The Radioactive Waste Management Conference

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Nuclear energy has been used on an industrial scale to generate electricity for nearly 30 years. The industry may thus be said to have reached maturity. Problems in the management of radioactive waste have been resolved adequately in the past; but given increasing concern about long-term safety and environmental protection they are becoming ever more crucial in the struggle to achieve eventual acceptance of nuclear power as a global, industrial source of energy.

It was therefore felt timely to organize earlier this year an international conference to review the entire spectrum of issues in radioactive waste management, and their bearing on national nuclear power programmes. The conference was held in Seattle, Washington, from 16 to 20 May. The response was gratifying, reflecting world-wide interest: it was attended by 528 participants from 29 Member States of the IAEA and eight international organizations. There were 21 sessions, at which 149 papers including a report on the IAEA's own work in this field were presented. An additional session was given over to two panel discussions, one on prospects for further international collaboration and the other summarizing the results of all the technical sessions.

The conference programme was structured to permit reviews and the presentation of up-to-date information on five major topics:

- Waste management policy and its implementation: national and international approaches; legal, economic, environmental, and social aspects (four sessions with 27 papers from 16 countries and four international organizations);
- handling, treatment, and conditioning of wastes from nuclear facilities, nuclear power plants and reprocessing plants, including the handling and treatment of gaseous wastes and wastes of specific types (five sessions with 35 papers);
- storage and underground disposal of radioactive wastes: general, national concepts, underground laboratories, and designs of repositories for high-level, and low- and intermediate-level waste disposal (five sessions with 35 papers);
- environmental and safety assessment of waste management systems: goals, methodologies, assessments for geological repositories, low- and intermediate-level wastes, and mill tailings (four sessions with 26 papers); and
- radioactive releases to the environment from nuclear operations: status and perspectives, environmental transport processes, and control of radioactive waste disposal into the environment (three sessions with 23 papers).

The papers presented were selected from nearly 500 submissions. The Scientific Secretariat made considerable efforts to ensure that the many reviews that have recently been undertaken by the Agency and other international organizations in specific areas of waste management, and of the status of waste management policy and its implementation in countries using nuclear power, were discussed. In addition, it was thought appropriate to include reviews of work in leading nuclear countries on underground disposal of wastes, on the treatment and conditioning of spent fuel and wastes from reprocessing, and on the management of tailings from uranium milling; and to attempt to give some perspective to radioactive waste management problems in comparison with other radiological impacts of the nuclear industry, and issues in the management of chemical wastes. About 70 of the papers presented were invited.

The opening session of the conference was addressed by the IAEA Director General, Dr Hans Blix, and by representatives of the US Government and of the State of Washington. Mr M.J. Lawrence, Deputy Director of the Nuclear Waste Policy Act Project Office of the US Department of Energy, said this conference was "especially appropriate and timely" as it focused on "a challenge that the international community must meet successfully if we are to assure the nuclear power for all", and on "an area where close international

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co-operation is demanded by our common interest in an acceptable global environment".

The tone of the conference was set by two keynote addresses, on the status of technology in waste management, and on major trends in research and development work in the implementation of waste management programmes. The first speaker was Mr. J.A. Liebermann, a pioneer in US waste management since the 1950s, who concluded that the technology is available to enable us to locate, design, construct, and operate waste management systems that meet stringent radiation protection requirements at acceptable costs, and that no technological breakthroughs are required. The second speaker was Mr J.F. Lefèvre, Director of the Department of Wastes and Effluents in the Commissariat à l'Energie Atomique, France. Both speakers recalled the long experience and research in radioactive waste management that now forms a solid base for implementing industrial systems and specific projects.

The Agency presented a report on the objectives, activities and results of its own waste management programme, with emphasis on recent developments and collaboration with other international organizations in relevant areas. Attention was drawn to the systematic and comprehensive work that has already been done or is under way internationally to assist in the implementation of national waste management programmes and to resolve related international issues.

