and fresh nuclear fuel, mixed with other materials in various forms, mainly as dust. The total activity of this material is estimated to be 700 x 10^{15} Bq of long-lived radionuclides. The sarcophagus has met the objectives set for the purposes of protection over the past 10 years. In the long term, however, its stability and the quality of its confinement are in doubt. A collapse of the structure could lead to a release of radioactive dust and the exposure to radiation of the personnel employed at the site. However, even in a worst case, widespread effects (beyond 30 km away) would not be expected.

It has been found that the sarcophagus is currently safe from the point of view of the occurrence of a criticality. It cannot be completely excluded that there exist configurations of fuel masses inside the sarcophagus that could reach a critical state when in contact with water. However, even if such a condition were to lead to elevated radiation levels inside the sarcophagus, large off-site releases would not be expected. The possible impact of such a state on site personnel needs to be clarified.

Opinions differ widely about the significance of the risk of an accident in Chernobyl Unit 3 caused by a collapse of the sarcophagus. More detailed investigations of this issue are required.

The safety of the remaining units and the stability of the sarcophagus are not the only major issues still to be resolved at the Chernobyl site. Further concerns relate to the potential for contamination, in particular to the radioactive material buried at the site. These issues are interrelated and an integrated approach is required to resolve them. The proposed construction of a second shelter over the sarcophagus should be part of such an approach. The actions financed by the EC in this area have contributed to achieving an integrated approach. This approach now needs to be generalized, and the knowhow of the competent organizations of the former USSR should be more effectively integrated. Research and development of an adequate design are necessary in order to ensure that the sarcophagus is ecologically safe.

A cost-effective procedure requires that suitable steps be taken, in accordance with the progress of studies and the financial circumstances. The first measure should be the stabilization of the existing sarcophagus. This would significantly reduce the risk of its collapse and would provide the time required for the careful planning of further measures (such as a second shelter).

Perspective and prognosis

Full rehabilitation of the exclusion zone is not currently possible owing to: the existence of "hot spots" of contamination near residential areas; the possibility of local radioactive contamination of groundwater; the hazard associated with the possible collapse of the sarcophagus; and severe restrictions imposed on diet and lifestyle.

Any estimates of the total number of fatal and non-fatal cancers attributable to the accident should be interpreted with caution in view of the uncertainties associated with the assumptions on which they must be based. Such projections do, however, provide a perspective on the magnitude of the long-term impact and help in identifying areas needing special attention, both now (such as the incidence of leukaemia among the liquidators and of thyroid cancer among children living in "contaminated" areas) and in the future.

There is a major discrepancy between the number of thyroid cancers appearing in those who were children at the time of the accident and the predicted number of such cancers on the basis of standard thyroid dosimetry and current risk projection models. This difference may be the result of several factors unique to the accident which are not typically incorporated into standard models. It is important to clarify these issues as well as to continue the programs for the detection of thyroid tumors.

The increase in the incidence of thyroid cancer will most probably persist for several decades. While it is not possible to predict with certainty on the basis of current data, the estimated number of thyroid cancers to be expected among those who were children in 1986 is of the order of a few thousand. The number of fatalities should be much lower than this, if cancer is diagnosed in the early stage and if appropriate treatment is given. These people should continue to be closely monitored throughout their lives.

Despite the extensive scientific and medical knowledge of radiation effects, there remain important open questions with regard to the human health effects of radiation. It is necessary to continue to support research into the biological effects of radiation.

Different factors, such as economic hardship, are having a marked effect on the health of the population in general, including the various groups exposed as a result of the accident. The statistics for the exposed populations are being examined in the light of the clear general increase in morbidity and mortality in the countries of the former Soviet Union so as to preclude the misinterpretation of these trends as being due to the accident.

The public perception of the present and future impact of the accident may have been exacerbated by the difficult socioeconomic circumstances in the USSR at the time, by the countermeasures that the authorities took to minimize the accident's impact, and by the public's impression of the risks from the continuing levels of radioactive contamination.

Past experience of accidents unrelated to radiation has shown that the psychological impact may persist for a long period. In fact, ten years after the Chernobyl accident, the evolution of symptoms has not ended. It can be expected that the importance of this effect will decrease with time. However, the continuing debate over radiation risks and countermeasures, combined with the fact that effects of the early exposures are now being seen (i.e. the significant rise in thyroid cancers among children), may prolong the symptoms. In evaluating the psychological impact, account should be taken of the psychological effects of the breakup of the USSR, and any forecast should take into account the economic, political and sociological circumstances of the three countries. The symptoms such as anxiety associated with mental stress may be among the major legacies of the accident.

In view of the low risk associated with the present radiation levels in most of the "contaminated" areas, the benefits of future efforts to reduce doses still further to the public would be outweighed by the negative economic, social and psychological impacts. It is important to develop a strategy that takes into account both the real radiological risk and the economic, social and psychological disbenefits in order to yield the greatest net benefit in human terms. In addition, measures to mitigate the psychological impact should be considered. ❐

Post-Chernobyl scientific perspectives:

Reports on topics addressed at technical sessions of the International Conference convened in Vienna 10 years after the Chernobyl accident

ENVIRONMENTAL CONSEQUENCES

Report by Ms. Mona Dreicer, United States, who served as Rapporteur, and Academician Rudolf Alexakhin, Institute of Agricultural Radiology and Agroecology, Obninsk, Russian Federation, who served as Vice Chairman, Topical Session 5: "Consequences for the environment".

A question often posed by the public and decision-makers is: "What is the expert view of the environmental damage that resulted from the Chernobyl accident, and what can be expected in the future?"

Deriving a single answer is difficult: there were large variations in the levels of environmental contamination, a lack of a common unit of measure with which to present the varied environmental consequences, and a broad range of possible interpretations of the consequences. Traditionally in radiation protection, the natural environment is considered to be protected if the human population is protected. So in most cases, the consequences are viewed solely in terms of impact on humans. It is for this reason that the most effective methods of restricting the natural course of the transfer of radionuclides in the environment (by so-called countermeasures) have been aggressively studied during the last 10 years. Besides providing important information for the development of radiation protection policy for the areas affected by the accident, advances have been made in basic radio-ecological research.

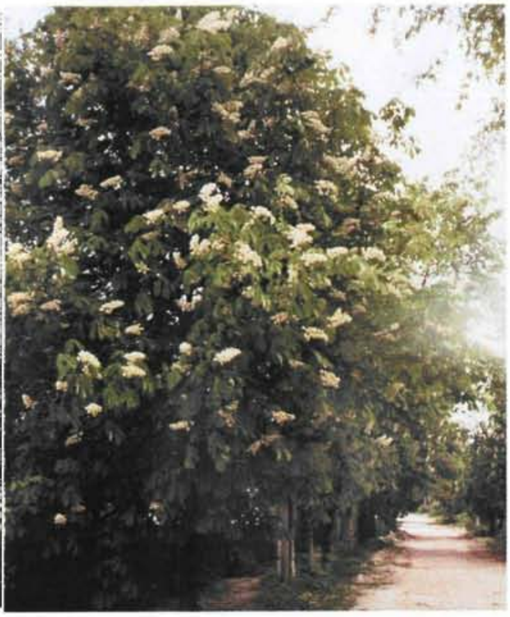
Presented here is a brief summary of recent estimates of the initial releases to the environment as a result of the Chernobyl accident, the observed impacts from increased levels of radiation on plants and animals near the site, and the transport of radionuclides in the environment.

Recent estimates of radioactive releases. Broad agreement has been reached among various estimates concerning the initial environmental release due to the accident. Most of the material released was short half-lived radionuclides. Releases to the environment of some radiologically important radionuclides (iodine-131, caesium-134, and caesium-137) are estimated now at a factor of two to three higher than in 1986, namely 2 exa-becquerel (EBq), 50 peta-becquerel (PBq) and 90 PBq, respectively. However, the reassessment of the source term has had no impact on the assessment of individual doses, which were based on the environmental or whole body measurements made in the affected areas. The total amount of radioactive material still present in the environment after 10 years has decayed to about 80 PBq of long-lived radionuclides, principally caesium-137 and strontium-90, or about 1% of the total amount released. *(See table, next page.)*

Overall patterns of contamination by these long-lived radionuclides have remained essentially unchanged over the last 10 years, with relatively little secondary transport of material. Hot fuel particles released from the reactor are one of the factors of this accident that differentiate it from weapons fallout material. Close to the reactor, these particles are beginning to disintegrate and further study is needed to understand their final distribution in the environment.

Direct effects on plants and animals. The highest doses immediately after the accident were received by plants and animals within a radius of 30 kilometers from the reactor. Contamination levels typically reached several tens of mega-becquerel (MBq) per m^2 (thousands of Ci/km^2) in some localities and external doses would correspondingly have been of the order of several tens of gray (Gy) to vegetation and small animals in the first month from the short-lived radionuclides. By the autumn of 1986, the dose rate at the soil surface dropped by a factor of 100 of the initial value.

Social, health, & environmental effects



Residual radioactive material in the global environment as a result of the Chernobyl accident in April 1986

Significant radionuclide	Released in 1986 (PBq*)	Remaining in 1996 (PBq)	Remaining in 2056 (PBq)
I-131	200–1700	0	0
Sr-90	8	6	1 5
Cs-134	44–48	1 6	0
Cs-137	74–85	68	17
Pu-238	0 03	0 03	0 02
Pu-239	0 03	0 03	0 03
Pu-240	0 044	0 044	0 03
Pu-241	5 9	3 6	0 2
Am-241**	0 005	0 08	0 2

*1PBq = 10^{15} Bq Estimate of release decay corrected to 26 April 1986, the day of the accident **The activity of americium-241 in 1996 has increased since 1986 as it is a daughter product of plutonium-241 (half-life 14 years) This increase has to be considered in any radiological prognosis, however, the doses from americium-241 will not exceed the present doses from other radionuclides

Above. **A chestnut tree in bloom inside the 30-km exclusion zone.** ***Right:*** **Where forests were cut down after the accident, new trees are regenerating near the Chernobyl plant, which is on the horizon** *(Credit Eric Voice)*

Direct radiation injury to plants and animals was reported only in local areas within the 30-km exclusion zone. Different organisms in the natural environment were exposed to high doses, and the lethal doses for some radiosensitive ecosystems were reached. These lethal effects were seen in the coniferous forests in the nearest areas and for some small mammals.

Severe direct effects of high radiation doses were observed in some individual animals, but were not necessarily significant in changing the overall health of the population. For example, cows grazing contaminated pastures near the reactor in the early phase after the accident received thyroid doses in the range of hundreds of Gy, resulting in atrophy and total necrosis of the thyroid. For other ecosystems, individual plants, and animals, no lethal effects were observed.

In most cases, the plant and animal populations affected by radiation returned to normal in a few years. An example of this can be seen in a 3000-hectare region around the plant by 1988–89 the damaged conifers had recovered their reproductive functions, and today it seems likely that they will recover fully. Chronic dose rates in some areas within the 30-km exclusion zone may have reduced the fertility of animals of some species but it appears that other affected animal populations have already recovered. The significance of the observed changes in the long-term health of the specific populations is difficult to determine at this time.

There were media reports of severe birth defects in agricultural animals outside the 30-km zone in 1988–89, however, the frequency of these reported defects was shown to be similar in highly contaminated and non-contaminated regions of Ukraine, leading to the conclusion that the defects were not due to increased radiation dose. There have been no further reports of severe effects observed in farm animals.

There have been some reports of damage to mitochondrial chromosomes that have been passed on to subsequent offspring in high dose rate areas, but other evidence supports general recovery from the radiation damage. Today, there is no general consensus on potential long-term hereditary impacts on plants and animals where the doses were very high.

After 10 years, the major contributors to the low-dose chronic radiation are the remaining caesium radionuclides. The external dose in some isolated spots can still be of the order of 1 mGy per day; however, even in the 30-km zone, the natural environment seems to be recovering. Owing to the relocation of people from the 30-km zone, there have been some changes in the numbers and variety of animal and plant communities, but these changes have resulted from disuse of the land, not from radiation effects. Some natural populations have thrived as a result of the lack of human interference. No evidence has been found that any plant or animal species have been permanently eliminated from the most contaminated areas, except where clean-up activities involving soil removal have drastically altered the ecosystem.

Contamination in the environment. In the semi-natural environment, the key factors controlling the migration of radionuclides from topsoil into plants in meadow ecosystems are the clay and organic content of the soil and soil moisture. In general, the current migration rate is slow and steady and is expected to continue over the coming decades, even as the level of radioactive material in the soil declines. The transfer of strontium-90 is faster than for caesium-137, but the influence of the different types of soil is similar. This rate of transfer is an important consideration in the decisions regarding the long-term use of meadows as cow pastures.

Today, nearly all the contamination in forest ecosystems is found in the topsoil. The radiocaesium in trees is concentrated in the new growth rings owing to the transfer from the soil through the roots. This is not a significant problem but will increase the caesium-137 concentration in wood. No cost-effective countermeasure to reduce this transfer has been found.

Game animals that graze in semi-natural pastures, forests or mountainous areas, and wild foods consumed by people, such as berries and mushrooms, will continue to show elevated caesium-137 levels over the next decades. These foods may still be contaminated above the strict nationally adopted limits in areas of Belarus, Ukraine, and Russia, as well as in Nordic countries and the United Kingdom. The caesium-137 in these areas will remain available to be transferred into food products for a longer time period than in agricultural environments.

Since 1986, in the agricultural environment, effective application of countermeasures resulting in significant reductions of caesium and strontium into food has been demonstrated. The level of contamination, type of soil, soil moisture, and crop type are important influencing factors. For example, depending on the type of soil, the transfer factor between pasture and milk varies by several hundred, clearly illustrating that the proper application of these actions are very site specific. Relatively simple, inexpensive and successful agricultural countermeasures include: deep ploughing of surface contaminated soils; addition of fertilizers or other chemicals to agricultural lands; change in crop type; changing feeding regimes and slaughtering times of cattle; the use of impregnated "Prussian Blue" salt licks and boli to reduce the transfer of caesium to cattle; and relocation of animals to uncontaminated pastures. *(See related article in this edition, page 38.)*

Aquatic ecosystems have been shown to be tolerant of the radioactive contamination that gradually concentrates in the sediments. Even in the cooling pond of the Chernobyl power plant, only certain populations were affected, and no long-term direct radiation effects have been documented. The amount of radioactive material that found its way into freshwater aquatic systems was small compared to the total amount deposited. The surface water activity levels fell dramatically within one month of the accident. The public's perception notwithstanding, current contamination levels in reservoirs are well below the criteria that indicate a degradation in water quality. Fish, however, may accumulate radionuclides and countermeasures may be necessary in some places (even in countries far away, such as Sweden).

Conclusions. It can be concluded that at high radiation levels the natural environment showed short-term impacts in some high dose rate areas but existence of significant long-term impacts remains to be seen; and that effective countermeasures can be taken to reduce the transfer of contamination from the environment to the human population but these are highly site specific and must be evaluated in terms of practicality. If agricultural countermeasures are appropriately implemented, the main source of future doses will be due to the gathering of food and recreational activities in natural and semi-natural ecosystems. ❐

SOCIAL/PSYCHOLOGICAL EFFECTS

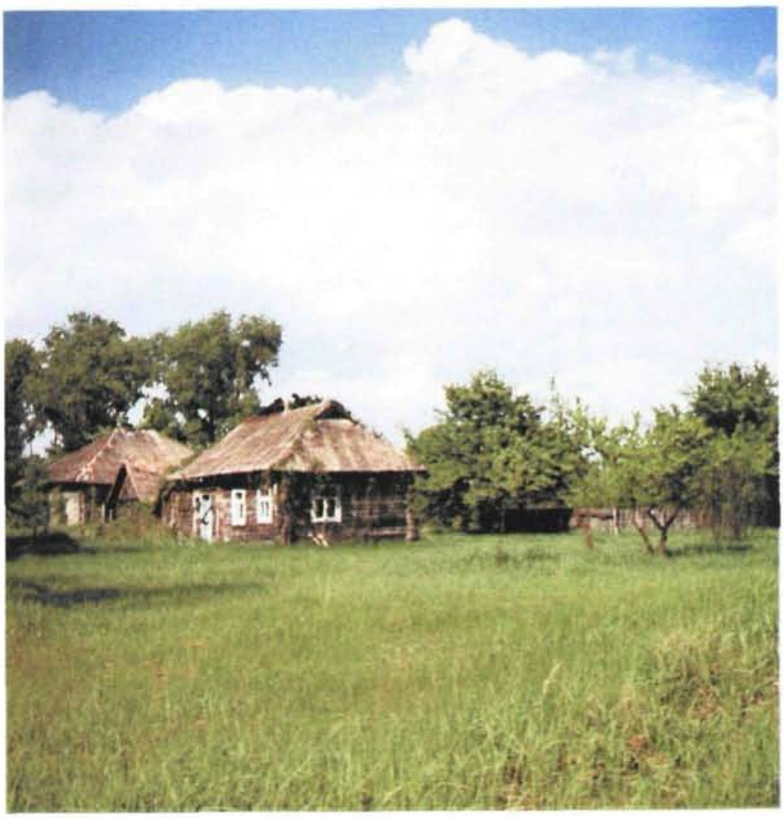
Report by Ms. Britt-Marie Drottz-Sjöberg, Centre for Risk Research, Sweden, who served as Chairperson, Topical Session 4, entitled "Other health-related effects: Psychological consequences, stress, anxiety", and by G.M. Rumyantseva, Serbsky Center of Social and Forensic Psychiatry, Moscow; A.I. Nyagu, Institute of Radiation Medicine, Kiev, Ukraine; and L.A. Ageeva, Institute of Sociology, Minsk, Belarus.*

Joint Study Project-2 — a collaboration between researchers from Europe and the Commonwealth of Independent States (CIS) and financed by the European Commission — was initiated in 1991-92 and concluded in 1995. One facet of research focused on Chernobyl's social and psychological effects.

Several investigations were designed to describe public reactions to the Chernobyl accident among directly affected people, i.e. people living in areas with different levels of contamination and people who had been resettled due to the accident. Such groups were compared to control groups living in radiologically non-affected areas. Interviews and survey studies focused on psychological reactions, including stress, experiences of personal mastery, common sentiments, and perceptions of risk related to various kinds of hazards. They also covered, for example, measures of trust in information sources, self-rated knowledge of radiation, perceived degree of radioactive contamination of the home area, and standards of living. A total of 5000 individuals were involved in the investigations.

Previous studies had shown that psychological problems associated with the Chernobyl accident were not decreasing with time. People experienced exposure to real risks, and resettled people often provided the highest risk ratings. Responses to a question about the ability to protect oneself from radioactive contamination were overall discouraging. People indicated an

*This summary is based on "The influence of social and psychological factors in the management of contaminated territories", by Ms. Drottz-Sjöberg, G.M. Rumyantseva; P.T. Allen, Robens Institute, University of Surrey, UK; H.V. Arkhangelskaya, Institute of Radiation Hygiene, St. Petersburg, Russia; A.I. Nyagu; L.A. Ageeva; and V. Prilipko, Institute of Radiation Medicine, Kiev, Ukraine. The paper was presented at the Minsk Conference, 18-22 March 1996, on "The Radiological Consequences of the Chernobyl Accident".



Inside the 30-km zone, some lifelong residents near Chernobyl have returned to the homes from which they were evacuated after the accident in 1986. Others who were relocated have not returned, leaving their former cottages, farms, and orchards abandoned. *(Credit: Eric Voice)* interest, however, in improving their knowledge of radiation and radioactive contamination. Worries were focused on health risks due to radioactive contamination, but there was also considerable concern about hardships of everyday life. Worries about everyday life increased stress. In the contaminated areas, factors specific to radiation also had effects — for example, self-attributed radiation knowledge had an effect in reducing stress.

Similarly, the extent to which people believed they could affect the amount of dose they received also reduced stress. The result furthermore indicated that people who tended to believe that things are determined by fate were somewhat more likely to have a higher dose compared to others. People who had resettled voluntarily and found the relocation justified indicated the lowest level of distress. Those who resettled involuntarily and who did not find the relocation justified reacted the strongest. Trust in various information sources was overall low, but foreign experts gained a higher rating than domestic experts, and health promotion bodies were more trusted than various political bodies.

