

International Atomic Energy Agency

GENERAL CONFERENCE

GC(XXVII)/INF/214

2 September 1983

GENERAL Distr.

Original: ENGLISH

THE INTERNATIONAL CONFERENCE ON RADIOACTIVE WASTE MANAGEMENT

1. In compliance with resolution GC(XXVI)/RES/398 adopted by the General Conference last year, the attached report on the IAEA's work in the field of radioactive waste management was presented at the International Conference on Radioactive Waste Management held at Seattle, United States of America, from 16 to 20 May 1983. The opportunity is taken here of describing the present situation in the field of radioactive waste management as it emerged at the Conference.
2. The presentations and discussions at the Conference showed clearly that waste management is now recognized world-wide as an integral part of nuclear power programmes that requires proper attention from the very start of the consideration of such programmes.
3. The following general conclusions can be drawn from the presentations and discussions:
 - (a) In most countries engaged in nuclear activities, the implementation of systems for the management and disposal of radioactive wastes is well under way. This has found reflection in related policy decisions and institutional and financial arrangements in many countries;
 - (b) Radioactive waste management has advanced from the technology development stage to the stage of full-scale industrial projects or, in the case of high-level waste, to feasible concepts. This is reflected in the frequently made statement that "the technology is available" to implement systems that meet the requirements of nuclear power programmes and long-term safety goals. However, this statement needs some qualification - it does not mean that the technology is equally available in all countries or at all facilities and that no further research work is necessary; generic studies are now being followed by site-specific studies in which further research work will be required;
 - (c) It is well recognized that timely solutions at the national level of the institutional, regulatory, financial and socio-political issues are prerequisites for a successful deployment of the available technology;

- (d) As the long-term health and safety implications of radioactive waste disposal are a subject of considerable 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 for gaining general understanding and acceptance. Considerable progress has been made nationally and internationally towards establishing the goals and criteria and devising safety assessment methods. Ways of applying the recommendations of the International Commission on Radiological Protection (ICRP) in specific areas of waste management were described at the Conference, and there is now confidence that certain questions of interpretation will be resolved within the next few years. To demonstrate compliance with long-term safety requirements one must rely on predictions, which requires the use of models; the validation of models will require further work;
- (e) The management of low- and intermediate-level wastes will need to receive continuing attention. Shallow ground or rock cavity disposal is a well-established practice and is being used or is planned to be used in many countries. Nevertheless, for some countries there is an interest in continuing the practice of sea dumping for low-level waste under the terms of the Convention on the Prevention of Marine Pollution by Dumping Wastes and Other Matter (London Dumping Convention). Waste acceptance criteria and economic factors provide a continuing incentive for improving waste volume reduction techniques and waste forms in connection both with interim storage and with disposal. There is a need to ensure the adequate management of wastes arising from decommissioning operations and emergency situations;
- (f) Increased environmental concern and the continuing search for improvements in safety approaches even in long-established industrial practices have drawn attention to the long-term radiological implications and the final disposition of uranium mill tailings;
- (g) For the development of repositories of high-level waste, design work and investigations in underground research laboratories have been or will soon be undertaken in many countries. The demonstration of full-size operating repositories is expected during the next 10-15 years in the United States of America and possibly also in some other countries. Also, it is expected that sites for repositories to become operational after the year 2000 will be selected in a number of other countries;
- (h) The technology available for the control of liquid and gaseous effluents is effective enough to make nuclear power an environmentally very clean source of energy. However, the radiological impacts of some radionuclides discharged to the environment may have transboundary implications and the resolution of this problem requires international guidance and consensus. Also, there is a continuing need to apply the existing technologies for the treatment of certain liquid and gaseous effluents and to improve the design and operation of the facilities involved so as to keep environmental releases as low as reasonably achievable.

4. In general, the Conference confirmed that nuclear power can be harnessed for mankind without creating an unmanageable waste disposal problem. There was a consensus that no technological breakthroughs are required for the safe management of radioactive waste.

**THE IAEA'S WORK IN THE FIELD OF
RADIOACTIVE WASTE MANAGEMENT**

**Report prepared in response to
General Conference Resolution GC(XXVI)/RES/398**

C O N T E N T S

0. ABSTRACT
1. INTRODUCTION
2. SCOPE OF THE REPORT
3. BACKGROUND OF THE WASTE MANAGEMENT PROBLEM
 - 3.1. Nuclear power development and radioactive waste
 - 3.2. Current status of waste management practice
 - Waste management technology
 - Underground disposal
 - Environmental discharges
 - Health, safety and other criteria
 - Status of international law and responsibilities of States and international organizations
 - Institutional aspects
4. IAEA OBJECTIVES AND FUNCTIONS IN WASTE MANAGEMENT
 - 4.1. Basic objectives in waste management
 - 4.2. IAEA objectives
 - 4.3. IAEA functions
 - Exchange of information
 - Safety standards and guidelines
 - Support of research
 - Technical assistance and co-operation
 - Organization of the Agency's Secretariat
5. IAEA'S ACTIVITIES IN RADIOACTIVE WASTE MANAGEMENT
 - 5.1. Historical development
 - 5.2. The current programme and its achievements - overview
 - 5.3. Handling and treatment of wastes at nuclear facilities
 - Treatment of low- and intermediate-level waste
 - Waste from nuclear power plants
 - Gaseous waste management
 - Decontamination and decommissioning of nuclear facilities
 - High-level and alpha-bearing waste
 - 5.4. Underground disposal
 - Disposal in shallow ground, rock cavities and deep geological repositories
 - Deposition of wastes from uranium mining and milling
 - 5.5. Environmental aspects of nuclear energy
 - Marine environment protection
 - The Agency's role under the London Convention
 - Environmental pathways of radionuclides
 - Environmental assessments
 - 5.6. Future trends
6. INTERNATIONAL GUIDELINES IN WASTE MANAGEMENT
 - 6.1. Status of IAEA guidelines
 - 6.2. Areas of interest
7. INTERNATIONAL CO-OPERATION CONCERNING WASTE MANAGEMENT
 - 7.1. General approach
 - 7.2. Co-operating organizations
 - 7.3. Particular questions
 - Special issues for countries with small nuclear programmes
 - Register of radionuclide releases
8. CONCLUSIONS

TABLES I - IX

ANNEX I

THE IAEA'S WORK IN THE FIELD OF RADIOACTIVE WASTE MANAGEMENT

ABSTRACT

The IAEA has been concerned with radioactive waste management since its inception. Its programme in this area was expanded in the mid 1970s as questions related to the management and disposal of radioactive wastes came into focus in conjunction with the further industrial development of nuclear power. The objectives of the Agency's wastes management programme are to assist its Member States in the safe and effective management of wastes by organizing the exchange and dissemination of information, providing guidance and technical assistance and supporting research. The current programme addresses all aspects of the industrial use of nuclear power under the aspects (a) technology of handling and treatment of wastes, (b) underground disposal of wastes, (c) environmental aspects of nuclear energy, including sea disposal of radioactive wastes. Systematic reviews have been made and publications issued concerning the technology of handling, treating, conditioning, and storing various categories of wastes, including liquid and gaseous wastes, wastes from nuclear power plants, spent fuel reprocessing and mining and milling of uranium ores, as well as wastes from decommissioning of nuclear facilities. As waste disposal is the current issue of highest interest, an Agency programme was set up in 1977 to develop a set of guidelines on the safe underground disposal of low-, intermediate- and high-level wastes in shallow ground, rock cavities or deep geological repositories. This programme will continue until 1990. Eleven Safety Series and Technical documents and reports have been published under this programme so far, which also addresses safety and other criteria for waste disposal. The environmental part of the waste management programme is concerned with the assessment of radiological and non-radiological consequences of discharges from nuclear facilities, including de minimis concepts in waste disposal and environmental models and data for radionuclide releases. The Agency's waste management programme has from the beginning given due attention to the preparation of guidance on the control of radioactive waste disposal into the seas. Since the London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter has entered into force, the Agency exercises responsibility for recommendations relating to radioactive aspects of marine pollution under this convention. It prepared a definition of high-level waste prohibited from being dumped and recommendations for dumping of waste not coming under this definition into the deep sea. The Agency does not, however, encourage sea dumping and has not assumed any mandate to monitor sea dumping operations carried out under the Convention.

I. INTRODUCTION

Since its establishment in 1957, the IAEA has been concerned with radioactive waste management within its general mandate to "seek to accelerate and to enlarge the contribution of atomic energy to peace, health and prosperity throughout the world". It continued its activity in this field with greater vigour after the United Nations Conference on the Human Environment held in 1972 asked for an expansion of international co-operation on these aspects and after the role that nuclear power plays in the energy economy of many countries became more evident in the 1970s.

During its 26th regular session in September 1982 the IAEA General Conference adopted a resolution (GC(XXVI)/RES/398) requesting the Secretariat to submit a report to the International Conference on Radioactive Waste Management about the work being done by the Agency in the field of radioactive waste disposal, including its collaboration with other international organizations, and that the General Conference be given a situation report on this matter at its 1983 regular session. This request is an expression of the concern that many governments have about the possible harm and the environmental consequences that might be caused from the radioactive wastes arising and accumulating from the use of nuclear power. The future growth of nuclear power and its acceptance depend, therefore, to a large extent on providing evidence that these wastes can be handled and disposed of safely.

The present report has been prepared in response to this request.

Waste disposal, the final step in waste management, is the subject of long-term safety considerations and concerns about actual and

potential public radiation exposures at present and in future. However, it cannot be discussed in isolation but must be considered an integral part of all waste management operations. Therefore, this paper extends its considerations to all areas of waste management including those prior to disposal, e.g. to all activities, technical, administrative and operational, that are involved in the handling, treatment, conditioning, transportation and storage of wastes.

2. SCOPE

This paper describes:

- The IAEA's objectives, functions and responsibilities in waste management
- The Agency's waste management programme, its components, activities and results
- The related publications
- The role of IAEA guidelines
- The Agency's collaboration with the UN and other international organizations
- The way in which the Agency in its programme responded to the requests and interests of its Member States and other UN organizations
- Some current issues in waste management that have been identified in Agency meetings or addressed to the Agency as requiring further attention in international co-operation under the auspices of the IAEA.

The information covers technical, environmental, safety and regulatory aspects. Reference is made to other IAEA activities and responsibilities in areas which are of relevance to waste management, such as the Agency's Basic Radiation Protection Standards, Transport Regulations for Radioactive Materials and Nuclear Safety Standards.

3. BACKGROUND TO THE WASTE MANAGEMENT PROBLEM

3.1. Nuclear power development and radioactive waste

It is useful to highlight first some key features of wastes arising from the use of nuclear power: considerations have to include both wastes produced by nuclear power plants and those produced by the associated nuclear fuel cycle facilities. In this regard it should be noted that

- (a) wastes from uranium mining and milling operations, which contain only low concentrations of naturally occurring radioactive materials of the U-decay chain, are generated in large volumes that must be deposited near the site of their arising, mostly for economic reasons;
- (b) wastes from research establishments, nuclear power plant operations, maintenance, repair or decommissioning contain fission products, corrosion and activation products, with low concentrations of long-lived radionuclides, in the low- and intermediate-activity level range. The waste arisings are not large and considerable experience exists for their treatment, conditioning and disposal either on site or in repositories away from the reactor, and
- (c) wastes from spent fuel reprocessing consist of (i) primary high-level wastes that contain nearly all the fission products and parts of the transuranium elements and can be concentrated to very small volumes, and (ii) secondary low- and intermediate-level wastes generated, in industrial terms, in relatively small volumes. This allows the use of extensive conditioning methods and interim storage prior to disposal. These wastes arise in a limited number of reprocessing plants and a considerable time (3-50 years) after the spent fuel has been removed from the reactor pending decisions on the time of reprocessing. Spent fuel can also directly be handled as high-level waste, if so declared.

There are obviously two major issues in regulating a proper waste management system, namely (a) the establishment of limits for the direct

discharge of radioactive effluents into the environment and (b) the definition of acceptable disposal methods for the various waste categories together with the requirements for their conditioning, for confinement and isolation. These are complex tasks the resolution of which is the goal of the current national and international waste management programmes.