Waste management policy and its implementation

The 27 papers from 16 countries and four international organizations in this subject area showed that governments are aware of the need for proper and timely implementation of radioactive waste management systems, including the definition of the related regulatory, institutional and financial arrangements. Policy decisions have already been taken in many countries. The spectrum ranges from those which plan to expand their nuclear programmes in coming years (such as Egypt) to those whose current nuclear policy foresees the use of nuclear power only until about 30 years from now (Sweden). Many countries have programmes with mandated schedules for the implementation of geological repositories for high-level wastes or spent fuels (USA), or for the selection of appropriate sites (for example, Argentina, the Fed. Rep. of Germany, Sweden, Switzerland), but there are some whose policy – in effect – calls as part of an overall waste management strategy for the deferral of decisions to proceed with the construction of such repositories (UK).

Some well-defined common ground was evident. The basic driving force for policy decisions was seen to be the need to assure the protection of human health. A well-defined legal, regulatory, institutional, financial, and administrative framework for the implementation of policy exists or is under active discussion in many countries. There was a general acknowledgement, even a consensus, that adequate technology for the safe management of radioactive wastes is available.

In many countries, underground facilities for the disposal of low- and intermediate-level wastes have already been established (for example, in France, India, the German Democratic Republic, the USSR, UK, and USA). In these and other countries national disposal concepts designed to meet the long-term requirements of nuclear programmes are being developed. There is a general tendency to employ land-based alternatives to the sea-dumping of nuclear wastes, though sea disposal is of continuing interest in some countries (the UK, Japan, Belgium, Netherlands, and Switzerland).

Socio-political issues related to waste management, generally recognized as posing problems for the further growth of nuclear power, were a reasonably common though perhaps not universal feature for discussion and resolution. While there is a need to put the risks of radioactive waste management in a proper perspective, to gain public understanding and acceptance, achieving this objective is a difficult task which needs national and international attention.

Available information on the economic implications of waste management indicates that including the full costs of spent fuel storage and final waste disposal will increase their proportionate share in the total cost of nuclear power (figures exceeding 10% have been mentioned). The costs of waste management are charged mostly to the price of electricity, and regulations to permit this have or will become effective in Sweden (2.3 mills* per kWh), USA (1 mill per kWh), the Fed. Rep. of Germany (6 mills per kWh), Switzerland (5%), and so on. Though such costs are higher than had been assumed previously, they do not seem likely to have a serious or decisive impact on the use of nuclear power – and this even in countries with small nuclear programmes Economics was not and will not be a major driving force for simplifying or reducing conservatism in radioactive waste management systems; elaborate systems that meet long-term safety and stringent radiation protection requirements can be afforded, even though they may not always be justifiable on technical grounds.

Some countries have set up special institutions to implement or operate waste disposal or spent fuel management systems which cannot be handled properly by the utilities themselves: for example, ONDRAF in Belgium, ANDRA in France, the SKBF in Sweden, NAGRA in Switzerland, and NIREX in the UK. In the USA, the Department of Energy has, in implementing the Nuclear Waste Policy Act signed by President Reagan in January 1983, established a new office exercising responsibility for civilian radioactive waste management, for the development of interim storage facilities and repositories for the storage and disposal of high-level radioactive waste and spent nuclear fuel,

* 1 mill = US 10^{-3} = 0.1 ¢.

An exhibition describing some of the Agency's work in the field of radioactive waste management was displayed at the venue of the Seattle conference. Here, participants discuss one of the exhibition panels.

and for establishing a programme for research, development, and demonstration for these and other purposes.

The positive rôle of international organizations was generally recognized, while noting the understandable fact that the larger the membership of an organization the more general its approach tends to be. The value of the IAEA as a source of information and guidance was evident. International co-operative ventures in waste disposal, and in particular the wish of smaller countries to have access to repositories in larger nuclear countries or to be able to transfer spent fuel, were discussed on more than one occasion, but operational activities in this area were acknowledged to be premature.

Waste handling, treatment, and conditioning

The 35 papers in this series of sessions reviewed techniques and experience in the handling, treatment, and conditioning of low-, intermediate- and high-level wastes that arise in the course of operation of nuclear power plants and reprocessing plants, from decommissioning operations and from some other nuclear facilities including those associated with advanced fuel cycles.