People who paid more attention to media also gave higher ratings of everyday worry. An analysis of selected Russian, Ukrainian, and Belarussian newspapers at various points in time showed as a common feature that a great majority of the articles were written by journalists. Material written by experts, specialists, and authorities was much less frequently published, but appeared to some extent in 1986 and then again from 1989-90 onwards. Another common feature was that newspaper materials in 1986 and 1987 tended to have a soothing emotional content. Emotionally strained materials appeared more frequently around 1990 and onwards. The appearance of strained material around 1990 has been interpreted as reflecting the uncertain political climate at the time of the USSR's dissolution, and the election campaigns.

The study also demonstrated different reactions to the accident and different needs among the population, with changes over time. The differences seem to be increasing between directly affected population groups and others. In the short- and medium-time perspective, similar needs for information, behavioural recommendations, and health care seem to appear.

For the long term, however, our results point to the importance of preparedness for the emergence of new needs generated by the countermeasures themselves, e.g. relocation. The results suggest that voluntariness or personal choice are associated with less psychological distress. In Russia, relocation strategies appear to have altered the psychological outlook, as well as reduced the stress. The policy was implemented in a staged manner, being mainly voluntary, spread over time, accompanied by significant financial benefits, and facilitating the maintenance of social networks. Regarding organized health care, it may be that preparedness for immediate and large-scale medical screening is a necessity after a radiological accident, but the medium-term strategy could include other options moving away from mandatory rules, e.g. services for counselling or for measuring personal dose or food products. The long-term management of health risk could be tailored to needs of affected and vulnerable groups.

Similarly it seems that financial support and compensation strategies become very important in the immediate and medium-term perspective, but that the beneficial effects may be threatened in the longer term if they create dependency rather than enhance self-sufficiency. One lesson of relocation which is seldom addressed concerns information and support to the communities which accommodate new members. Although relocated people may be provided with newly constructed housing they will nevertheless have an impact on the local community. Well-being could be increased in the communities if long-term risk management includes a review of common resources and helps accommodate common needs.

The results of the investigations must be related to the changes introduced by the policy of *perestroika* and *glasnost*, and the intensified social uncertainty which occurred during the mid-1980s and early 1990s. The Chernobyl accident divides a more than 70-year-old social system from a new time. Its significance will therefore remain salient in people's minds for a long time. Peoples' reactions to a radiological accident may have lasting emotional, social, and economic effects on a community or society. If these reactions become better understood, the knowledge facilitates improved risk management, effective risk mitigation, optimal use of financial resources, and relief from unnecessary suffering. Our empirical studies contribute new information and knowledge due to the massive scale of investigations and detailed analyses of specific groups. Control groups have been involved to adjust for overall major social and political changes. The project has also shown the feasibility of investigating citizens' personal experiences for facilitating specific current needs and future planning. The research further has gained knowledge because of international co-operation and the personal exchange of experience and information. ❐

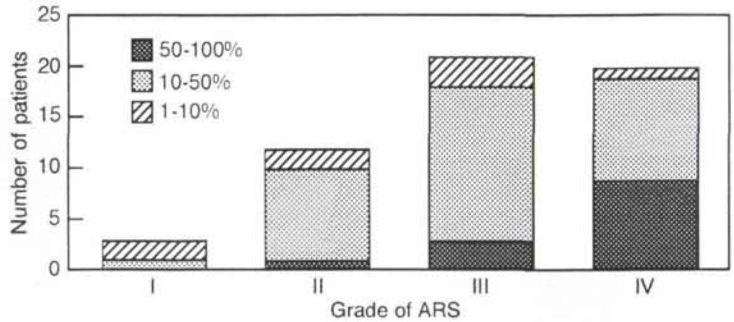
CLINICALLY OBSERVED EFFECTS

*Report by Gerard Wagemaker, Erasmus University, European Commission, who served as Rapporteur, Topical Session 1: "Clinically observed effects" and by Angelina K. Guskova, Institute of Biophysics, Moscow, Russia, who served as Session Vice-Chairwoman, and Vladimir G. Bebeshko, Scientific Center of Radiation Medicine, Kiev, Ukraine; and Nina M. Griffiths, ISPN, Fontenay aux Roses, France, both members of the Session's Expert Committee.**

When radiation doses to the tissues of a mammalian organism are large enough, there may be a partial or complete loss of function. In extreme cases, there may be complete tissue death. If the tissue is vital, it may result in death. There have been many accidents with radiation sources that have caused serious local injury, sometimes calling for the amputation of limbs.

Among the victims of the Chernobyl accident were people who were accidentally exposed to high doses of radiation. Such high-dose exposures — which acutely and severely affect blood cell production, resistance against infections, and intestinal functions — may result in severe damage to the skin. The complex of disease symptoms from such exposures is known as "acute radiation syndrome", or ARS. Its most common symptoms are initially nausea, vomiting, and diarrhea and, later on, bleeding and generalized infections with high fever, often caused by micro-organisms that are normally not harmful. If untreated, ARS is lethal, even following radiation doses which are not necessarily incompatible with survival of the human organism and are regularly used in clinical medicine to treat some forms of cancer. In an accident situation, the radiation damage is frequently even more complicated by other injury, such as thermal burns.

ARS and skin damage in Chernobyl patients



A patient with skin lesions being examed at the Institute of Biophysics in Moscow within the framework of an EU-supported project. *(Credit: Wagemaker/EC)*

The Chernobyl accident resulted in a total number of 237 individuals who were suspected of suffering from ARS. The diagnosis was confirmed in 134. Of these, 41 had mild (grade I) ARS; all survived; one additional case is still disputed. Fifty patients had grade II ARS, of whom one died. Twenty-two patients had grade III ARS, of whom seven died. Of the 21 patients most severely affected, who suffered from grade IV ARS, all died except one. Among this group, gastrointestinal damage was the most severe problem in patients who received doses greater than 10 Gy and resulted in early and lethal changes in intestinal function. Deaths in 26 patients in the first three months after the exposure were associated with skin lesions involving over 50% of the total body surface area. In general, there appeared to be a relation between ARS and the skin area damaged, indicating that almost all severely affected patients had combined injury. *(See graph.)*

The Chernobyl nuclear power plant accident led to exposure with high amounts of beta irradiation (both contamination and incorporation), causing a clinical pattern of involvement which

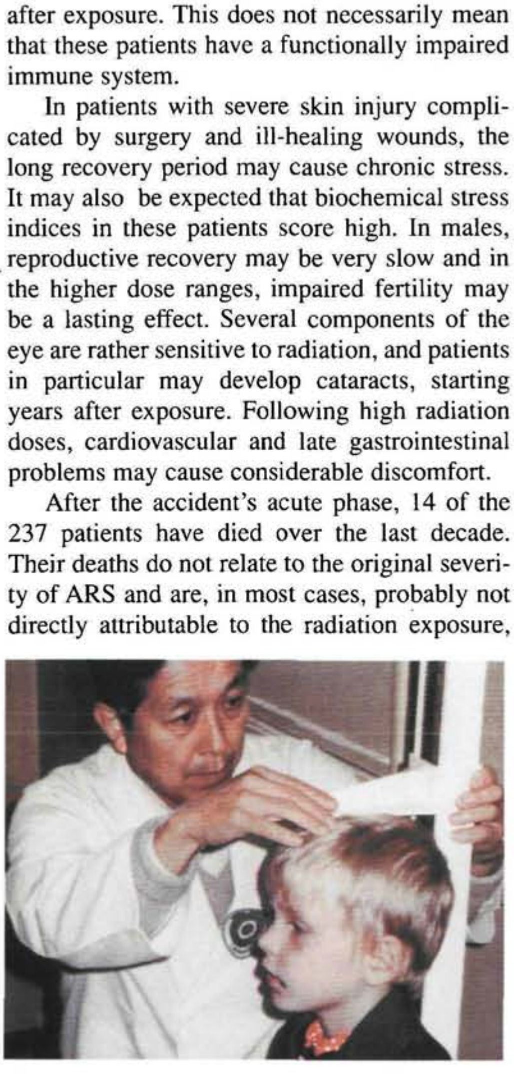
*The authors are indebted to material supplied by Alexander A. Baranov, State Research Center, Institute of Biophysics, Moscow, Russia; John W. Hopewell, The Research Institute, Oxford University, United Kingdom; Ralf U. Peter, Department of Dermatology, Ludwig-Maximilians-University, Munich, Germany; and T.M. Fliedner, Department of Clinical Physiology and Occupational Medicine, University of Ulm, Germany. Research has been partly supported by Nuclear Fission Safety contracts of the Commission of the European Communities.

was different from the experience at Hiroshima and Nagasaki. From the onset, a striking feature was the large number of patients suffering from radiation-induced damage of the skin and mucous membranes, especially of the upper digestive and respiratory tract, due to contamination by beta and gamma-emitting isotopes, such as caesium-137, caesium-134, and strontium-90. Skin lesions and/or oropharyngeal mucositis were a major contribution to the death of patients who died as an immediate consequence of the accident.

Patients surviving ARS have all been subjected to a traumatic experience with extensive physical injury and long convalescence periods. Some will bear the marks of their trauma for the rest of their lives, both in the psychological and somatic sense, just as victims of other severe accidents have done. Although the extreme bone marrow suppression may have been resolved in a couple of months, full reconstitution of immune functions may take at least half a year and may well not normalize within years after exposure. This does not necessarily mean that these patients have a functionally impaired immune system.

In patients with severe skin injury complicated by surgery and ill-healing wounds, the long recovery period may cause chronic stress. It may also be expected that biochemical stress indices in these patients score high. In males, reproductive recovery may be very slow and in the higher dose ranges, impaired fertility may be a lasting effect. Several components of the eye are rather sensitive to radiation, and patients in particular may develop cataracts, starting years after exposure. Following high radiation doses, cardiovascular and late gastrointestinal problems may cause considerable discomfort.

After the accident's acute phase, 14 of the 237 patients have died over the last decade. Their deaths do not relate to the original severity of ARS and are, in most cases, probably not directly attributable to the radiation exposure,



A physician from Japan examines a child in a village near the Chernobyl plant during the 1990 International Chernobyl Project.
(Credit: Mettler/USA)

although it is difficult to exclude an impact from the accident. In fact, five of these 14 patients did not suffer from ARS in the first place and may have received only very low doses of radiation.

The remaining patients who have suffered ARS are in general in an acceptable health condition and are being monitored regularly. There is good evidence that the quality of life of the surviving patients may be amenable to improvement. At least the more severely affected patients suffer presently from multiple diseases and are in need of up-to-date treatment and secondary prevention; also their mental health might be suboptimal. Therefore, more has to be done in the future to distinguish in the encountered disease patterns those that are attributable to the radiation exposure and those that are due to confounding factors intrinsic to the population. The follow-up of these patients needs to be assured for the forthcoming two to three decades, preferably co-ordinated by a single center of high clinical and research competence.

The Chernobyl cases have taught us that much needed (and still needs) to be improved in the clinical management of ARS in accident situations generally complicated by radiation injury to the skin and injuries that are not radiation related. There is little doubt that ARS patients, and those with severe skin injury, have received the best possible treatment in line with the state of knowledge at the time in the most experienced center available.

The therapy of bone marrow transplantation recommended at the time was of little benefit for the most severely affected patients. From today's knowledge this is understandable. In any future accident, it is inconceivable that bone marrow transplantation as applied in the most severe cases of the Chernobyl accident will be used. New agents have become available, in particular a group of cytokines collectively known as hemopoietic growth factors, which have the capacity to stimulate recovery of the blood and immune system.

Bone marrow damage can in future cases best be managed by rapid administration of hemopoietic growth factors, even though the most optimal combination and dose scheduling still needs to be worked out. However, advances in the transplantation of blood stem cells and tissue typing make it very likely that transplantation will still be considered as a life-saving supportive measure, especially in cases where bone marrow damage is too severe to expect an effective response to the newer therapeutics. Also for other radiation damage, new diagnostic tools may contribute to a more accurate prognosis and more tailored treatment. ❐

THYROID EFFECTS

Report by Prof. E.D. Williams, Cambridge University, UK, who served as the Scientific Secretary, Prof. A. Pinchera, University of Pisa, Italy, who served as Chairman, of Topical Session 2: "Thyroid effects", and Prof. D. Becker, Cornell Medical Center, USA, Prof. E.P. Demidchik, State Medical Institute, Belarus, Prof. S. Nagataki, Nagasaki University School of Medicine, Japan, and Prof. N.D. Tronko, Institute of Endocrinology and Metabolism, Ukraine, all members of the Session's Expert Committee.

The population in the area around Chernobyl, particularly southern Belarus and northern Ukraine, was exposed to high levels of fallout from the Chernobyl accident including large amounts of radioactive iodine. As the thyroid gland concentrates iodine, it was exposed to higher levels of radiation than other body tissues. The radioactive isotope of iodine, iodine-131, has been extensively and safely used in the treatment of thyrotoxicosis. Thus, the report of increased numbers of thyroid carcinoma in children in areas exposed to fallout from Chernobyl was surprising to some, both because of the previous lack of thyroid carcinoma in patients treated with radioactive iodine, and because of the very short time (four years) between exposure and the start of the increase.

This report considers the size of the increase in thyroid carcinoma after taking into account the evidence that the increase is related to exposure to fallout from Chernobyl, the isotope or isotopes responsible, and the likely future effects.

The Chernobyl accident was the first time such a large population was exposed to high levels of radioactive fallout. The amounts of radioactive material released were huge, and one of the main constituents was iodine-131. Very short-lived isotopes of iodine were also released. Direct data on the uptake of the very short-lived isotopes of iodine are not available; measurements of iodine-131 uptake were made after the time of peak uptake.

The estimated absorbed doses to the thyroid from iodine-131 in different settlements, which are not necessarily representative of the whole district, ranged from 790-2400 mGy for infants, and 190-370 mGy for adults. Exposure to short-lived isotopes of iodine increases this figure by an unknown amount, and the early estimates of thyroid dose may need recalculation. Some studies suggest that the average dose in Gomel oblast for children aged 0-7 was about 420 mGy, while doses reported in the recent Nuclear Energy Agency appraisal show that the average dose of children aged 0-7 assessed in Gomel oblast was about 1 Gy, with over 9% having doses in the range of 10-40 Gy.

In the first four years after the accident, the numbers of childhood thyroid cancers occurring in Belarus were in single figures, while in 1990, 29 cases were diagnosed, rising to 79 in 1993 and 82 in 1994. At the time of medical operation, about half of the cases showed direct invasion of surrounding tissues, while two-thirds showed lymph node metastases. Only four cases have been seen in children born after 1986, although it must be remembered that they were no more than eight years old in 1994.

At the Endocrine Institute in Kiev, Ukraine, eight to 11 cases of childhood thyroid cancer were diagnosed annually during the first four years after the accident. But the figure rose to 26 in 1990 and to 43 in 1993, with 39 in 1994. Of these cases, 60% showed soft tissue invasion at surgery, and lymph node metastases were present in 60% of cases. Only one of the 114 confirmed cases seen at the Institute was in a child born after 1986. In Russia, only one child with thyroid cancer was recorded in Bryansk oblast between 1986-89, while between 1990-94 inclusive 23 cases of thyroid carcinoma were reported in children under the age of 15 at diagnosis.

A recent survey of the histological diagnosis of the thyroid cancers from Belarus found 98% agreement in 134 cases studied jointly by staff of the Pathology Institute in Belarus and the Department of Histopathology in Cambridge. In the whole series of 298 cases seen in the Institute of Pathology in Belarus between 1990-94, a total of 98% were papillary carcinomas, 1.3% were follicular carcinomas, and 0.3% medullary carcinomas.

The findings in the cases from Ukraine were remarkably similar to those from Belarus. Of the 122 cases of thyroid cancer diagnosed in children under the age of 15 at the Institute of Endocrinology in Kiev between 1990-94 inclusive, 114 cases have been studied jointly in Kiev and Cambridge, and the diagnosis agreed in over 97% of them. Of the cancers with agreed diagnosis, 94% were papillary in type, 2% were medullary, and 4% follicular carcinomas. Material from ten cases of childhood thyroid cancer in children from contaminated areas of Bryansk, Kaluga, or Tula oblasts of Russia have been studied by pathologists from the RAMS in Obninsk and Cambridge. No tumour was present in the material available for study in one case, the remaining nine cases were all papillary carcinomas, including one papillary microcarcinoma. Overall these results confirm diagnoses of thyroid malignancy made in the CIS. They also show that while the same types of childhood thyroid cancer are seen in the exposed areas as are found in an unexpected population, types other than papillary carcinoma form only a very small proportion of the cases in the exposed areas.

The results of molecular biological studies show a close link between the type of oncogene involved and the pathological type of tumour found, so that the increased frequency of thyroid carcinoma in children in areas around Chernobyl is an increase in a particular type of thyroid tumour, papillary carcinoma, associated in many cases with rearrangement in a particular oncogene, ret. No increase has been shown in activation of the other types of oncogenes known to be associated with thyroid carcinogenesis which were studied, the three ras genes, TSHr and p53.

In Belarus, the Gomel oblast, which borders Ukraine close to Chernobyl, received the highest exposure to fallout. During 1990-94, a total of 172 cases occurred in children from Gomel, with a current population of 0.37 million children, compared to 143 cases in the rest of Belarus, where 1.96 million children live. The crude rates for childhood thyroid cancer in Gomel during 1990-94 are therefore 92 per million children per year, and for the rest of Belarus 14.6 per million children per year.

Similarly in Ukraine, the northern oblasts bordering Belarus received a much higher exposure than the remainder of Ukraine. A total of 112 cases occurred during 1990-94 in the six contaminated oblasts, with a population of 2 million children, and 65 cases in the rest of the Ukraine with a population of 8.8 million children. The crude rates for the northern oblasts of Ukraine are 10.6 per million children per year, and for the rest of the Ukraine 1.5 per million children per year.

The rates in Belarus and Ukraine before Chernobyl, and the rate in England and Wales in a 30-year study, are all about 0.5 per million children per year. We can therefore conclude that there has been a very large increase in incidence of childhood thyroid carcinoma in the areas around Chernobyl and that this is correlated to the exposure to fallout.

When the cases of childhood thyroid carcinoma occurring in Belarus are divided into cohorts based on the age at exposure to the Chernobyl accident, the ratio of observed to expected number of cases was greatest in the children who were youngest at the time of Chernobyl, and dropped rapidly with increasing age at exposure. This increased sensitivity of very young children to the effects of fallout on the thyroid is consistent with observations of the increased sensitivity of young children to the carcinogenic effect of X-radiation on the thyroid. The reduction in the chance of developing thyroid tumours with increasing age requires more observations for accurate quantification but there is a considerable difference between newborns and 10 year olds. The observations also require extension into the adolescent age group. The reduction in sensitivity with increasing age is also consistent with the lack of any carcinogenic effect of iodine-131 treatment in adults with thyrotoxicosis, although other factors are also likely to be relevant.

Several thyroid-related effects of radiation other than cancer are known to occur, of which the most obvious is the development of hypothyroidism after exposure to large amounts of either external or internal radiation. A study supported by the Sasakawa Foundation found that both nodularity and hypothyroidism were more frequent in Gomel, the area with the greatest exposure to fallout, while other conditions not related to radiation occurred at a broadly similar frequency in all five areas studied. This suggests that radiation may be linked to a high frequency of nodularity and hypothyroidism in Gomel.

The evidence presented shows clearly that there has been a major increase in histologically confirmed thyroid cancers in children in Belarus and Ukraine since the Chernobyl accident. A smaller increase has probably occurred in the Bryansk Oblast in Russia, but firm population-based evidence on the incidence of confirmed cases of childhood thyroid cancer is needed. The diagnosis of thyroid cancer has been confirmed in well over 90% of over 250 cases in both Belarus and Ukraine in an international co-operative study.

The evidence that the increase in thyroid cancer is related to isotopes of iodide present in fallout is strong but indirect. So far, no firm evidence is available of any major increase in any malignancy other than thyroid cancer in the population exposed to high levels of fallout. Increases in the incidence in a range of tumours have been reported, the scale of the increase is very much less than in the thyroid; the size of the reported increase is in the range which may make it difficult to separate a true exposure-related increase from an effect of better reporting and increased ascertainment.

