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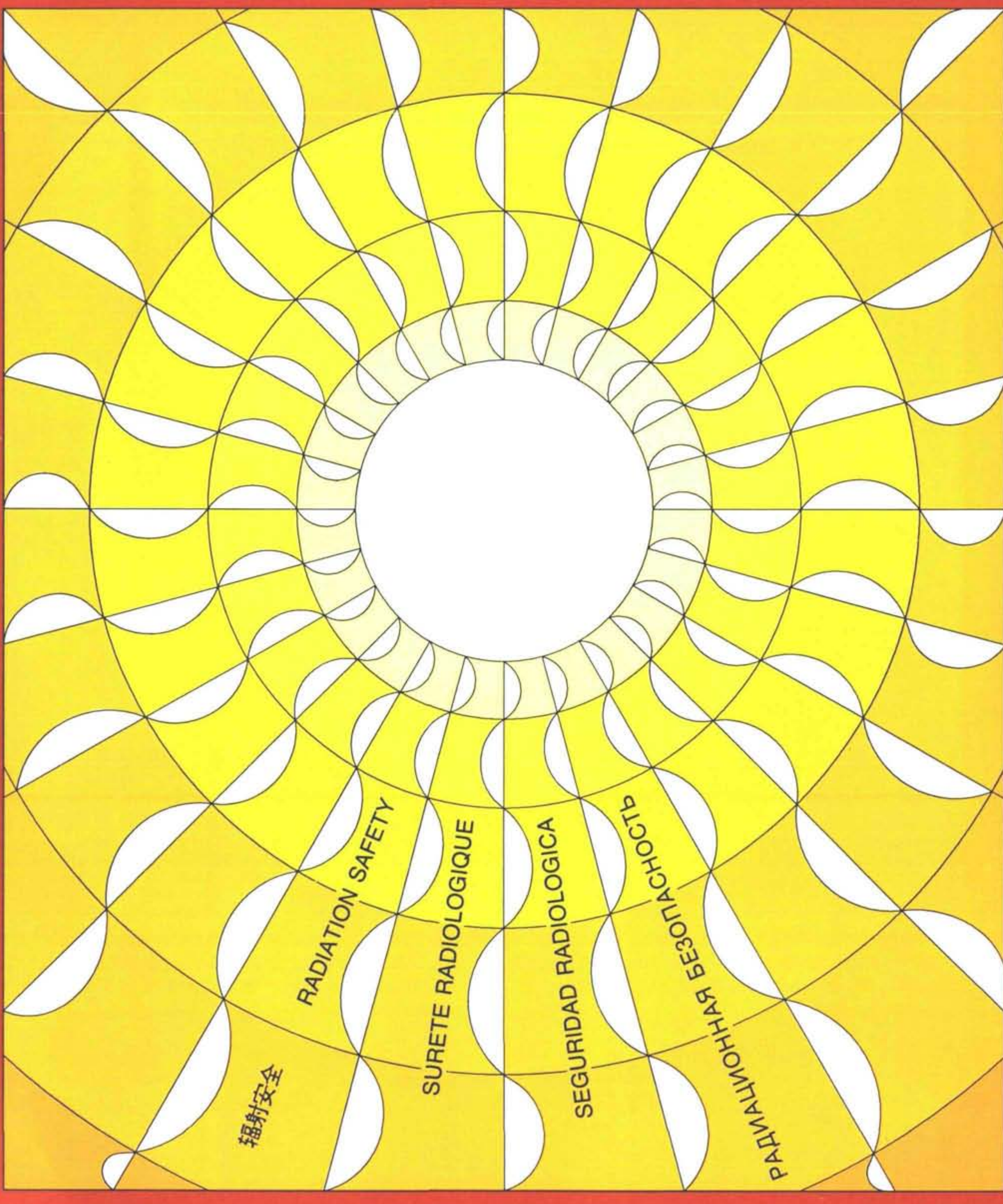