By the end of 1982, 294 nuclear power reactors with an installed capacity of 173 108 MW(e) were in operation in 25 countries, providing about one tenth of the world's electricity production. An additional 215 power reactors with a capacity of 196 860 MW(e) are currently under construction in 27 countries. It is expected that the installed nuclear capacity will increase to 311 GW(e) by 1985, 425 GW(e) by 1990 and between 750 and 1100 GW(e) by the year 2000. Spent fuel reprocessing capacity will probably increase from the present 3200 tonnes HM/year to more than 7000 tonnes Heavy Metal/year (HM/year) by the year 2000. Cumulative spent fuel arisings by then will be about 300 000 tonnes and a significant part of this amount will be in storage. If all this spent fuel were to be reprocessed, then some ten thousands cubic metres of conditioned high-level waste and nearly one million cubic metres of conditioned low- and intermediate-level wastes would require eventual disposal. From the operation of nuclear power plants, the low- and intermediate-level conditioned wastes that need to be disposed of will amount to some millions of cubic metres ¹⁾.

Though the use of nuclear power increasingly determines the magnitude of the waste management problems, other sources of wastes such as those from the production and use of radioisotopes in industry, medicine, agriculture and research deserve due attention. It may also be recalled that waste management problems existing today in some major nuclear countries originate often from previous or ongoing nuclear

1) These data are based on the IAEA Power Reactor Information System, the IAEA Energy and Economic Data Bank and information from the International Fuel Cycle Evaluation Study (INFCE) and International Spent Fuel Management Study (ISFM)

weapons programmes. This, however, in turn is recognised to have provided the background for our understanding today of the problems involved in handling high-level and transuranic-bearing wastes from commercial spent fuel management.

Countries that use nuclear power have obviously, depending on their degree of involvement in the fuel cycle, to consider and decide on

- (a) today's needs and methods for the handling and disposal of the low- and intermediate-level wastes from reactor operations on their territory and
- (b) the need for future measures for handling and disposal of the high-level and transuranic-bearing wastes from spent fuel management pending decisions on spent fuel reprocessing, disposal or transfer to the supplier country.

3.2. Current status of waste management practice

3.2.1. Waste management technology

Technological steps in waste management range from waste collection, interim storage for delay and decay, treatment of effluents for environmental discharge of the bulk of the material and retention of radionuclides, treatment of the primary wastes and waste concentrates for volume reduction, fixation of the waste radionuclides, conditioning of the wastes for storage, transportation and disposal, and waste disposal itself, together with appropriate quality assurance and surveillance measures. The status of technology and operational experience for managing low- and intermediate-level wastes, including decontamination measures, storage and transportation, are such that present needs can be satisfied and adequate solutions and techniques either exist, can be adapted or further be developed to meet future needs and to cope with the great variety of physical and chemical waste compositions. However, further improvements of details and optimization of the overall system are ever-continuing and challenging tasks. As regards high-level and transuranic-bearing wastes it is generally agreed that such wastes must be converted into a stable form of low leachability. Numerous methods are being used or studied to produce such forms, but pilot-scale

industrial operational experience for the vitrification of high-level wastes has so far been gained only in France. Other immobilization processes are under development for future uses. There exists therefore today an adequate technical base for actions to implement timely waste disposal programmes. Considerable work remains, however, to be done in many areas to make the results of ongoing R&D efforts industrially mature and to implement appropriate waste treatment and conditioning methods using the best technology available in the nuclear facilities concerned.

3.2.2. Underground disposal

Underground disposal on land under national jurisdiction is, with today's technology, considered to be the most appropriate and practicable method of safely disposing of radioactive wastes that result from the use of nuclear power in a Member State. Disposal of low- and intermediate-level wastes by emplacement in shallow ground repositories, in rock cavities (e.g. abandoned mines) or otherwise deep underground has been practised and studied for more than 20 years in many countries, and these methods are now operational and well founded. Current studies concerning these waste categories are mostly oriented towards providing long-term solutions for waste disposal for the needs of national nuclear power programmes. For disposal of high-level and transuranic-bearing wastes the disposal concepts most generally accepted are emplacement of the conditioned wastes in mined repositories in deep, stable geological formations. These concepts are scientifically and technically feasible and can be implemented with today's mining technology. The first repositories for these wastes, including pilot projects for demonstration purposes, are expected to be commissioned in some countries in the 1990s. Many countries are now studying whether the geological formations under their territory would allow the disposal of such wastes.

Management of wastes from uranium mining and milling has been industrial practice for more than three decades. During the recent past, long-term radiological impacts from uranium mill-tailings have received increasing attention though it is recognized that consequences of a breach of their confinement system would in radiological terms be very small and never catastrophic. Currently, the best practical means available for the impoundment of mill tailings, their final stabilization

and rehabilitation are the subject of consideration in many countries in order to ensure their long-term disposal in shallow ground in accordance with the radiological protection principles underlying waste management.

3.2.3. Environmental discharges

Radioactive materials are prevented from being released into the environment to the extent possible, following the basic principles of radiation protection that public radiation exposure should be kept as low as reasonably achievable ("ALARA" principle) and below permissible limits. Environmental discharges are, therefore, generally not considered or encouraged as a means of disposing of radioactive wastes. National regulatory bodies set authorized limits as upper values for the environmental release of radioactive materials with liquid effluents into rivers, lakes or coastal waters and with gaseous effluents into the atmosphere. This is being done on the basis of internationally accepted radiation protection standards as recommended by the ICRP and adopted by the IAEA. Records about the effluents released from nuclear facilities are kept by the competent national authorities. Proper effluent monitoring as well as either facility-oriented and/or facility-independent environmental surveillance are performed to verify that the environmental discharge of radioactive materials is controlled as needed. Where in the past liquid or gaseous effluents had been released without using the best appropriate treatment methods available, this has been largely corrected by improved means of treatment and operating procedures.

Some States have found dumping of some types of wastes into the sea more suitable than land-based alternatives, e.g. disposal in underground repositories on national territory. Sea dumping does not rely on long-term containment and isolation and must, therefore, be considered as discharge of waste materials into the marine environment that are subject to dispersion. The dumping of radioactive wastes in the oceans is controlled by the London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (see sections 3.2.5. and 5.5.2.).

It is, however, a controversial subject and recently demands have been made for either banning the dumping of radioactive wastes immediately or phasing this practice out in the future ²⁾.

3.2.4. Health, safety and other criteria

In the management of radioactive wastes the overriding safety concern is the protection of humans from possible exposures to ionizing radiation. Effective protection of man can be achieved by adhering to the basic principles of radiation protection. In addition, the general principles of environmental protection and sound environmental management have also to be complied with for ensuring good practice in radioactive waste management.

Regulations on radiation protection and environmental protection that also govern the principles of radioactive waste management have been issued within the national regulatory framework of most countries. The radiation protection principles recommended by the ICRP in 1977 were in 1982 adopted by the IAEA in its Basic Radiation Protection Standards ³⁾ which are now being considered as the basis for the review of many national regulations. The application of the above radiation protection standards, in particular the ALARA principle, to waste management and disposal requires additional consideration since special attention has to be devoted to potential detriments to future generations and weighing them against the detriments to people living now. Besides clarification which is desirable for the direct application of the ICRP recommendations to the long-term aspects (post-operational phase of a waste repository) there is a need to derive firm technical criteria against which waste disposal systems could be judged as well as to state clearly in national regulations the regulatory requirements and the

2) Related resolutions were considered by the Seventh Consultative Meeting of the Contracting Parties to the Convention in February 1983 and a non-binding resolution was passed calling for a two-year moratorium on such dumping.

3) Basic Safety Standards for Radiation Protection, IAEA Safety Series No. 9 (1982 edition).

institutional and financial responsibilities. These issues are under active discussion nationally and internationally. Only in a few countries have the related regulatory matters been approached and appropriate regulations been drafted or issued.

3.2.5. Status of international law and related responsibilities of States and international organizations

A variety of international and regional conventions concerning the protection of the marine environment have been adopted and entered into force during the past two decades. These cover, directly or indirectly, radioactive substances as one of the polluting agents, even if provisions for these substances are not specifically detailed. The governments are generally asked "to take all necessary measures to prevent, reduce and control the pollution of the marine environment from any source" and "to adopt national laws, regulations and other measures ... not less effective than established global and regional rules, standards and recommended practices and procedures". Compliance with these conventions is the responsibility of national governments, whereas international organizations can assist in drafting and negotiating such conventions and executing Secretariat functions for the contracting parties.

The London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, which became effective in 1975, regulates also the dumping of radioactive wastes into the oceans. The IAEA has, as the competent international organization for radioactivity matters, provided the definition of "high-level" wastes which is prohibited from being dumped and the recommendations as to under which conditions radioactive wastes not coming under the above definition could be dumped into the deep ocean. National governments of countries who wish to dump have to issue a special permit and to ensure that all provisions of the convention and the related IAEA recommendations (see section 5.5.2.) are fully complied with. The International Maritime Organization (IMO), which performs Secretariat functions for this Convention, has to be notified about the issuance of such permits together with related information. The marine environment of regional seas, such as the Mediterranean or the Baltic Sea, is governed by special

Conventions (e.g. Barcelona Convention of 1976, Helsinki Convention of 1974) which exclude the dumping of radioactive wastes into these seas.

The discharge of radioactive effluents into the atmosphere and surface waters may involve transboundary aspects, including those of regional and global interest in the case of some long-lived radionuclides. Discharge limits are set by national authorities to meet local protection requirements, based on the already-mentioned internationally recommended radiation protection standards. No need has so far arisen to provide for general international agreements or to specify related matters in existing international conventions, such as the European Convention on Long-Range Transboundary Air Pollution of 1979.

3.2.6. Institutional aspects

It is recognized that waste management not only includes technical and safety aspects but also requires timely solutions concerning institutional and financial matters including those from some parts of waste management that may be beyond the time of plant operation or the capability of utilities. The need for appropriate and timely regulatory procedures and institutional arrangements for waste management, in particular waste disposal, as an integral part of regulating and implementing nuclear power programmes, has been increasingly realized during the past decade. Some countries have set up specialized organizations for establishing or running national waste disposal systems and most governments have recognized the need to assume responsibility for regulating waste management in conjunction with the regulation of nuclear power plants.

4. IAEA OBJECTIVES AND FUNCTIONS IN WASTE MANAGEMENT

4.1. Basic objectives in waste management

It is the basic objective of radioactive waste management to prevent the release into the environment of unacceptable amounts of radionuclides

and to handle and dispose of wastes safely and effectively so as to protect man and his environment by keeping the total radiation detriment to workers and to the public at present and in future below permissible levels and as low as reasonably achievable. This requires consideration on the following subjects:

- Minimization, collection and control of waste streams at their point of origin
- Provision of techniques for maintaining radionuclide releases well below acceptable levels
- Treatment and conditioning of wastes so as to reduce their volume and confine the radionuclides contained for storage and disposal
- Storage and disposal of wastes in repositories
- Environmental discharge of radioactive effluents and the assessment of their distribution and dispersion in the Environment and the resulting radiological impact.
- Assessment of the safety and cost-effectiveness of the above operations.

4.2. IAEA objectives

The overall objective of the IAEA in the field of waste management is to assist its Member States in achieving the above objectives in their national programmes and in related international matters, for wastes arising from the peaceful use of atomic energy. The objective is met by organizing co-operation among Member States including

- The exchange of information on experience, approaches and research in national programmes
- The development of guidance and international recommendations for use by national authorities
- The development and exercising of responsibilities under international law for the protection of the environment, if the IAEA is requested to do so
- The provision of training and technical assistance
- Considerations of waste management and disposal in the frame of international co-operation in the field of nuclear technology and the nuclear fuel cycle.

The Agency's particular role is characterized by reviewing and generalizing technical, regulatory and scientific information, converting it into internationally recommended good practice, safety codes, standards and guidelines and by making the knowledge and experience of nuclearly advanced Member States available to those embarking on nuclear power. The objectives in waste management - a subsystem of nuclear power utilization - are closely related to the Agency's objectives in other areas such as those in radiological protection, nuclear safety, environmental protection, nuclear fuel cycle and nuclear reactor development, marine radioactivity, isotope hydrology, technical co-operation and others.

