Environmental impact of radioactive releases: Addressing global issues

New information presented at an IAEA symposium is helping the global community to address radioecological concerns

by Gordon Linsley

In the decade after the United Nations Conference on the Human Environment, held in Stockholm in 1972, the IAEA organized a series of international meetings with themes concerned with radionuclides and their behaviour in the environment. In the atmosphere of concern for the environment which followed the UN Conference, the IAEA-sponsored meetings provided a focal point for international discussion and served to summarize the state of knowledge on radionuclide behaviour in different environmental media. A considerable amount of research was, at that time, being directed in IAEA Member States towards achieving an understanding of the behaviour of radionuclides, and especially of long-lived radionuclides, in the terrestrial and aquatic environments. The last symposium in this sequence of meetings was held in Knoxville, Tennessee, in the United States in 1981 with the title, "The Environmental Migration of Long-Lived Radionuclides".

Today, there is a new and increasing concern for the environment stemming from various evidences that the environment is being seriously affected by the activities of human beings. We are all aware of the effects of regional pollution and the possible threats of global warming and ozone layer depletion. It was to address these and other similar concerns that the UN held its Conference on Environment and Development in Rio de Janeiro in 1992. In the context of radionuclides in the environment there has also been a renewed interest; however, the stimulus in this case has come from a different direction. The relaxation of tensions between the countries of the east and the west has allowed much previously classified information on matters related to radioactive releases and their environmental impacts to become available. It is this new source of environmental information, together with the environmental information from the Chernobyl accident, which has renewed interest and stimulated research on radionuclides in the environment in recent years. In many cases, the need to gain greater understanding of radionuclide behaviour in the environment is linked to the plans for cleaning up the environmental contamination which resulted from weapons production operations and the early days of nuclear fuel cycle development.

It was with these developments in mind that the Agency organized the International Symposium on Environmental Impact of Radionuclide Releases, in Vienna in May 1995.* A total of 222 experts from 39 countries and five international organizations participated. This article summarizes the Symposium's highlights in selected topical areas that were addressed.

Studies in the marine environment

Since the time it was revealed that high- and low-level radioactive wastes had been dumped in the shallow waters of the Kara Sea in the Arctic over a period of 30 years, many studies have been initiated to evaluate the implications of the dumping. Shortly after the revelations in late 1991 and 1992, the IAEA, in collaboration with affected countries, launched an international project aimed at assessing the current and possible future impacts on health and the environment of the dumping. This project, known as the International Arctic Seas Assessment Project (IASAP), is still continuing but some preliminary results were reported at the Symposium. Other presentations from Norway and the Russian Federation and from the IAEA's Marine Environment Labo-

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ratory (IAEA-MEL) described the investigatory cruises to the affected area and associated experimental studies. The cruises have succeeded in locating some of the dumped high level wastes and measurements have been made *in situ* and also on samples taken in the vicinity of the dumped objects (submarines, reactor compartments, waste containers). The studies have shown that contamination can be detected close to some of the objects but at distances greater than a few tens of meters little or nothing can be detected. Since the wastes are located in a remote and inhospitable region, it has been concluded that they pose no threat to health or to the environment at the present time. However, there remains concern about the possible hazards which might result from leakage of radionuclides from the wastes at some future time. This issue is being evaluated as part of the IASAP together with an analysis of the feasibility of carrying out remediation actions on the wastes.

The session on the marine environment also contained presentations on the analysis of the impact of the discharges from the Sellafield reprocessing plant in the United Kingdom, a subject which has been controversial in recent years. The presentations focused on the historical development of discharge control at the site. They showed how discharges have been dramatically reduced from the levels in the 1970s and early 1980s by the introduction of effluent clean-up technology. At the same time, methods for analyzing the environmental impact of the discharges have also developed in sophistication and sensitivity.

Environmental model testing

The session on this subject was mainly focused on the IAEA programme called VAMP (Validation of Environmental Model Predictions) which ran from 1988 to 1994. The programme was aimed at taking advantage of the widespread distribution of radionuclides in the environment after the Chernobyl accident. The results of the subsequent measuring and monitoring programmes formed a basis for testing the predictions of mathematical models.