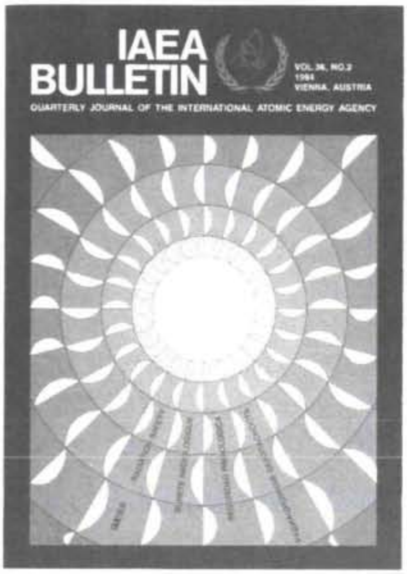

Front cover: Radiation is all around us, and the extent of our exposure to it varies. In the interests of preventing harmful exposures, national and international regulatory bodies have adopted standards of radiation protection and safety, both for people in the workplace and the general public. Over the past 3 years, the IAEA and five other international organizations have headed an unprecedented joint global effort to update and harmonize the international basic standards of radiation safety. Once endorsed by all sponsoring organizations, these new standards will supercede any previous ones in this field, providing renewed practical guidance for the protection of public health and safety. *(Cover design: Ms. Hannelore Wilczek, IAEA)*

Facing page: Children in the marketplace, Guatemala. *(Credit: J. Marshall, IAEA)*

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Radiation safety: New international standards

The forthcoming International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources are the product of unprecedented co-operation

by Abel J. González

By the end of the 1980s, a vast amount of new information had accumulated to prompt a new look at the standards governing protection against exposures to ionizing radiation and the safety of radiation sources.

First and foremost, a re-evaluation of the radioepidemiological findings from Hiroshima and Nagasaki suggested that exposure to low-level radiation was riskier than previously estimated.

Other developments — notably the nuclear accidents at Three Mile Island in 1979 and at Chernobyl in 1986 with its unprecedented transboundary contamination — had a great effect on the public perception of the potential danger from radiation exposure. Accidents with radiation sources used in medicine and industry also have attracted widespread public attention: Cuidad Juárez (Mexico), Mohamadia (Morocco), Goiânia (Brazil), San Salvador (El Salvador), and Zaragoza (Spain) are names that appeared in the news after people were injured in radiation accidents. Furthermore, the decade saw the rediscovery of natural radiation as a cause of concern for health: some dwellings were found to have surprisingly high levels of radon in air; natural radiation exposures of some non-radiation-related workers were discovered to be at levels much higher than the occupational limits specified in recognized standards.

Following these developments, the International Commission on Radiological Protection (ICRP) in 1990 revised its standing recommendations. The concerned organizations of the United Nations family and other multinational agencies promptly followed by triggering a review of their own standards.

Dr González is Deputy Director of the IAEA Division of Nuclear Safety.

This article highlights an important result of this work for the international harmonization of radiation safety: specifically, it presents an overview of the forthcoming *International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources* — the so-called BSS. They have been jointly developed by six organizations — the Food and Agriculture Organization of the United Nations (FAO), the International Atomic Energy Agency (IAEA), the International Labour Organization (ILO), the Nuclear Energy Agency of the Organization for Economic Co-operation and Development (NEA/OECD), the Pan American Health Organization (PAHO), and the World Health Organization (WHO).

