Radiation levels: WHO reports on Chernobyl

Experts estimate radiation dose commitment in Europe

Measurements have shown that there were very large differences in the deposition of radioactive materials in Europe after the Chernobyl accident; principally, these can be explained by the meteorological conditions during and after the accident and especially by the patterns of rainfall. In some cases, the high depositions necessitated the introduction of restrictions on the distribution and consumption of foodstuff. Due to understandable emphasis on the radiation levels in these so-called "hot spot" areas, the impression may have been created that such levels applied to large regions or whole countries, whereas the levels over most of Europe remained significantly below those recorded in these "hot spot" areas.

The concentration and deposition patterns over Europe were reconstructed by the use of large-scale dispersion models, in particular the MESOS model (Imperial College, United Kingdom) and the GRID model (RIVM/KNMI, Netherlands). The models proved to be generally capable of reasonable agreement, both with each other and with reported measurements of radioactivity in central Europe. (The iodine-131 deposition maps generated by the two models are presented in the figures on page 29; the MESOS results apply to a longer time period). The model and measurement results show that, apart from the Ukraine, high radioactive depositions are found in central Scandinavia and central Europe. Iodine-131 depositions over 100 kilobecquerel per square metre (kBq/m^2) are found in these areas, increasing up to about 1000 kBq/m^2 in very local areas. The levels of caesium-137 in these areas in general are over 20 kBq/m^2, with local maxima up to 140 kBq/m^2 (see accompanying figure, page 28).

Population exposure

Exposure of the population occurs through three main pathways: inhalation of airborne material, external irradiation from material deposited on the ground, and ingestion of contaminated foodstuff. Doses from external radiation and ingestion will dominate the overall dose. In areas of low deposition, all three pathways may be of similar importance. The working group prepared a preliminary estimate of doses from these three pathways, but it is important to note that some estimates are subject to a greater degree of uncertainty than others.

- *Doses from inhalation* can be estimated with reasonable reliability since it is necessary only to know the measured radionuclide concentrations in the air and to apply standard values for inhalation rates to obtain committed dose equivalents. In most of Europe, the effective dose equivalent (EDE) for adults by inhalation of iodine-131 varies between 1 microsievert (μSv) and 100 μSv.

This article is based on the summary report of 22 July 1986 of the Working Group on Assessment of Radiation Dose Commitment in Europe due to the Chernobyl Accident. Convened by the WHO Regional Office for Europe, the group met in Bilthoven, Netherlands, 25 to 27 June 1986. The WHO Regional Office for Europe is at 8 Scherfigsvej, DK-2100 Copenhagen, Denmark.

Background of WHO report

On 6 May 1986, the World Health Organization (WHO) Regional Office for Europe convened a meeting of experts to evaluate the immediate problems in various European countries caused by the Chernobyl nuclear reactor accident of 26 April 1986.* The experts did not attempt to draw any conclusions about the long-term impact of the accident because a detailed knowledge of the extent and geographical distribution of caesium-137 deposition was not then available. They recommended that this should be the subject of future study.

The WHO Regional Office for Europe therefore subsequently convened a working group of experts in the fields of radiation medicine, health physics, agriculture and food, public health and meteorology, together with representatives of international and intergovernmental organizations, to make a preliminary estimation of the radiation dose commitment in Europe due to the Chernobyl accident. This meeting was held in Bilthoven, Netherlands, from 25 to 27 June 1986, and was organized in co-operation with two WHO collaborating centres, the Institute of Radiation Hygiene of the Federal Health Office at Neuherberg, Federal Republic of Germany, and the National Institute of Public Health and Environmental Hygiene at Bilthoven, Netherlands.