The surveys were based mostly on recent reviews by international groups of experts. They showed that techniques for handling low- and intermediate-level

wastes have been proven by industrial experience – though this does not diminish the need to search for further technological development. A remarkable effort has been undertaken in countries of the European Communities to characterize the properties of low- and intermediate-level waste, in order to obtain the required level of quality assurance for waste forms and packages for storage and disposal, and to establish a data bank. Similarly, the results of the IAEA co-ordinated research programme on the evaluation of conditioned high-level waste forms showed the importance of common investigation methods, and of assessing the behaviour of the waste forms under "real" repository conditions.

A number of pilot or prototype plants for the vitrification of high-level waste are under construction or are undergoing active testing in a number of countries. Industrial experience with "real" high-level waste vitrification has so far been gained only in France. A paper on the treatment of special wastes at Three Mile Island Unit 2 drew attention to the variety of problems that might arise when decontamination measures and remedial actions have to be undertaken after accidents affecting nuclear facilities. An international review on the decommissioning of nuclear facilities showed that the body of experience and capability in engineering and planning is adequate to allow the making of reliable cost estimates, and the implementation of appropriate measures for ultimate disposal of decommissioning wastes.

A presentation on the management of wastes arising at nuclear power plants dealt with techniques of compaction, incineration, bituminization, and cementation, and with specific problems associated with the handling of spent ion-exchange resins and tritium-bearing wastes. The importance of further improvement in volume reduction techniques was underlined, in particular to ease interim storage: the Fed. Rep. of Germany, for example, aims to reduce the volumes of waste from nuclear power stations by a factor of five.

The most important problem in the management of gaseous wastes is the recovery and storage of significant quantities of four radionuclides – krypton-85, iodine-129, tritium, and carbon-14 – originating from the dissolution of fuel in reprocessing plants. Release of any of these radionuclides would result in increases in the dose commitments of people in both regions around the plants and world-wide. The management of airborne contaminants is complex because their recovery, immobilization, and storage require different technologies for each element. Recovery and storage of iodine-129 and to a lesser extent carbon-14 and krypton-85 appear to be justified. None of the criteria evaluated support a decision to control releases of tritium, therefore its recovery was not recommended.

A CEC paper contained an overview of R&D activity in the management of radioactive waste from the decommissioning of nuclear power plants. Highly efficient decontamination techniques are being developed – in particular, using a chemically aggressive decontaminant in liquid and gel form. Electrochemical and hydromechanical techniques are also under examination. Some encouraging results have also been obtained in the decontamination of concrete surfaces by rapid heating, causing a thin layer to fall off.

National experience and approaches for managing all kinds of radioactive wastes from reprocessing plants were presented by authors from France, the Fed. Rep. of Germany, India, Japan, the UK, and USA. These countries have built effective treatment plants which are either in industrial use, or are at the demonstration stage; and many years' experience from industrial operations has been acquired. The use of techniques such as evaporation, co-precipitation, incineration, and compaction, measures to recover plutonium, bituminzation, and cementation for the conditioning of low- and intermediate-level wastes are common. Comprehensive reviews were given on US experience and projects for treating and conditioning the great variety of wastes produced by the reprocessing plants at Hanford, Idaho and Savannah River. Experience gained at the French reprocessing plant at La Hague, including provisions for new facilities being built at that site, was also presented.

Considerable efforts are made to treat and condition wastes stored for final disposal at US Department of Energy plants, in accordance with the requirements of the US Nuclear Waste Policy Act of 1983. Techniques for the separation of caesium-137, strontium-90, krypton-85, and americium-241 from high-level waste have been developed and applied.

Experience reported from UK reprocessing plants drew attention to the fact that questions of managing intermediate-level wastes have become more important than those of managing high-level wastes, for which vitrification plants are being built. Particular efforts are being made at the Wiederaufarbeitungsanlage Karlsruhe (WAK), in the Fed. Rep. of Germany, to improve plutonium recovery and the treatment of organic solvents and to reduce the volumes of waste arisings. A programme in India, where a vitrification plant has been constructed, and pilot plants in Italy are based on technologies that are similar to those used in other countries.