The framework for harmonization

In 1991, within the framework of the Inter-agency Committee on Radiation Safety, the six organizations created a Joint Secretariat under the co-ordination of the IAEA. The action capped decades of continuing efforts and marked an unprecedented international co-operation that has involved hundreds of experts from the Member States of the sponsoring organizations for establishing the BSS. These international standards supersede any previous ones in the field of radiation safety, in particular those developed under the auspices of the IAEA. *(See box, next page.)*

Radiation effects. From the time of early studies on X-rays and radioactive minerals it was recognized that exposure to high levels of radiation can harm exposed tissues of the human body. These radiation effects can be clinically diagnosed in the exposed individual; they are called *deterministic effects* because, given a radiation dose, they are determined to occur. Posteriorly, long-term studies of populations ex-

A number of bodies have supported the work to harmonize international radiation safety standards which draw upon information derived from extensive research and development by scientific and engineering organizations at national and international levels. For its part, the IAEA has the statutory authorization "to establish or adopt, in consultation and, where appropriate, in collaboration with the competent organs of the United Nations and with the specialized agencies concerned, standards of safety for protection of health...". In discharging this function, the IAEA Board of Governors first approved Agency health and safety measures in March 1960. The Board approved the first version of the IAEA's *Basic Safety Standards for Radiation Protection* in June 1962 and a revised version in September 1965. A third revision was published by the IAEA as the 1982 Edition of *Safety Series No. 9;* this edition was jointly sponsored by the IAEA, the ILO, the OECD/NEA, and the WHO.*

The Inter-Agency Committee on Radiation Safety (IACRS). A number of years ago, the IAEA promoted the formation of IACRS as a mechanism for consultation and collaboration in radiation safety matters with competent organs of the United Nations and with the specialized agencies. The Committee aims *inter alia* to encourage the co-ordination of policies and consistency in radiation safety principles and standards. Members are the FAO, ILO, NEA/OECD, PAHO, UNSCEAR, WHO, Commission of the European Communities (CEC) and the IAEA. A number of organizations — the ICRP, the International Commission on Radiation Units and Measurements (ICRU), the International Electrotechnical Commission (IEC), the International Radiation Protection Association (IRPA) and the International Standards Organization (ISO) — have observer status.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). In developing the BSS, UNSCEAR provided the scientific information on which the standards are based. The Committee — which was established by the UN General Assembly in 1955 and today includes representatives from 21 countries — compiles, assesses, and disseminates information on the health effects of radiation and on the levels of radiation exposure from different sources.

International Commission on Radiological Protection (ICRP). Radiation safety standards are based on the recommendations of the ICRP, a non-governmental scientific organization founded in 1928. Its most recent recommendations were issued in 1990 (Publication 60, *Annals of the ICRP*, Vol. 21, No.1-3)) and form the basis of the BSS.

International Commission on Radiation Units and Measurements (ICRU). The quantities and units used in the BSS are primarily those recommended by the ICRU, a sister organization of the ICRP. *(See box, next page.)*

The International Nuclear Safety Advisory Group (INSAG). This advisory body of nuclear safety experts serves as a forum for the exchange of information and for the provision of advice to the IAEA on safety issues of international significance. In 1988, it issued through the IAEA the *Basic Safety Principles for Nuclear Power Plants* (Safety Series No. 75-INSAG-3). Many of these principles are relevant to the safety of other radiation sources and installations and have been used in the BSS.

* For a description of these previous international standards see the author's article in the *IAEA Bulletin*; Vol. 25, No. 3; (September 1983).

International harmonization in radiation safety

posed to radiation, especially of the survivors of the atomic bombing of Hiroshima and Nagasaki, have demonstrated that exposure to radiation also has a potential for the delayed induction of malignancies and possibly of hereditary effects. These radiation effects cannot be related to any particular individual exposed but can be inferred from epidemiological studies of large populations; they are called *stochastic effects* because of their aleatory statistical nature. *(See box, next page.)*

Human activities and radiation exposure: practices and interventions. Many beneficial human activities involve the exposure of people to radiation from both natural and man-made sources. These activities, which are planned in advance, may be expected to increase the background exposure that people already receive: they are termed *practices.*

On the other hand, there are radiation exposures incurred *de facto* by people. The activities which are intended to reduce these exposures are termed *interventions.*