The experts recognized that, although it would be tentative, an estimate of the radiation dose commitment would be useful in providing an overview of the European situation in the short term. They noted that the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) intended to prepare a more detailed and comprehensive review of the long-term health consequences, which should be available in 1988. On the basis of available measurements, prevailing meteorological conditions, and the application of appropriate predictive models, the experts reviewed the deposition of radionuclides. They also estimated the nature and extent of the contamination of foodstuffs, and made tentative predictions of population doses associated with the various exposure pathways, on the basis of information they had collected from the various countries.

As a result of discussions held at the 39th World Health Assembly and of comments made during the special session on 21 May 1986 of the Board of Governors of the International Atomic Energy Agency, the working group also produced a preliminary overview of the need to improve information exchange and public health preparedness in Europe in the event of major nuclear accidents.

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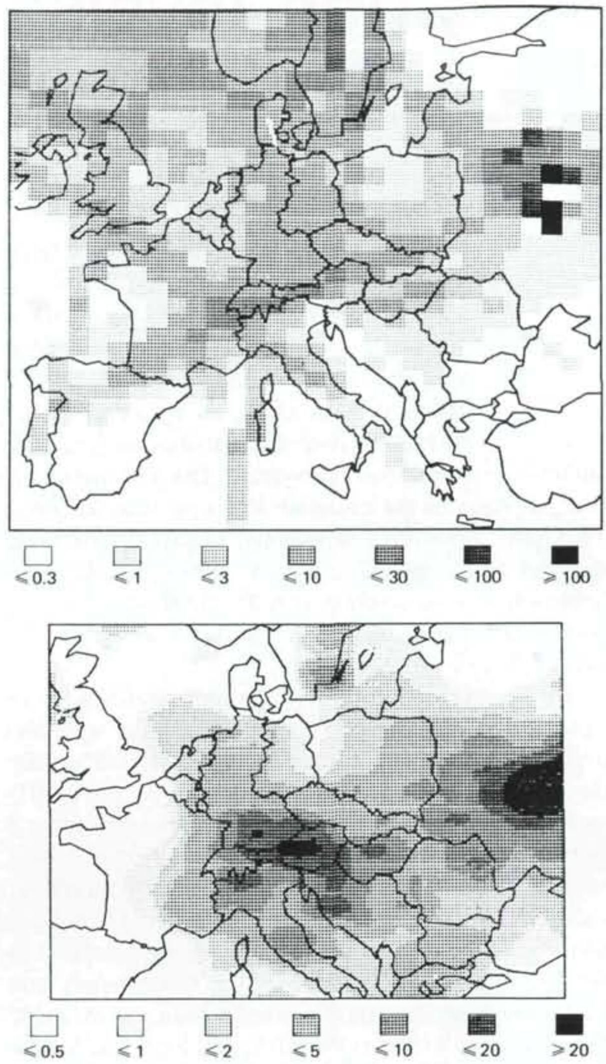
* See the *News in brief* section of the *IAEA Bulletin*, Vol. 28, No.2 (Summer 1986) for a summary of the report from the May meeting.

• *External irradiation* from deposited material can also be estimated with reasonable reliability either from measured exposure rates or from measured deposition per unit area. Calculations of dose equivalent need to take account of the time spent indoors and the shielding factor afforded by buildings; these will vary from country to country, but average values can be determined for each country. The estimated values of the EDE for the current year range for adults from 1 μSv in western France to 100 μSv in highly exposed regions of Poland and Sweden.

• *Doses from ingestion* arise mainly from iodine-131, caesium-134, and caesium-137. For iodine-131, the important foodstuffs are milk and leafy vegetables. Because of the short physical half-life of this nuclide (about eight days), these doses had already been completely absorbed by the time of writing (27 June 1986). They can be estimated from the concentrations that were measured in foodstuff, and from a knowledge of average consumption rates and standard values of committed dose equivalent per unit ingestion. Again, the calculated doses will vary from country to country because of differences in diet and consumption patterns, but average values can be established for each age group within each country. The measurement of iodine-131 in human thyroids was a means of confirming estimates based on inhalation and ingestion. In Europe, the estimated iodine-131 dose to the infant thyroid ranges from 0.05 millisievert (mSv) to 200 mSv. When protective measures were used, the upper values could be reduced by a factor of six.