Other papers reported the status of vitrification pilot plants in Belgium, the Fed. Rep. of Germany, Italy, the USSR, and at the US West Valley site where waste from previous commercial reprocessing activities is being stored. Other examples of improved technologies for treating low- and intermediate-level wastes are the acid digestion process for the treatment of combustible alpha-waste – a preliminary step in plutonium recovery – and the slag incineration process used in Belgium for the integrated treatment of alpha-, beta-, and gamma-emitting materials. This latter would

appear to be a particularly promising process for achieving high volume reductions and stable waste forms. The Synroc process as an alternative to vitrifying high-level waste is being given further study in Australia; investigations there include assessment of the industrial feasibility of this process in pilot-scale plants, and research into alternative waste-rock compositions including those incorporating spent fuels in solution.

All the presentations indicated that the technology for managing high-level and alpha-bearing wastes at reprocessing facilities has essentially passed the R&D stage, and is now sufficiently mature to be introduced on an industrial scale in plants in operation or under construction in various countries. There is, however, room for further improvement and there are also areas which might require further study. This is true particularly of the recovery of gaseous nuclides such as krypton-85, iodine-129, carbon-14, and tritium. Experience to date in France with wastes from fast breeder reactors and their fuel cycle indicates that these wastes are manageable and will not pose substantially new technological problems.

A general conclusion from all the presentations in this series of sessions is that the technical means for managing radioactive waste at nuclear facilities are proven and available. Their further development need not be an obstacle to current nuclear power programmes.

Storage and underground disposal of radioactive wastes

The 35 papers in this series of sessions dealt with experience, actual practice, and further improvements in the underground disposal of low- and intermediate-level wastes, and with the storage of spent fuels and high-level wastes. The well-advanced status of conceptual developments and practical preparation for the final disposal of high-level waste and spent fuel were described *in extenso.*

The common ground in all the work presented lay in the need for generally accepted radiological protection objectives for the underground disposal of radioactive waste which will enable the derivation of criteria for the different disposal options. The guidelines given in some recent IAEA reports – such as Safety Series Nos 54, 56, and 60, prepared as a part of the Agency's programme of work in this field – would be of relevance in this context.

For spent fuel and vitrified high-level waste two stages – interim storage and final disposal – must be distinguished. Two papers discussed the storage and handling technology available. Two decades of experience of spent fuel storage lead to the conclusion that it can be used for several more decades, leaving time to determine without haste the optimum timing for the transition from storage to final disposal. With respect to final disposal of either spent fuel or vitrified high-level waste, a number of papers showed how repository concepts have been developed and site surveys carried out using geophysical, geochemical, and other methods of investigation. Results obtained for different rock types such as granite, salt, clay, basalt, and tuff show clearly that radiological protection objectives can be achieved in various ways. A Swedish paper describing the concept of disposing of packaged spent fuel in a granite repository was of particular interest. It concluded that the present technology is such that it is possible to acquire knowledge adequate to make predictions far into the future, and that the total repository system would provide protection well beyond the requirements of society today.

An entire session was devoted to underground rock laboratories and pilot projects in which very large resources have been invested in Belgium, Canada, the Fed. Rep. of Germany, Sweden (the Stripa project), Switzerland, and the USA. The pilot projects are obviously very much system-dependent. They vary according to disposal concept and type of host rock: granite (Canada, Sweden, Switzerland, USA); salt (the Fed. Rep. of Germany, USA); clay (Belgium); basalt (USA); and so on. The presentations showed how the objective of establishing deep geological repositories can and will be reached. The conceptual methodology used is quite similar in Argentina, Belgium, Canada, France, Sweden, Switzerland, and the USA. In all cases but one, repositories are planned to accept high-level waste well after the turn of the century – the exception being a repository in the USA in basalt, tuff or salt which should be operational in 1998.