Because of the radiation effects on health, practices and interventions need to be subject to certain standards of radiation safety to protect those persons adventitiously exposed.The BSS are intended to harmonize internationally the basic requirements for protecting people against undue radiation exposure in practices and interventions. *(See box, page 5.)*

Radiation health effects

Exposure to radiation can cause detrimental health effects. At large acute doses, radiation effects — such as nausea, reddening of the skin and, in severe cases, acute syndromes — are clinically expressed in exposed individuals within a short period of time after exposure. Large chronic dose rates also cause clinically detectable deleterious effects. These effects are called **deterministic** because they are certain to occur if the dose exceeds a certain threshold level.

At low doses as well, radiation exposure can plausibly induce severe health effects, such as malignancies, which are statistically detectable in a population, but cannot be unequivocally associated with an exposed individual. Hereditary effects due to radiation exposure have been statistically detected in mammals and are presumed to occur in humans as well. All these statistically detectable effects are called **stochastic** effects because of their aleatory nature.These effects are expressed after a latency period, presumably over the entire range of doses without a threshold level. In addition, there is a possibility of health effects in children exposed to radiation *in utero* during certain periods of pregnancy, including a greater likelihood of leukaemia and severe mental retardation.

Deterministic effects are the result of a process of cell killing due to radiation exposure, which, if extensive enough, can impair the function of the exposed tissue. The severity of a particular deterministic effect is higher as doses increase above the threshold which varies depending on the type of effects. The lower thresholds are a few sieverts for acute exposures and a few hundred millisieverts per year for chronic exposures. The likelihood of incurring the deterministic effect, therefore, is nil at lower doses and approaches certainty at threshold doses.

Stochastic effects may develop if an irradiated cell is modified rather than killed. Modified cells may, after a prolonged delay, develop into a cancer. The body's repair and defense mechanisms make this a very improbable outcome as doses become small; nevertheless, there is no evidence of a threshold dose below which cancer cannot result. The probability of occurrence of cancer is higher for higher doses, but the severity of any cancer that may result from irradiation is independent of the dose. If a stem cell whose function is to transmit genetic information is damaged owing to radiation exposure, it is conceivable that hereditary effects of various types may develop in the descendants of the exposed person.The likelihood of stochastic effects is presumed to be proportional to the dose received without dose threshold. The likelihood of severe radiation-induced stochastic effects during a lifetime is currently estimated to be around 5% per sievert of radiation dose for the general population.

Quantities and units in radiation safety

Although most of the requirements of the BSS are qualitative by nature, they also establish quantitative limitations and guidance levels. The quantities and units used in the BSS are based on the ICRP and ICRU recommendations.

The main physical quantities on which the BSS are based are: the **activity** or rate of emission of radiation from a radionuclide and; the **absorbed dose** or energy absorbed by a unit mass of a substance from the radiation to which it is exposed.

The **unit of activity** is the reciprocal second (number of emissions per second) which is named **becquerel (Bq)**. The **unit of absorbed dose** is the joule per kilogram, called the **gray (Gy)**.

The **absorbed dose** is the basic physical dosimetric quantity of the BSS but it is not entirely satisfactory for radiation protection purposes because effectiveness in damaging human tissue differs for different types of ionizing radiation. Consequently, the absorbed dose in tissues is multiplied by a weighting factor to take account of the effectiveness of the given type of radiation in inducing health effects.

The **equivalent dose** is the quantity resulting from weighting the absorbed dose with the effectiveness of the radiation type. But the likelihood of injurious effects due to a given equivalent dose differs for different organs and tissues. Consequently, the equivalent dose to each organ and tissue is multiplied by a tissue weighting factor to take account of the organ radiosensitivity.

The **effective dose** is the quantity resulting from the sum total of the equivalent doses weighted by the radiosensitivity of organs and tissues for all exposed organs and tissues in an individual.The **unit of equivalent dose and effective dose** is the same as the unit of absorbed dose, namely joule per kilogram, but the name used for the unit is **sievert (Sv).**

When radionuclides are taken into the body, the resulting dose is received throughout the period of time such radionuclides remain in the body.