The VAMP programme proved to be very successful and involved well over 100 scientists from many different countries. Several presentations based around the results of the four VAMP working groups (Terrestrial, Urban, Aquatic (Lakes and Rivers and Reservoirs) and Multiple Pathways) were made at the Symposium. The exercises in VAMP provided a unique opportunity for testing the accuracy of model predictions. In some cases, existing models and transfer coefficients were shown to give a reasonable representation of the transfer of radionuclides through the environment. In other cases, previous generic assumptions regarding, for example, dietary intakes and food sources, were shown to be inappropriate for application to a particular environment. A general lesson from the studies is that each environment is different to the extent that it is unlikely that reliable predictions of radionuclide transfer to humans can be made without a detailed knowledge of the characteristics of the environment and of the habits of the exposed population group. In the model testing studies, there was a general trend towards over-prediction. One of the most likely reasons for this is associated with the use to which models are normally put, that is, they are most commonly used for the purpose of comparing radiation doses received by critical population groups from releases of radionuclides from operating practices with dose limits. In this application, there is a need to be sure that doses do not exceed the dose limit and so the assumptions and parameter values in the models tend to be selected in a way which will make underestimation unlikely.

Another feature of the VAMP programme, illustrated by presentations at the Symposium, was the opportunity for reviewing the state-of-the-art in modelling important transfer processes. Expert reviews carried out in the course of the VAMP programme have resulted in IAEA publications on the modelling of the resuspension process (ground to air), the interception and retention of radionuclides on plant surfaces, transfer in natural ecosystems, and the effectiveness of food preparation methods for the removal of radionuclide contaminants.

Radiation dose reconstruction

Operations in the early years of nuclear weapons development were directed at production targets and so the proper management of radioactive and other wastes was not usually given a high priority. Operational releases of radionuclides to the atmosphere occurred at high levels from several of the nuclear weapons production facilities. There were also releases to the environment from accidents at some of the facilities and also as a result of nuclear weapons testing. Information on these events has become available in recent years as previously classified documents have been released for public scrutiny.

The concern of potentially affected population groups and, in some cases, the legal action taken against the responsible authorities, has

Annual Dose from Natural Radiation Sources in the Environment (in areas of normal background radiation)

Source	Annual effective dose (micro-sievert)		
	External	Internal	Total
Cosmic rays	380		380
Cosmogenic radionuclides		12	12
Terrestial radionuclides			
Potassium-40	130	170	300
Uranium-238 series:			
$^{238}U \rightarrow {}^{234}U \rightarrow$ Thorium-230	140	1	
Radium-226		4	1400
Radon-222 → Polonium-214		1200	
Lead-210 → Polonium-210		50	
Thorium-232 series	190	80	270
Total (rounded)	**840**	**1520**	**2400**

Long Term Committed Doses from Man-Made Sources

Source	Main radionuclides	Collective effective dose (man-Sv)
Atmospheric nuclear testing	Carbon-14, Caesium-137, Strontium-90, Zirconium-95	30 000 000
Chernobyl accident	Caesium-137, Caesium-134, Iodine-131	600 000
Nuclear power production	Carbon-14, Radon-222	400 000
Radioisotope production and use	Carbon-14	80 000
Nuclear weapons fabrication	Caesium-137, Ruthenium-106, Zirconium-95	60 000
Kyshtym accident	Cerium-144, Zirconium-95, Strontium-90	2 500
Satellite re-entries	Plutonium-238, Plutonium-239, Caesium-137	2 100
Windscale accident	Iodine-131, Polonium-210, Caesium-137	2 000
Other accidents	Caesium-137, Xenon-133, Cobalt-60, Iridium-192	300
Underground nuclear testing	Iodine-131	200

Most significant releases of radionuclides to the environment from human activities have been from atmospheric nuclear weapons testing. Next in importance is the Chernobyl accident, followed by long-term exposures from carbon-14 and radon-222 associated with nuclear power production. A large part (86%) of the collective dose from nuclear weapons testing is due to long-term exposure from carbon-14. Some perspective on these estimated doses from human activities can be gained by comparison with those from natural sources. An estimated 13,000,000 man-sievert due to natural sources (e.g., cosmic rays, potassium-40 in the body, and radon gas) is delivered each year to the world population (2400 micro-sievert x 5.4 x 10^9 persons).