4.3. IAEA functions

To meet the above objectives the Agency uses its well-established mechanism in international collaboration including the convening of conferences, symposia and seminars, the holding of technical committee and advisory group meetings, the use of recognized experts as consultants, the sponsoring of research programmes and training courses, study tours, etc.

4.3.1. Exchange of information

Information in the field of waste management has been collected and revised by the holding of many symposia and technical committee meetings but also through co-ordinated research programmes and special questionnaire actions, and the running of INIS. Information in this field has been disseminated to date in the form of 26 books of proceedings of symposia and conferences, 40 reports within the Technical Reports Series, 20 publications within the IAEA Safety Series, 22 IAEA Technical Document (unpriced publications) and 14 issues of Waste Management Research Abstracts.

4.3.2. Safety Standards and guidelines

Guidelines in radioactive waste management cover, as in other areas, those published under the Agency's Safety Series or those issued as technical guidebooks in the Agency's Technical Reports Series.

Publications on safety matters within the Safety Series are divided into four categories, namely:

- Cat. 1 Safety Standards, codes of practice and regulations which define minimum safety requirements that shall be met and which are approved by the Agency's Board of Governors
- Cat. 2 Safety Guides describing safety measures which might be followed in implementing Cat. 1 documents
- Cat. 3 Recommendations concerning safety practices and measures
- Cat. 4 Procedures and data pertaining to safety matters.

Cat. 2, 3 and 4 documents are issued under the authority of the Director General of the Agency. In the field of waste management three documents at the level of Safety Series Category 1 have been issued, another one is under preparation and two others will follow within the next five years (see section 6.2.).

4.3.3. Support of research

The Agency has limited funds available for supporting scientific research in selected fields of waste management by organizing co-ordinated research programmes and awarding contracts to laboratories in developing countries. Such programmes which are being performed over periods of three to six years are intended to bring laboratory investigators into direct contact by holding meetings and, in particular, to allow investigators from laboratories in developing countries to join the studies of scientists from leading laboratories in advanced countries. Since 1975 the Agency has conducted or initiated several such programmes; these are listed in Table I.

4.3.4. Technical assistance and co-operation

The Agency's Department of Technical Co-operation with the active involvement and support of the Department of Nuclear Energy organizes seminars, training courses, study tours, scientific visits; awards fellowships and provides expert missions and field experts and also assists in the implementation of specific projects in Member States. Table II lists the training courses and study tours held so far specifically in this field. In addition, waste management aspects were also covered in training courses and study tours related to radiological protection and nuclear fuel cycle activities. An example of an IAEA technical assistance project in waste management is the construction of a treatment facility for low- and intermediate-level wastes in Egypt.

4.3.5. Organization in the Agency's Secretariat

The IAEA waste management programme is conducted by the Agency's Waste Management section, which is part of the Division of Nuclear Fuel Cycle, Department of Nuclear Energy and Safety. There are - waste management being an interdisciplinary area - inputs from, and close contacts with, other organizational structures of the Agency, in particular the Nuclear Materials and Fuel Cycle Technology Section of the same division, the Radiological Safety Section and the Nuclear Installation Safety Section of the Division of Nuclear Safety, the International Laboratory of Marine Radioactivity ("Monaco Laboratory") and the Isotope Hydrology Section of the Division of Research and Laboratories, Department of Research and Isotopes and the Legal Division of the Department of Administration.

5. IAEA ACTIVITIES IN RADIOACTIVE WASTE MANAGEMENT

5.1. Historical development

Activities in radioactive waste management in the IAEA were originally handled in the Division of Health, Safety and Waste Management which later, stimulated by the UN Conference on the Human Environment, was restructured as the Division of Nuclear Safety and Environmental Protection. The increasing attention paid to questions of radioactive waste in conjunction with the growing nuclear power development resulted in attaching the Agency's Waste Management Section to the newly established Division of Nuclear Fuel Cycle of the Agency's Department of Nuclear Energy and Safety. The Agency's waste management programme has from the beginning mainly dealt with the collection, review and dissemination of scientific, technical and environmental information. It centred on wastes resulting from the use of radioisotopes and nuclear research centres with some attention to wastes from nuclear power plants in the 1960s and on both radiological and non-radiological environmental aspects including sea dumping of radioactive wastes in the 1970s. Increasing consideration has been given to wastes from the industrial use of nuclear power, e.g. nuclear power plants and facilities of the associated fuel cycle, since the mid 1970s: items included in the programme were management of wastes from uranium mining and milling, decommissioning of nuclear facilities, and, with growing importance, underground disposal of radioactive wastes. Consideration was given also to waste management in the context of regional co-operation in the nuclear fuel cycle.

The systematic development of guidelines on waste management (see sections 6.1. and 6.2.) is now receiving increasing attention, following many suggestions that the Agency should play an active role in these areas. This can now be done because most of the background information needed for that purpose on the technology, safety and environmental and regulatory aspects involved in the various areas of waste management, is now available in Member States and has systematically been collected and

reviewed. Also, safety standards and other guidelines on related subjects are now available, such as those developed under the Agency's radiological safety and Nuclear Safety Standards (NUSS) programme. In the previous Agency programme guidelines on waste management were developed on a case by case approach according to the needs: one of the first guidelines prepared by the Agency was concerned with the control of radioactive waste disposal into the sea (Safety series No. 5, 1961, see section 5.5.1.).

5.2. The current programme and its achievements - overview

Waste management activities can be categorized in various ways. The development with time of the main components of the Agency's waste management programme since 1976 is given in Table III which also indicates the change of emphasis on particular issues of interest. The current IAEA programme lists under these three major components according to the weight of interest:

- Handling and treatment of radioactive wastes at nuclear facilities
- Underground disposal of radioactive wastes
- Environmental aspects of nuclear energy.

The main activities of the current programme are oriented towards:

- Collecting, reviewing or updating technical information on the management of all types of wastes;
- Developing guidelines for waste disposal;
- Preparing recommendations for radioactive matters under conventions protecting the environment, and
- Providing methodology for the assessment of environmental consequences of nuclear facilities.

All publications that have been produced or are currently in print, from activities of the Agency's waste management programme are listed in Annex I to this report. Table IV summarizes the various areas covered in the programme components and indicates also the inputs from other Agency

programmes. The whole area of waste management was also discussed in major IAEA conferences on the use of nuclear power, such as the 1977 Conference on Nuclear Power and its Fuel Cycle and the 1982 Conference on Nuclear Power Experience. To provide for uniform use of terminology in the Agency's work a first draft of a glossary on Radioactive Waste Management has recently been prepared. For providing information exchange on ongoing research work, the previous IAEA publication "Waste Management Research Abstracts" is now being continued in an improved form following an evaluation of its relation to INIS to avoid duplication of work.

5.3. Handling and treatment of wastes at nuclear facilities

Within this programme component efforts so far have been predominantly to collect and review information on the current status of the technology and scientific basis for the various methods of handling, treating, conditioning and storing radioactive wastes at nuclear power plants, fuel reprocessing plants and the production and use of radioisotopes. The areas addressed, the related activities during 1976-1982 and those planned in 1983/84 as well as the resulting products are summarized in Table V.

5.3.1. Treatment of low- and intermediate-level wastes

The developments that have taken place concerning techniques for the handling, treatment and conditioning of low- and intermediate-level liquid and solid wastes have been reviewed and resulted in updating previous IAEA publications in three reports: solid waste treatment, liquid waste treatment and conditioning of waste concentrates. This includes alpha-bearing waste. The handling of ³H-bearing waste and the treatment of spent ion-exchange resins were studied within co-ordinated research programmes ⁴⁾. Reviews remain to be made on new developments concerning the techniques for transportation and interim storage of such wastes and the evaluation of conditioned waste forms for disposal.

4) See these Proceedings, papers IAEA-CN-43/21, 170, 455.

Sufficient experience exists to proceed to the preparation of guidelines on the design and operation of treatment facilities.

5.3.2. Wastes from nuclear power plants

Particular attention has been and will be given to the management of wastes at nuclear power plants as this is currently of highest interest to most countries operating or constructing such plants. Based on results from a Symposium, Seminar and some Technical Committee and Advisory Group meetings held during 1976-1981, work is now in progress to prepare a Code of Practice on the management of waste from nuclear power plants. A draft Code was recently published and will be completed by 1984 after review by Member States and advisory groups. A number of related guides may be prepared later, in co-ordination with the NUSS and Radiological Safety programme. The subject code requires that a government take appropriate regulatory measures for waste disposal in conjunction with the licensing of nuclear power plants. It serves as an umbrella for many other documents. There are some technical aspects which might deserve future attention: special types of intermediate-level wastes such as reactor components, spent filter materials and wastes from decontamination and decommissioning.

5.3.3. Gaseous waste management

Gaseous effluents and waste treatment have been and will continue to be of particular importance in protecting the environment from airborne radionuclide releases both under normal and accident conditions at nuclear facilities. The techniques for removal of ^{85}Kr , ^3H , iodine, semivolatile and other airborne radionuclides and particulates from off-gases from reprocessing and nuclear power plants as well as the testing and operation of off-gas cleaning systems were subject to reviews by several Technical Committee meetings, a Symposium and a Seminar. Methods of particulate filter testing were the subject of a comparative study. Future activities may proceed to the preparation of guidelines on design and operation of off-gas and ventilation air cleaning systems and to more detailed studies concerning the behaviour and retention of airborne waste during normal and accident conditions at nuclear facilities.

5.3.4. Decontamination and decommissioning of nuclear facilities

Decommissioning of nuclear facilities, e.g. their decontamination, disassembly and final dismantling, is essentially a waste management operation. It was one of the areas which evoked broad interest in past years and several meetings were held, including a joint IAEA/NEA Symposium. Recent information is summarized in a Technical Report (in press) ⁵⁾. Decontamination of technological systems and rooms is of increasing interest for plant maintenance, repair and decommissioning and will be paid due attention in future activities.

5.3.5. High-level and alpha-bearing wastes

During 1974-1981 a Technical Committee on High-level and Alpha-bearing Waste met several times to exchange information on national programmes between Member States who have significant efforts in the field of reprocessing. The techniques for handling and storing liquid high-level waste from aqueous reprocessing and its solidification have been reviewed. There are a great number of ways of solidifying high-level waste and further developments in this areas have led to the initiation of a co-ordinated research programme on the evaluation of high-level waste products. The Agency is paying particular attention to the ever-improving developments being made on the characteristics of waste forms, especially in view of the relationship between waste forms, the various disposal environments and conditioning technology. As extended storage of high-level wastes prior to disposal plays an important role in policy considerations, the technology and economics of handling and storage of conditioned wastes have also been reviewed ⁶⁾.

5) See these Proceedings, paper IAEA-CN-43/189.

6) See these Proceedings, paper IAEA-CN-43/39.

Partitioning and transmutation of transuranium elements have been considered as a potentially desirable option in waste management to reduce the requirements for long-term isolation for some radionuclides. A Co-ordinated Research Programme contributed to clarify the limited value of this concept. Experience and trends in the handling of alpha-bearing waste, including partitioning and transmutation, were discussed at an IAEA/CEC Symposium in 1980.

5.4. Underground disposal

5.4.1. Disposal in shallow ground, rock cavity and deep geological repositories

In the 1970s it was increasingly recognized that the industrial development of nuclear power could not proceed without the provision of safe methods for the disposal of the associated wastes and implementing appropriate measures. Along with this, the Agency paid particular attention to formulating a programme on the disposal of all kinds of radioactive waste on land (see Table VI), in response to the needs indicated by its Member States. Previous expert groups had also advised that criteria for underground disposal for high-level wastes should be developed before suggested international repository concepts could seriously be considered. Following the recommendations of an Advisory Group held in 1978 the Agency launched an integrated programme on the underground disposal of radioactive wastes that incorporated disposal in shallow ground, in rock cavities and in deep continental geological formations in continuation and expansion of previous efforts on particular subjects. This programme intends (a) to enhance the exchange of information on experience, projects and ongoing research, as also was done by holding a joint IAEA/NEA Symposium on this subject in 1979, and (b) to develop internationally a set of guidelines and supporting technical documents on various areas of interest for the disposal of low-, intermediate- and high-level wastes in underground repositories.