The **committed dose** is the total dose delivered during the period of time the radionuclides remain in the body, and is calculated as the time integral of the rate of receipt of the dose. Any relevant dose restriction is applied to the committed dose from the intake. The **unit of committed dose** is the **sievert.**

The total impact of the radiation exposure delivered by a given practice or source depends on the number of individuals exposed and on the dose they receive.

The **collective dose**, defined as the summation of the products of the mean dose in the various groups of exposed people and the number of individuals in the group, is therefore used to characterize the radiation impact of a practice or source.The **unit of collective dose** is the **man-sievert**.

For operational purposes, the BSS use the **ambient dose equivalent** and the **personal dose equivalent.**These are quantities defined by the ICRU to facilitate measurement and monitoring while conforming with the radiation protection basic quantities.

Objective of the BSS

The declared aim of the BSS is to prevent the occurrence of deterministic effects of radiation and to restrict the likelihood of occurrence of stochastic effects.

For any justified *practice*, the objective is achieved by requirements for protecting the exposed individuals and for ensuring the safety of the source of exposure. Thus,

- the risk to any exposed individual is restricted, regardless of where or when the individual would commit the exposure, by keeping individual doses below specific dose limits; and
- any source of exposure is kept safe by, *inter alia*, a) constraining both the doses expected to be delivered by it with certainty and also the probability of delivering radiation doses due to (potential) exposures that may but are not certain to occur; b) keeping the delivered doses, the probabilities of incurring doses, and the number of exposed individuals as low as reasonably achievable under the prevailing circumstances; and c) applying to the source a number of administrative, technical, and managerial requirements intended to ensure its safety.

For any justified *interventions*, the objective is achieved by:

- keeping, under any foreseeable circumstance, the individual doses lower than the threshold levels for deterministic effects; and
- keeping all doses expected to be averted by the intervention as low as reasonably achievable under the prevailing circumstances.

Scope of the BSS

Exclusions. Any radiation exposure essentially unamenable to control through the BSS requirements is excluded from the BSS scope. Examples are the exposure caused by the naturally radioactive potassium, which is a normal constituent of the body, exposure to cosmic rays at ground level, and generally other naturally occurring exposures.

The BSS, moreover, only apply to:

- human beings (it is considered that standards of protection that are adequate for this purpose will also ensure that no other species is threatened as a population, even if individuals of the species might potentially be harmed); and
- ionizing radiation, namely gamma and X-rays and alpha, beta and other particles that can induce ionization; (the BSS do not apply to non-ionizing radiation, neither do they apply to the control of other non-radiological aspects of health and safety).

Apart from these exclusions, the BSS scope extends to any practices, including any radiation sources within those practices, provided they are not *exempted* from the BSS requirements, and to any interventions, including any related exposures.

Practices. The practices to which the BSS apply include:

- the use of radiation or radioactive substances for medical, industrial, agricultural, educational, training, and research purposes; and
- the generation of energy by nuclear power, comprising any activity in the nuclear fuel cycle which involves or could involve exposure to radiation or radioactive substances.

Sources. Within a practice, the BSS apply to any source of radiation being used in the practice, both natural sources and artificial sources, including:

Practices and interventions

Planned human activities that add radiation exposure to that which people normally receive due to background radiation, or that increase the likelihood of incurring exposure, are termed *practices.* The human activities that seek to reduce the existing radiation exposure, or the existing likelihood of incurring exposure, are termed *interventions.*

The BSS apply to both the commencement and the continuation of practices that involve or could involve radiation exposure, and also to existing, *de facto* situations in which exposure or its likelihood can be reduced or ruled out by means of some intervention. For a practice, provisions for radiation protection and safety can be made before its commencement, and the associated radiation exposures and their likelihood can be constrained from the outset. In the case of intervention, the circumstances giving rise to exposure or the likelihood of exposure already exist, and their reduction can only be achieved by means of remedial or protective actions.