It is clear that no other tumour has shown an increase in frequency comparable to that

INSIDE
TECHNICAL CO-OPERATION

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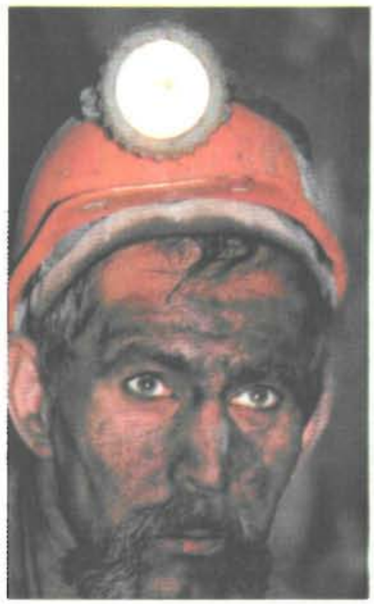
CONTENTS:

Nuclear technology cleans coal emissions

Fresh air is a luxury around Poland's northern industrial city of Szczecin, near the port of Gdansk. Heavy use of low grade coal for power generation pollutes the atmosphere with large quantities of sulphur dioxide (SO_2) and nitrogen oxide (NO_x). As a direct consequence, the surrounding forests are damaged and the incidence of many respiratory system diseases is alarmingly high.

When fossil fuels (especially coal and oil) are burned, "acid rain" is produced as SO_2 aerosols become sulphuric acid and NOx aerosols change into nitric acid by photochemical conversion in the atmosphere. Not only does acid rain destroy vegetation and buildings, the gases are also believed to contribute to "global warming." Most nations around the world are now committed to containing them, and recent global treaties require all countries to pass and implement laws limiting national SO_2 emissions.



Thousands of jobs in Poland depend on clean use of domestic coal. (Credit: PAP/CAF R.Koszowski)

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Restoring agriculture in contaminated zones

Life today in many ways appears normal in rural areas of Belarus and Ukraine affected by the 1986 Chernobyl nuclear accident. But appearance masks a serious difference: there remains virtually no market for products of these farming areas. The crops and foodstuffs do contain radionuclides, but often at levels well below the conservative limits set by the Codex Alimentarius of the United Nation's Food and Agriculture Organization (FAO) and the World Health Organization (WHO). Nonetheless, public perception continues to shun foodstuffs from contaminated areas.

IAEA technical co-operation projects in Belarus and Ukraine are seeking to address this problem by offering cropping alternatives and introducing new technologies. In Belarus, the concept is to promote production of rapeseed and convert its oil into industrial lubricants (greases, oils and other products). Belarus scientists have found that some rape varieties store radioactive nuclides from the soil — caesium and strontium (Cs137 and Sr90) are the ones of concern now — in

continued next page

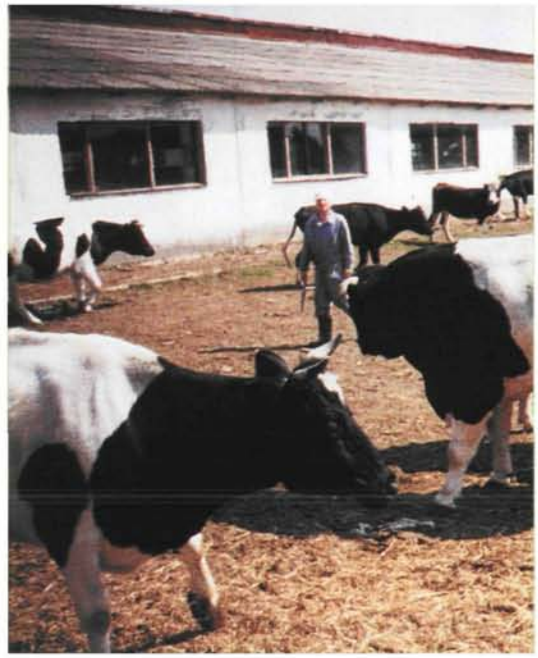
the stalk and seed coat, not in the seed. Rapeseed oil can be easily processed to make biofuels. Belarus has refineries and therefore the technology and know-how to do this.

IAEA's TC project began in 1995 by assisting its principal counterpart, the Belarus Research Institute for Soil Science and Agrochemistry (BRISSA), to identify rapeseed varieties that could provide high seed yields in that area, and optimal cultivation conditions and practices. These are crucial factors because while 200,000 ha are suitable for rapeseed, only 40,000 ha can be sown each year to comply with a five-year crop rotation regime.

Several key issues must be addressed: What can be done with the stalks? Can they be buried, or must they be incinerated? Can the protein-rich seed coat be treated to make animal feed and replace some of the expensive food concentrate that is now imported? Can rapeseed be widely grown as a sort of natural 'vacuum cleaner', just to collect radionuclides from the soil?

Over the next few years, the Belarus authorities, with technical assistance from the IAEA, will be working on these issues. The first stage is to develop a pilot plant to process rapeseed oil and produce lubricants. Already, some greases produced on a laboratory scale have been tested at the Technical University in Vienna. This development could lead to scaling up the industrialization process. The required financial support is expected, mostly through the European Union.

An important IAEA restoration effort in Ukraine focuses on milk and milk products from a factory in Ovruch, an historic northern town 100 kilometres west of Chernobyl, which once processed 550 tons of milk a day. Since the accident, production has dipped significantly because the number of dairy cows in the region has declined and milk from the affected areas has varying amounts of radionuclides. The project takes a two-pronged approach: determining the radionuclide content of milk from all sources that supply the plant, so that the agriculture ministry can identify the farms producing contaminated milk and initiate improved on-farm practices; and, at the plant itself, monitoring the level of contaminants in milk and other products during bulk processing.



Contaminated milk produced on Ukrainian farms may soon be made safe using a new process. (Credit: E. Voice)

The project is providing laboratory equipment to the plant and training personnel in using instruments to detect and accurately measure caesium-137 and strontium-90 in incoming milk and outgoing products. The milk plant director Anatoliiy Kushnirchuk is optimistic that dairy farming would increase in the contaminated areas if, in addition to on-farm help, contaminated milk could also be processed in the factory to make radionuclide-free products.

The technology to do the latter may be at hand: magnetic separation. It was recently invented by scientists in Bristol, England, to remove radionuclides from contaminated water at nuclear sites. The patent is now owned and marketed by a company called Selentec in Atlanta, Georgia. It has been tried and tested and "works very well for water... takes everything out", an expert told *Inside TC*. A large scale test for milk clean up was carried out in the US and confirmed the technology's effectiveness. Field tests in Ukraine were an astounding success. Levels of radioactive caesium-137 were reduced by 95% making the milk safe to drink. The US Government is prepared to invest US$1.5 million in a pilot plant at Ovruch.

Magnetic separation would enable the Ovruch plant to process milk products in bulk, and expand production to fruit juices and baby foods as well. There are some 1.5 million small children who would benefit from this local production of milk and foods. Safe baby food is now 'imported' from other areas and costs savings on transportation alone would be sizeable.

Only when these contaminated lands regain some economic value and produce saleable products will the economic dilemma of rural areas begin to be addressed. Rapeseed and milk products offer a promising new beginning to farm communities that have been very hard hit over the decade since the accident.

Nuclear technology *(from page 1)*

One way is to switch from coal to other primary energy sources such as hydropower, natural gas or nuclear. But for Poland these are not currently options: It has no viable hydro source; it cannot afford to pay hard currency to import natural gas from Russia; and its nuclear power programme is postponed indefinitely. For the foreseeable future, Poland must rely on its huge reserves of brown coal (estimated at over 14 billion tons). Indeed, the livelihoods of hundreds of thousands depend on the industry.

The key question is how to ensure that new industrial production is not as environmentally damaging as in the past and that gas emissions are in line with EU standards. Polish legislation enacted in the early 1990s requires utilities to progressively reduce SO_2 emissions, beginning in 1997. Technologies are readily available for removing either SO_2 or NO_x from the flue gases of individual coal fired power plants before they are emitted into the atmosphere, but to date there was none that could extract both in one single-stage process.

A coal-fired power plant in Szczecin is now the site of a four-year IAEA technical co-operation Model Project to demonstrate, on an industrial scale, a 'novel' technology that can do just that. Electron beam dry scrubbing (EBDS) works by recycling the flue gases through a chamber, before they escape from the chimney, and exposing them to low-energy electron radiation from an accelerator. As a result the toxic SO_2 and NO_x are transformed to other chemical forms. By adding ammonia to the chamber, the resulting by-product, a dry powder, can be used as fertiliser. Other cleaning systems do not have this beneficial effect and produce a lot of waste. Although it is a radiation process, no radioactivity is produced in the operation and there is no residual radiation.

EBDS was developed some 20 years ago, principally in Germany and Japan. It is novel only in that it has not been used on an industrial scale, except in demonstration plants in Germany, Japan and the United States. By the time it came out of the laboratory and became available for industrial scale use in the mid-80s, utilities in these heavily regulated countries had already fitted most older coal-fired power plants with other proven scrubbing techniques, or had committed to installing more efficient boilers that would produce less emissions.

Studies carried out in Germany, Japan, USA, as well as in Poland - where an earlier Agency technical co-operation project helped set up a pilot EBDS plant near Warsaw in 1988 - have shown that the technique is 25-30% less costly to install and to operate than conventional systems. When NO_x removal also becomes compulsory, the advantages of EBDS will be greater. The value of the agricultural by-product and the relatively much smaller waste disposal problem make it additionally attractive.

There is a strong interest in EBDS across the energy sector in Poland, among its neighbours and in developing countries that are industrialising fast and have large coal reserves. Ukraine has an ongoing programme and the Agency has just launched a new technical co-operation project to assess the option in Bulgaria.

Poland has opened the doors to the Szczecin plant, allowing the IAEA to bring visitors from other countries who are keen to see it operating. Of these, China which plans to install cleaning systems in some 60 power plants has recently contracted with a Japanese company to fit a power plant with EBDS. Further down the road are India, Indonesia, Malaysia, the Republic of Korea, Singapore and Thailand. In Latin America, Brazil, Chile and Mexico already have pilot projects and are closely watching progress in Szczecin.

The Polish Government is investing 60% of the $20 million needed to set up the EBDS system, and all the personnel and operation costs. The remaining 40% is shared between Japan, the Republic of Korea and the IAEA. Sweden and the US may also contribute. The project plant is scheduled to be fully operational by the end of 1998. Hopefully, it will show Poland a way to attain European emission standards without having to compromise industrial growth and demonstrate to the energy sector a cost efficient and environment friendly technology. Currently industrial restructuring and privatisation are influencing the energy sector and, at the end of the day, the economics and efficacy of EBDS itself may also decide its future in Poland and in many other developing countries.

Many developing countries are investigating the EBDS technology demonstrated in Szczecin. (Credit: M. Samiei/IAEA)

Getting a handle on water pollution

Protecting water resources from harmful and costly chemical, biological and radiological pollution is a high priority on the global environmental agenda. In collaboration with several national and multilateral agencies, the IAEA has been carrying out specialized scientific studies that are proving critical in plans to prevent irreversible damage to Egypt's Lake Manzala and Europe's Black Sea.

Lake Manzala is a 50 km long coastal lagoon in Egypt's Nile Delta, located Northwest of Cairo and bordered on its eastern side by the Suez Canal and the city of Port Said. The lake is a depository for large quantities of untreated city sewage and contaminants, which ultimately flow into the Mediterranean. Left uncontrolled, this pollution threatens the health and livelihood of millions of inhabitants across a densely populated region.

A pre-project study, funded by UNDP, to measure contamination in Lake Manzala was carried out with the active participation of the IAEA Marine Environment Laboratory (MEL) in Monaco. This initiative, undertaken jointly with scientists from Egypt's National Research Centre in Cairo, involved a wide sampling of water, sediment, and fish in major areas of contamination. MEL's participation centred on analyzing chemical contaminants such as chlorinated and petroleum hydrocarbons and trace elements, a task that has required specialized equipment and expertise.

Findings from the data collected enabled a comprehensive environmental impact assessment of the lake. Moreover the study has made a critical contribution toward development of an artificial wetland that would prevent pollutants from Cairo from seeping through the Nile delta into the Mediterranean. This upcoming Global Environment Facility project (GEF) will cost over US$ 11 million and will demonstrate the value of engineered wetlands as a cost-effective, ecologically sound method for trapping sediments and pollutants from municipal, industrial and agricultural sources.

Sampling of weeds to determine organic contaminants in Lake Manzala.
(Credit: M. Horvat/IAEA/MEL)

In many other locations around the world, MEL is using isotope based analytical techniques in to understand both freshwater and marine pollution problems. These techniques are very helpful in identifying contaminants, whether radioactive or not, tracing their complex pathways in the environment and investigating their biological effects.

They are now being extensively employed in assembling information on pollution of the Black Sea. Its extended river network, or catchment area, comprises some 300 rivers, extending as far as Munich to the west, Minsk to the north, and Ankara to the south. Some of Europe's largest tributaries, such as the Danube, Dniester and Dnieper, flow into the Black Sea. The larger geographical area is home to an some 160 million people.

Little more than 30 years ago, the Black Sea harboured a teeming animal and plant life, which included dolphins and monk seals. Its waters served as the breeding grounds for a vast array of fish, a vital source of protein for the six countries sharing its shores (Bulgaria, Georgia, Romania, Russia, Turkey and the Ukraine). Hundreds of thousands of eager summertime vacationers flocked to its beaches to relax, swim, and cool off.

But today, the Black Sea ranks as one of the world's most heavily polluted water bodies, with its life-supporting capabilities very seriously impaired. Across the area, beaches are regularly cordoned off due to unsanitary conditions. Commercial fishing has all but disappeared, and the tourism sector is in crisis.

Governments of the six adjacent countries have launched concerted actions aimed at stemming pollution. Responding to this strong regional commitment, international aid organizations have became involved. In 1993, the GEF started a series of large-scale projects aimed at saving the Black Sea, however none of these sought to directly address radioactive pollution, a major concern, or to apply radiochemical tracer techniques, which the Agency's MEL has several decades of experience. Following an inter-agency meeting between GEF, UNEP, the World Bank and others, the IAEA was invited to add its expertise.

MEL is now collaborating with local Black Sea scientific institutions including Turkey's Çekmece Nuclear Research and Training Centre, Ukraine's Institute of Biology of the Southern Seas at Sevastopol, Romania's Environmental Radio-activity Laboratory and Bulgaria's

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IAEA: Improving the environment

Some 25 years from now about 60% of the world's population will live in urban areas. Meanwhile the size of many cities — particularly in developing countries — is expanding beyond the capacity of infrastructure to sustainably support it. Environmental problems including water and air pollution, sanitation, ozone depletion are having serious human health consequences for many of the new "mega-cities" such as Mexico City, where air pollution contributes to 12,000 deaths per year, and Bangkok, where high lead exposure from car emissions has been found to reduce the average IQ of children.

This edition of *INSIDE TC* explains how IAEA is building new partnerships with governments and international organizations to assess and plan environmental mitigation, and apply nuclear techniques to help solve environmental pollution problems in a sustainable manner. These investigations and techniques involve a variety of applications, from studies using isotopes as tracers for selected pollutants to adaptation of electron accelerators for cleaning flue gases from fossil-fueled power plants. As described in the last edition of *INSIDE TC*, the IAEA is also an important technical resource for national programmes in water management, geothermal energy production and environmental management including the mitigation of marine pollution.

MEL scientists taking samples in the Persian Gulf. (Credit: MEL)

Guarding the oceans:

Uncontrolled human activities are putting great strains on the marine environment in many regions of the world. Cities such as Cairo, Sao Paulo, and Jakarta spew tons of pollution into the ocean every day turning coastal areas into dumps void of any underwater life and threatening the livelihood of people and the ecology of the sea. Knowledge about pollutants as well as their interaction with natural marine processes provide the basis for making informed decisions for effectively managing international waters and preventing a further degeneration of the marine environment. Only with such understanding can the right choices be made.

The IAEA Marine Environment Laboratory (MEL) helps Member States to address the problems of polluted oceans and coastal zones. Numerous analytical techniques are used to investigate radionuclide contamination, sedimentation, chemical concentrations and dispersion of waters among others. MEL's training programme both in-house and in the field aims at increasing Member States capacity to understand, monitor and protect the marine environment. The laboratory is also an international centre for analytical quality control services for radioactive and non-radioactive marine pollutants.

Selected isotopic tools in hydrological and environmental studies

Isotope systems	Chemical form	Application
^3H $^3He/^3H$ ^{85}Kr	H_2O	Indication of recent recharge; infiltration rates in the unsaturated zone; transport mechanisms: fissure flow, matrix exchange; delineation of protection zones.
$^2H/^1H$ $^{18}O/^{16}O$	H_2O	Identification of recharge areas; interconnection with surface waters; aquifer leakage; salinization mechanisms; recycling of irrigation water; identification of paleowaters.
$^{14}C/^{12}C$ $^{13}C/^{12}C$	HCO_3	Identification of paleowaters; groundwater dynamics; validation of groundwater flow models.
$^{15}N/^{14}N$ $^{18}O/^{16}O$	NO_3 NH^{+}_4 N_2	Identification of pollution sources; and of microbial dentrification.
$^{13}C/^{12}C$ $^2H/^1H$	CH_4	Identification of methane sources.
$^{34}S/^{32}S$	$SO_4^{=}$	Pollution processes in groundwater, acidification; sources of H_2S, salinity; acid mine drainage; groundwater flow in geothermal systems.

Looking into the Greenhouse

Isotopic techniques have long proved valuable in studying groundwater and improving water resource management. More recently, they have been applied to investigating "global warming" and climate changes.

Spanning more than 6 million km², the Amazon Basin contains roughly half of the world's tropical forest. This gigantic evaporative basin accommodates roughly 80,000 plant species and possibly 30 million animal species, mostly insects. The Amazon River contributes 20 percent of the world's river discharge into oceans. But accelerating deforestation is seriously threatening this unique ecosystem and, with it, the global environmental balance.

Data collected on precipitation may provide clues for a long-term solution to global warming. (Credit: J. Marshall/IAEA)

The IAEA has been working to understand this phenomenon for more than a decade. In 1985, the Agency launched a project supporting environmental research in Brazil. The multi-disciplinary, isotope-aided studies of the effects of changing land use on the ecology and climate of the Brazilian Amazon combined the efforts of some 80 scientists from several Brazilian institutes. The Agency supplied laboratory equipment and provided expert missions to co-ordinate and advise local counterparts, 23 of whom were granted training abroad. The initiative received five years' funding from Sweden and support from other research organizations outside Brazil. The joint FAO/IAEA Division and the Isotope Hydrology Section of the Agency's Division of Physical and Chemical Sciences provided technical back-up.

Concluding their work in 1993, the Amazon Basin studies validated a regional isotope model of the transport of water, revealing that 50 percent of the Basin's precipitation consists of recycled water. This high contribution of recycled water makes the water cycle sensitive to deforestation, which on such a large scale will change the regional water balance through reduction of the evapotranspiration flux to the atmosphere. This causes more water to run off to the rivers and local temperatures to rise. Results from today's climate models suggest, moreover, that a complete and rapid destruction of the Amazon forest would be irreversible, having serious consequences not only for the local but also for the global climate.

The Amazon Basin studies are but one example of the widening scientific concern that large-scale human activities — such as deforestation and energy production — may significantly alter the world's climate in the near future. Global warming due to the steadily increasing concentrations of the so called "greenhouse" gases (GHGs) is one part of that impact. Naturally occurring GHGs, primarily water vapour and carbon dioxide (CO_2), are vital in regulating the temperature of the earth and its atmosphere. However, excess emissions — mainly of CO_2 from the combustion of fossil fuels, methane (CH_4) produced from agricultural production and chlorofluorocarbons (CFCs) synthesized in various industrial processes — could cause temperature and rainfall patterns to shift and natural ecosystems to be destroyed.