The situation is different for the disposal of low- and intermediate-level wastes, in shallow ground or in repositories in rock cavities. Disposal in shallow ground has been in practical use for decades and many papers presented an interesting compilation of the experience gained in France, India, and the USA. In earlier disposal operations, the packages were often not planned to provide a confinement barrier which would last a long time (for example, some containers were made of cardboard). Nevertheless, measurement in associated groundwaters of specific radionuclides over periods of many years permit the conclusion to be drawn that under normal hydrological, topographic, and climatic conditions releases are well within acceptable limits.

One paper dealt specifically with geohydrological problems in shallow ground disposal in the USA. In spite of identified problems which have resulted from earlier and current disposal practices, the authors were nevertheless optimistic. They stated that none of the problems observed has resulted in apparent human harm, that the experience gained in investigating problems of radionuclide migration has led to a better understanding of earth science requirements, and that each of the problems identified is amenable to practical solution by appropriate site selection, design and operation of the repositories.

A number of papers showed progress in repository design. Repositories range from unlined underground

trenches to above-ground mounds and monoliths. The newer designs of the latter type in France have a built-in water collection system which allows control over radionuclide migration out of the repository.

The use of cavities in rocks of different types, whether they are abandoned mines or special excavations, seems to be gaining in importance in the disposal of low- and intermediate-level wastes. Some countries have operational experience of rock cavity repositories (the Fed. Rep. of Germany [abandoned mines], the German Democratic Republic, and Spain), and others are planning to construct such repositories in hard rock (Finland, Sweden, Switzerland, and the UK).

Management practices for uranium mill tailings were reviewed with an emphasis on recent attempts to reduce environmental impacts. Efforts are being made, supported by Governments, to improve the protection of groundwaters and to reduce the release of long-lived radionuclides of environmental significance. Countries concerned with such problems are aware of the long-term implications of releases from mill tailings and are looking accordingly for improved methods of containment and management.

Goals and methodologies for environmental and safety assessments

Twenty-six papers were presented in the sessions dealing with the environmental and safety assessment of waste disposal systems. There was considerable discussion of the basic criteria for setting the goals, and a consensus on requirements for present and future dose limitation. The philosophy of the International Commission on Radiological Protection seems to have become well-accepted. It was suggested that a fraction of the dose limit for individuals should be used as an upper bound. Difficulties were encountered in the discussion of doses which might result from disruption of a repository, as events of both high and low probability of occurrence are involved.

Factors that would have to be considered in the optimization of radiological protection were discussed at length. An interesting part of this discussion was the clarification of problems in the integration of *collective* doses in the extremely far future. It became clear that the only relevant part of the collective dose is that which is influenced by choice of option, because the remaining part cancels out in the subtraction from one option to another. That would make attempts at assessment over shorter times more reasonable than integration over geological times. Another interesting point is that in selecting options one would have to consider that part of the collective dose which is less uncertain, because if the overall value is taken with its enormous uncertainties, determination and precision in the selection between one option and another are lost. Of these two factors, the part which is influenced by choice of option and the part which is less certain would determine the period of integration into the future – which cannot be infinite.

There was discussion on ways of choosing between options. One was cost-benefit analysis, which seems quite transparent as long as the major decisions are made beforehand regarding some of the components. Other methods such as decision analysis were also discussed, and there was considerable discussion of what is "reasonable". Those who carry out assessments seem to have a preference for standards based only on individual future doses, with some sort of acceptable value of uncertainty and perhaps some criteria for the reduction of dose. But, on the whole, approaches seem to be converging towards the application of a sophisticated radiation protection philosophy to the assessment of waste management practice.

There were papers dealing specifically with safety assessments in the disposal of low- and intermediate-level wastes, and mill tailings. In the case of mill tailings attempts have been made to use or at least to outline what are basic issues in optimizing decisions. There has been some analysis as well of technologically feasible ways of reducing radon emissions, and of assessing their real significance in the long term. With respect to low- and intermediate-level wastes, the key issue is probably the attempt to quantify what is meant by "safety" and not merely the assessment of whether a system is "good" or "not good". There have been some analyses of "normal" mechanisms of release by water transport, and comparisons with criteria based on individual dose. The most probable disruptive event has also been identified: for example, perforation of the formation; and assessments of the minimum surveillance time needed to ensure compliance with basic goals. Discussions on deep geological repositories related mainly to assessments of safety and performance. There were also papers on assessment of the safety of idealized repositories in differing rock types, and on site-specific assessments. In all cases, the performance of the different barrier systems was analysed, starting with the actual dissolution of the matrix containing the waste, moving to the package, buffer, and barrier materials and their behaviour, migration through the rock system to the biosphere, and ending with an estimate of the resulting population doses.