The table presents the UNSCEAR summary of the relative radiological impact from some practices as well as from severe accidents that required intervention. The levels of radiation exposure are expressed as equivalent periods of exposures to natural sources.

Levels of radiation exposure

Exposure resulting from	Basis	Equivalent period of global exposure to average natural background
Nuclear weapons testing	All past tests	2.3 years
Apparatus and substances used in medicine	One year of practice at the current rate	90 days
Severe accidents	Accidents to date	20 days
Nuclear power generation (under normal operating conditions)	Total nuclear generation to date	10 days
	One year of practice at the current rate	1 day
Occupational activities	One year of occupational activities at the current rate	8 hours

The justification of practices and interventions

The justification of practices and interventions involves many factors, including social and political aspects, with radiological considerations usually playing a minor role. Some practical guidance on justification for practices and interventions provided by the BSS is summarized here.

Unjustified practices. The BSS provide guidance on unjustified practices. These practices include those that would result in an increase of the amount of radioactive substances in food, beverages, cosmetics, or other commodity or product intended for ingestion, inhalation or percutaneous intake by, or application to, a human being (except for medical purposes); and practices involving the frivolous use of radiation in commodities or products such as toys, personal jewelry, or adornments. Additionally, certain medical exposures are also deemed to be not justified: radiological examination for occupational, legal, or health insurance purposes; radiological examinations for theft detection purposes; exposure of population groups for purposes of mass screening; and the exposure of humans for medical research (unless it is in accordance with the provisions of the Helsinki Declaration, follows the guidelines for its application prepared by the Council for International Organizations of Medical Sciences (CIOMS) and WHO, and is subject to the advice of an Ethical Review Committee and to applicable national and local regulations).

Interventions. Intervention shall be justified if it is expected to achieve more good than harm, having regard to health, social and economic factors. The BSS establish that protective actions shall be nearly always justified if the doses in an intervention situation are expected to approach the values in the table below. However, actual intervention levels should be optimized and usually lead to much lower doses *(see table, page 10).*

Individual dose levels at which intervention shall be expected under any circumstances

Acute exposures

Organ or Tissue	Projected absorbed dose to the organ or tissue in less than 2 days (Gy)
Whole body	1
Lung	6
Skin	3
Thyroid	5
Lens of the eye	2
Gonads	3

Chronic exposures

Organ or Tissue	Annual equivalent dose rate (Sv/year)
Gonads	0.2
Lens of the eye	0.1
Bone marrow	0.4

- radioactive substances and devices that contain radioactive substances or produce radiation, such as consumer products, sealed sources, unsealed sources, and radiation generators; and
- installations and facilities which contain radioactive substances or devices which produce radiation, such as irradiation installations, mines and mills processing radioactive ores, installations processing radioactive substances, nuclear installations, and radioactive waste management facilities. (When an installation could release radioactive substances or emit radiation into the environment, it is as a whole considered as a source and the BSS apply to each individual source of radiation within the installation and to the installation as a whole.)

Exemption and clearance. Practices, and sources within a practice, may be *exempted* from BSS requirements if they meet established exemption criteria. The exemption criteria ensure that the individual risks arising from an exempted source are negligible and that the collective radiological impact does not warrant regulatory concern. Moreover, an exempted source must be inherently safe.

The exemption criteria are also expressed in exemption levels, i.e. levels of [radio]activity or activity concentration in materials below which exemption is almost automatic.

Materials and objects from practices and sources already subject to BSS requirements may be released from these requirements subject to satisfying *clearance* levels which shall not exceed the specified exemption levels.

Interventions. The intervention situations to which the BSS apply include any *de facto* situation causing people's exposure which can justifiably be reduced by intervention measures.