So far, it appears that man-induced changes on the climate are fewer than those occuring naturally. Nevertheless, climate change remains a serious long-term concern because any alteration in the radiative balance of the atmosphere will lead to changes in evaporation and precipitation. To understand the complex processes regulating the global ecosystem, an integrated research approach needs to be taken involving analysis of both present and past climate changes. Here again, environmental isotopes are powerful investigative tools.

The IAEA-initiated Global Network for Isotopes in Precipitation (GNIP) became operational in 1961 when a world wide survey of the isotope composition of monthly precipitation began in collaboration with the World Meteorological Organization (WMO). The

continued next page

In Brief: Updates of stories and news events

Partnership with Uppsala University develops

The IAEA is a Board member of the International Science Programme (ISP) of the Uppsala University in Sweden, which promotes research capacity in developing countries through the exchange of scientists and post-graduate education in physical and chemical sciences among others. The Agency is making arrangements with Uppsala University to strengthen co-operation in two areas.

To benefit from their so called "sandwich programme", Agency fellows receive training both in-country, in Sweden and in other nordic countries under ISP supervision to obtain advanced degrees and return home to train others in the application of nuclear techniques for scientific and economic development.

This IAEA sponsored training activity is specially targeted at LDC's, and a dozen candidates from Ethiopia, Namibia, Senegal, Sudan and Zaire have already been selected. The IAEA is also securing Uppsala's active collaboration for the implementation of TC projects in fields of mutual interest such as environmental monitoring and treatment of industrial waste water.

Interested undergraduate students in related disciplines should contact their national Atomic Energy Commission for further information.

Sterile flies released throughout Zanzibar

An eradication trend continues to be documented through field data recording "zero wild fly capture" over the last several weeks. The female tsetse colony size at Tanga, Tanzania has grown to 635,000 enabling a production of over 80,000 sterile males per week. The project management team has decided to expand aerial releases of sterile males from the southern part of the island to cover its entirety (see Cattle Killer meets its match, *INSIDE TC*, March 1996).
During a field visit by the Director General in early May, a Zanzibari herdsman stated that his cattle were healthier and stronger since the wild tsetse fly population had been reduced.

Looking into *(from page 6)*

primary aim was to collect systematic global isotope data (oxygen-18, deuterium and tritium) to characterize the spatial and temporal variability of isotope concentrations in precipitation. The data gathered has been used extensively in hydrological investigations within the scope of water resources inventories, planning and development.

The network started with around 100 meteorological stations collecting data from more than 60 countries and territories. Some years later, the total number of stations in operation reached 220. The network's database has also proved indispensable in palaeo-climatology, and provides important input for verifying and improving atmospheric circulation models.

In support of these global investigations, the Agency has provided training and equipment in isotope applications through 13 technical cooperation projects during the last 10 years at a total budget of $28.1 million. Over 100 scientists from developing member states have been trained in related disciplines through workshops and training courses during the period. Support continues to be provided through coordinated research programmes (CRPs) that support national environmental investigations. For instance, Argentina is participating in a CRP to reconstruct paleoclimatic and palaeoenvironmental conditions during the last glacial cycle (20,000 years ago), in cooperation with 13 other countries. Argentina's lead scientist on the project is Dr. Hector Osvaldo Panarello of the National Atomic Energy Commission, who participated in Agency training courses in Latin America during 1991 and 1993. Initial results from the project are quite significant as they reveal a temperature difference between Holocene and the Last Glacial Maximum of about 5 degree Celsius. These results have important implications for the modeling of global climate.

Getting a handle *(from page 4)*

National Institute of Meteorology and Hydrology. Technical co-operation is helping build local scientific capacity and quality control, with the goal of assembling reliable and representative baseline data, and ultimately enabling recipient institutions to undertake pollution monitoring activities on their own.

Within two to three years, the four countries currently participating in the project will be able to analyze marine samples for all the significant radionuclides, and to apply radiotracer techniques to study the behaviour of non-radioactive pollutants. For the first time, they will have in their own hands the tools to assess the ecological destiny of the once bountiful Black Sea. With such knowledge in hand, the burden shifts to the region's decision-makers, business enterprises and the wider public to translate this scientific knowledge into positive environmental action.

Tracking pollution in the River Plate

Montevideo is justifiably proud of its urban beaches which lie, in long stretches, along the Uruguayan capital's frontage on the River Plate. But pride has been invaded by concern in recent years as routinely taken samples began to show coliform bacteria in excess of 3,000 per 100 millilitres. This level of bacterium indicates the presence of sewage, but its exact source was unknown.

The River Plate is an unusual river. It would be a sea if its water was clear and salty. In fact it is a giant basin formed by the outflow of two great rivers, Parana and Uruguay. Shaped like an inverted funnel it flows in a northwest-southeast direction, between Argentina and Uruguay, into the Atlantic Ocean. Where the brown river meets the blue ocean it is more than 100 kilometres wide.

Nor are the pollution problems of the River Plate limited to organic matter. The vast basin is brimming with industrial wastes from hundreds of small tanneries around Montevideo Bay and effluent from Uruguay's premier port. The once popular beach resort of Carasco has been closed for many years because of high pollution. Most of Montevideo's 1.5 million people live quite close to the river and the basin is heavily used for fishing and recreation. But resources and data to address growing environmental problems are limited and much remains unknown.

Montevideo has been constructing a modern sewage system for many years but it remains incomplete. A lot of raw sewage is deposited into two small rivers, Pantanoso and Miguelete, which pollute Montevideo Bay and the River Plate. The main part of the present engineered disposal system uses a well-tried technology called an "outfall" that pipes sewage from a coastal station and discharges it in the

Pollution threatens Uruguay's beaches. (Credit: J. Marshall/IAEA)

Plate, several kilometres away and at a depth of about 10 metres. Sewage is discharged at a pressure calculated to disperse it so that bacteria die-off is achieved.

Tracking the movements of sewage and other pollution in this vast expanse is a herculean high tech task. An IAEA technical co-operation project that began in 1991 used isotopic techniques to establish that sewage from far out in the river could flow back infrequently to the beaches when specific riverflow, tides, winds and ocean currents combined. But it has also confirmed, happily, that the outflow system is functioning well. Project-generated data on the river dynamics are being used as inputs in city plans by the Uruguayan Ministries of environment, health, and industry as well as the Montevideo Municipal Authority. They are now working in partnership with the directorate of nuclear technology (DINATEN), which is the IAEA's counterpart to monitor pollution and plan remedial action.

Through project-provided training, know-how and technology — including gamma counters, a gamma detection system and an automatic multi-sample analyser, and devices for water sampling at various depths — DINATEN and the municipal authority have improved their environmental monitoring capabilities.

Other IAEA technical co-operation projects have been planned to help in a systematic manner. While the initial project focused on water flow patterns, a second, now being completed, used isotopes and fluorescent tracers at various points of the basin and ocean side of the city, to study the movement of sediment. A new project, expected to start in 1997 will analyse the contaminant load of sediment in and around the bay and the 'age' of the contaminants so that the planners know what has been deposited there in the past 30-40 years. Expert services and training will be provided to prepare the very special field equipment such as dredges with detectors, and to do the tracer injections and measurements. The technique to date sediment using environmental lead-210 will be applied for the first time in the basin.

Step by step the scientific evidence generated through isotopic techniques is providing the foundation for the Uruguayan authorities to formulate sound environmental policies and take effective remedial action. It is a long-term process requiring a solid developmental partnership--one that the IAEA has committed itself to in Uruguay and in many other developing Member States.

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seen in the thyroid. This makes it highly likely that exposure to radioactive isotopes of iodine is responsible for the thyroid cancer increase. Radioistopes of iodine are known to have been present in high levels in the fallout; they are very greatly concentrated in the thyroid gland, so that the radiation exposure in the gland is many times that of other tissues. Absolute proof of the causal relationship between exposure to radioiodine and the development of thyroid cancer is not available, but the circumstantial evidence is very strong, and no other plausible explanation for the increase is available.

It is not possible to predict with certainty whether the relative high risk for the development of thyroid cancer will remain at its present figure; more than five years of observation are needed. It is possible that follicular carcinomas have a longer latent period than papillary carcinomas, and that they may increase in incidence in later years. Evidence from external radiation suggests that the relative risk increases up to 20 years after exposure, then declines. But an increased risk is still present at 40 years after exposure and it would be prudent to make this assumption when considering the likely future rates of occurrence of thyroid carcinomas in the exposed population.

If the future risk is estimated on the basis of present trends in the exposed areas using a relative risk model, then the incidence of those exposed as children in Gomel will be about 200 times that of the United Kingdom. There are many uncertainties, and an exact prediction of the expected numbers of thyroid carcinomas in the future is not possible. However, it would be prudent for advance planning of screening and health care to consider that a large increase is a possible outcome.

Thyroid carcinoma in adults is in most cases a tumour of relatively low malignancy, causing death in only a minority of cases. It is rather more aggressive in very young children, and a long follow-up period is needed. The number seen in Belarus and Ukraine constitutes a major challenge, both for treatment and for our understanding of the relationship between exposure to fallout from a nuclear accident and the subsequent development of malignancy.

The increased susceptibility of very young children to the subsequent development of thyroid carcinoma needs further study, but it may be possible to target screening to the cohorts most at risk. ❐

HEALTH EFFECTS

Report by Dr. Fred A. Mettler, University of New Mexico, United States, who served as Chairman of Topical Session 1: "Clinically observed effects". This report reviews the health hazards as investigated by the International Chernobyl Project, which was conducted in 1990.

The International Chernobyl Project (ICP) was conducted during 1990 about four and a half years after the accident. The health effects portion of the project represented the combined effort of about 100 physicians and scientists from 12 countries. The project was difficult due to the very large area of heavy contamination that extended for hundreds of kilometres from the reactor site. Ultimately, the project was designed using an age-matched cohort comparison from nearby uncontaminated settlements.

The ICP was specifically designed to study issues related to persons still living on highly contaminated territories. These persons were continuing to receive radiation exposure and there were pressing issues related to intervention and potential dose reduction. It was well known that there were hundreds of thousands of emergency workers who had been exposed, but in 1990 there was no possibility for dose reduction in these groups. Both the International Red Cross and the World Health Organization had sent health assessment teams to the area in 1988-89. These were relatively small projects, but reached essentially the same conclusions as the ICP did.

There have been a number of publications relative to the ICP, including brief summaries and overviews. The Technical Report is more than 500 pages. Its extensive scientific explanation, limited availability, and price have undoubtedly deterred many people from actually reading it. Summaries are the most commonly available literature on this project and it is these that have been read by the public and media. Persons with a serious interest in this subject, however, should obtain and read the Technical Report that was approved by the project's International Advisory Committee.*

It is important to examine the specific findings of the ICP health effects group and see how they have held up in light of an additional five

*_The International Chernobyl Project: Technical Report_, STI/PUB/885, (ISBN 92-0-129191-4) published by the IAEA, Vienna (1991).

years of research which was presented at the International Chernobyl Conference in April 1996.

The health effects group collected extensive data on a number of concerns expressed by local physicians. A few examples of issues that we were able to address and bring to closure are given here. While there were children with anaemia, there was not a difference between clean and contaminated settlements. Lead poisoning was a concern of many parents as a result of potential emission of materials dumped on the destroyed reactor. Children in all villages had blood lead levels which were generally lower than those normally found in Western Europe and the United States. These and a number of other ICP findings have since been corroborated by other groups.

With regard to immune issues, it was clear in 1990 that overall lymphocyte levels were not affected. In the ICP Technical Report, it was stated that "the independent medical team remains unable to state absolutely that there are not some subtle immunological changes in the population; however, if there are such changes they appear to be of little clinical importance." While some papers about immunological abnormalities were proffered to the Chernobyl Conference in April 1996, these were at significant variance with each other, both in terms of their findings and the time course. While there have been claims in the media of "Chernobyl AIDS", there were no papers nor was there a general consensus at the Conference to support this concept.

The ICP concluded in 1990 that there were significant non-radiation related health disorders in both control and contaminated settlements. Between 10% to 15% of persons examined were in need of prompt medical treatment. Hypertension and dental care were pointed out to be major public health problems. This has been supported by subsequent work of other groups. In the last five years, the average lifespan in most of the former Soviet Union has decreased due to non-radiation related health problems such as stroke, heart disease, accidents, suicide, and alcoholism.

The ICP health effects teams spent the majority of their effort on children. Up to 1990, fetal malformation data did not show evidence of a significant radiation related increase. Comments and papers presented at the 1996 Chernobyl Conference about this emotional issue indicated that while most scientific groups feel that there has been no radiation-related increase, there still are some persons who feel that there has been an effect.

Psychological investigations of the ICP showed that up to 90% of persons living in contaminated settlements thought they had, or might have, an illness due to radiation exposure. Interesting enough, in clean settlements the comparable percentage was 75%. The psychological issues were summarized in the Technical Report by stating that, "The psychological problems related to Chernobyl are major. Most of the people have genuine concerns and are not acting in an irrational fashion, given their circumstances." These findings have since been corroborated by many scientific groups and the many speakers at the 1996 Chernobyl Conference concluded that this remains the major health effect today.

Obviously there were (and still are) concerns about thyroid problems. This related primarily to thyroid enlargement, nodules, and cancer. In 1990, about 3% of children were found by palpation to have enlarged thyroids and 0.5% had nodules. But there was no statistical difference between clean and contaminated areas. Papers presented in the last five years and proffered to the 1996 Chernobyl Conference indicate little consensus about whether there is now an increase in thyroid nodules.

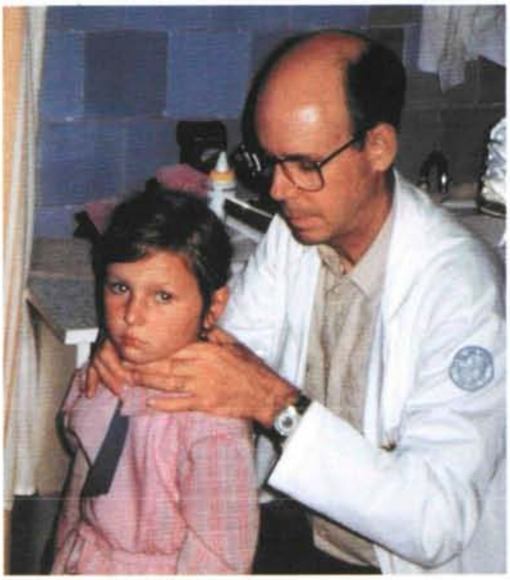
A major portion of the ICP was directed toward estimation of future health effects, particularly leukaemia and cancer. A 1990 review of health data showed that cancer had been increasing each year, both before and after the accident. The rate of increase appeared to be stable. The incidence of cancer has continued to increase at about the same rate in the last five years but the major cause of recent reduction in lifespan has not been due to cancer.

Thyroid cancer was a major concern in 1990. In the Technical Report (page 510), we stated that "available data reviewed did not provide an adequate basis for determining whether there had been an increase in leukaemia or thyroid cancers as a consequence of the accident. The data were not detailed enough to exclude the possibility of an increase in the incidence of some tumour types."

The health effects group also was asked to estimate future and lifetime health effects. Since we did not know the exact doses for each of the thousands of contaminated settlements nor the number of persons in each, the ICP gave an example of a representative settlement and what the expected consequences might be. We used a hypothetical settlement of 10,000 persons with

a dose from external radiation of 0.1 Sv over 70 years. In such a typical village, we predicted that thyroid cancers would almost double, that there would be about a 40% increase in leukaemia, and about a 3% increase in all cancer deaths over 70 years. The ICP Technical Report stated that "most of the thyroid cancers would be expected to occur in children because of their larger absorbed thyroid dose, longer lifespan, and increased sensitivity relative to adults" and that "with the large release of radioiodine during the accident, it is expected that there will be a radiogenic excess of thyroid cancer cases in the decades to come. This risk relates to thyroid doses received in the first months after the accident."

The ICP also indicated that "reported estimates of thyroid dose in children are such that there may be a statistically detectable increase in the incidence of thyroid tumours in the future" and that "certain high risk groups (such as children with high absorbed thyroid doses) will need specific medical programs based on their potential risks." We did point out that with limited resources, it would be too costly and impractical to follow all persons who were exposed and that the concept of WHO to concentrate on combined international studies for high-risk populations should be endorsed. This recommendation has not come to pass and there remain multiple competing scientific investigations that cover identical issues, particularly related to thyroid cancer and leukaemia.



Medical doctors on the ICP health team examined hundreds of children living in towns of Belarus, Russia, and Ukraine. More than 100 physicians and scientists from 12 countries took part in the 1990 project. *(Credit: Mettler/USA)*

In summary, the International Chernobyl Project represented an historic event. It was an unprecedented international effort with co-operation between scientists, physicians, and just plain people. The health effects group findings helped focus attention to areas of importance. The subtitle of the 1996 Chernobyl Conference was "Summing Up the Consequences of the Accident". There is the implication that the issue is finished. It is clear from the atomic bomb survivor data that any final summary of consequences from large radiation exposures of a population will take at least five decades and not just one decade to complete. Effects in children and psychological issues will remain at the forefront. ❒

LONG-TERM HEALTH EFFECTS

Report by E. Cardis, International Agency for Research on Cancer, France, who served as Scientific Secretary of Topical Session 3: "Longer-term effects," Prof. A.E. Okeanov, Centre for Medical Technology, Belarus, who served as the Session's Vice-Chairman, and by V.K. Ivanov, Medical Radiological Research Centre, Russian Federation, and A. Prisyazhniuk, Scientific Centre for Radiation Medicine, Ukraine, who both served on the Session's Expert Committee.*

If the experience of the survivors of the Japan atomic bombing and of other exposed populations is applicable, the major expected radiological impact of the Chernobyl accident will be deaths from cancer. The total lifetime numbers of excess cancer deaths will be greatest among the "liquidators" (emergency and recovery workers employed in 1986-87) and among the residents of "contaminated" territories. Any estimate of this excess is very unclear because of uncertainties in individual doses and in the exact magnitude of effects of low-dose protracted radiation exposure. Currently, however, our best estimates are: some 2000 extra cancer deaths lifetime among almost 200,000 liquidators from 1986 and 1987; and 4600 deaths among some 6.8 million residents of contaminated territories. Increases of this magnitude would be extremely difficult to detect epidemiologically against an expected background number of 41,500 and 800,000 cancer deaths, respectively, among the two groups.

On the basis of the data from other populations exposed to radiation, the major radiological impact expected to date (i.e. within the first ten years after the accident) is leukaemia. The increase is mainly expected among liquidators; indeed, if the experience of the atomic bomb survivors is applicable, the increase in this population should be detectable epidemiologically. Increases in leukaemia among liquidators have been reported, but they are not consistent. They are, moreover, difficult to interpret: the cases have not all been verified yet and the increases may reflect the effect of increased surveillance of the liquidators and under-registration of cases in the population in countries where systematic centralized cancer registration was limited at the time of the Chernobyl accident. No consistent increase has been reported to date. However, the present reports concern only a two-year period and the ability to detect such an increase is much reduced.

Increases in thyroid cancer among those exposed as children were observed in the more heavily contaminated regions of Belarus, Ukraine, and Russia, at rates much higher than predicted from previous studies. These increases may reflect either particular sensitivity of the population, due to host or environmental factors; or under-estimation of doses to the thyroid; or a higher carcinogenic potential of very short-lived iodine isotopes. Increases in thyroid cancer are now also reported among liquidators and the general population; for reasons mentioned above, these must, however, be verified before attributing them to the Chernobyl accident.

There is a tendency to attribute fluctuations and/or increases in cancer rates over time to the Chernobyl accident. It should, however, be noted that increases in the incidence of several neoplasms have been observed in some countries in the last decades, prior to the accident. A general increase in mortality has been reported in recent years in many regions of the former USSR which does not appear to be related to radiation levels. This must be taken into account when interpreting the results of studies.

Increases in the frequency of a number of non-specific detrimental health effects other than cancer among exposed populations, particularly among liquidators, have been reported. It is difficult to interpret these findings because exposed populations undergo a much more intensive and active health follow-up than the general population.

Based on results of animal experiments, it is possible that in addition to cancers, a small increase in hereditary disorders may occur following radiation exposure. On the basis of these data, the predicted occurrence of genetic effects induced by radiation from the accident would be very low, ranging from 0 to 0.03% of all live births and from less than 0.1% to 0.4% of all genetic disorders among the live births to the exposed population.