Within the programme to develop guidelines on the safe underground disposal of radioactive wastes, (see also section 6.2.)⁷⁾ which is guided by a Technical Review Committee, it is planned to prepare by 1985 about 30 documents, of which today 11 have been published with three more in press in the Agency's Safety and Technical Report Series (see Annex I). Continuous attention is being paid to disposal of high-level and transuranic-bearing wastes in deep geological formations, though initial priority was on the disposal of low- and intermediate-level wastes in shallow ground and rock cavities⁸⁾.

5.4.2. Deposition of wastes from uranium mining and milling

The management of wastes from the mining and milling of uranium and thorium ores has been included as separate part of the underground disposal programme as the final deposition of these wastes is similar to shallow ground disposal of low-level wastes. The Agency started its activities in this area, following the recommendations of the UN Conference on the Human Environment, by preparing a Code and Guide to the Code in 1974/75. Increasing attention has been given to review related technical, environmental and safety issues in recognition of the long-term radiological implications of mill tailings management. A symposium on this subject was held in 1981 and groups of experts prepared a review on current practices and options for the confinement of mill tailings. Further developments in this area necessitate the review of the previously issued Code of Practice for which work has been initiated. An ongoing co-ordinated research programme on the environmental migration of radium and other contaminants in such tailings supports this work.

5.5. Environmental aspects of nuclear energy

The increasing industrial use of nuclear power has raised various questions regarding its long-term environmental impacts. These include the consequences from:

7) See these Proceedings, paper IAEA-CN-43/171.

8) See these Proceedings, paper IAEA-CN-43/143.

- Actual or potential radioactive emissions into the atmosphere and surface waters, including its local, regional and global aspects as part of air and water protection
- The dumping of the low-level solid wastes into the sea and direct releases of liquid effluents into coastal waters
- The disposal of radioactive wastes on land
- The activities in mining and milling of uranium ores.

Environmental impacts are primarily of local interest. They may, however, become of international concern when transboundary effects are involved or international waters are affected. All of these areas are covered by the Agency's programme relating to environmental matters. This programme was reviewed by an Advisory group in 1979, who recommended that priority be given to the problems directly associated with radioactive waste disposal and effluent discharge. The particular objective of the environmental part of the waste management programme is to discharge the Agency's responsibilities in protecting the marine environment, to consider data and models on the environmental dispersion and pathways of radionuclides discharged with effluents from nuclear facilities, and to consider methodologies for assessing the related radiological and non-radiological environmental consequences of nuclear facilities. Table VII indicates the areas and activities of this particular programme component. There are inputs from other Agency programmes, in particular the Radiological Safety and the Nuclear Safety Standards Programmes. These concern principles for establishing limits for the release of radioactive substances into the environment, environmental monitoring and atmospheric and hydrological dispersion and radiological protection aspects relating to nuclear power plant siting. An overview on the environmental and health aspects of nuclear power has recently been presented in the joint IAEA/WHO publication "Nuclear Power, the Environment and Man".

5.5.1. Marine environment protection

The control of disposal of radioactive wastes into the marine environment has been a subject of consideration in the Agency's waste management programme since this problem had specifically been addressed

to the Agency after the 1958 UN Conference on the Law of the Sea. The present situation in this field is described in a report (currently in press), which replaces a previous Agency landmark document published in 1961 under the title "Radioactive Waste Disposal into the Sea". The new document takes account of the major changes in philosophy, radiological protection, marine sciences and international law that have occurred during the last 20 years. There were many other Agency panels, symposia and research efforts in that period to assess the impacts of radionuclide releases into the marine environment and provide methodologies for related studies. The Agency's International Laboratory of Marine Radioactivity played an important role in these efforts particularly in providing new research data.

5.5.2. The Agency's role under the London Convention

The London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (see also sections 3.2.3. and 3.2.5) gave the IAEA the responsibility of defining high-level radioactive wastes unsuitable for dumping at sea, and of making recommendations for those radioactive wastes which could be dumped in the deep ocean. Similar considerations regarding the protection of the marine environment of regional seas, such as the Mediterranean (Barcelona Convention) or the South Pacific, also involve the Agency. Provisional "Definition and Recommendations" were prepared in 1974 and reviewed during 1975-77. The Agency's revised "Definition and Recommendations" have been operative under the London Convention since 1978. The recommendations describe the requirements for site selection and assessment, waste packaging, and operational control of dumping, which must be followed by national authorities ⁹⁾ when granting a special permit for dumping of radioactive wastes. It should be noted that the Agency's "Recommendations" are not to be construed as encouraging the dumping of radioactive wastes at sea. Nor has the Agency assumed a mandate to monitor and control activities to ensure that these requirements are

9) The OECD Council established in 1977 a multilateral consultation and surveillance mechanism for sea dumping of radioactive wastes to provide regional co-operation and further the objectives of the London Convention.

adhered to in dumping operations, though suggestions of this kind have been made at recent meetings of the Contracting Parties to the London Convention. The Agency's "Definition and Recommendations" are kept under review and the next revision will be completed by 1985. Following the request of the Contracting Parties, supplementary guidelines are being prepared for the environmental assessment of sea dumping of radioactive wastes together with factors to be considered in justifying sea dumping versus land-based alternatives. Also, concepts for defining de minimis levels of radioactivity for waste which could be dumped, such as non-hazardous wastes, under a general permit, are under review. The review of the definition of radioactive waste unsuitable for dumping into the deep ocean will take into account improved oceanographic models. A review of these models has recently been made upon request by the Agency within the UN joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) ¹⁰⁾. Supporting research is also being performed by the Agency on the behaviour of radionuclides in the marine environment in its Monaco Laboratory ¹¹⁾.

5.5.3. Environmental pathways of radionuclides

Principles and procedures for establishing limits for the release of radioactive materials into the environment that are based on the ICRP recommendations have been prepared and are being updated under the Agency's Radiological Safety programme. The assessment of environmental pathways of radionuclides to man is a necessary step in the evaluation of the radiological consequence of radioactive releases and in setting authorized release limits. A number of symposia and expert group meetings have in the past addressed various aspects of aquatic, atmospheric and terrestrial dispersion and behaviour of radionuclides (see Annex I). The Agency reviewed short-range atmospheric and aquatic pathway models under its Nuclear Safety Standards (NUSS) programme related to the siting of thermal nuclear power plants. Recently, a review was also made of generic models and parameters for the environmental transfer of radionuclides to man for general non-site-specific pre-operational assessments. A seminar will be held in 1983 on

10) See these Proceedings, paper IAEA-CN-43/435.

11) See these Proceedings, paper IAEA-CN-43/6.

the environmental transfer of radionuclides to man from routine releases from nuclear facilities. Studies have also been encouraged on the environmental behaviour of nuclides of particular radiological concern. The behaviour of tritium in the environment was the subject of a symposium in 1978 and of a co-ordinated research programme from 1974-78. Other research programmes concern the behaviour of radium in aquifers and waterways, the migration of radionuclides from the storage of radioactive wastes in the terrestrial environment, transuranic cycling behaviour in the marine environment, the role of sediments in the aquatic migration process and carbon-14 from nuclear facilities (see Table I). In 1981 a symposium was devoted to the migration of long-lived radionuclides in the terrestrial environment.

5.5.4. Environmental assessment

Currently consideration is being given to the impact of radionuclide releases on a regional and world-wide basis ¹²⁾. Regional and long-range atmospheric pathways, in particular, are reviewed for the eventual preparation of recommendations regarding measures to be taken for the control of such releases, if the need arises. Another area of regulatory importance is the discussions on de minimis concepts in radioactive waste disposal for the uncontrolled land disposal of very low-level solid wastes.

The Agency has, as a joint effort of various units, co-operated with the United Nations Environment Programme (UNEP) in the preparation of a report on "The environmental impacts of nuclear energy" and on the comparative assessment of the environmental impact of different energy sources. As a result of this, realizing the widely differing views of what should be covered by environment assessments, the Agency is now considering the preparation of a general methodology on this subject for nuclear facilities. Consideration has also been given to non-radiological aspects of nuclear energy utilization, in particular to the environmental aspects of cooling systems and thermal discharges from

12) See these Proceedings, paper IAEA-CN-43/436.

nuclear power plants. This was the subject of symposia and a co-ordinated research programme. Attention will be drawn also to the beneficial aspects of using waste heat released from nuclear facilities.

5.6. Future trends

Waste management will continue to be of high interest as part of necessary measures for ensuring the safety of nuclear power utilization until appropriate management and disposal methods have been completely integrated in national nuclear power programmes, their industrial applications have been demonstrated and, hence, public confidence in appropriate solutions been gained. Waste management issues from the currently established nuclear power and fuel cycle technology will prevail over the next decades, and no significant changes in emphasis on the programme components are therefore expected. However, waste management implications from the development of nuclear technology and related policy and regulating measures will require timely attention.

6. INTERNATIONAL GUIDELINES IN WASTE MANAGEMENT

6.1. Status of IAEA guidelines

There is an interest among nations using nuclear power to reach a common understanding of what techniques of waste management and disposal are appropriate, what safety requirements are to be applied, and by which means compliance with these requirements can be shown. Internationally developed guidelines can be of assistance for national authorities in ensuring that the basic requirements are understood by all the parties involved, and contribute to harmonizing approaches among nations. Such guidelines can be used by planning authorities, regulatory bodies, utilities, designers and are also helpful for the Agency's safety and technical assistance missions. They are of particular importance for countries that embark on nuclear power programmes, establish long-term waste-management systems and set up their related regulatory procedures. It is quite obvious that such guidelines have to reflect the fact that a

variety of solutions and techniques are available and can be adopted by the competent national authorities, depending on conditions which may be specific for a given plant design, site, and the legal and administrative structure of the country. The Agency's safety standards and guidelines, as described in section 4.3.2., constitute recommendations to Member States involving a varying degree of commitment but they are generally expected to be used as a base for national practice and regulation.

In addition to guidelines developed for use by national authorities within national jurisdiction, international recommendations and guidelines may be prepared upon request to form part of or supplement international conventions or may become otherwise effective in international law in particular agreements. In waste management, currently only the Agency's "Definition and Recommendations" under the London Convention (see sections 3.2.5. and 5.5.2.) belong to this type of guidelines.

6.2. Areas of interest

There are many areas in waste management in which internationally prepared guidelines are useful or required. These range from providing a common terminology for waste management to facilitate an international dialogue on the subject, through uniform test methods for comparing results of research work (e.g. on characteristics of conditioned waste forms), recommendations for selecting possible disposal options and waste management systems, to the formulation of safety standards, codes of practice and related guides. Table VIII summarizes the current status and areas of IAEA guidelines related to radioactive waste management. Such guidelines are being developed on a time schedule appropriate for the status of the various technologies, the extent of their use, and the need for specific information. Guidelines in waste management have to be consistent and integrated with other Agency safety and technical standards, such as those developed under the NUSS and radiological safety programme. As already included in the description of the Agency's programme in Section 5, areas of current importance for the development of guidelines are:

- The safe underground disposal of radioactive wastes (see section 5.4.1)
- The safe management of wastes at and from nuclear power plants (see section 5.3.2)
- The safe management of wastes from the mining and milling of uranium and thorium ores (5.4.2)
- The protection of the marine environment from disposal of radioactive wastes at sea (5.5.2)
- The control of environmental releases of radionuclides.

In most of these areas safety standards, codes of practice or other recommendations that are subject to approval by the Board of Governors have been, or are planned to be, prepared, eventually together with related safety guides.

Table IX lists these documents together with Safety Series Category 1 documents in related fields.