These include:

- emergency situations such as those created by environmental contamination in the aftermath of an accident; and

● chronic situations such as exposure to natural sources of radiation (e.g. radon in dwellings) and to radioactive residues from previous events and activities (e.g. chronic environmental contamination from past activities).

Exposures. The BSS apply to any exposure due to:

● any relevant practice or source, including: normal exposures (i.e. exposures that are certain to occur); potential exposures (i.e. exposures that may or may not occur); occupational exposures (i.e. exposures of workers); medical exposures (i.e. mainly exposures of patients); or public exposures (i.e. the remaining type of exposures).

● any relevant intervention situation involving: emergency exposure, including exposures requiring prompt intervention and other temporary exposure due to situations in which an emergency plan or emergency procedures have been activated; and chronic exposure, including exposure to natural radiation sources, exposure due to radioactive residues from previous events, and exposure due to radioactive contamination from practices and sources which, for whatever reason, have not been under regulatory control.

Natural sources. According to the BSS, exposure to natural sources shall normally be considered as a chronic exposure situation and be subject to requirements for intervention. Exceptions to this are: activities involving natural sources that cause increased public exposure due to, for example, discharges of radioactive substances into the environment and certain occupational exposures to radon which shall be subject to the requirements for practices if the intervention cannot reduce such exposure below action levels given by the BSS.

Individual dose limitation

The dose limits established by the BSS are intended to ensure that no individual is committed to unacceptable risk due to radiation exposure.

Dose Limits for Occupational Exposure

● an effective dose of 20 mSv per year averaged over 5 consecutive years;
● an effective dose of 50 mSv in any single year;
● an equivalent dose for the lens of the eye of 150 mSv in a year; and
● an equivalent dose for the extremities (hands and feet) and for the skin of 500 mSv in a year.

(In special circumstances, workers undertaking intervention may be exposed to up to 100 mSv in a single year.)

Dose Limits for Members of the Public

● an effective dose of 1 mSv in a year;
● in special circumstances, an effective dose up to 5 mSv in a single year provided that: the average dose over 5 consecutive years does not exceed 1 mSv per year; and the dose for special circumstances is specifically authorized by the regulatory authority;
● an equivalent dose for the lens of the eye of 15 mSv in a year; and
● an equivalent dose for the skin of 50 mSv in a year.

Application of the Dose Limits

The dose limits apply to the sum of the relevant doses from external exposure in the specified period and the relevant committed doses from intakes in the same period (the period for calculating the committed dose shall normally be 50 years for adults and 70 years for intakes by children). Compliance with this requirement can be determined through compliance with the condition that the personal dose equivalent from penetrating radiation during the year plus the sum of committed doses due to the intake of radionuclides during the year are lower than the relevant limit.

Obligations

The BSS establish general obligations in relation to both practices and interventions. The obligations are that, unless the exposure is excluded from the BSS:

● no practice shall be adopted, introduced, conducted, discontinued, or ceased and no source within the practice shall, as applicable, be mined, milled, processed, designed, manufactured, constructed, assembled, acquired, imported, exported, sold, loaned, hired, received, sited, located, commissioned, possessed, used, operated, maintained, repaired, transferred, decommissioned, transported, stored or disposed of, except in accordance with the requirements of the BSS, unless the practice or source is exempted from the requirements of the BSS; and

● whenever justified, existing *de facto* exposures shall be reduced through intervention, by undertaking remedial or protective actions in accordance with the requirements of the BSS.

Additionally, the BSS establish that any source containing radioactive substances shall be transported in accordance with the provisions of the IAEA *Regulations for the Safe Transport of Radioactive Material* (Safety Series No. 6, IAEA, Vienna (1990)) and with any applicable international convention.

Requirements

To enable fulfillment of the above obligations, the BSS establish the basic requirements for protection and safety.