A study on environmental impacts – part of a more comprehensive study of geological waste disposal carried out by the Waste Isolation System Panel of the National Research Council of the USA – was reported by Thomas H. Pigford, Chairman of one of the panels. Site-specific hydrological and geochemical parameters supplemented with generic parameters, where necessary, enabled calculation of future radiation doses to maximally exposed individuals, for conceptual repositories in basalt, granite, salt, and tuff. These were compared with a performance criterion of 10^{-4} Sv·y^{-1} for radiation exposure from "probable" events. The maximum expected individual dose was shown, on the assumptions

of this study, to be much below the performance criterion. The study also made a number of recommendations and conclusions. These included the need for a well-defined general criterion that defines acceptable overall performance of the geologic waste isolation systems; guidelines and approaches to be taken in the technical and other areas; and means of reducing uncertainties in predictive accuracies for future releases to the environment.

Papers presented in these sessions showed how sophisticated safety assessments have become. Perhaps the most important point is that a considerable amount of data arises which is not very definite and that sensitivity analyses are therefore extremely important, especially in quantifying the effect of uncertainty in different physical parameters. Some physical parameters have a strong effect on the end result while others do not. Also, the way in which uncertainties are approached is quite different. In the "deterministic" approach the uncertainty would have to be taken into consideration in maximizing the final collective dose for comparison with some sort of goal. In the case of the "probabilistic" approach best estimates in combination with the corresponding probabilities are necessary.

Environmental transport processes and models

The 23 papers in the sessions on environmental transport processes and models dealt with the development of technical means for assessing the consequences of releases to the environment. One paper, describing a model for the transport of long-lived radionuclides released to the environment, pointed out some deficiencies in models for the transport of tritium and iodine-129, particularly when doses close to the point of release are required. Another paper was a preliminary report on what will eventually be a most important international intercomparison, the INTRACOIN project. This is comparing some 20 computer codes for modelling radionuclide transport in the geologic far field; taking part in the study are modelling groups from Canada, Denmark, France, Sweden, Switzerland, the UK, and USA.

Several papers concerned with investigations and measurement emphasized the complexity of the environment and the sensitivity of radionuclide transport to chemical and biochemical interactions. In particular, the effect on nuclide mobility of association with complexing agents such as EDTA and other organic species such as carboxylic acids is being studied at the Maxey Flats low-level waste disposal site in the US.

There is clearly a need for more realism in predictive models as emphasis shifts to site-specific studies and concentrates more on optimization of waste disposal facilities and procedures. On the other hand it will be a daunting task if models are required to simulate in detail all the complex interactions in the conditions of an actual disposal site. It is necessary to find the right balance.

Most papers in the session on the control of radioactive waste disposal to the marine environment were concerned with the sea-dumping of packaged solid wastes. Considerable internationally co-ordinated research is being carried out at present within the various disciplines needed to re-assess the hazard from sea-dumping and to look again at the definition of high-level waste formulated by the IAEA. Several papers described aspects of this research, including an oceanographic modelling review just completed by the UN joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP), the co-ordinated research and environmental surveillance programme set up by the Nuclear Energy Agency of the OECD (NEA) and experimental measurements being carried out at the IAEA International Laboratory of Marine Radioactivity in Monaco. The consensus of these papers is that improved, more appropriate, and more realistic models will be available soon, for use with the improved data base now being generated, to carry out the various studies which are needed. None of the investigations carried out to date indicate that previous assessments of the hazard have been too low. If anything, more processes retarding the transfer of radionuclides to man have been identified. This is a clear area where international scientific collaboration is of the essence, and the IAEA continues to play a crucial and active rôle.