Accumulated caesium-137 deposition (kilobecquerel per square metre)



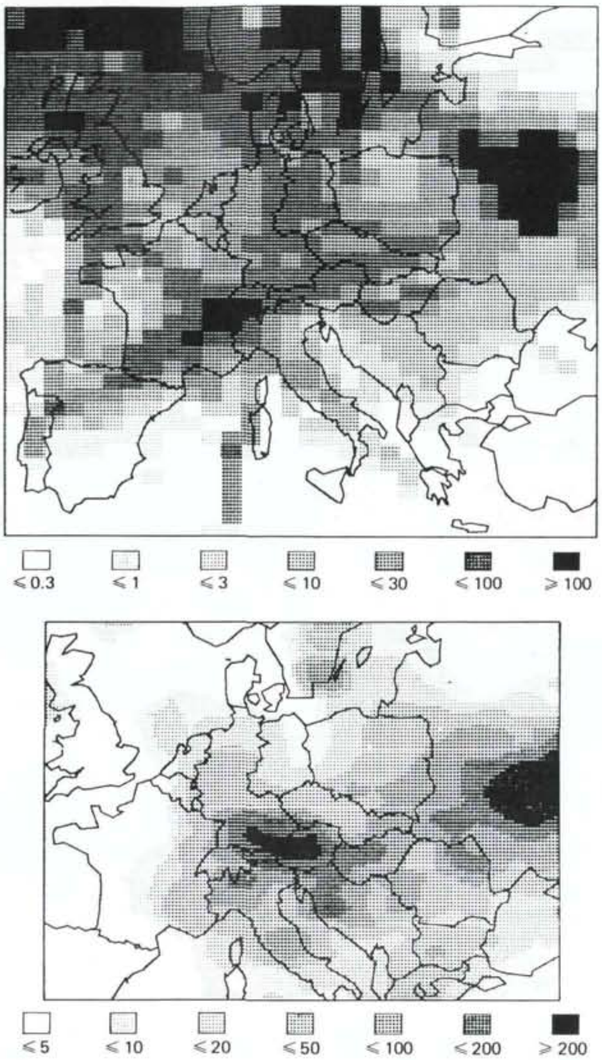
Note: Shown are results from two models using different scales and shading schemes. The top graph was calculated by the MESOS model up until 8 May 1986; the bottom graph by the GRID model up until 6 May 1986.

Estimating doses from caesium

The estimation of doses from caesium isotopes poses a greater problem since these isotopes will persist in the environment for many years. It is therefore necessary to consider not only the doses from the ingestion of foodstuff in the current year, but also the doses that will be received in the future, following long-term transfer through the food chains. The transfer to plants and animals depends on many factors that will vary widely across Europe. The estimated values of the dose from the ingestion of caesium isotopes must therefore be considered as preliminary ones that can be refined later. An accurate dose assessment in the (current) first year is difficult, especially because the amount of the penetration of caesium-134 and caesium-137 into plants via their leaves and their subsequent transport into the edible parts of the plants is subject to large variations. A rough estimation indicates that the EDE in the current year would not exceed 1 mSv, even in highly exposed regions. In the future, when plants will be contaminated only by root-uptake of caesium-137, the dose to man will be about 2 μSv in regions with a radioactive deposition of 1 kBq/m^2. The variations in exposure due to differences in the food basket were considered to be substantial, but of less importance than those resulting from the large differences in local deposition of radioactive material.