In the current waste management programme, strong efforts are being devoted to developing guidelines on underground disposal (see section 5.4.1.). The first stage of the programme, which is planned to be completed by 1984, includes the preparation of recommendations and procedures under the Agency's Safety Series reports as well as technical reports. This first stage will be followed by the preparation of relevant codes and guides when the subjects are sufficiently mature in all areas and more experience has been gained in Member States. The need to arrive at internationally acceptable guidelines and technical criteria for underground disposal has been expressed by Member States in recent years. The Agency has given due priority to this aspect and on the recommendations of the Scientific Advisory Committee of the Agency, action is being initiated to develop a safety standards report which will be of value to national authorities, regulatory organizations and licensing bodies in the development of quantitative site-specific criteria.

As may be seen from Table VIII, there are a number of other areas in which guidance in the level of safety series recommendations and procedures and data will be developed during the next years. These are related particularly to

- The design and operation of facilities for the treatment of liquid wastes
- Design, operation, testing and in-plant monitoring of off-gas and ventilation air-cleaning systems
- Methodologies for environmental assessments
- Control of atmospheric releases with long-range transboundary significance
- De minimis concepts in radioactive waste disposal.

7. INTERNATIONAL CO-OPERATION

7.1. General approach

The Agency's waste management programme involves co-operation with many intergovernmental and non-governmental organizations. This can, according to the needs and responsibilities, take a variety of forms, such as the joint organization of meetings and issuance of joint documents and publications, regular exchange of information on programmes and their results, co-ordination of activities, mutual invitation to meetings at policy and/or technical level; consultations on particular subjects. This collaboration is normally formalized by agreements or memoranda of understanding with the organization concerned. Also, according to needs, contributions are provided to studies on the potential for international co-operation in particular areas of nuclear technology, which studies may be performed by the Agency or by special initiatives of governments, e.g. as INFCE. Such particular co-operative ventures that could be within the scope of the statutory functions of the IAEA would be subject to determination by the Agency's Board of Governors.

7.2. Co-operating organizations

The following international organizations co-operate with the Agency in its waste management programme: WHO, IMO, UNEP, UN(UNSCEAR), UNESCO, WMO, ECE (all UN-organizations), OECD/NEA, CEC, CMEA, Nordic Council (all other inter-governmental organizations), UNIPEDE, ICRP, (non-governmental organizations).

With UNEP, the Agency has co-operated in UNEP's programme on the environmental impacts of the production and use of energy, also in considerations given to the comparability of such impacts from different sources of energy (fossil, nuclear, renewable). Studies by the Agency on non-radioactive pollutants in the marine environment at the Monaco International Laboratory of Marine Radioactivity contributed to UNEP's Regional Sea programme, which in turn provides necessary inputs for the Agency's work on environment assessments, in particular in relation to radioactive waste disposal into the marine environment. UNEP supported from 1973 to 1978 the Agency's waste management programme financially within a joint project on the long-term management of high-level and alpha-bearing wastes.

Co-operation with WHO relates its programme on environmental health, which includes radiological protection, public health aspects of nuclear power and problems of handling non-radioactive wastes and pollutants ¹³⁾. There have been many joint undertakings, as evidenced by joint symposia, or the recent publication of the booklet "Nuclear Power, the Environment and Man". The IAEA also co-operated with WHO in the preparation of WHO publications on health implications of nuclear power production, health aspects of transuranium elements and health implications of high-level waste disposal. The work of UNSCEAR ¹⁴⁾ with its systematic collection of information and analysis of radionuclide releases and radiation exposures resulting from nuclear power production, provide the necessary perspective for the radiological implications of waste management and information on environmental modelling and data.

The Agency co-operates with IMO ¹⁵⁾ in marine environment protection according to the responsibilities entrusted by the London Dumping Convention (see section 5.5.2.). The IAEA regularly reports to meetings of the Contracting Parties to this Convention, which are organized annually by IMO, and had joint activities with IMO in many

13) See these Proceedings, paper IAEA-CN-43/414

14) See these Proceedings, paper IAEA-CN-43/42

15) See these Proceedings, paper IAEA-CN-43/173

related matters. IMO, UNESCO, UNEP, WHO, WMO, FAO and IAEA are joint sponsors of GESAMP, from which IAEA gets advice on scientific aspects of marine pollution. Information on IAEA activities in the field of the environment is regularly also included in a document prepared by ECE for the attention of the Senior Advisors of ECE Governments on Environmental Problems.

There are close contacts with those multinational governmental organizations having significant programmes in waste management such as OECD/NEA and CEC. The Agency organized jointly with NEA 14 symposia and other technical meetings. With CEC four joint meetings have been held so far. The programmes of these organizations provide directly or indirectly through their Member States important technical inputs for the Agency's programme, assisting in particular in its world-wide functions to provide guidelines. With OECD/NEA, programme co-ordinating meetings at high level aim at avoiding unjustified duplication of work. The Agency is participating in many NEA activities, including NEA's Radioactive Waste Management Committee, Co-ordination Group in Geological Disposal and environmental surveillance research programme related to sea disposal of radioactive wastes at the NEA's North Atlantic Dump Site. The Agency also co-operates with ISO, which prepares various standards defining test methods for solidified high-level waste products, irradiation stability, corrosion, thermal and mechanical stability, measurement of Pu in waste, etc.

7.3 Particular questions

7.3.1. Special issues for small nuclear programmes

Economy of scale, the special safety requirements and unfavourable geological conditions often disfavour the development of own national systems for the disposal of high-level and alpha-bearing wastes on national territory, in particular in countries with small nuclear power programmes. Therefore, the concept of regional repositories for high-level wastes, of accepting foreign waste in national repositories, or of solving the problem by transferring the spent fuel back to the

supplier country or to the reprocessing country without returning the waste, has attracted attention as a way of meeting the interest of such countries. The concept of regional repositories was considered a part of regional or international planning of the nuclear fuel cycle (co-location of waste repositories and regional reprocessing plants) in the IAEA Study Project on Regional Nuclear Fuel Cycle Centres published in 1977.

Discussions on institutional aspects of national, multinational and international repositories and other solutions have taken place in the International Fuel Cycle Evaluation (INFCE) study, Working Group 7 on waste management and disposal, for which the Agency provided scientific secretariat functions. The question of international co-operation in these fields is continually raised. Obviously, a country that produces radioactive waste will first have to consider disposing of the waste in its own territory before seeking international solutions.

Internationally accepted guidelines on underground waste disposal may, therefore, be an important step in proceeding from national to international projects and to commercial solutions for this part of the back end of the fuel cycle. The potential for successful international co-operation in this field and the role that IAEA might play would require further exploration.

7.3.2. Register for radionuclide releases

On several occasions, including in the recommendations of the UN Conference on the Human Environment in 1972, it has been proposed to establish a register of releases to the biosphere of significant quantities of radioactive materials. The wish was repeatedly expressed to set up a global register on radioactive inputs into the marine environment. However, there is not enough agreement among Member States for the establishment of such a register. In practice, however, partial steps in that direction have been taken: UNSCEAR has given continuing attention to evaluating effects of releases of radioactive substances, based on published data, in its reports to the UN General Assembly¹⁶⁾. It should be noted, however, that IMO keeps a register

16) See these Proceedings, paper IAEA-CN-43/42.

of radioactive inputs from sea dumping operations according to the terms of the London Convention (see sections 3.2.5. and 5.5.2.) which requires the reporting of the "nature and quantities of all matter permitted to be dumped and the location, time and method of dumping".

8. CONCLUSIONS

In general, the ongoing waste management programme of the Agency has sought

- (a) to provide a suitable framework for world-wide co-operation among IAEA Member States having an interest in this subject
- (b) to respond in detail, depth and timing sufficiently to the current needs of most Member States using nuclear power.

In future, consideration will be given to provide the right balance, according to the funds available, between activities related to the collection of information, development of guidelines and support of research. Of increasing importance is the full inclusion of countries embarking on nuclear power in the ongoing programme.

TABLE I

IAEA Co-ordinated Research Programmes related to

Waste Management

Programme	Results
Evaluation of solidified high-level waste forms (ongoing since 1977)	Technical Report 187 (1979) IAEA-TECDOC-239 (1981)
Hazard assessment of the separation of actinides followed either by transmutation or separate disposal (1977-1981)	Technical Report 214 (1982)
Handling of tritium contaminated wastes and effluents (1978-1982)	IAEA-TECDOC- (under publication)
Treatment of spent ion exchange resins (1979-1982)	Internal doc. (1981)
Testing methods for particulate filters (1977-1982)	IAEA-TECDOC- (in preparation)
Studies on the source, distribution, movement and deposition of radium in inland waterways and aquifers (1975-1980)	IAEA-TECDOC- (1983) The behaviour of radium in waterways and aquifers (in preparation)
Environmental migration of radium and other contaminants present in liquid and solid wastes from the mining and milling of uranium ores	ongoing since 1982
Migration and dispersion of radionuclides from the storage of radioactive waste in the terrestrial environment (1978-1981)	internal document
Role of sediments in the transport and accumulation of radioactive pollutants in rivers and estuaries	ongoing since 1982
Transuranic cycling behaviour in the marine environment (1977-1980)	IAEA-TECDOC-265 (1982)
* Marine behaviour of long-lived radionuclides associated with deep ocean disposal of radioactive waste	started 1982
Physical and biological effects on the environment of cooling systems from nuclear power plants (1975-1978)	Technical report 202 (1980) "Environmental Effects of Cooling Systems"

* conducted by the Agency's International Laboratory on Marine Radioactivity.

Table I (continued)

** Carbon-14 from nuclear facilities	ongoing since 1981
** Study of radioactive materials in the Baltic Sea	ongoing since 1981
** Radiological and environmental protection studies in the Danube river catchment area (1976-1981)	IAEA-TECDOC-219: International Studies on the Radioecology of the Danube River; IAEA Bulletin Vol. 22, No.2 article on page 46

** conducted by the Agency's Radiological Safety Section

TABLE II:

List of IAEA Training Courses and
Study Tours in Radioactive Waste Management

- Study Tour: Waste management techniques and programmes in
Czechoslovakia, Poland and the Soviet Union (1969),
Study Tour Report - STR/3
- Study Tour: Waste management techniques in Belgium, France, the Federal
Republic of Germany, Czechoslovakia and Hungary (1982).
- Training Course: Management of radioactive waste from nuclear facilities
September 1982, Karlsruhe, Federal Republic of Germany
- Training Course: Management of radioactive waste from nuclear facilities
September 1983, Karlsruhe, Federal Republic of Germany

TABLE III: Progress in the development of the Agency's
waste management programme

1976 - 1979

CURRENT

- | | |
|-----------------------------------------------------|-----------------------------------------------------|
| • TREATMENT AND
DISPOSAL OF
RADIOACTIVE WASTE | • HANDLING AND
TREATMENT OF
RADIOACTIVE WASTE |
| • NUCLEAR ENERGY AND
ENVIRONMENTAL
IMPACT | • UNDERGROUND
DISPOSAL |
| • DECOMMISSIONING
OF NUCLEAR
FACILITIES | • ENVIRONMENTAL
ASPECTS OF
NUCLEAR ENERGY |