Two papers dealt with the possibility of disposing of high-level waste on the seabed. Work on this topic is being carried out under the auspices of the NEA Seabed Working Group and the development, current organization, and programmes of this Group were described in one of the papers. It seems that seabed disposal is technically feasible, but there are many technical questions and institutional issues which require resolution before this option could be considered for implementation.

There was an informative review of the public exposure resulting from the discharge of transuranium nuclides to the sea from Sellafield, in the UK (perhaps better known as Windscale). The UK paper emphasized the rôle of feed-back from measurement programmes in assessing dose and the difficulty of predicting realistically doses in the future from such long-lived radionuclides.

The results of a nine-year field study of radionuclide migration from a low-yield underground nuclear test explosion in tuffaceous alluvium at the Nevada Test Site were presented in a US paper, which indicated that most of the radioactivity was found to have been retained in fused debris in the cavity region. Samples obtained at depths from just below the ground surface to 50 metres below the detonation point were analysed: it was found that no activity above background levels was present in the deepest samples, and that only tritium and strontium-90 were present in water in the cavity at levels greater than the concentrations recommended for water in uncontrolled areas.

Several other papers in this session, which was concerned with releases to the environment from nuclear generation, reviewed general levels of environmental contamination and consequent doses. An example was a summary of the 1982 report of the UN Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). There were also discussions on procedures for authorization of discharges, and on the need to consider broader possibilities in optimization such as comparing hold-up, solidification, and disposal with direct discharge for some nuclides. A further problem lies in determining what allowance should be made for build-up in the environment and for doses delivered far into the future at points distant from the discharge site.

An important international development is the effort to try to reach agreement on the control of transfrontier pollution. The key to this is recognition that as much weight should be given to doses delivered to "foreigners" as to nationals of the country releasing the radionuclides. The IAEA is playing a major part in this effort.

A paper from the World Health Organization (WHO) served as a reminder that the magnitude of concern, knowledge, and complexity of approach that is being applied to radioactive waste disposal is much higher than that applied to other toxic wastes. The practical efforts required to put the radioactive waste management issue in the right perspective are not clear.

Prospects for international co-operation

In addition to presentations from various international organizations and of the results of international reviews of specific topics during the technical sessions, a panel composed of representatives from related international organizations and some Member States discussed the prospects for further international co-operation.

The chairman, Mr. E. Svenke, from the Swedish Nuclear Fuel Supply company, referred to what he called the "three dimensions of threat" from nuclear power – the "threat of nuclear weapons", the "threat of radiation", and a "third dimension" characterized by the time-span during which radioactive wastes must be in final isolation. He concluded that international collaboration is not only valuable but in this field indispensable because of the "moral" dimension of the long-term safety requirements. These lead, without questioning today's national sovereignties and boundaries, at least to the need for international consensus on general principles and assessment methods. The potential usefulness of multi-national repositories was mentioned.

Representatives from the ICRP, IAEA, WHO, NEA, CEC and the Council for Mutual Economic Assistance (CMEA) described their fields of responsibility and activities; and this was followed by consideration of what countries such as France, India, Sweden, and the USA have experienced or could expect from international co-operation. In addition to general motivations for international co-operation such as the sharing of experience, obtaining economy of scale or the pooling of resources, there may be substantial influences on harmonization of national approaches or explaining their differences and getting socio-political and public acceptance. Several areas where international co-operation would be important were mentioned, but there was a consensus that the development of internationally agreed safety criteria, including methodologies and basic input data to demonstrate compliance with long-term safety requirements, should be a fundamental goal in order to show that safe disposal of all kinds of radioactive wastes is possible and that related designs and projects can be assessed and accepted for implementation.

The benefits from international co-operation are obvious. Given a broad international consensus on principles, and also on the safety assessment methods and input data, popular confidence that proper safety measures are taken can be built up.

There was also a recognition that the nuclear community might need more purposeful integration within society in general, and it was suggested that the IAEA as an international organization of high-standing could perhaps explore ways of communicating objectively with other professional and interested groups.