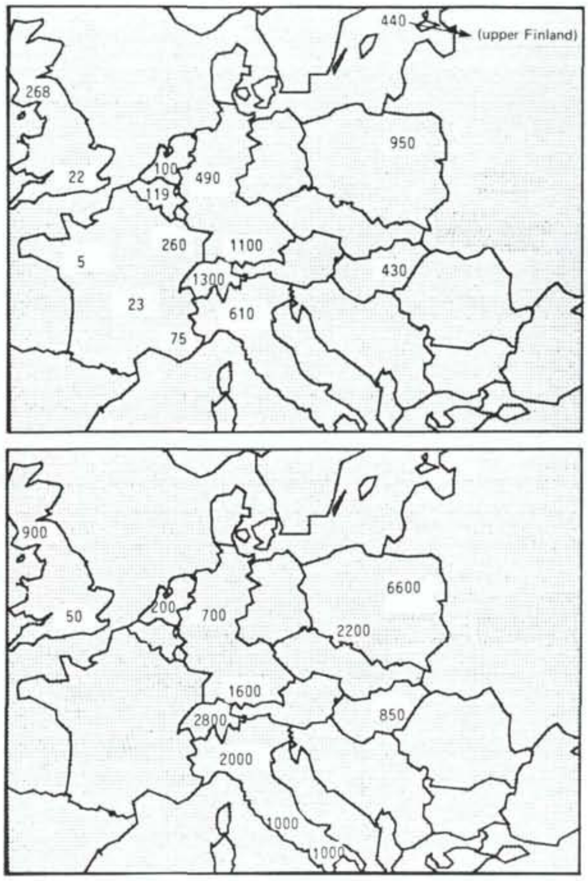
The total dose commitment (the sum of external dose, inhalation, and ingestion dose for the first year after the accident as reported by the various countries) is presented for adults and children in the accompanying maps. These maps can be compared with the models of iodine-131 deposition (primarily representative of external radiation) and of caesium-137 deposition (representative of ingestion in the coming years over Europe). The deposition maps support what is generally known about the distribution of total dose commitments over Europe. At very local "hot spot" areas, where the deposition due to local rainfall was up to 10 times the average values for a given grid cell (of an area of 10 000 square kilometres), the total dose commitment is expected to be correspondingly higher, but some levelling out will take place as a result, for instance, of local foodstuffs being mixed with those from other areas.

Accumulated iodine-131 deposition (kilobecquerel per square metre)



Note: Shown are results from two models using different scales and shading schemes. The top graph was calculated by the MESOS model up until 8 May 1986; the bottom graph by the GRID model up until 6 May 1986.

Total effective dose equivalent from external irradiation, inhalation, and ingestion



The maps show the total effective dose equivalent (in microsievert) for adults (top) and children as reported by various countries.

Around the periphery of Europe the total dose commitment is about 100 μSv, implying an increase of some 10% above the existing background level. For children, the total dose commitments are 2 to 3 times higher than those estimated for adults.

Recommendations

There have been significant inconsistencies in the measurement procedures used and the manner in which data have been reported, thus causing serious difficulties in interpretation. Guidance is needed at the international level on agreed methods for sample collection and analysis and the manner in which data are reported. To achieve a uniform assessment of data in the future, a protocol was developed and explained by means of examples.

Once the measurement data have been finalized, they will have to be reviewed in conjunction with the model results. On the basis of these results, it should be possible to verify and improve the existing transport and dispersion models.

Some inconsistencies were noted within and between European countries in the level of protective measures taken, such as restrictions on the movement and consumption of foodstuff. General acceptance of a pre-established method of providing guidance on protective measures at the national level could have obviated this situation to a large extent. International guidelines on intervention levels for different foodstuffs should be developed.

The attempts to predict the doses from future ingestion should be augmented by appropriate diet studies designed to take into account the actual food consumption patterns. Such a programme would be a direct method of checking predictions from food-chain models.

International guidance is needed on the composition of geographically specific food baskets to facilitate the calculation of exposure by ingestion. To avoid overestimating calculated exposures, particularly taking into account international trade, it is necessary for information to be available at the international level on public health restrictions on individual foodstuffs.