prompted investigations of the radiation exposures received by local populations as a result of the releases. At the Symposium, presentations on "dose reconstruction" themes were made in connection with the 1957 Khyshtym accident (Russian Federation) and with nuclear weapons testing at Semipalatinsk (Kazakhstan), and the Nevada Test Site (United States). The long time periods which have elapsed since the releases occurred have created problems for radiological assessment "detectives" to solve, and, for example, it has necessitated the development of new

environmental techniques for estimating the doses received by exposed populations up to 40 years ago.

Environmental remediation

The historical problems discussed above have also created a legacy of environmental contamination in many parts of the world. In addition to the contamination of parts of the terrestrial and aquatic environments created by weapons production and testing activities, many countries are affected by the residues from uranium and thorium mining operations, and from other non-nuclear related mining activities. Contamination from the Chernobyl accident still affects some countries, especially in forested and upland areas. Research into cost-effective and environmentally friendly solutions to these problems is going on in many countries. Presentations at the Symposium included descriptions of ameliorative techniques to be applied to soils, water, vegetation and cattle.

Topical discussion sessions

Discussion sessions were held on two topics which are currently subjects of controversy and debate within the radioecological community.

Environmental Protection. The generally accepted position on this subject is that if human beings living in the environment are adequately protected from ionizing radiations then it can be assumed that other living species are also adequately protected at the population level although not necessarily at the individual level. This is the view currently taken by the International Commission on Radiation Protection (ICRP) and the position has been supported by an IAEA study published in 1992.*

However, circumstances can be envisaged in which this assumption, on its own, may be insufficient to guarantee protection of non-human species, for example, where radionuclides are released to an area where no humans are present. There could also be presentational reasons for wishing to have specific criteria for protecting environmental species; the accepted ICRP approach might be misunderstood and interpreted as an attitude of unconcern for the environment. Explicit criteria for protecting non-human species might, therefore, be justified on these grounds. On the other hand, the introduction of specific environmental protection criteria could carry with it the requirement for more environmental monitoring and assessment than is currently practiced and, overall, it could involve substantial extra costs for utilities and regulators. These are some of the points debated during the session on environmental protection and it is clear that more discussions on the subject will take place over the next few years.

The Precautionary Principle. The principle of precautionary action has appeared in various international documents in recent years, notably in UNCED's Rio Declaration (Agenda 21)and in some regional conventions on protection of the marine environment. It is stated in various different ways; one example, taken from the Convention on the Protection of the Marine Environment of the Baltic Sea is as follows: "to take preventive measures when there is reason to assume that substances or energy introduced, directly or indirectly, into the marine environment may create hazards to human health, harm living resources and marine ecosystems, damage amenities or interfere with other legitimate uses of the sea even when there is no conclusive evidence of a causal relationship between inputs and their alleged effects".

The final part of the definition is obviously controversial and it was the focal point of the discussion session on the precautionary principle at the Symposium. On the one hand, it can be argued that most present legislation on waste discharge can be seen as unsatisfactory in that it requires scientists to prove that there is an effect from a harmful substance in the environment before regulatory measures will be introduced. The precautionary approach would require a "reversal of the burden of proof". Such a development could be useful in cases where little is known about the substance that is planned to be discharged or where the biogeochemical cycle and risks of the substance in the environment are poorly understood. On the other hand, the precautionary principle, if taken literally, could imply that no discharges of substances to the environment should be allowed since it is likely to be impossible to provide absolute proof that no harm will occur.

It is clear that while the precautionary approach is appropriate as a general concept, it needs to be interpreted for application to particular situations. It should be applied in ways which do not prevent the controlled release of substances to the environment whose properties are well known and whose behaviour in the environment to which they are being released is well understood. ❐

* *Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards,* IAEA Technical Reports Series No. 332, Vienna (1992).