General conclusions

Mr B.A. Semenov, IAEA Deputy Director General, Head of the Department of Nuclear Energy and Safety, chaired a concluding panel. Five experts who had acted as chairmen of some of the technical sessions presented the salient points that had emerged under each of the five major topics. The following general conclusions can be drawn.

1. It had not been expected that the conference would disclose any revolutionary scientific or technological developments, and it did not; but it did show that in most countries the implementation of systems for the management and disposal of radioactive wastes has taken shape. In many countries, this is reflected in policy decisions and in institutional and financial arrangements.

2. Waste management technology has left the developmental stage and is now at the start of full-scale industrial implementation. It is often said that "the technology is available" to implement proper waste management systems that meet the requirements of nuclear power programmes and long-term safety goals. This statement may need some qualification, as it does not mean that the technology is equally in hand or accessible in all countries or facilities to the same level of sophistication (if at all), or that no further research is necessary. Current programmes are characterized by progress from the preceding generic to current site- and

facility-specific projects; further research work will be required in the course of industrial implementation.

3. There is a clear recognition that timely solutions to institutional, regulatory, financial, and socio-political issues are pre-requisites for a successful deployment of the technology which is "available", and that these issues are particularly important if public concerns are to be alleviated.

4. As the long-term health and safety implications of waste disposal are the main concern, a clear formulation of the related safety goals and technical criteria and a demonstration that these goals and criteria can be met are essential if understanding and acceptance are to be won.

5. Considerable progress has been made nationally and internationally toward establishing such goals, criteria, and safety assessment methods. Ways of applying the ICRP recommendations to the specific subjects of waste disposal were presented at this conference, and there is now confidence that some questions of interpretation will be resolved during the next few years. To demonstrate compliance with long-term safety requirements one must rely on predictions. Reduction of uncertainty and validation of models will require further work, but the mechanisms governing the release of radionuclides will be better understood when more site-specific data from projects become available. What constitutes validation of long-term safety assessments will certainly require expert discussion, and further interdisciplinary research and studies of natural analogues will help in the achievement of consensus.

6. The radiological implications of nuclear power production and the contribution that waste management makes to the total radiation dose in both the short- and long-term as derived from data presented in the 1982 UNSCEAR report, as well as the information presented by WHO on the management of toxic chemical wastes, allow radioactive waste management problems to be put in a better perspective.

7. While the conference put the major emphasis on high-level waste management, there was also a clear indication that the management of low- and intermediate-level wastes will need continuing attention if the need of the nuclear industry today to dispose of its wastes properly and without undue delay is to be satisfied. The conference showed that shallow ground or rock cavity disposal of such wastes is a well-established practice, used or proposed in many countries. Nevertheless, there is in some countries interest in continuing the practice of sea-dumping for low-level waste under the terms of the London Dumping Convention. To meet waste acceptance criteria and for economic reasons, both for interim storage and for disposal, there is a continuing incentive to improve both volume reduction techniques and waste forms. The need for adequate management of wastes arising from decommissioning operations and emergency situations was also indicated.

8. The continuing search for improvements in safety approaches even in long-established industrial practice, and increased environmental concern, have also drawn attention to the long-term radiological implications of tailings from uranium milling operations.

9. Many countries have undertaken or will soon begin design work and investigation in underground pilot-research laboratories for the development of repositories for high-level waste. Demonstration of full-sized operating repositories is expected during the next ten to fifteen years in the USA and possibly also in some other countries. Sites for repositories, to be operational after the year 2000, will be selected by a number of other countries.

10. The conference underlined once more that the technology available for the control of liquid and gaseous effluents is sufficiently effective to make nuclear power a very clean source of energy. Discharges of some radionuclides to the environment may however have transboundary radiological impacts. The resolution of these problems requires international consensus and guidance. There is also a continuing challenge to adapt existing technologies for the treatment of liquid and gaseous effluents to particular radionuclides, and to improve their operational régime and design, in order to keep environmental releases always as low as reasonable achievable.

In general, the conference confirmed the conclusions of previous studies: namely, that nuclear power can be harnessed for mankind without creating an unmanageable waste disposal problem.