When considering predictions of the likely health effects of radiation from the Chernobyl accident, it is important to recognize that the current estimates of doses to exposed populations are uncertain; in particular, doses received early after the accident are not well known. The

* The authors are indebted to L. Anspaugh, Lawrence Livermore National Lab, United States, a member of the Expert Committee, and to consultants K.Mabuchi, Radiation Effects Research Foundation, Japan, and I. Lichtarev, Department of Scientific Centre for Radiation Medicine, Ukraine.

exposures received by populations due to the Chernobyl accident are, moreover, different (in type and pattern) from those of the survivors of the atomic bombing of Japan. Predictions derived from studies of those populations are therefore uncertain. Although an increase in thyroid cancer in children as a result of the Chernobyl accident was envisaged, the extent of the increase was not foreseen. Only ten years have passed since the accident, and on the basis of epidemiological studies of other populations, any increases in the incidence of cancers other than leukaemia are usually not visible until at least ten years after exposure. Therefore it is essential that monitoring the health of the population be continued to assess the public health impact of the accident, even if an increase in cancers caused by radiation from Chernobyl (except leukaemia among liquidators and thyroid cancer) may be difficult to detect.

Epidemiological studies of selected populations and diseases are also needed in order to study observed or predicted effects; careful studies may in particular provide important information on the effect of exposure rate and exposure type in the low to medium dose range and on factors which may modify radiation effects. As such, they may have important consequences for the radiation protection of patients and of the general population in the event of any future accidental exposure. Both cohort and case control studies are generally much more powerful than descriptive studies for investigating dose relationships. To be informative, however, studies of the consequences of the Chernobyl accident must fulfill several important criteria: they must cover very large numbers of exposed subjects; the follow-up must be complete and non-selective; and precise and accurate individual dose estimates (or markers of exposure) must be available. In particular, the feasibility and the quality of epidemiological studies largely depend on the existence and the quality of basic population-based registers, and on the feasibility of linking information on a single individual from different data sources.

In conclusion, ten years after the Chernobyl accident, there is, apart from the dramatic increase in thyroid cancer in those exposed as children, no evidence of a major public health impact to date of radiation exposure as a result of the Chernobyl accident in the three most affected countries. No major increase in all cancer incidence or mortality has been observed that could be attributed to the accident. In particular, no major increase has been detected in rates of leukaemia — even among liquidators — one of the major concerns after radiation exposure. This is generally consistent with predictions based on studies of other radiation-exposed populations, in particular the survivors of the atomic bombings in Japan. ❒

Press briefing at the International Chernobyl Conference, where the accident's health effects commanded close attention.
(Credit: Pavlicek/IAEA)

AGRICULTURAL COUNTERMEASURES

Report by John I. Richards, Head of the FAO/IAEA Agriculture and Biotechnology Laboratory at the IAEA's Seibersdorf Laboratories, who was a designated FAO participant at the International Chernobyl Conference, and Raymond J. Hance, Head of the Agrochemicals and Residues Section of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture.

One of the lessons of Chernobyl is that farming is vulnerable to the effects of a nuclear accident hundreds, even thousands, of miles away from the site. Therefore plans are needed for countermeasures that can reduce contamination of agricultural produce, regardless of whether or not a country has its own nuclear programme. The primary aims of such plans should be to minimize radioactive contamination of crops and animal products and return the land to productive use as far as, and as soon as, possible. These aims must balance the costs to governments with the benefits to human health, and the disruption to daily life with the well-being of communities. The plans need to specify radiation levels for foods and feedstuffs at which intervention is necessary and to include a range of countermeasures to be taken to protect agriculture under a range of possible post-accident situations.

Criteria for setting intervention levels have been established internationally. In general, food legislation prohibits unsafe levels of contamination and does not distinguish between contaminants whether they are pesticide residues, heavy metals, mycotoxins, pathogenic microorganisms, or radionuclides. At low levels of contamination, where the risk to health is low or difficult to eliminate altogether, contaminant levels are set which allow for foods to be sold, bought, and consumed. The limits must be unambiguous so that they can be easily understood by all concerned in administering them.

The FAO/WHO Codex Alimentarius Commission has developed international standards for radionuclide contamination to be applied to food moving in international trade. *(See table.)* Many countries have adopted these in their national legislation, not least because internationally recognized intervention levels help to maintain credibility, confidence, and trust in national authorities and prevent anomalies that might otherwise occur along borders of neighbouring countries. In addition Codex standards will be applied by the World Trade Organization.

The levels are based on a number of conservative assumptions in order to be confident that there will be essentially no effect over a lifetime of exposure. Hence, if alternative food is not available, higher values would be acceptable in the short term. On the other hand, lower levels may be appropriate, for example if external radiation makes a high contribution to the total dose.

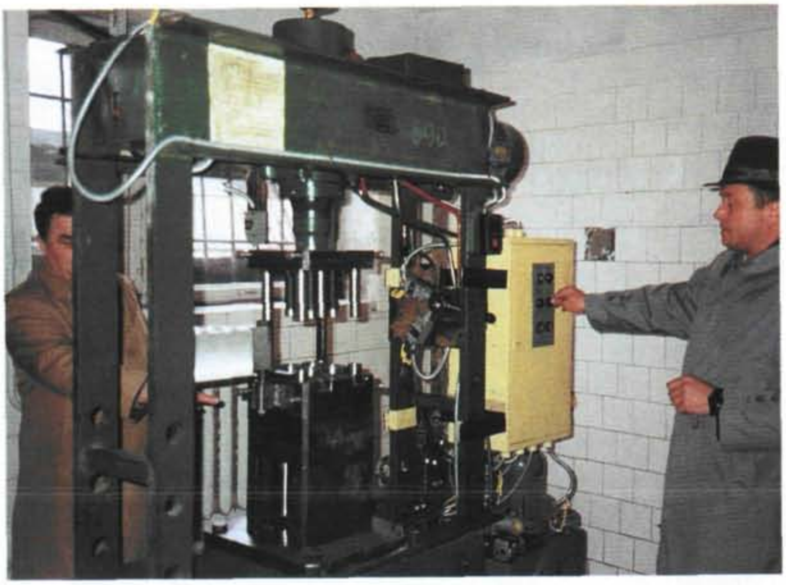
Against this background it can be seen that an important purpose of agricultural countermeasures is to maximize the quantity of food produced which passes intervention criteria.

Agricultural countermeasures

The Joint FAO/IAEA programme on nuclear techniques in food and agriculture has approached agricultural countermeasures in three ways. The first was to bring together as much as possible of the information and experience acquired after the Chernobyl accident in order to prepare guidelines for agricultural countermeasures. The second was to assist affected Member States to develop and implement particular countermeasures. The third was to support work to generate data that can be used to refine existing countermeasures or develop new ones.

Guidelines for Agricultural Countermeasures Following an Accidental Release of Radionuclides (IAEA Technical Reports Series No. 363, 1994). The Chernobyl accident stimulated considerable scientific research and much practical experience was obtained by those dealing with its consequences. This document, prepared by nearly 40 scientists from 19 countries, summarizes the information generated. It aims to give general advice on the development of emergency response plans. The main elements are a general strategy for the introduction of agricultural countermeasures, a review of available countermeasures for use in decision-making, and guidance for the preparation of specific national guidelines. (A Russian translation of the document is available as IAEA TECDOC-745.)

The effectiveness of measures taken to protect the agricultural sector (people, land, crops and livestock) from the effect of a nuclear accident depends on plans prepared in advance. The *Guidelines* outline a strategy for the development of such emergency plans which should not



In southern Belarus, where areas were affected by radioactive fallout from the Chernobyl accident, small farmholders are applying countermeasures to reduce levels of contamination in milk, meat, and other products. They are being assisted through projects supported by the Norwegian government and the FAO/IAEA programme. Shown here is a typical small farm in the region; equipment for mixing "Prussian Blue" compounds and for making boli which are used to reduce radiocaesium levels in cows; and scientists monitoring the body gamma radiation of livestock given Prussian Blue. *(Credit: Richards/IAEA)*

Guideline levels for radionuclides in foods following accidental nuclear contamination for use in international trade

Dose per unit intake factor	Representative radionuclides	Level (Bq/kg)
	Foods destined for general consumption	
10^{-6}	Americium-241, Plutonium-239	10
10^{-7}	Strontium-90	100
10^{-8}	Iodine-131, Caesium-134, Caesium-137	1000
	Milk and infant foods	
10^{-5}	Americium-241, Plutonium-239	1
10^{-7}	Iodine-131, Strontium-90	100
10^{-8}	Caesium-134, Caesium-137	1000

Notes These levels are designed to be applied only to radionuclides contaminating food moving in international trade following an accident and not to naturally occurring radionuclides which have always been present in the diet The Codex Alimentarius Guideline Levels remain applicable for one year following a nuclear accident By an accident is meant a situation where the uncontrolled release of radionuclides to the environment results in the contamination of food offered in international trade

only specify criteria for taking prompt short-term action but also criteria for longer term action which will do much to sustain public confidence in the competence and integrity of the authorities

The *Guidelines* recognize two distinct phases in which to consider countermeasures. In the planning and preparation of responses to an accident, possible protective actions should be assessed in a general way in relation to a range of credible accident scenarios. From this, the first criteria for action to be used immediately and for a short time after an accident can be developed. These plans require a database which includes information about the transfer of the radioisotopes of caesium and strontium between local soil, water, plants, animals, and fish. These are the isotopes most likely to cause more than transient problems to agriculture. In addition, data on soils, weather patterns, local dietary preferences, and some feasible countermeasures with estimates of their costs should be included A network of laboratories for radionuclide analysis must also be identified.

The second phase begins some time after a real accident has happened when specific information on its nature and likely consequences is available. Specific protective measures can then be considered. However, in many cases the choice of countermeasures will be constrained by social factors and infrastructure of the region, so it is important that the database for decision-making includes this information too.

The *Guidelines* then go on to consider particular agricultural countermeasures with some assessment of their efficacy. Such countermeasures address long-term health effects in the human population; the more immediate impact of radiation exposure on plant and animal life is not directly considered.

Some measures can be taken before and during deposition of radioactive fallout, such as housing animals and covering feed/food stores. Given adequate warning, it may be possible to harvest a crop (grass, grain, cash crop) before deposition occurs.

Countermeasures applied during the first few weeks after deposition are concerned particularly with reducing exposure from short-lived radionuclides such as iodine-131. Thus, crops may be harvested and stored, or harvesting may be delayed, to allow for radioactive decay before consumption. Similarly, milk contaminated with iodine-131 can be converted to storable products (e.g. milk powder, cheese).

Once radioactive contamination is distributed through the biosphere, a wider range of countermeasures needs to come into play which takes into consideration the transfer of the relevant radionuclides from soils into the food chain. For example, since mineral uptake by plants is related to the total available and relative abundance of their different ions, the application of high levels of potassium fertilizer can reduce radiocaesium uptake; and liming, by increasing calcium levels can reduce radiostrontium uptake. Sometimes it is possible to use alternative crops or varieties that accumulate lower levels of radionuclides than those normally grown in a region — for example, cereals in place of leafy vegetables and pasture Another possibility is to grow crops such as sugar-beet or oilseed rape where the edible product is processed and contamination reduced. In order to maintain some form of agriculture wherever possible, the production of non-food crops such as flax and cotton for fibre, oilseed for lubricants or biofuel, and ornamental plants must be considered. Finally, burying the contaminated surface of the land by deep ploughing can be an effective procedure for large farms provided the proper ploughs are available

Contamination of animal products can be reduced most effectively by limiting their intake of radionuclides or reducing their absorption. Feeding uncontaminated stored feedstuffs is an example of the first category while the use

Level of pasture contamination (Bq/kg)	*Intake/day (kBq)	Meat		Milk	
		Caesium-137 level equilibrium (Bq/kg)	Caesium-137 level following boli (Bq/kg)	Caesium-137 level equilibrium (Bq/kg)	Caesium-137 level following boli (Bq/kg)
250	17.5	280	90	112	34
500	36	700	234	280	94
1,000	70	1,400	450	550	186
1,500	105	2,100	700	840	280
2,000	140	2,800	920	1,120	374
3,000	210	4,200	1,400	1,680	560
5,000	350	7,000	3,000	2,800	920
10,000	700	14,000	4,600	5,600	1,860

The table illustrates the relationship between levels of pasture contamination and caesium-137 levels in meat and milk, and the effect on meat and milk levels of administering boli.

*Assumes daily intake of 70 kg fresh herbage/animal.

of Prussian Blue (discussed in more detail later) is an example of the latter. In the case of meat-producing animals, feeding uncontaminated feed may only be necessary close to the time of slaughter since the biological half-life of radiocaesium, for example, is of the order of two to four weeks depending on the species. Ideally this should be supplemented by monitoring live animals in the slaughterhouse or at the farm to identify those that require a further period of feeding with uncontaminated feed. With game animals, changing the hunting season may be effective where the animals have seasonal feeding habits. For example, mushrooms and lichens, which can be highly contaminated, are frequently most abundant in the autumn, so animals should not be hunted during this period.

These are merely examples of countermeasures; there are many more possibilities. However, decisions on whether to apply countermeasures and which ones are appropriate require information about the nature and extent of radioactive contamination. As a considerable infrastructure is necessary to produce an effective response, a large section of the *Guidelines* is concerned with organizational structures. Finally, the document briefly reviews the responses of selected countries to the Chernobyl accident.

Assistance with countermeasures in contaminated areas

The application of many different countermeasures in Belarus, Ukraine, and western Russia following the Chernobyl accident led to a significant reduction in radiocaesium contamination of milk and meat produced on State and collective farms. However, many of the countermeasures were difficult to apply by small-scale farmers for economic reasons. In 1990 up to 50,000 dairy cows were still producing milk that exceeded temporary permissible levels, or TPLs, (111 Bq/L in Belarus; 370 Bq/L in Ukraine and Russia). Therefore, an alternative approach was required which was simple, effective, and cheap.

Effects of countermeasures on caesium-137 levels in milk and meat

A project sponsored by the Norwegian Government developed a countermeasure to lower the levels of radiocaesium in both domesticated and game ruminants using a mixture of compounds known as "Prussian Blue" (PB). Executed through the United Nations, the project involved the Norwegian Agricultural University and Radiation Hygiene Institute, the Ukrainian Research Institute of Agricultural Radiology in Kiev, the Belarussian Branch of the All-Union Institute of Agricultural Radiology in Obninsk, and Queen's University, Belfast. The IAEA's Seibersdorf Laboratories, the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, and the IAEA's Division of Nuclear Safety provided co-ordination, expert services, equipment, and materials to the major counterpart institutes in three countries for conducting trials in the worst affected villages.

Successful trials were conducted in 1990-92 involving over 3,000 cows in 21 settlements in Belarus, 10,000 cows in 54 settlements in the Ukraine, and an unspecified number of cattle in villages in Russia. Thereafter, each State's

Benefit	Comment
Individual dose reduction	Overall reduction of about 60% (probably more than 80% in areas where the uptake factor from soil to grass is particularly high)
Collective dose	Perhaps a few hundred man Sv; relatively small because of the extremely low TPLs being used in the CIS. Nevertheless it is cost effective
Additional milk production	An additional 50 million litres of milk per annum would meet TPLs without the need for distribution of "clean" feed and milk.
Clean feed needed for milk production	The time needed for "clean feeding" could be reduced by 40-50 days, resulting in a reduction by a factor of 5 of the area of "clean" pasture needed.
Social/psychological	Some 50,000 farmers could return to traditional farming practices with a corresponding increase in their sense of well-being and improvement in their quality of life. Many farmers destined for translocation would no longer have to move house.
Compensation	The number of individuals receiving compensation for exceeding an annual criterion could be reduced by approximately 50%.

Summary of benefits of using Prussian Blue compounds

Minister of Agriculture authorized the widespread use of PB in livestock for reducing the content of caesium-137 in milk and meat.

The term "Prussian Blue" refers to a number of ferric hexacyano ferrates; ammonium ferric cyanoferrate (or AFCF) is perhaps the most commonly used caesium-binding compound. Given as a bolus into the rumen, in compounded concentrate feed, in salt licks, or simply sprinkled on the diet, AFCF reacts with consumed radiocaesium in the intestine to form a complex that is eliminated in the dung instead of passing into the animal's blood stream. The PB bound radiocaesium in dung is only slowly available to plants. Depending on the dose and type of PB compound given, radiocaesium reductions of two to eight times can be achieved in milk and meat from cattle grazing contaminated fodder. This significantly reduces the internal dose to the human consumer and is often enough to allow village communities to remain in contaminated areas. As a result, the need to translocate whole communities, with its attendant traumas, has been curtailed and huge costs have been averted. Not surprisingly, the benefits of employing PB compounds have been greatly welcomed by farmers and government alike.

While successful countermeasures have been applied on state and collective farms and foodstuffs with acceptably low radionuclide content are now grown on previously contaminated land, public acceptance of "clean" foods coming from these areas is still a problem. The Belarussian and Ukrainian authorities are thus anxious to use this land in other ways. Through its joint programme with Food and Agricultural Organisation, the IAEA's Technical Co-operation Department is currently supporting a project in Belarus to investigate the potential of oil seed crops (primarily rapeseed) as an alternative crop. Initial research indicates that oil produced from certain varieties of rapeseed on land with radiocaesium levels of 15-40 Ci/km^2 is devoid of the radionuclide (and radiostrontium); the contamination is restricted to the straw and residual oil seed meal. The Belarus authorities sowed about 20,000 hectares of contaminated land with rapeseed in 1995 and intend refining the oil into lubricants which currently have to be imported. Should the project be successful, the land area sown will be expanded two- to threefold for lubricant production.

IAEA assistance is also being given to Ukraine to improve the skills and facilities for the measurement, control, and consequently the reduction of radionuclides in foodstuffs. The programme is based on the Ovruch Milk Canning Integrated Works which processes 200-500 tons of milk per day, much of it from farms within the Chernobyl contaminated zone. The United States government is currently providing additional resources to assess a commercial magnetic separation system for decontaminating liquid milk.

Generation of data. Belarus is receiving assistance through the IAEA Technical Co-operation programme to obtain more data on the occurrence and migration of radionuclides in soils, forests, and water bodies. These will be used in forecasts of the likelihood of success and of the time required for the restoration of contaminated regions to normal economic activity.

Applying lessons learned

Values for the transfer of radionuclides between different components of the biosphere and experience in dealing with the consequences of a nuclear accident are largely confined to temperate regions, primarily in Europe. However, there are nuclear power stations in

In Belarus, an IAEA-supported technical co-operation project is investigating the use of rapeseed (in background) as an alternative rotation crop on some contaminated lands.
(Credit Richards/IAEA)

some parts of the world that could conceivably affect tropical countries in the event of an accident. Therefore, a Co-ordinated Research Programme (CRP) involving the IAEA Division of Radiation and Waste Safety and the Joint FAO/IAEA Division is in progress to measure transfer factors for radiocaesium and radiostrontium from soil to major tropical crops and also from water to tropical fish. These data will be of value for both planning countermeasures and for establishing permissible levels of radionuclides in industrial effluents in the tropics. There are also plans to establish a further CRP which will examine the efficacy in tropical conditions of countermeasures that have proved effective in Europe.

In devising and applying agricultural countermeasures, more consideration should be given to the management of the whole contaminated environment, especially forests and water bodies because of the interactions between them and agricultural land. There is a need to develop secondary reference levels (so-called "operational intervention levels") for animal feeds and pasture. This requires additional data on transfer factors or at least re-examination of existing knowledge.

A range of agricultural countermeasures is currently available to reduce the impact of radiocaesium contamination in the food chain. The same cannot be said for radiostrontium contamination. Considerable laboratory and field research and development are required to improve the situation. For example, a number of materials have been proposed for selectively absorbing/adsorbing strontium in foodstuffs but none can yet be recommended unequivocally because data are inadequate. Alternative approaches, such as filters and magnetic separators for liquid food products, are currently available commercially although they have not been evaluated critically under the conditions prevailing in the contaminated regions.