TABLE IV: Overview on areas covered in the IAEA WASTE MANAGEMENT PROGRAMME

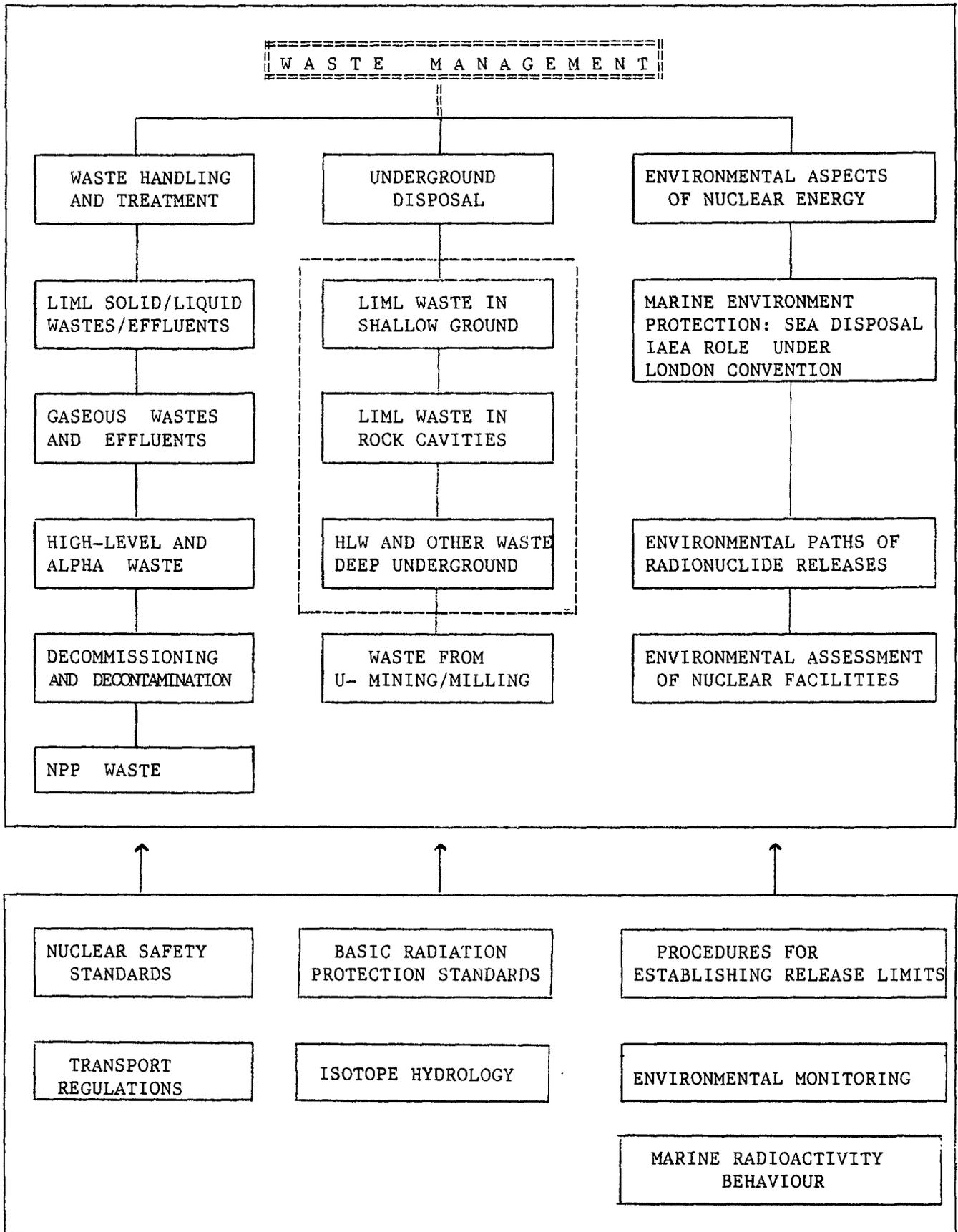


TABLE V

HANDLING AND TREATMENT OF RADIOACTIVE WASTE AT NUCLEAR FACILITIES
- IAEA - ACTIVITIES -

AREA	ACTIVITIES 1976 - 1982	PRODUCTS	EMPHASIS IN FUTURE WORK
I WASTE FROM REFINING, ENRICHMENT, FUEL FABRICATION	<ul style="list-style-type: none"> Refining/Conversion (AG) Enrichment - Fuel Fabrication - 	TECDOC -241 (1981) - -	No Activity
II WASTE FROM NPP (see III, IV, VI below)	<ul style="list-style-type: none"> Symposium (1979) Waste Management at NPP (AG) Fuel Handling at NPP (2 TC) Seminar (1981) Draft Code 	TR 198 (1980) TR 189 (1978) TECDOC-276 (1982) TECDOC-272 (1982)	SC (1984) MLW Components, 1 M)
III TREATMENT OF LLW and MLW (including alpha waste)	<ul style="list-style-type: none"> Solid Waste (TC) Conditioning Techniques (TC,AG), Symposium 1982 Spent Ion Exchange Resins (TC, CRP) Tritium Waste (TC, CRP) Liquid Waste (TC, AG) 	TR 223 (1982) TR 222 (1982) TECDOC-238 (1981) TR 203 (1980)	Guidelines on Liquid Waste, Facility Design/Operation, Conditioning for Disposal, MLW AG, TC, CRP)
IV GASEOUS WASTE MANAGEMENT	<ul style="list-style-type: none"> General - Symposium Vienna 1980 From Reprocessing (TC) Kr-85 Removal (TC) J-131/129 Removal, semivolatiles (TC) Retention at NPP (TC, AG) Particulate Filtration (CRP) Testing & Operation of Off-Gas Cleaning Systems (Seminar 1982, TC, AG) 	P (1981) TR IAEA-209 (1978) TR 199 (1980) TR 201, 220 TR (1984) TECDOC- (1984) TR (1984)	Guidelines on design and operation of off-gas and ventilation air cleaning systems (AG); I-129 Handling (TC); CRP on Iodine and particulate behaviour.
V HLW and ALPHA-BEARING WASTE TREATMENT (See III above)	<ul style="list-style-type: none"> General: Symposium (1976) 4 Review Committee Meetings Alpha Waste Handling: Symposium (1980) Liquid HLW Storage (AG) HLW Solidification (AG) HLW Product Evaluation (CRP) Partitioning - Transmutation (CRP) Storage of Conditioned Waste (TC 1981) Conditioning Techniques (Symposium 1982) 	P (1977) P (1981) TR 191 (1979) TR 176 (1977) TR 187 (1979) TR 214 (1982) TR (1983) P (1983)	Conditioning for Storage and Disposal, CRP on Product Evaluation.
VI DECOMMISSIONING DECONTAMINATION	<ul style="list-style-type: none"> General Practice: Symposium 1978 Factors for Decommissioning (TC, AG) Decontamination at NPP (TC) Decommissioning Techniques (TC 1981) 	TR/IAEA-179 (1975) P (1979) SR (1980) TECDOC-248 (1981) TC (1983)	Review of Techniques for Decontamination (TC)

SC = Safety Series Report, Category 1

SR = Safety Series Report, Categories 2, 3, 4 (Recommendations, Procedures, Data)

TR = Technical Report

TC = Technical Committee

AG = Advisory Group

CRP = Co-ordinated Research Programme

NPP = Nuclear Power Plant

P = Proceedings of Symposia

TABLE VI

UNDERGROUND DISPOSAL OF RADIOACTIVE WASTE
- IAEA - ACTIVITIES -

AREA	ACTIVITIES 1976 - 1982	PRODUCTS	EMPHASIS IN FUTURE WORK
<p>Disposal of low, intermediate- and high-level waste in underground repositories</p> <p>a) General and regulatory matters, safety assessments, criteria</p> <p>b) Site selection and investigations</p> <p>c) Design and construction of repositories</p> <p>d) Operation, shutdown, surveillance of repositories</p> <p>e) Waste acceptance criteria</p>	<p>General review of practice: Symposium 1979</p> <p>IAEA Programme to develop guidelines:</p> <ul style="list-style-type: none"> • Programme review (CM, AG 1978) Technical Review Committee (annually) • General matters under item a) and e) <ul style="list-style-type: none"> - regulation (TC) - basic guidance (TC, AG) - safety assessment (AG) - criteria (2 AG) - conditioning requirements (AG) • Shallow ground disposal <ul style="list-style-type: none"> - item a): guidebook (3 AG) safety analysis (AG) - item b): (2 AG) - item c) + d): (2 AG) • Rock cavity disposal <ul style="list-style-type: none"> - item a): guidebook (TC, AG) - item b), c), d) (TC, 2 AG) • Deep geological disposal <ul style="list-style-type: none"> - item a): regulation (TC) safety analysis (2 AG) - item b): 3 AG - hydraulic fracturing 	<p>P (1980)</p> <p>Intern. recommendations</p> <p>TECDOC-230, SR 51 (1980) SR 54 (1981) SR 56 (1981) SR (1984) TECDOC-285 (1983)</p> <p>SR 53 (1981) SR (1983)</p> <p>TR 216 (1982) SR (1983)</p> <p>SR (1983) SR (1984)</p> <p>SR 51 (1981) SR (1983) TR 177 (1977), TR 215 (1982) TR (1983)</p>	<ul style="list-style-type: none"> • Criteria, conditioning requirements • Technical background reports on near- and far-field effects, operational experience, system performance • TC, AG, Seminar (1984) • SC by 1988
<p>Deposition of waste from uranium mining and milling *</p>	<ul style="list-style-type: none"> • review of general practice: 2 AG (1975) Symposium (1982) • review of mill tailings management (2 AG) 	<p>SC 44 (1976) P (1982) TR 209 (1982)</p>	<p>Review of SC</p>

* This subject was previously covered under the programme component Handling and Treatment of Wastes

SC = Safety Series Report Category 1

SR = Safety Series Report Categories 2, 3, 4 (Recommendations, Procedure, Data)

TR = Technical Report

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TABLE VII

ENVIRONMENTAL ASPECTS OF NUCLEAR ENERGY
- IAEA - ACTIVITIES -

A R E A	A C T I V I T I E S 1976 - 1982	P R O D U C T S	E M P H A S I S I N F U T U R E W O R K
<p>MARINE ENVIRONMENT PROTECTION:</p> <ul style="list-style-type: none"> ● IAEA responsibility for radioactivity matters under the London Convention on the Prevention of Marine Pollution by Dumping (LDC) ● Sea Disposal of Radioactive Waste (general) 	<ul style="list-style-type: none"> ● Definition and Recommendations required for LDC - oceanographic basis (AG, GESAMP 1978-82) ● - radiological basis (AGs) ● Site Selection and Surveillance (AG, 1978) ● Environment Assessment Methodology (TC, 1982) ● De minimis - quantities (AG, CM) ● Packaging for Dumping ● Impact of Radionuclide Releases to the Ocean (Symposium 1980) ● Methodology for Impact Assessment on Aquatic Ecosystems (AGs) ● Review SR Disposal of Radioactive Waste into the Sea (TC) 	<p>Operative 1978 TECDOC-210 (1978) TECDOC-211 (1978)</p> <p>TECDOC- (1983) TECDOC-244 (1981) TECDOC-240 (1981)</p> <p>P (1981)</p> <p>TR 190 (1979) TR 172 (1976) SR (1983)</p>	<ul style="list-style-type: none"> - Review of Definitions and Recommendations and supplementary guidance for LDC, - Responsibility under other relevant International Conventions - Continued collaboration with IMO, UNEP
<p>ENVIRONMENTAL PATHWAYS OF RADIONUCLIDES</p>	<ul style="list-style-type: none"> ● Assessment of Generic Models (TC, AG) ● Tritium - Behaviour (Symposium 1978) (CRP 1976-78) ● Radium Migration (CRP 1977-81, ongoing) ● Radionuclide Migration in Terrestrial Environment (1978-81) ● Role of Sediments in Hydrological Migration (CRP ongoing) ● Transuranic Behaviour in Aquatic Environments (TC, CRP 1978-81, ongoing) ● Pathways of Radionuclides of Regional and World-wide Interest (TC, AG) ● Migration of Long-lived Radionuclides (Symposium 1981) ● Atmospheric Dispersion Models (AG, TC) 	<p>SR 57 (1982) P (1979) TR 207 (1981) TECDOC (1983)</p> <p>TECDOC</p> <p>TECDOC-265</p> <p>TECDOC (1983) 279</p> <p>P (1982) TR (1984)</p>	<p>Recommendations on control of radionuclide releases of regional and global interest</p> <p>CRP continued</p> <p>Seminar (1983)</p>
<p>GENERAL ENVIRONMENTAL IMPACT ASSESSMENT</p>	<ul style="list-style-type: none"> ● Contribution to UNEP-Study on Nuclear Energy ● Contribution to UNEP-Study on Comparative Assessment of Environmental Aspects of Energy Sources ● IAEA/WHO Booklet "Nuclear Power, the Environment and Man" 	<p>UNEP-Study (1980)</p> <p>UNEP-Study (1981)</p> <p>Book (1982)</p>	<p>Continued collaboration with UNEP, ECE, WHO</p> <p>Recommendations on general methodology for environmental assessment (AG)</p>
<p>OTHER ENVIRONMENTAL ASPECTS</p>	<p>Environmental Effects of Cooling Systems (CRP 1975-78)</p>	<p>TR 202 (1980)</p>	<p>Beneficial Use of Waste Heat (TC)</p>

LDC = London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter

SR = Safety Series Report Categories 2, 3, 4 (Recommendations, Procedure, Data)

TR = Technical Report

P = Proceeding of Symposia

AG = Advisory Group

CRP = Co-ordinated Research Programme

TC = Technical Committee

TABLE VIII

Status of IAEA guidelines for radioactive waste management:

areas of interest and kind of reports prepared or under consideration

(For the full titles of the publications mentioned see list in Annex I and Table IX.)