To conclude, the Chernobyl accident highlighted the need for each country to develop a set of agricultural countermeasures ready for immediate application in the event of a nuclear accident. Lessons have been learned on the usefulness of many countermeasures and the infrastructures needed to implement them. Work remains to be done to ensure that these lessons are applied. This is particularly important for tropical environments as most of our experience has been obtained in temperate climates. ❐

NUCLEAR SAFETY ASPECTS

Report by Luis Lederman, Acting Head of the Safety Assessment Section in the IAEA Department of Nuclear Safety, who served as Scientific Secretary of Topical Session 7: "Nuclear safety remedial measures".

From 1-3 April 1996 an International Forum "One Decade After Chernobyl: Nuclear Safety Aspects" was convened at the IAEA in Vienna, Austria. It was organized by the IAEA in co-operation with the UN Department of Humanitarian Affairs (UNDHA). The objective was to review the remedial measures taken since the Chernobyl accident to improve the safety of RBMK reactors and the Chernobyl containment structure (sarcophagus). The results were presented at the International Conference on Chernobyl held in the following week.

This article features excerpts of the conclusions of the Safety Forum related to the safety of Chernobyl-type reactors (RBMKs) and to conditions at the site of the Chernobyl plant itself.

Causes of the accident

The events which led to the accident in Unit 4 of the Chernobyl nuclear power plant on 26 April 1986 have been investigated by many teams of scientists over the past ten years. Although there are still some gaps in knowledge relating to details of some phenomena involved in the accident, the knowledge acquired is sufficient to identify the causes and to take effective measures to prevent a repetition of such an event.

From today's viewpoint the main causes of the accident can be summarized as follows:

- severe deficiencies in the reactor's physical design and in the design of the shutdown facilities;
- high positive void effect during operational conditions with high burn-up;
- positive scram effect under conditions of the reactor before the accident;
- failure to incorporate the operating reactivity margin (ORM) into reactor protection;
- lack of safety culture in the responsible organizations leading to the inability to remedy important weaknesses, even though they had been known long before the accident;
- an insufficiently reasoned and examined test programme with respect to technical safety;
- violation of operating procedures;
- operation and operating equipment imposing undue requirements on the responsible staff;
- insufficient protection against accidents beyond the design basis.

The safety of RBMKs

There is broad agreement that the original design of the RBMK core and shutdown system had severe deficiencies. This holds for all generations of RBMK plants. Between 1987 and 1991, a first stage of safety upgrading was performed for all RBMK units addressing the most serious problems in this area.

The void reactivity effect has been reduced by installing 80-90 additional absorbers and by increasing the operative reactivity margin up to 43-45 manual control rods, and by increasing the fuel enrichment to 2.4%.

The efficiency of the scram system has been increased by elimination of water columns; increasing the number of bottom control rods driven in the core together with the upper rods after trip signals; the speed of rod insertion; a new fast-acting shutdown system; and additional signals for the control and safety system.

Organization and operation has been strengthened by more frequent computation and display of the operative reactivity margin; and improved operating rules and procedures. Progress has also been achieved in further areas, such as installation of remote shutdown stations, non-destructive testing and training of personnel (simulator). The realization of these measures varies from plant to plant.

There remain issues beyond the scope of the first stage of upgrading which require further attention. These needs largely depend on the different stages of RBMK development.

There is no doubt that significant improvements were achieved regarding the safety deficiencies relevant for the Chernobyl accident. For other safety issues, safety upgrading is under way or planned. The realization of this second stage of upgrading continues to

Aerial view of the Chernobyl nuclear power plant. The sarcophagus (foreground) encases the unit destroyed in the accident.
(Credit: Mouchkin/IAEA)

encounter major financial difficulties. That may be characterized as an important if not the main current problem for RBMK safety.

Remaining problems of RBMKs. The analysis performed so far shows that, from a technical point of view, the known safety deficiencies of second and third generation RBMKs could be overcome in a way broadly consistent with the defense-in-depth concept. Many of the steps to be taken have been already defined and internationally agreed.

The practicability of backfitting first generation RBMKs raises further questions in addition to the issues relevant for the second and third generations of the plant. There have been significant doubts in Western countries about the feasibility and the cost effectiveness of backfits. However, from today's perspective it must be recognized that the existing upgrading programmes address most safety concerns. They include the backfitting of essential safety features such as control and protection systems, emergency core cooling systems, and partial confinement. It is evident that they will lead to significant improvements even if they will not always reproduce the technical solutions implemented in the new RBMK plants. Where "classical" approaches are difficult to implement, they often rely on "compensating solutions".

Particular problems at Chernobyl

Most of the above considerations on RBMK safety also hold for the Chernobyl plant. Nevertheless, the situation at Chernobyl is a particular one as there exists a range of site specific problems. These problems concern both the safety of the remaining units and the accident consequences.

Although there are plans to shut down the Chernobyl reactors in the near future, programmes for upgrading them, that have been agreed internationally, should be implemented to ensure safety during their remaining lifetime.

Overview of international activities on RBMK safety

In response to a request initiated by the former Soviet Union, the IAEA started a programme on the safety of RBMKs in 1992.* It aims at consolidating results of various national, bilateral, and multilateral activities and to establish international consensus on required safety improvements and related priorities. It assists both regulatory and operating organizations and provides a basis for technical and financial decisions.

A wide range of activities are covered, and since 1992, a number of reviews and assessments have been conducted. Smolensk-3 and Ignalina-2 have served as RBMK reference plants during the programme's first phase.

European Commission. An international RBMK consortium on the "Safety of Design Solutions and Operation of Nuclear Power Plants with RBMK Reactors" was established in 1991 under the auspices of the European Commission. Eight Western countries (Canada, Finland, France, Germany, Italy, Spain, Sweden, United Kingdom) and the three countries operating RBMKs (Lithuania, the Russian Federation, and Ukraine) have participated in the consortium. The following topical areas were studied: systems engineering and accident progression, control and protection systems, core physics, external events, engineering quality, operating experience, human factors, regulatory interface and probabilistic safety assessment (PSA).

More than 300 recommendations for safety improvements have been made. Many of these had been previously recognized by designers and operators and already acted upon while others are important new recommendations.

World Association of Nuclear Operators (WANO). In 1992 an International User's Group for Soviet-Built Reactors identified common requirements to improve RBMK safety. They include measures already implemented or fully developed for implementation and those yet to be implemented.

European Bank for Reconstruction and Development (EBRD). By the end of 1995, fourteen countries and the European Union had pledged to the 245 MECU Nuclear Safety Account (NSA).

Assistance to the Ignalina plant includes in-service inspection equipment, a full-scope simulator, fire protection, and the preparation of a Safety Analysis Report.

Assistance to the Leningrad RBMK relates to a safety improvement programme with provision of equipment like that for Ignalina.

The NSA Chernobyl Project focuses on short-term safety improvements to Unit 3 including in-service inspection, neutron flux instrumentation, and the hydrogen monitoring system.

Funding is also being provided for decommissioning facilities, namely a low- and intermediate-level liquid radwaste treatment plant and a spent fuel storage facility.

Bilateral programmes. ***Sweden and Lithuania.*** This programme includes support to the regulatory body VATESI, co-operation between the Swedish Nuclear Industry and Ignalina plant, and various technical projects. Main areas where assistance is being provided relate to the legal framework (review of the Lithuanian Energy Law), development of the regulatory system, material inspection, management, and organization, and a PSA level-1 study (of the Barselina plant).

Main technical projects cover areas such as fire protection, enhancement of the relief capacity from the reactor cavity, enhancement of the ALS system, storage capacity of spent fuel, waste compaction, improvement of the plant's physical protection, and upgrading the communications system.

Russia and Canada, France, Germany, Japan, Italy, Sweden, Switzerland, UK, USA. Bilateral programmes with Russia include those related to: development of symptom-based emergency operating procedures (USA); fire protection; fuel channel sealing plugs; instrumentation and control improvements; in-service inspection; leak detection system (Japan); metallurgical analysis; probabilistic safety assessment; quality assurance; thermal hydraulic and neutronic codes.

Outlook. It is generally agreed that the results from international assistance have increased confidence that the major shortcomings and the required safety improvements of RBMK reactors have been identified.

The plant-specific status of implementation of safety improvements varies considerably. Therefore a major effort is still required to complete plant-specific safety analyses and to implement the required safety improvements.

*An overview of this Programme was published in the *IAEA Bulletin*, Volume 38, No. 1 (March 1996).

For the consequences of the accident, concerns focus on the sarcophagus built around the destroyed reactor, on the radioactive material contained inside the sarcophagus, and on the radioactive material buried on the site.

The sarcophagus. The possible instability of the sarcophagus is a significant problem. The concern is mostly related to the fact that essential supports of the main construction had to be built by remote control without fixings such as welding and bolt connections. As a consequence, there is considerable uncertainty regarding the resistance to potential internal and external impacts. This relates above all to the withstanding of loads due to external burden or impact, such as loads due to wind, snow, or earthquake, for example. There is broad agreement that the risk of a partial or total collapse during the initially projected design lifetime of the sarcophagus of about 30 years is not negligible if no countermeasures are taken.

Even in the worst case of a complete collapse, widespread effects are not to be expected. Nevertheless, the stabilization of the sarcophagus is an issue of high priority.

Water entering the sarcophagus is another significant safety issue. The presence of water stimulates the disintegration of fuel masses into dust and degradation of building structures by corrosion, and can increase the reactivity of fuel masses. Regarding the risk of groundwater contamination, the existence of water in the sarcophagus bears some risk in the long term. However, this risk is assumed to be much smaller than that from contact of water with the radioactive material buried in the ground outside the sarcophagus.

Possibilities of recriticality have been widely investigated. It has been found that the sarcophagus is currently safe from a criticality point of view. Nevertheless, it cannot completely be excluded that there exist configurations of fuel masses inside the sarcophagus which could reach a critical state when in contact with water. However, even if this could lead to significant radiation fields inside the sarcophagus, neither large off-site releases nor mechanical effects would have to be apprehended in such an event. The impact on the operating personnel of the other units should also be clarified.

Another specific issue for the Chernobyl plant is the possible implications for safety of the proximity of the sarcophagus and the destroyed reactor to the adjoining operating Unit 3. The risks are generally assumed to be low; however, the issue needs further investigation. (Note: Opinions differ widely about the significance of the risk of an accident in Chernobyl Unit 3 caused by a collapse of the sarcophagus. More detailed investigations of this issue are required.)

Other site-specific problems

Further site-specific problems relate to the contamination, in particular to the radioactive material buried at the site. The type and extent of the contamination are well known by measurements. Although the local dose rate is considerably high, most areas are accessible. The provisional depositories of highly radioactive material, such as nuclear fuel ejected out of the reactor during the accident, however, represent an obstacle for construction and reconstruction measures. Furthermore, radioactive substances get into the groundwater there. At present the contamination is still low. In the long term there is, however, a considerable risk, and an orderly disposal of the provisional depositories is absolutely required.

Step-by-step site restoration

Given the scale of the problems to be solved at Chernobyl, it is evident that major long-term efforts are needed. The stability of the sarcophagus must be ensured, the destroyed reactor permanently secured, the wastes disposed of, and the site reconstructed. This will require substantial resources.

There is a broad agreement that these problems call for an integrated approach divided into suitable steps. This approach should be based on realistic targets which take into account the radiological conditions at the site and appropriate safety and waste disposal priorities. It should begin with a stabilization of the existing sarcophagus. That stabilization could significantly reduce the risk of a collapse of the shelter and provide time for a careful reflection and planning of further measures, such as the construction of a new encasement and waste management. This would include the recovery or partial recovery of fuel masses inside the sarcophagus, and the disposal of radioactive material buried on the site. ❒

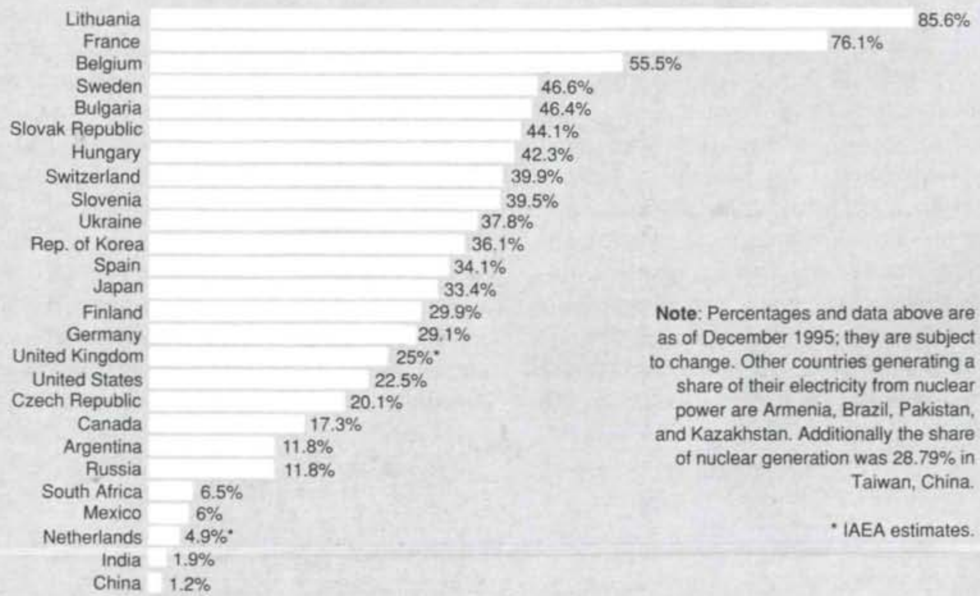
Nuclear power status around the world

	In operation		Under construction	
	No. of units	Total net MWe	No. of units	Total net MWe
Argentina	2	935	1	692
Armenia	1	376		
Belgium	7	5 631		
Brazil	1	626	1	1245
Bulgaria	6	3 538		
Canada	21	14 907		
China	3	2 167		
Czech Republic	4	1 648	2	1 824
Finland	4	2 310		
France	56	58 493	4	5 810
Germany	20	22 017		
Hungary	4	1 729		
India	10	1 695	4	808
Iran			2	2 146
Japan	51	39 893	3	3 757
Kazakhstan	1	70		
Korea, Rep. of	11	9 120	5	3 870
Lithuania	2	2 370		
Mexico	2	1 308		
Netherlands	2	504		
Pakistan	1	125	1	300
Romania			2	1 300
Russian Federation	29	19 843	4	3 375
South Africa	2	1 842		
Slovak Republic	4	1 632	4	1 552
Slovenia	1	632		
Spain	9	7 124		
Sweden	12	10 002		
Switzerland	5	3 050		
United Kingdom	35	12 908		
Ukraine	16	13 629	5	4 750
United States	109	98 784	1	1 165
World total*	437	344 422	39	32 594

* The total includes Taiwan, China where six reactors totalling 4884 MWe are in operation.

Notes to table: During 1995, two reactors were shutdown (including Bruce-2 in Canada which could restart in the future).

Nuclear share of electricity generation in selected countries



Note: Percentages and data above are as of December 1995; they are subject to change. Other countries generating a share of their electricity from nuclear power are Armenia, Brazil, Pakistan, and Kazakhstan. Additionally the share of nuclear generation was 28.79% in Taiwan, China.

* IAEA estimates.

40th regular session of IAEA General Conference

The 40th regular session of the IAEA General Conference is set to open 16 September 1996 at the Austria Center in Vienna. At sessions throughout the week, high-level governmental delegations from the Agency's 124 Member States will take decisions on matters affecting the IAEA's policies, programmes, and budget.

The provisional agenda includes items related to strengthening international co-operation in nuclear, radiation, and waste safety; strengthening of the IAEA's technical co-operation activities; strengthening the effectiveness and efficiency of the safeguards system; measures against illicit trafficking in nuclear materials and other radioactive sources; extensive use of isotope hydrology for water resources management; the implementation of the safeguards agreement between the IAEA and the Democratic People's Republic of Korea; the implementation of UN Security Council resolutions relating to Iraq; an African nuclear-weapon-free zone; the application of safeguards in the Middle East; and the Agency's programme and budget for 1997.

In conjunction with the Conference, a number of events are being organized. They include a special scientific programme featuring three subjects — the advanced nuclear fuel cycle, new concepts for the future; IAEA information management for Member States, the development of information technology; and trends in research reactor applications. Additionally, a briefing session is being organized on the IAEA's safeguards development programme. Also scheduled is the traditional meeting of senior officials on nuclear safety, which will include coverage of the outcome of the International Chernobyl Conference convened by the IAEA and other organizations in April this year.

More information about the General Conference is available from the Division of Public Information and through the IAEA's *World Atom* Internet services on the World Wide Web at http://www.iaea.or.at/worldatom.

IAEA Board of Governors meetings

A committee of the IAEA Board of Governors is scheduled to hold its second meeting in October 1996 on a draft Protocol to provide the IAEA with additional access to information and locations as part of efforts to strengthen the safeguards system. The Committee on Strengthening the Effectiveness and Improving the Efficiency of the Safeguards System was established by the Board 14 June and held its first meeting 2-4 July at IAEA headquarters. Representatives from 65 States and the European Commission and the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials attended the meeting; the Committee is under the chairmanship of Ambassador J. Th.H.C van Ebbenhorst Tengbergen of the Netherlands, the current Chairman of the IAEA Board of Governors.

At its July meeting, the Committee had its first reading of the draft Protocol, which would be an additional legal document to comprehensive safeguards agreements. The document would define *inter alia* the nature of additional access to information and to nuclear-related locations for the Agency's inspectors.

In establishing the Committee, the Board acknowledged that additional information, including the taking of environmental samples and increased physical access, would strengthen the Agency's ability to detect undeclared nuclear material and activities. It emphasized that the new measures should strike a balance between the Agency's need for information and access on the one hand and the State's need to protect its legitimate interests and to respect its constitutional obligations on the other. It further emphasized that implementation of these measures should be subject to strict rules of confidentiality to be observed by the Agency, with regard both to information received and to the entire process of verification.

The Board further considered that, in order to strengthen the Agency's capability to detect in the States concerned undeclared nuclear material and activities in an effective manner and increase the efficiency of the safeguards programme, co-operation is needed from all States. In this connection, it welcomed the willingness expressed by the nuclear-weapon States to consider how best to contribute to the implementation of the strengthened programme under consideration.

Safeguards implementation in 1995. During 1995, the IAEA did not find any indication of the diversion of nuclear material, or of the misuse of any facility, equpment, or non-nuclear material placed under safeguards.

It therefore concluded that such items remained in peaceful use or were otherwise accounted for. However, the Agency was still unable to verify the initial declaration made by the Democratic People's Republic of Korea (DPRK). The DPRK is not in full compliance with its safeguards agreement.

At the end of 1995, Agency safeguards agreements were in force with 125 States (and Taiwan, China). Sixty-six of these States (and Taiwan, China) had nuclear activities and were inspected. Safeguards were also implemented in five States with bilateral or multilateral agreements covering specified nuclear or non-nuclear material, facilities or equipment, as well as at designated installations in the five nuclear-weapon States. During 1995, a total of 554 nuclear facilities and other locations containing nuclear materials were inspected. A total of 2285 inspections were carried out requiring 10,167 person-days of inspection effort.

The IAEA employs approximately 200 field inspectors for this work, and the budget for this activity in 1995 was US $88.6 million, plus a further US $14 million of extrabudgetary funds contributed by eight Member States. Most of the IAEA's inspection work is carried out under agreements pursuant to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), which was extended indefinitely in May 1995.

Other highlights of the IAEA's safeguards activities in 1995. The IAEA maintained, and still maintains, a team of inspectors in Iraq and in the DPRK. In the United States, safeguards were applied on nuclear material released from the US military programme in 1995 and voluntarily placed under Agency safeguards, in addition to material already released in 1994. Also in 1995, the IAEA conducted verification activities on the initial inventories of nuclear materials submitted by Belarus, Kazakhstan, and Ukraine, three of the Newly Independent States emerging from the former Soviet Union.

Although the IAEA's safeguards activities were effective in 1995, several implementation difficulties have been encountered. These included technical difficulties with the Agency's surveillance equipment and also administrative restrictions imposed by several States on the designation of inspectors and on the availability of long-term multiple entry visas for inspectors. The Agency is taking steps to resolve these problems.

Mururoa radiological study

During July and August 1996, international teams of scientists collected terrestrial and marine samples at the Pacific atolls of Mururoa and Fangataufa in the context of the radiological study requested from the IAEA by the Government of France. Teams visited the atolls in relays, to collect samples including plankton, fish, seawater, lagoon sediment, coral, soil, coconuts, and vegetation. The samples will be shared subsequently with a grid of analytical laboratories worldwide, including the Pacific region. Results will be forwarded to the IAEA in Vienna, whose own laboratories in Seiberdorf, Austria, and in Monaco will also be participating both in the sample-taking and the analytical work. Data from French studies already undertaken will be available for comparative purposes in the scientific work to determine the radiological situation at the atolls. This part of the overall study is expected to take up to six months to complete.

Separately under the study, geological specialists will be examining the situation regarding possible future scenarios, including the very long term, using modelling techniques taking as their starting point *inter alia*, the geological characteristics of the atolls, experience gained at other nuclear test sites, and information provided by the French authorities regarding their own series of tests. The results of this work will then be consolidated with other parts of the study and made publicly available. The final report is expected to be published in early 1998.

The study was requested by France in 1995 and announced by IAEA Director General Hans Blix at the IAEA General Conference that year. It is being conducted under the guidance and direction of an International Advisory Committee of distinguished scientists from ten countries, chaired by Dr. E. Gail de Planque of the United States, and including *ex officio* representatives of the South Pacific Forum, the UN Scientific Committee on the Effects of Atomic Radiation, the World Health Organization, and the European Commission. The Committee itself intends to visit French Polynesia at a later date, at which time a press conference is foreseen on the study's progress.

IAEA Annual Report for 1995

Being issued in September, the IAEA's *Annual Report for 1995* summarizes the most important achievements of the IAEA for the safe development of nuclear technologies and the verification of their peaceful uses. The past year saw a significant degree of progress in some important areas of the IAEA's work, with efforts geared towards further improving the impact and efficiency of Agency activities.

Among the activities noted in the report are:

Strengthening of safeguards. In 1995, the IAEA's Board of Governors accepted the Director General's plan to implement at an early date under existing legal authority measures aimed at strengthening the present safeguards system. The measures include broader access to information, greater physical access to sites and locations, and the optimization of the present system through greater co-operation with States and the introduction of new safeguards measurement and surveillance systems. In December 1995, the Board also initially reviewed other proposed measures which would require additional legal authority to implement.

Illicit trafficking in nuclear materials. The IAEA established a special programme in this area in 1995 and set up a database of trafficking incidents to provide factual information to Member States and the public. Also conducted were training courses in the implementation of systems for accounting and control of nuclear materials and in physical protection methods and technology. Technical support further was co-ordinated for a number of Member States.

Radiological studies. Studies of the radiological situation at former nuclear test sites were conducted or initiated in 1995. The IAEA organized a re-examination of the site at the Bikini Atoll in the Marshall Islands, and also undertook a review of an area in Kazakhstan where nuclear weapons had been tested for many years. At the request of France, the Agency further started preparations to assess the radiological situation in the atolls of Mururoa and Fangataufa.

Waste safety. The IAEA Board convened an open-ended group of legal and technical experts in 1995 for purposes of preparing a draft Convention on the Safe Management of Radioactive Waste. Two meeting were held during the year with good progress.

Sustainable development and nuclear energy. Among other activities, the IAEA, in co-operation with nine other international organizations, convened an international symposium in October 1995 on comparative assessment in support of decision-making in the electricity sector. The symposium focused on the information required for deciding upon and implementing sustainable electricity policies, taking into account economic, social, health, and environmental factors.

Strengthening technical co-operation. Several initiative were undertaken in 1995 to strengthen the IAEA technical co-operation programme and to make it more effective for sustainable development. Many of these initiatives concentrated on improved planning. A Standing Advisory Group on Technical Assistance and Co-operation (SAGTAC) also was established and met for the first time in December; it will review policy and strategy and make recommendations to the Agency.

Nuclear and radiation-based applications. The IAEA's programmes in research and development of nuclear-based technologies registered some notable achievements in 1995. A number of countries reported successful applications of radiation-based techniques to control insect pests threatening to agriculture. New programmes also were launched in fields of health care and nutrition in co-operation with the World Health Organization. The IAEA further started a new research programme on the use of irradiated sewage sludge to increase soil fertility and crop yields and help preserve the environment. In March 1995, water problems were in focus at an Agency-sponsored symposium that practical applications of the techniques being used in the management of groundwater resources.

Safety of radiation sources. As part of efforts to assist countries in safely managing radiation sources used in industry, medicine, and other fields, the IAEA issued a computer-based package and documentation for use by register administrators who monitor and inventory sealed radiation sources.

Nuclear safety in Eastern Europe and the former USSR. Progress was recorded in the Agency's efforts to assist countries operating specific types of nuclear power plants in these regions. Since international consensus has already been achieved on proposed improvements, the emphasis was on reviewing the status of their implementation.

The *Annual Report* may be obtained from the Division of Public Information. An electronic version also is available on-line through the IAEA's *WorldAtom* Internet services at the address http://iaea.or.at/worldatom.

Update on nuclear desalination

A report on the IAEA's activities for assisting countries in need of potable water resources will be considered by the IAEA General Conference in September 1996. The report focuses on efforts related to seawater desalination using nuclear energy. The Agency has undertaken a number of feasibility studies and monitored nuclear desalination programmes in Member States, among them Morocco, Indonesia, Egypt, the Republic of Korea, India, and the Russian Federation.

IAEA activities noted in the report include the finalization of a feasibility study for the North African region and the organization of several meetings in 1995 and early 1996 that reviewed advances in the field, the design of nuclear reactors for desalination applications, and global experience in coupling nuclear plants with district heat networks and desalination processes. About 500 reactor-years of operational experience from nuclear co-generation and heat-only reactors has been accumulated worldwide, mostly in the former Soviet Union and Eastern European countries. Nuclear energy for seawater desalination has been used at locations in Japan and in Kazakhstan. While in Japan the desalted water is mostly consumed at the nuclear power plants, in Kazakhstan the desalination complex supplies water to a nearby residential area.

All told, 22 countries and a number of organizations are supporting the IAEA's workplans for assisting States to produce potable water economically. Over the next several years, the Agency is looking to conduct a range of activities related to nuclear desalination. Among them are a follow-up study on the North African feasibility study and provision of expert services for a review of the regional infrastructure capabilities. A next step in the technology's development would be for one or more countries to proceed with preparatory actions for demonstration projects.

Also being organized is an international symposium on nuclear desalination in May 1997, and a Steering Committe has been established with representatives from nine countries and international organizations. The European Commission, the Global Technology Development Center, the International Desalination Association, the United Nations Industrial Development Organization (UNIDO), the World Health Organization (WHO) , and the World Meteorological Organization (WMO) have expressed their willingness to support the Symposium in various ways.

Mexico: Nuclear information seminar

Mexico recently hosted a Regional Seminar on Atoms for Development organized by the IAEA in co-operation with the country's National Commission of Nuclear Energy (ININ). The seminar commemorated ININ's 40th anniversary and the centennial of the discovery of radioactivity. It included invited journalists, government officials, and nuclear communicators from Mexico and other countries in the region, including Cuba, Ecuador, Panama, and Venezuela. About 500 participants attended sessions organized 18-20 June at ININ just outside Mexico City and at the Colegio de Ingenieros.

In an opening address, IAEA Director General Hans Blix focused on the subject of nuclear energy and sustainable development, citing projects in Mexico and other countries that are demonstrating the practical and potential roles of nuclear technologies that support environmentally sound development. The Director General also attended a special programme including a discussion with Mexico's President, Mr. Ernesto Zedillo.

Other speakers addressed a range of topics, including nuclear energy's use for electricity generation, the safety of radiation technologies, applications of radioisotopes in fields of agriculture, hydrology, and health care, the transfer of technolgies through technical co-operation programmes, and regional aspects of nuclear non-proliferation. The seminar was organized under an extrabudgetary public information programme being funded by Japan.

Peru: Looking at SIT

Peru is taking a closer look at the Sterile Insect Technique (SIT), a radiation-based technology, for an eradication campaign against the Mediterranean fruit fly (Medfly) in the country. The Medfly is a pest that destroys millions of dollars in fruit per year in infested areas. The SIT technique relies on rearing vast numbers of male insects in special facilities that are sterilized by low doses of radiation and then released into the wild where they mate without producing offspring.

In co-operation with Chile, Peru is seeking to eradicate the Medfly in the southern regions of the country, and to prepare for an integrated control campaign in other regions. Project officers from Peru and Chile, which are jointly pursuing technical assistance for the proposed project, met this July in Vienna with IAEA officials and technical staff to prepare strategies and work plans concerning the project. It is foreseen that the Agency's support would include providing Medfly genetic sexing technology to the mass-rearing facility in Chile, as well as training, specialized equipment, and technical backstopping to field activities in Peru. Under the project, the Chilean mass-rearing facility would provide the sterile flies to Peru.

The eradication campaign already has started in Tacna, the southernmost valley in Peru. Through a co-operative effort mainly financed by Chile, more than 20 million sterile Medflies produced in Chile's Arica facility are being shipped and released weekly in the Peruvian region. The Medfly is a costly problem for Peru, whose multi-million dollar fruit production covers more than 175,000 hectares. Estimated losses attributed to the fruit fly amount to more than US $25 million per year. Mango, grapes, mandarin, and other citrus are the main fruits for export.

The activities planned in Peru are part of an ambitious National Fruit Fly Control and Eradication Programme. In the coastal zones, there is the potential to create Medfly-free areas because of the geographical isolation of fruit-producing valleys. The country also plans to build two new mass-rearing facilities and to upgrade an older facility in Lima. They will be used to produce sterile Medflies and *Anastrepha* fruit flies, which co-exist with Medflies in many regions and also must be controlled.

Romania: First nuclear plant

Cernavoda, the first nuclear power plant in Romania, was connected to the national electricity grid in July at low power. Reports noted that the reactor is expected to go fully on line in September, after final testing is completed. The plant, a 700-megawatt unit, was built in co-operation with Canada.

Four other Candu nuclear units are planned at the Cernavoda site. Unit-1's capacity could meet up to 10% of all the electricity currently being produced in Romania, which relies heavily on coal, oil, and hydropower electrical generating stations.

Georgia: IAEA membership

The Republic of Georgia officially became a member of the IAEA earlier this year. The

Agency was notified in late May that the Government had deposited its instrument of acceptance of the IAEA Statute.

The IAEA's membership now stands at 124 Member States.

Belarus: Ratifies Chemical Convention

Belarus has become the 56th State to ratify the Chemical Weapons Convention, depositing the necessary legal instruments 11 July. The Convention has been signed so far by 160 States, and will enter into force 180 days after the deposit of the 65th instrument of ratification.

The Convention prohibits the development, production, acquisition, retention, stockpiling, transfer, and use of chemical weapons. It is the first multilateral disarmament agreement that provides for the total elimination of an entire category of weapons of mass destruction. Now being formed, the Organization for the Prohibition of Chemical Weapons (OPCW) will have responsibility for ensuring the implementation of the Convention; OPCW is headquartered in The Hague, Netherlands.

More information may be obtained from the Preparatory Commission for the OPCW, Laan van Meerdervoort 51, 2517 AE The Hague; facsimile: 31-70-360-0944 or on the Internet at the address http://www.opcw.nl/

United States: Progress on nuclear costs, waste legislation

Production costs at nuclear power plants in the United States have declined again, dropping 5% in 1995, reports the Utility Data Institute (UDI), based in Washington, DC. For the US nuclear industry as a whole, production costs per net megawatt-hour of electricity production stood at $19.11 in 1995. Electricity output rose 5% in 1995, to 674 million megawatt-hours, UDI reported.

Nuclear plants at the top of UDI's performance list were North Anna in Virginia, Vogtle in Georgia, and Wolf Creek in Kansas. All had operating and maintenance costs well below $12 per megawatt-hour.

Production costs at US nuclear plants have been on a steady decline over the past decade after rising steeply in the 1970s to mid-1980s. In 1995, the costs among the top 25 nuclear units ranged from $11.16 per megawatt-hour at North Anna to $17.35 at the Brunswick nuclear plant in North Carolina. All told, more than 100 nuclear power plants are operating in the United States.

More information is available from UDI, a database and directory publishing division of the McGraw-Hill Companies, 1200 G. Street NW, Suite 280, Washington, DC 20005-3802, USA. Facsimile: 001-202-942-8789. Email: info@udidata.com.

Nuclear waste legislation. The United States Senate has begun consideration of new legislation that will reform the country's current waste management programme, and specifically address the problem of spent fuel storage, transportation, and disposal.

The legislation would retain important provisions of importance to the US nuclear industry, reports the Nuclear Energy Institute (NEI), the industry's trade organization based in Washington, DC. These include development of an integrated nuclear waste management system, including construction of a central, interim storage facility and a repository, and a transportation network to move used fuel to both facilities; provision of interim storage capacity to meet the industry's needs through the year 2019; and the resolution of funding problems in a manner that puts a ceiling on the fee per kilowatt-hour.

Full details of the current US waste mangement programme, and about the new legislation being considered in the US Senate, may be obtained from NEI, Suite 400, 1776 Eye Street, NW, Washington, DC 20006-3709. Facsimile: 001-202-785-4113.

Argentina and Brazil: ABACC updates

Updates about the work of the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials are being provided in *ABACC News*, a periodical newsletter.

ABACC was established to administer and apply a common system for safeguards on all nuclear materials found in all nuclear activities in Argentina and Brazil; its activities are co-ordinated with the IAEA. The newsletter's first edition of 1996 notes that ABACC conducted 49 inspections through April 1996 in co-ordination with safeguards inspections carried out by the IAEA.

More information may be obtained from ABACC, Av. Rio Branco, 123 —grupo 515, CEP 20040-005, Rio de Janeiro, Brazil. Facsimile: 55-21-507-1857/232-0382.

NEW IAEA APPOINTMENTS. Four new appointments have been announced by the IAEA. ***Mr. Zygmund Domaratzki,*** from Canada, has been appointed Deputy Director General, Department of Nuclear Safety, effective 1 August 1996. From 1992-94, he served as chairman of the Expert Group convened by the IAEA for the preparation of the Convention on Nuclear Safety. He succeeds ***Mr. Morris Rosen,*** Assistant Director General, of the United States. ***Ms. Annick Carnino,*** from France, has been appointed Director of the Division of Nuclear Installation Safety, Department of Nuclear Safety, effective 1 July 1996; she has been at the IAEA since 1990. ***Mr. Abel J. González,*** from Argentina, has been appointed Director of the Division of Radiation and Waste Safety, Department of Nuclear Safety, effective 1 July 1996. He was formerly Deputy Director of the former Division of Nuclear Safety. ***Mr. Swapan Kumar Datta,*** from India, has been appointed Director of the Division of Languages, Department of Administration, effective 1 September 1996; he was previously Head of the IAEA English Translation Section. He succeeds ***Mr. Jean Rivals,*** from France.

ENVIRONMENTAL REFERENCE. The annual review and reference on international co-operation in environmental development — the *Green Globe Yearbook* — has been issued by the Fridtjof Nansen Institute in Norway. The Yearbook includes evaluations on the Montreal Protocol, regional seas conventions, the United Nations Environment Programme, the World Health Organization's AIDS programme, and the integration of environmental concerns in development assistance. It further features profiles on the work of international organizations, including the IAEA, and of 13 countries of the Organization for Economic Co-operation and Development. The latest edition also provides references of Internet sources about international co-operation on environment and development, including a brief guide to electronic conferences in the field. More information may be obtained from the Institute, P.O. Box 326, N-1324 Lysaker, Norway. Facsimile: 47-67-111910. Email: green.yearbook@fni.no.

WORLD ENERGY OUTLOOK. Strong economic growth is expected to substantially boost world energy demand over the next two decades, reports the Energy Information Administration (EIA) of the US Department of Energy. The largest gains in energy use are projected to occur in the Asian region, where energy demand is seen to rise by 150% to the year 2015, led by the economies of China and India. The EIA notes that higher standards of living in emerging economies are propelling increased use of energy for electric power generation and for personal automobile transportation. Over the next two decades, electric power is projected to be the fastest-growing source of end-use energy supply worldwide, the EIA reports. Nuclear power will keep providing a good share of that supply, though fewer than half the countries having nuclear programmes are projected to expand capacity over the next 20 years. Growth is expected mainly in developing countries, the EIA reports. The projections are contained in the *International Energy Outlook 1996*, and more information may be obtained from EIA, Forrestal Building, Room 1F-048, Washington, DC 20585. Email: infoctr@eia.doe.gov.

ANNIVERSARY AWARD. Dr. Sigvard Eklund, Director General *Emeritus* of the IAEA, has been presented with an honorary certificate by the Technical and Natural Science Faculty, Upsala University, Sweden. Born in 1911 in Sweden, Dr. Eklund received his doctorate 50 years ago and the award was presented on the occasion of the anniversary of that achievement. Dr. Eklund served as Director General of the IAEA from 1961-81.

POSTS ANNOUNCED BY THE IAEA

NUCLEAR SAFEGUARDS INSPECTOR (several positions) (96/SGO-4), Department of Safeguards. These P-4 posts articipate in the implementation of the Agency's safeguard system as safeguards inspectors subject to the approval of the Board of Governors. They require a university degree in chemistry, physics, engineering or electronics/instrumentation or equivalent with at least 10 years of relevant experience with the nuclear fuel cycle, processing of nuclear materials, material accounting or non-destructive analysis, preferably in plant operation conditions.
Closing date: 31 December 1996.

UNIT HEAD (96-056), Department of Research and Isotopes. This P-4 post supervises the isotopic analysis unit in the Safeguards Analytical Laboratory (SAL) in Seibersdorf, and is responsible for the performance of isotopic analyses of samples of safeguarded nuclear materials. It requires a Ph.D. in chemistry, physics or equivalent with at least 10 years of experience in the isotopic analysis of nuclear fuel material, specifically but not exclusively, uranium, plutonium, and americium.
Closing date: 25 October 1996.

SECTION HEAD (96-055), Department of Research and Isotopes. This P-5 post assists the Division Director in matters related to nuclear medicine, covering all *in-vivo* and *in-vitro* applications of radionuclides in medical diagnosis, treatment and research and also all matters related to ancillary subjects like medical physics, instrument maintenance and radiopharmaceuticals. It requires a university degree in medicine with at least 15 years comprehensive and recent specialized clinical experience in all aspects of *in-vivo* and *in-vitro* nuclear medicine, and familiarity with informatics related to image processing (hardware and software). *Closing date: 25 October 1996.*

SYSTEMS PROGRAMMER (96-053), Department of Nuclear Energy. This P-3 post is responsible for the provision of systems programming support for the LAN environment, LAN server and workstation operation systems, and for the connected network of the VIC (server-based global applications). It requires a university degree in computer science, related field or equivalent plus at least 6 years of relevant practical experience.
Closing date: 14 October 1996.

INSTRUMENTATION SYSTEMS ANALYST (96-052), Department of Safeguards. This P-4 post provides the broad interdisciplinary computer/instrumentation support needed in the development section to collaborate effectively with MSSPs (Member State Support Programs) in all matters concerning Unattended Integrated Monitoring Systems and IAEA Integrated Safeguards Instrumentation Programme recommendations. It requires an advanced university degree in engineering, with specialization in electronics or computer science.
Closing date: 14 October 1996.

UNIT HEAD (96-051), Department of Research and Isotopes. This P-4 post is Head of the Chemistry Unit of the Agency's Laboratories at Seibersdorf. It requires a Ph.D. in radiochemistry, analytical chemistry or inorganic chemistry (or equivalent advanced degree) with at least ten years practical experience in nuclear and non-nuclear modern analytical chemistry with emphasis on trace element analysis and environmental radioactivity. *Closing date: 14 October 1996.*

RESEARCH REACTOR SPECIALIST (96-050), Department of Research and Isotopes. This P-4 post provides assistance to developing Member States in the acquisition, upgrading and utilization of research reactors. It requires a Ph.D. or equivalent in nuclear engineering or reactor physics with 10 years of relevant experience, and experience with research reactor operations and maintenance, reactor ageing issues, and research reactor organizations.
Closing date: 14 October 1996.