Major subjects	Areas	Kind of guidance, Current status, Plans
Management of waste from a specific facility of the nuclear fuel cycle	Mining and milling of uranium and thorium ores	Code of practice and related guide (1976, review planned)
	Refining and conversion of uranium	(IAEA-TECDOC 1981) No further plans
	Fuel fabrication	No plans
	Nuclear power plants	Code of practice under preparation (draft 1982) co-ordination with NUSS programme and underground disposal programme
	Spent fuel reprocessing plants	No plans
	Isotope users	Code of practice (1965)
Underground disposal of radioactive waste in shallow ground, rock cavity and deep geological repositories	Generic activities, regulation, safety assessments, criteria	Programme to prepare set of recommendations, procedures, technical reports (1977-84), Code of Practice and Safety Criteria planned after 1984
	Siting	
	Design and construction	
	Operation, shut-down, surveillance of repositories	
	Waste acceptance criteria	

Major subjects	Areas	Kind of guidance, Current status, Plans
Design, and operation of facilities for waste treatment	Low-, intermediate-level liquid waste	Preparation of guides to the Code on Management of Waste from Nuclear Power Plants planned for design and operation of liquid waste treatment and off-gas-cleaning facilities (1983-85)
	Solid waste	
	Ventilation air and off-gas cleaning (particulates, iodine, noble gases)	
	High-level waste storage and treatment	No plans
Decommissioning of nuclear facilities	Decontamination	Safety Series report on factors relating to the decommissioning of nuclear reactors published No specific further guidelines planned as decommissioning will be covered by other codes and guides relating to nuclear power plant-waste and the NUSS-programme Technical reviews under preparation
	Disassembly and waste management	
Transport of radioactive waste	Transport of low-, intermediate-level waste	Subject is covered in the Agency's regulations for the safe transport of radioactive materials (currently under review, next revision 1984)
	Transport of high-level waste	
Test methods for particular processes	Evaluation of high-level waste forms	No current plans to formalize test methods but co-operation with ISO and other organizations; co-ordinated research programmes
	Evaluation of low-level waste forms	
	Leach test, irradiation stability test	
	Measurement of alpha-emitters in waste	
	Particulate and radio-iodine filter tests	
	Test for compliance with conditioning requirements	

Major subjects	Areas	Kind of guidance, Current status, Plans
Sea disposal of radioactive waste (international guidelines under the London Convention on the Prevention of Marine Pollution by Dumping of Waste)	Definition of waste prohibited from being dumped; Recommendations for waste not prohibited from being dumped	IAEA definition and recommendations of 1978, next review by 1985
	Supplementary guidelines on environmental assessment and 'de minimis' quantities	Related methodology on environmental assessment under preparation
Effluent discharge into the environment	Establishing of limits for the release of radio-active materials into the environment	Safety Series No. 45 (1978), prepared and under review within the Radiological Safety Programme
	Atmospheric, aquatic and terrestrial pathway models and parameters for assessing the environmental transfer of radio-nuclides to man (to predict radiation exposure)	Guides on local atmospheric and aquatic dispersion prepared under the NUSS programme (1982)
	Control of aquatic and atmospheric releases of radionuclides (e.g. Kr-85, C-14, H-3, I-129) with potential regional and global implications	Safety Series Report on generic models and parameters (1982)
	'De minimis quantities' for low-level waste for release into the terrestrial environment or material reuse	Atmospheric dispersion models under review (1982-83)
	General methodology to prepare environmental assessment for nuclear facilities summarizing both non-radiological and radiological aspects	Need for recommendations under discussion
Environmental impact assessment for nuclear facilities	General methodology to prepare environmental assessment for nuclear facilities summarizing both non-radiological and radiological aspects	Procedures under consideration
	Terminology	Recommendations planned for 1984
General matters	Terminology	Draft radioactive waste management glossary published as IAEA-TECDOC (1982) intended for IAEA use.

TABLE IX

Safety Series Category 1 documents in Waste Management

1. The Management of Waste Produced by Radioisotope Users. A Code of Practice. Safety Series No. 12 (1965). To be reviewed later.
2. Management of Wastes from the Mining and Milling of Uranium and Thorium Ores. A Code of Practice and Guide to the Code. Safety Series No. 44 (1976).
(Being revised for publication in 1985.)
3. Management of Radioactive Waste from Nuclear Power Plants. A Code of Practice. (Under preparation for publication in 1985). A draft of this code is available as IAEA TEC-DOC-276 (1982).
4. IAEA revised Definition and Recommendations of 1978 concerning radioactive waste and other radioactive matter (under the London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter) INFCIRC/205/Add 1, Rev. 1 (1978).
5. Disposal of Radioactive Waste in Shallow Ground Rock Cavities and in Deep Geological Repositories. A Code of Practice and Guide to the Code for (To be published by 1988). This document will be based on the review of guidelines published under the underground disposal programme.
6. Criteria for Underground Disposal of High-level Radioactive Waste. Safety Standard (To be published in 1988). Activities in this regard were started by the preparation of a Safety Series report on this subject in the underground disposal programme.

Safety Series Category 1 documents in related areas

1. Basic Safety Standard for Radiation Protection, Safety Series No. 9 (1982).
2. Regulations for the Safe Transport of Radioactive Materials, Safety Series No. 6 (1973), (Revised regulations will be published in 1984).
3. Nuclear Safety Standards (Code of Practice)
 - Governmental Organization for the Regulation of Nuclear Power Plants, Safety Series No. 50-C-G (1978)
 - Safety in Nuclear Power Plant Siting, Safety Series No. 50-C-S (1978)
 - Design for Safety of Nuclear Power Plants, Safety Series No. 50-C-D (1978)
 - Safety in Nuclear Power Plant Operation, including Commissioning and Decommissioning, Safety Series No. 50-C-0 (1978)
 - Quality Assurance for Safety in Nuclear Power Plants, Safety Series No. 50-C-QA (1978).

A N N E X I

PUBLICATIONS OF THE IAEA WASTE MANAGEMENT PROGRAMME

0. GENERAL

International Conference on Radioactive Waste Management (IAEA Conference, Seattle, USA 1983)	Proceedings of Conference
Radioactive Waste Management and Disposal Session at IAEA International Conference on Nuclear Power Experience (Vienna, 1982)	Proceedings of Conference
Radioactive Waste Management Research Abstracts	Issue No. 14 (1983) Issue No. 13 (1982) Issues No. 1-12 (1965-78)
Nuclear Power, the Environment and Man (Revision of a 1973 IAEA/WHO information booklet)	1982
Radioactive Waste Management Glossary	IAEA-TECDOC-264 (1982)
Radioactivity management (Sessions at the IAEA Conference on Nuclear Power and its Fuel Cycle) (IAEA Conference Salzburg, 1977)	Proceedings of Conference (1977)
Management of radioactive wastes from the nuclear fuel cycle (IAEA-OECD/NEA Symposium Vienna, 1976)	Proceedings of Symposium (1976)
Standardization of radioactive waste categories	Technical Reports Series No. 101 (1970)
Basic factors for the treatment and disposal of radioactive waste	Safety Series No. 24 (1967)
The management of radioactive waste produced by radioisotope users: Technical Addendum	Safety Series No. 19 (1966)
The management of radioactive waste produced by radioisotope users	Safety Series No. 12 (1965)
Technology of radioactive waste management avoiding environmental disposal	Technical Reports Series No. 27 (1964)

I. TECHNOLOGY OF HANDLING AND TREATMENT OF RADIOACTIVE WASTES AT NUCLEAR FACILITIES

Management of wastes from the refining and conversion of uranium ore concentrates to uranium hexafluoride IAEA-TECDOC-241 (1981)

Waste from nuclear power plants

Management of radioactive waste from nuclear power plants (Seminar, Karlsruhe, Germany F.R., 1981) Proceedings as IAEA-TECDOC-276 (1983)

IAEA Provisional Code of Practice on Management of Radioactive Waste from nuclear Power Plants IAEA-TECDOC-272 (1982)

Guide to the safe handling of radioactive waste at nuclear power plants Technical Reports Series No. 198 (1980)

Storage, handling and movement of fuel and related components at nuclear power plants Technical Reports Series No. 189 (1979)

On-site management of power-reactor waste (OECD/NEA-IAEA Symposium, Zurich 1979) Proceedings published by OECD/NEA (1979)

Management of radioactive wastes at nuclear power plants Safety Series No. 28 (1968)

Treatment of low- and intermediate-level waste

Treatment of low- and intermediate-level liquid waste Technical Reports Series (in preparation)

Conditioning of radioactive wastes for storage and disposal (IAEA/OECD/CEC symposium, Utrecht, 1982) Proceedings of symposium (1983)

Treatment of low- and intermediate-level solid radioactive wastes Technical Reports Series No. 223 (1983)

Conditioning of low- and intermediate-level radioactive wastes Technical Reports Series No. 222 (1983)

Management of spent ion-exchange resins from nuclear power plants IAEA-TECDOC-238 (1981)

Storage tanks for liquid radioactive wastes: their design and use Technical Reports Series No. 135 (1972)

Use of local minerals in the treatment of radioactive waste Technical Reports Series No. 136 (1972)

Waste management techniques and programmes in Czechoslovakia, Poland and the Soviet Union Study Tour Reports STR/3 (1971)

The volume reduction of low-activity wastes	Technical Reports Series No. 106 (1970)
Bituminization of radioactive wastes	Technical Reports Series No. 116 (1970)
Management of low- and intermediate-level radioactive wastes (IAEA-ENEA Symposium, Aix en Provence, France, 1970)	Proceedings of Symposium (1970)
Chemical treatment of radioactive wastes	Technical Reports Series No. 89 (1968)
Design and operation of evaporators for radioactive wastes	Technical Reports Series No. 87 (1968)
Economics in managing radioactive wastes	Technical Reports Series No. 83 (1968)
Treatment of low- and intermediate-level radioactive waste concentrates	Technical Reports Series No. 82 (1968)
Operation and control of ion-exchange processes for treatment of radioactive wastes	Technical Reports Series No. 78 (1967)
Practices in the treatment of low- and intermediate-level radioactive wastes (IAEA-OECD/NEA Symposium, Vienna, 1966)	Proceedings of Symposium (1966)
<u>Gaseous waste management</u>	
Testing and operation of off-gas cleaning systems (IAEA Seminar, Karlsruhe, 1982)	Proceedings of Seminar (available on microfiches only)
Comparison of methods for testing of particulate filters	IAEA-TECDOC- (in preparation)
Testing and in-plant monitoring of off-gas cleaning systems	Technical Reports Series (in preparation)
Control of semivolatile radionuclides in gaseous effluents at nuclear facilities	Technical Reports Series No. 220 (1982)
Handling of tritium-bearing wastes (1981)	Technical Reports Series No. 203 (1981)
Radioiodine removal in nuclear facilities: methods and techniques for normal and emergency situations	Technical Reports Series No. 201 (1980)
Separation, storage and disposal of krypton-85	Technical Reports Series No. 199 (1980)
Management of gaseous waste from nuclear facilities (IAEA-OECD/NEA Symposium, Vienna, 1980)	Proceedings of Symposium (1980)

- Removal, storage, and disposal of radionuclides from airborne effluents : Report of Technical Committee Meeting Vienna IAEA-TECDOC-209 (1978)
- Control of iodine in the nuclear industry Technical Reports Series No. 148 (1973)
- Air filters for use at nuclear facilities Technical Reports Series No. 122 (1970)
- Treatment of airborne radioactive wastes (IAEA Symposium in co-operation with USAEC and Harvard University, New York, 1968) Proceedings of symposium (1968)