UNIT HEAD (96-049), Department of Technical Co-operation. This P-4 post administers the various components of the Agency's Group Fellowship and Scientific Visitors Programme. It requires an advanced university degree or equivalent in nuclear science, engineering, or nuclear applications, and at least 10 years of experience in research, engineering and administration in one of the above-mentioned fields including 4 years of management experience at a national and/or international level.
Closing date: 14 October 1996.

RADIOIMMUNOASSAYIST (96-048), Department of Research and Isotopes. This P-4 post assists in formulating, guiding, monitoring and evaluating the Agency's programme for assisting Member States to use radionuclide-based microanalytical techniques such as radioimmunoassay (RIA) and radioimmunometric assay (IRMA). It requires an advanced university degree (M.D., Ph.D. or equivalent) in medicine, biochemistry, chemical pathology, pharmacology or allied discipline with ten years of research and management experience in the use of radionuclide based microanalytical methods for disease diagnosis.
Closing date: 14 October 1996.

ASSOCIATE EXPERTS/JUNIOR PROFESSIONAL OFFICERS. The Government of Finland has undertaken to provide the IAEA with Finnish Associate Experts and Junior Professional Officers (generally qualifed persons under 32 years of age) for technical co-operation activities. The assignments, made at the P-2 grade, are normally for a period of one year. Interested candidates should directly contact the responsible authorities in Finland.

READER'S NOTE:

The ***IAEA Bulletin*** publishes short summaries of vacancy notices as a service to readers interested in the types of professional positions required by the IAEA. They are ***not*** the official notices and remain subject to change. On a frequent basis, the IAEA sends vacancy notices to governmental bodies and organizations in the Agency's Member States (typically the foreign ministry and atomic energy authority), as well as to United Nations offices and information centres. Prospective applicants are advised to maintain contact with them. Applications are invited from suitable qualified women as well as men. More specific information about employment opportunities at the IAEA may be obtained by writing the Division of Personnel, P.O. Box 100, A-1400 Vienna, Austria.

ON-LINE COMPUTER SERVICES. IAEA vacancy notices for professional positions, as well as sample application forms, now are available through a global computerized network that can be accessed directly. Access is through the Internet. The vacancy notices can be accessed through the IAEA's *World Atom* services on the World Wide Web at the following address:
http://www.iaea.or.at/worldatom/vacancies
Also accessible is selected background information about employment at the IAEA and a sample application form. Please note that applications for posts cannot be forwarded through the computerized network, since they must be received in writing by the IAEA Division of Personnel, P.O. Box 100, A-1400 Vienna, Austria.

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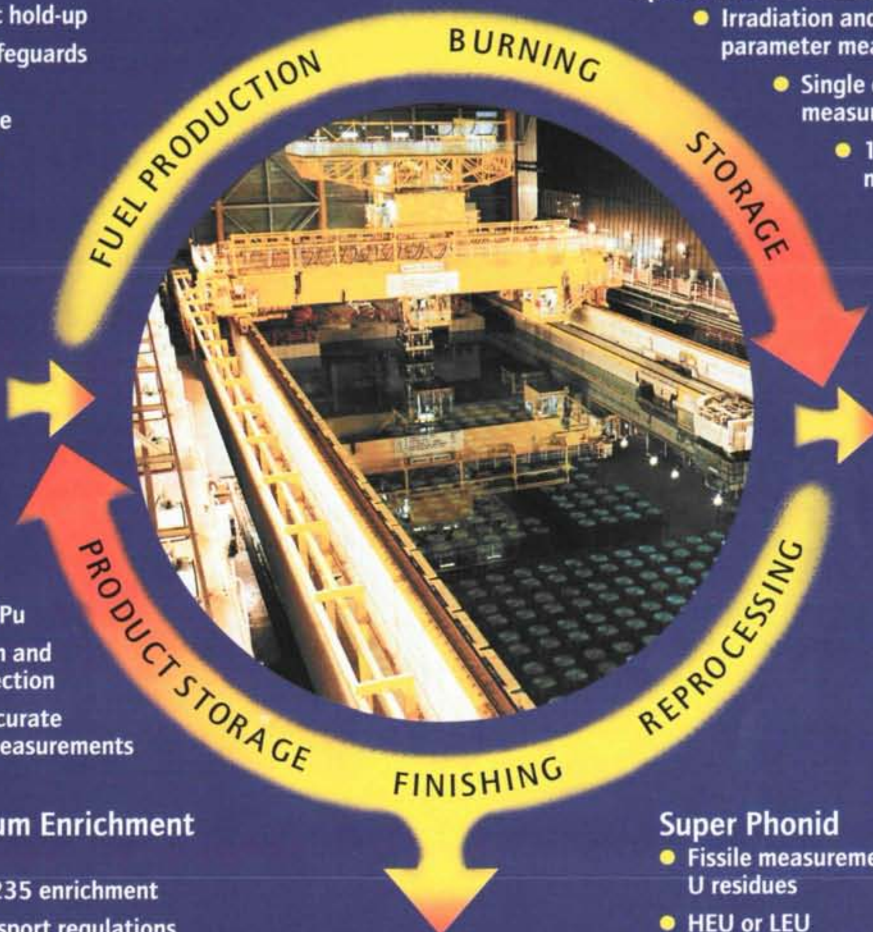

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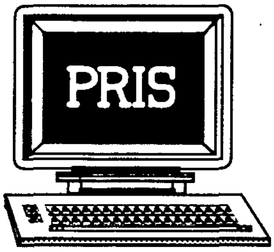

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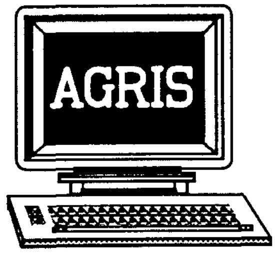
NES@IAEA1.IAEA.OR.AT

Scope

Worldwide information on power reactors in operation, under construction, planned or shutdown, and data on operating experience with nuclear power plants in IAEA Member States.

Coverage

Reactor status, name, location, type, supplier, turbine generator supplier, plant owner and operator, thermal power, gross and net electrical power, date of construction start, date of first criticality, date of first synchronization to grid, date of commercial operation, date of shutdown, and data on reactor core characteristics and plant systems; energy produced; planned and unplanned energy losses; energy availability and unavailability factors; operating factor, and load factor.



Database name

International Information System for the Agricultural Sciences and Technology (AGRIS)

Type of database

Bibliographic

Producer

Food and Agriculture Organization of the United Nations (FAO) in co-operation with 172 national, regional, and international AGRIS centres

IAEA contact

AGRIS Processing Unit
c/o IAEA, P.O. Box 100
A-1400 Vienna, Austria
Telephone (43) (1) 2060
Telex (1)-12645
Facsimile +43 1 20607
Electronic mail via BITNET/INTERNET to ID:
FAS@IAEA1.IAEA.OR.AT

Number of records on line from January 1993 to date

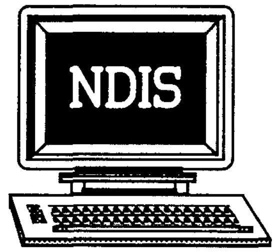
more than 130 000

Scope

Worldwide information on agricultural sciences and technology, including forestry, fisheries, and nutrition.

Coverage

Agriculture in general; geography and history; education, extension, and information; administration and legislation; agricultural economics; development and rural sociology; plant and animal science and production; plant protection; post-harvest technology; fisheries and aquaculture; agricultural machinery and engineering; natural resources; processing of agricultural products; human nutrition; pollution; methodology.



Database name

Nuclear Data Information System (NDIS)

Type of database

Numerical and bibliographic

Producer

International Atomic Energy Agency in co-operation with the United States National Nuclear Data Centre at the Brookhaven National Laboratory, the Nuclear Data Bank of the Nuclear Energy Agency, Organisation for Economic Co-operation and Development in Paris, France, and a network of 22 other nuclear data centres worldwide

IAEA contact

IAEA Nuclear Data Section,
P.O. Box 100
A-1400 Vienna, Austria
Telephone (43) (1) 2060
Telex (1)-12645
Facsimile +43 1 20607
Electronic mail via BITNET/INTERNET to ID:
RNDS@IAEA1.IAEA.OR.AT

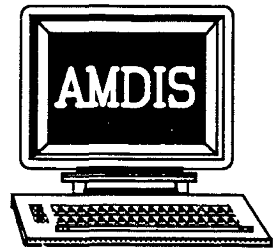
Scope

Numerical nuclear physics data files describing the interaction of radiation with matter, and related bibliographic data.

Data types

Evaluated neutron reaction data in ENDF format; experimental nuclear reaction data in EXFOR format, for reactions induced by neutrons, charged particles, or photons; nuclear half-lives and radioactive decay data in the systems NUDAT and ENSDF; related bibliographic information from the IAEA databases CINDA and NSR; various other types of data.

Note: Off-line data retrievals from NDIS also may be obtained from the producer on magnetic tape



Database name

Atomic and Molecular Data Information System (AMDIS)

Type of database

Numerical and bibliographic

Producer

International Atomic Energy Agency in co-operation with the International Atomic and Molecular Data Centre network, a group of 16 national data centres from several countries.

IAEA contact

IAEA Atomic and Molecular Data Unit, Nuclear Data Section
Electronic mail via BITNET to: RNDS@IAEA1;
via INTERNET to ID:
PSM@RIPCRS01.IAEA.OR.AT

Scope

Data on atomic, molecular, plasma-surface interaction, and material properties of interest to fusion research and technology

Coverage

Includes ALADDIN formatted data on atomic structure and spectra (energy levels, wave lengths, and transition probabilities); electron and heavy particle collisions with atoms, ions, and molecules (cross sections and/or rate coefficients, including, in most cases, analytic fit to the data); sputtering of surfaces by impact of main plasma constituents and self sputtering; particle reflection from surfaces; thermophysical and thermomechanical properties of beryllium and pyrolytic graphites.

Note: Off-line data and bibliographic retrievals, as well as ALADDIN software and manual, also may be ob-tained from the producer on diskettes, magnetic tape, or hard copy.

For access to these databases, please contact the producers.
Information from these databases also may be purchased from the producer in printed form.
INIS and AGRIS additionally are available on CD-ROM.

Database name
International Nuclear Information System (INIS)

Type of database
Bibliographic

Producer
International Atomic Energy Agency in co-operation with 91 IAEA Member States and 17 other international member organizations

IAEA contact
IAEA, INIS Section, P.O. Box 100, A-1400 Vienna, Austria
Telephone (+431) 2060 22842
Facsimile (+431) 20607 22842
Electronic mail via BITNET/INTERNET to ID: ATIEH@NEPO1.IAEA.OR.AT

Number of records on line from January 1976 to date
more than 1.6 million

Scope
Worldwide information on the peaceful uses of nuclear science and technology; economic and environmental aspects of other energy sources.

Coverage
The central areas of coverage are nuclear reactors, reactor safety, nuclear fusion, applications of radiation or isotopes in medicine, agriculture, industry, and pest control, as well as related fields such as nuclear chemistry, nuclear physics, and materials science. Special emphasis is placed on the environmental, economic, and health effects of nuclear energy, as well as, from 1992, the economic and environmental aspects of non-nuclear energy sources. Legal and social aspects associated with nuclear energy also are covered.

IAEA UPCOMING CO-ORDINATED RESEARCH PROGRAMMES

Intercomparison for individual monitoring of external exposure from photon radiation
To promote the implementation of the operational quantities for individual monitoring of external exposure from photon radiation.

Validation of thin-layer chromatographic screening methods for pesticide residue analysis
To validate relatively cheap procedures based on thin-layer chromatography that can be used to screen food and environmental samples for pesticide residues to identify those that must be analyzed by more elaborate nuclear and related techniques.

Specialized software utilities for gamma-ray spectrometry
To develop and make available to Member States modern algorithms, routines, programmes and libraries dealing with current topics in gamma-ray spectral analysis. These algorithms will improve the analyses in areas such as expert systems, spectra generation, data libraries, detector efficiency calibration, quality assurance, quality control, high-activity sources and coincidence corrections.

Dose determination with plane-parallel ionization chambers in therapeutic electron and photon beams
To investigate the accuracy of the data and procedures included in the new code of practice. In addition, differences with existing recommendations will be quantified to analyze the possible impact in patient dosimetry.

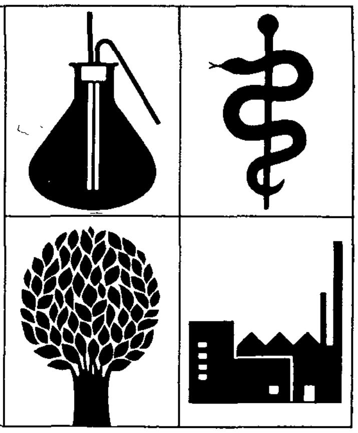
Compilation and evaluation of photonuclear data for applications
To develop a data file of evaluated photonuclear reaction cross sections. The list of nuclei should include natural elements and isotopes of importance in biological, structural and shielding materials, as well as actinides, fission products and a few others.

Assuring structural integrity of reactor pressure vessel
To facilitate the international exchange of information, provide practical guidance in the field of monitoring reactor pressure vessels and to develop and assess a uniform procedure of testing specimens for the assessment of RPV structural integrity.

Development of radiological basis for the transport safety requirements for low specific activity materials and surface contaminated objects
To assist the Agency in developing transport safety requirements. This CRP will provide a basis for classifying low level radioactive materials (such as low level waste) and for modelling potential releases in the event of transport accidents.

Development of methodologies for optimization of surveillance testing and maintenance of safety related equipment at nuclear power plants
To provide an exchange of experience in investigating and analyzing different strategies to improve and optimize maintenance and surveillance testing focusing on nuclear power plant safety, and to stimulate the exchange of methodologies and techniques to carry out such optimization processes.

These are selected listings, subject to change More complete information about IAEA meetings can be obtained from the IAEA Conference Services Section at the Agency's headquarters in Vienna, or by referring to the IAEA quarterly publication ***Meetings on Atomic Energy*** (see the *Keep Abreast* section for ordering information) More detailed information about the IAEA's co-ordinated research programmes may be obtained from the Research Contracts Administration Section at IAEA headquarters The programmes are designed to facilitate global co-operation on scientific and technical subjects in various fields, ranging from radiation applications in medicine, agriculture, and industry to nuclear power technology and safety



IAEA SYMPOSIA & SEMINARS

OCTOBER 1996

16th IAEA Fusion Energy Conference
Montreal, Canada (7 - 11 October)

Symposium on Reviewing the Safety of Existing Nuclear Power Plants
Vienna, Austria (8 - 11 October)

NOVEMBER 1996

Symposium on Harmonization of Health-Related Environmental Measurements Using Nuclear Analytical Techniques
Hyderabad, India
4 -7 November)

Seminar on the Use of Isotope Techniques in Marine Environmental Studies
Athens, Greece
(11-22 November)

APRIL 1997

Symposium on Diagnosis and Control of Livestock Diseases Using Nuclear and Related Techniques: Towards Disease Control in the 21st Century
Vienna, Austria (7 - 11 April)

International Symposium on Applications of Isotope Techniques in Studying Past and Current Environmental Changes in the Hydrosphere and the Atmoshpere
Vienna, Austria (14 - 18 April*)
*tentative date

Seminar on Current Status of Radiotherapy in the World
New York, USA (17 - 19 April)

MAY 1997

Seminar on Nuclear Techniques for Optimizing the Use of Nutrients and Water for Plant Productivity and Environmental Preservation
Piracicaba, Brazil (12 - 16 May)

Symposium on Desalination of Seawater with Nuclear Energy
Taejon, Republic of Korea
(26 - 30 May)

JUNE 1997

Symposium on Nuclear Fuel Cycle and Reactor Strategies — Adjusting to New Realities
Vienna, Austria (2 - 6 June)

SEPTEMBER 1997

Symposium on Radiation Technology in Conservation of the Environment
Venue to be determined
(15 -19 September)

OCTOBER 1997

Symposium on International Safeguards
Vienna, Austria (13 - 17 October)

IAEA BULLETIN

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IAEA MEMBER STATES

1957
Afghanistan
Albania
Argentina
Australia
Austria
Belarus
Brazil
Bulgaria
Canada
Cuba
Denmark
Dominican Republic
Egypt
El Salvador
Ethiopia
France
Germany
Greece
Guatemala
Haiti
Holy See
Hungary
Iceland
India
Indonesia
Israel
Italy
Japan
Korea, Republic of
Monaco
Morocco
Myanmar
Netherlands
New Zealand
Norway
Pakistan
Paraguay
Peru
Poland
Portugal
Romania
Russian Federation
South Africa
Spain
Sri Lanka
Sweden
Switzerland
Thailand
Tunisia
Turkey
Ukraine
United Kingdom of Great Britain and Northern Ireland
United States of America
Venezuela
Viet Nam
Yugoslavia

1958
Belgium
Cambodia
Ecuador
Finland
Iran, Islamic Republic of
Luxembourg
Mexico
Philippines
Sudan

1959
Iraq

1960
Chile
Colombia
Ghana
Senegal

1961
Lebanon
Mali
Zaire

1962
Liberia
Saudi Arabia

1963
Algeria
Bolivia
Côte d'Ivoire
Libyan Arab Jamahiriya
Syrian Arab Republic
Uruguay

1964
Cameroon
Gabon
Kuwait
Nigeria

1965
Costa Rica
Cyprus
Jamaica
Kenya
Madagascar

1966
Jordan
Panama

1967
Sierra Leone
Singapore
Uganda

1968
Liechtenstein

1969
Malaysia
Niger
Zambia

1970
Ireland

1972
Bangladesh

1973
Mongolia

1974
Mauritius

1976
Qatar
United Arab Emirates
United Republic of Tanzania

1977
Nicaragua

1983
Namibia

1984
China

1986
Zimbabwe

1991
Latvia
Lithuania

1992
Croatia
Estonia
Slovenia

1993
Armenia
Czech Republic
Slovakia

1994
Former Yugoslav Republic of Macedonia
Kazakhstan
Marshall Islands
Uzbekistan
Yemen

1995
Bosnia and Herzegovina

1996
Georgia

Eighteen ratifications were required to bring the IAEA's Statute into force. By 29 July 1957, the States in bold face had ratified the Statute.

Year denotes year of membership. Names of the States are not necessarily their historical designations.

For States in italic, membership has been approved by the IAEA General Conference and will take effect once the required legal instruments have been deposited.

The International Atomic Energy Agency, which came into being on 29 July 1957, is an independent intergovernmental organization within the United Nations System. Headquartered in Vienna, Austria, the Agency has more than 100 Member States who together work to carry out the main objectives of IAEA's Statute: To accelerate and enlarge the contribution of atomic energy to peace, health, and prosperity throughout the world and to ensure so far as it is able that assistance provided by it, or at its request or under its supervision or control, is not used in such a way as to further any military purpose.

IAEA headquarters, at the Vienna International Centre.

Until now, one of the biggest problems with reading personal exposure doses has been the size of the monitoring equipment. Which is precisely why we're introducing the Electronic Pocket Dosimeter (EPD) "MY DOSE mini™" PDM-Series.

These high-performance dosimeters combine an easy-to-read digital display with a wide measuring range suiting a wide range of needs.

But the big news is how very small and lightweight they've become. Able to fit into any pocket and weighing just 50~90 grams, the Aloka EPDs can go anywhere you go. Which may prove to be quite a sizable improvement, indeed.

Model	Energy	Range	Application
PDM-101	60 keV ~	0.01 ~ 99.99 μSv	High sensitivity, photon
PDM-102	40 keV ~	1 ~ 9,999 μSv	General use, photon
PDM-173	40 keV ~	0.01 ~ 99.99 mSv	General use, photon
PDM-107	20 keV ~	1 ~ 9,999 μSv	Low energy, photon
PDM-303	thermal ~ fast	0.01 ~ 99.99 mSv	Neutron
ADM-102	40 keV ~	0.001 ~ 99.99 mSv	With vibration & sound alarm, photon

SCIENCE AND HUMANITY

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