High-level and alpha-bearing waste treatment

- Handling and storage of conditioned high-level wastes Technical Reports Series No. (1983) (in print)
- Evaluation of actinide partitioning and transmutation Technical Reports Series No. 214 (1982)
- Management of alpha-contaminated wastes (IAEA-CEC Symposium, Vienna, 1980) Proceedings of Symposium (1981)
- Evaluation of solidified high-level waste forms IAEA-TECDOC-239 (1981)
- Handling and storage of high-level radioactive liquid wastes requiring cooling Technical Reports Series No. 191 (1979)
- Characteristics of solidified high-level waste products Technical Reports Series No. 187 (1979)
- Techniques for the solidification of high-level wastes Technical Reports Series No. 176 (1977)
- Treatment and storage of high-level radioactive wastes (IAEA Symposium, Vienna, 1962) Proceedings of Symposium (1962)

Decommissioning and decontamination

- Decommissioning of nuclear facilities: decontamination, disassembly and waste management Technical Reports Series (in preparation)
- Decontamination of operational nuclear power plants IAEA-TECDOC-248 (1981)
- Factors relevant to the decommissioning of land-based nuclear reactor plants Safety Series No. 52 (1980)
- Decommissioning of nuclear facilities IAEA-TECDOC-179 (1975)
IAEA-TECDOC-205 (1977)
- Decommissioning of nuclear facilities (IAEA-OECD/NEA Symposium, Vienna, 1978) Proceedings of Symposium (1979)

II. UNDERGROUND DISPOSAL OF RADIOACTIVE WASTES

II.1. Disposal in shallow ground, rock cavity and deep geological repositories

General

Underground disposal of radioactive waste (IAEA-OECD/NEA Symposium, Otaniemi, Finland, 1979)	Proceedings of Symposium (1980)
Regulatory aspects of underground disposal of radioactive waste	IAEA-TECDOC-230 (1980)
Disposal of Radioactive Wastes into the ground (IAEA Symposium, Vienna, 1967)	Proceedings of Symposium (1967)
Radioactive waste disposal into the ground	Safety Series No. 15 (1965)

Guidelines under the underground disposal programme

General

Characteristics of radioactive waste forms conditioned for storage and disposal. Guidance for the development of waste acceptance criteria	IAEA-TECDOC-285 (1983)
Safety assessment methods for the underground disposal of radioactive waste	Safety Series No. 56 (1981)
Underground disposal of radioactive waste: basic guidance	Safety Series No. 54 (1981)
Criteria for underground disposal of solid radioactive wastes	Safety Series No. 60 (1983)

Shallow ground disposal

Methodologies for safety analysis for radioactive waste repositories in shallow ground	Safety Series No. (in preparation)
Design, construction, operation, shut-down and surveillance of repositories for solid radioactive waste in shallow ground	Safety Series No. (in preparation)
Site investigations for repositories for solid radioactive waste in shallow ground	Technical Reports Series No. 216 (1982)
Shallow ground disposal of radioactive waste: a guidebook	Safety Series No. 53 (1981)

Rock cavity disposal

Disposal of low- and intermediate-level solid radioactive waste in rock cavities: a guidebook	Safety Series No. 59 (1983)
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Site investigations, design, construction, operation, shut-down and surveillance of repositories for radioactive waste in rock cavities Safety Series (in preparation)

Disposal of high-level and transuranics-bearing waste in deep geological formations

Concepts and examples of safety analysis for radioactive waste repositories in deep continental geological formations Safety Series No. 58 (1983)

Analysis for performance of components and elements of the waste isolation system IAEA-TECDOC- (under preparation)

Site investigations for repositories for solid radioactive wastes in deep continental geological formations Technical Reports Series No. 215 (1982)

Development of regulatory procedures for the disposal of solid radioactive waste in deep, continental formations Safety Series No. 51 (1980)

Site selection factors for repositories of solid high-level and alpha-bearing waste in geological formations Technical Reports Series No. 177 (1977)

Hydraulic fracturing

Disposal of radioactive grouts into hydraulically fractured shale Technical Reports Series (under publ.)

II.2. Deposition of waste from uranium and thorium mining and milling

Management of wastes from uranium mining and milling (IAEA-OECD/NEA Symposium, Albuquerque, USA 1982) Proceedings of Symposium (1982)

Current practices and options for confinement of uranium mill tailings Technical Reports Series No. 209 (1981)

Management of wastes from the mining and milling of uranium and thorium ores - A code of practice and a guide to the code Safety Series No. 44 (1976)

III. ENVIRONMENTAL ASPECTS OF NUCLEAR POWER

Sea disposal of radioactive wastes - Marine environment protection

Control of radioactive waste disposal into the marine environment (to replace Safety Series No. 5: Radioactive waste disposal into the sea)	Safety Series No. (in print)
Impacts of radionuclide releases into marine environments (IAEA-OECD/NEA Symposium, Vienna, 1980)	Proceedings of Symposium (1981)
Methodology for assessing impacts of radioactivity in aquatic ecosystems	Technical Reports Series No. 190 (1979)
Effects of Ionizing radiation on aquatic organisms and ecosystems	Technical Reports Series No. 172 (1976)
Reference methods for marine radioactivity studies II	Technical Reports Series No. 169 (1975)
Design of radiotracer experiments in marine biological systems	Technical Reports Series No. 167 (1975)
Impacts of nuclear releases into the aquatic environment (IAEA symposium, Otaniemi, Finland, 1975)	Proceedings of Symposium (1975)
Radioactive contamination of the marine environment (IAEA Symposium, Seattle, USA, 1973)	Proceedings of Symposium (1973)
Disposal of radioactive wastes into rivers, lakes and estuaries	Safety Series No. 36 (1972)
Reference methods for marine radioactivity studies I	Technical Reports Series No. 118 (1970)
Disposal of radioactive wastes into seas, oceans and surface waters (IAEA Symposium, Vienna, 1966)	Proceedings of Symposium (1966)
Methods for surveying and monitoring marine radioactivity	Safety Series No. 11 (1965)
Disposal of radioactive wastes into fresh water	Safety Series No. 10 (1963)

IAEA responsibilities under the London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter

Environmental assessment methodologies for sea disposal of radioactive wastes	IAEA-TECDOC- (1983) (in preparation)
A model for the dispersion of wastes disposed of in the deep sea	GESAMP Reports and Studies No. 20 (1983)
Considerations concerning de-minimis quantities of radioactive waste suitable for dumping at sea under a general permit	IAEA-TECDOC-244 (1981)
Packaging of radioactive waste for sea-disposal	IAEA-TECDOC-240 (1981)
IAEA revised definition and recommendations of 1978 concerning radioactive waste and other radioactive matter	INFCIRC/205/Add.1/ Rev. 1 (1978)
The radiological basis of the IAEA revised definition and recommendations concerning high-level waste unsuitable for dumping at sea	IAEA-TECDOC-211 (1978) (revision 1983)
The oceanographic basis of the IAEA revised definition and recommendations concerning high-level radioactive waste unsuitable for dumping at sea	IAEA-TECDOC-210 (1978) (revision 1984)

Environmental dispersion and behaviour of radionuclides

Regional and global environmental behaviour of radionuclides from the nuclear fuel cycle	IAEA-TECDOC-279 (1983)
Radium in inland waterways and aquifers (Co-ordinated research programme 1975/80)	IAEA-TECDOC- (1983) (in preparation)
Atmospheric dispersion models related to radionuclide discharges	Technical Reports Series (in preparation)
Modelling of hydrodynamic mechanisms of pollutant propagation in coastal zones (bilingual English-French)	IAEA-TECDOC-274 (1982)
Generic models and parameters for assessing the environmental transfer of radionuclides from routine releases: exposures of critical groups	Safety Series No. 57 (1982)
Transuranic cycling behaviour in the marine environment	IAEA-TECDOC-265 (1982)
Techniques for identifying transuranic speciation in aquatic environment (IAEA/CEC Technical Committee meeting, Ispra, 1980)	Panel Proceedings (1982)

Environmental migration of long-lived radionuclides (IAEA-OECD/NEA-CEC Symposium, Knoxville, USA 1982)	Proceedings of symposium (1982)
* Hydrological dispersion of radioactive material in relation to nuclear power plant siting	Safety Series No. 50-SG-S6 (1982)
Tritium in some typical ecosystems (Co-ordinated Research Programme 1973/78)	Technical Reports Series No. 207 (1981)
* Atmospheric dispersion in nuclear power plant siting	Safety Series No. 50-SG-S3 (1980)
Behaviour of tritium in the environment (IAEA-OECD/NEA Symposium, San Francisco, USA, 1978)	Proceedings of symposium (1979)
Transuranium nuclides in the environment (IAEA-US ERDA Symposium, San Francisco, USA, 1975)	Proceedings of symposium (1976)
Physical behaviour of radioactive contaminants in the atmosphere (IAEA-WMO symposium, Vienna, 1973)	Proceedings of Symposium (1974)
Environmental behaviour of radionuclides released in the nuclear industry (IAEA-OECD/NEA-WHO Symposium, Aix en Provence, France, 1973)	Proceedings of Symposium (1973)

Other environmental aspects

De minimis concepts in radioactive waste disposal. Considerations in defining de minimis quantities of solid radioactive waste for uncontrolled disposal by incineration and landfill	IAEA-TECDOC-282 (1983)
Environmental effects of cooling systems (Co-ordinated research programme 1975/78)	Technical Reports Series No. 202 (1980)
Application of environmental impact analysis to the nuclear power industry (Proceedings of IAEA Seminar, Buenos Aires, Argentina, 1977)	IAEA-TECDOC-212 (1978)
Impacts of nuclear releases into the aquatic environment (IAEA Symposium, Otaniemi, Finland, 1975)	Proceedings of Symposium (1975)
Environmental effects of cooling systems at nuclear power plants (IAEA-ECE Symposium, Oslo, 1974)	Proceedings of Symposium (1975)
Combined effects of radioactive chemical and thermal releases to the environment (IAEA-OECD/NEA Symposium Stockholm, 1975)	Proceedings of Symposium (1975)
Thermal discharges at nuclear power stations	Technical Reports Series No. 155 (1974)

* prepared under the Agency's NUSS programme.

Other Agency's publications relating to environmental matters **

Annex to principles for establishing limits for the release of radioactive materials into the environment	Safety Series No. 45 Annex 1982
Principles for establishing limits for the release of radioactive materials into the environment	Safety Series No. 45 (1978)
Application of dose limitation systems in nuclear facilities and other radiation practice (IAEA/WHO/NEA/ICRP Symposium, Madrid, 1981)	Proceedings of Symposium (1982)
Health Impacts of different sources of energy (IAEA/WHO/UNEP Symposium, Nashville, 1981)	Proceedings of Symposium (1982)
Biological implications of radionuclides released from the nuclear power industry (IAEA Symposium, Vienna, 1979)	Proceedings of Symposium (1980)
Application of the dose limitation systems for radiation protection (Seminar, Vienna, 1979)	Proceedings of Seminar (1980)
Monitoring of airborne and liquid releases from nuclear facilities to the environment	Safety Series No. 46 (1978)
Monitoring of radioactive effluents from nuclear facilities (IAEA Symposium, Portoroz)	Proceedings of Symposium (1977)
Objectives and design of environmental monitoring programmes for radioactive contaminants	Safety Series No. 41 (1975)
Population dose evaluation and standards for man and his environment (Seminar, Portoroz, 1974)	Proceedings of Seminar
Environmental surveillance around nuclear installations (IAEA Symposium, Warsaw, 1973)	Proceedings of Symposium (1974)
Environmental aspects of nuclear power stations (IAEA/USAEC Symposium, New York, 1970)	Proceedings of Symposium (1970)
Environmental monitoring in emergency situations	Safety Series No. 18 (1966)
Techniques for controlling air pollution from the operation of nuclear facilities	Safety Series No. 17 (1966)
Manual on environmental monitoring in normal operation	Safety Series No. 16 (1966)

** mostly prepared under the Agency's Radiological Safety programme.