The requirements have to be fulfilled in all activities involving radiation exposure with the

Guidance levels for diagnostic radiological procedures for a typical adult patient

Radiography

Examination	Entrance surface absorbed dose per radiograph (mGy)	
Lumbar spine	AP	10
	LAT	30
	LSJ	40
Abdomen, intravenous urography & cholecystography	AP	10
Pelvis	AP	10
Hip joint	AP	10
Chest	PA	0.4
	LAT	1.5
Thoracic spine	AP	7
	LAT	20
Dental	Periapical	7
Skull	AP	5
	PA	5
	LAT	3

PA= Posterior - anterior projection, LAT= Lateral projection, LSJ= Lumbo- sacral-joint projection; AP= Anterior - posterior projection

Computed tomography

Examination	Multiple scan average absorbed dose (mGy)
Head	50
Lumbar spine	35
Abdomen	25

Mammography

Average glandular dose per cranio-caudal projection
1 mGy (without grid) 3 mGy (with grid)

Fluoroscopy

Mode of operation	Entrance surface absorbed dose rate (mGy/min)
Normal	25
High level	100

force that is derived from the statutory provisions of the sponsoring organizations. They do not entail any obligation for States to bring their legislation into conformity with them, nor are they intended to replace the provisions of national laws or regulations, or the standards in force. Rather, they aim to serve as a practical guide for public authorities and services, employers and workers, specialized radiation protection bodies, and safety and health committees, laying down basic principles and indicating the different aspects that should be covered by an effective radiation protection programme.

Moreover, they are not intended to be applied as they stand in all countries and regions. Rather, they should be interpreted to take account of local situations, technical resources, and the scale of installations — factors which will determine the potential for application. As the BSS cover a broad range of practices and sources, many of the requirements have been drafted in general terms so that any given requirement may have to be fulfilled differently according to the type of practice, and source, or intervention, the nature of the operations, and the potential for exposures.

Requirements for practices. The BSS include requirements for administration, radiation protection, management, technological aspects and verification:

Administrative requirements. These include notification of intentions to carry out practices; registration or licensing of sources; responsibility of registrants and licensees; and exemption and decontrol (clearance) of sources.

Radiation protection requirements.These include justification of practices; dose limits for individuals; optimization for protection and safety; dose constraints for sources; and guidance levels for medical exposure. *(See boxes and tables, pages 5, 6, 7, and 8.)*

Management requirements. These include safety culture; quality assurance; human factors; and qualified experts. *(See box, page 9.)*

Technical requirements. These include security; defense in depth; and good engineering practice. *(See box, page 9.)*

Verification. This includes safety assessments; compliance; and records.

Requirements for intervention. The BSS establish administrative and radiation protection requirements for intervention as follows:

Administrative requirements. These include responsibilities of intervening organizations, registrants and licensees; and notification of situations requiring protective actions.

Radiation protection requirements. These include justification of intervention; and optimization of intervention and action levels. *(See box and tables, page 6 and 10.)*

The BSS are appended with detailed requirements for all types of exposure as follows:

For occupational exposures: Responsibilities of employers, registrants, licensees, workers; conditions of service (special compensatory arrangements, pregnant workers, alternative employment, conditions for young persons);

BSS technical requirements

The BSS establish technical requirements that address:

Security of sources. Sources are to be kept secure so as to prevent theft or damage and to prevent any unauthorized person from carrying out any of the actions specified in the obligations of the BSS, by ensuring that: ● control of a source not be relinquished without complying with all relevant requirements specified in the relevant registration or licence and without immediately communicating to the Regulatory Authority, and when applicable to the relevant sponsoring organization, information regarding any lost, stolen, or missing source; ● a source not be transferred unless the receiver possesses a valid authorization; and ● a periodic inventory of sources be conducted at a frequency appropriate to confirm that they are in their assigned locations and are secure.

Defense in depth. A multilayer system of protection and safety provisions commensurate with the radiation hazards involved is to be applied to sources, such that a failure at one layer is compensated for or corrected by subsequent layers, for the purposes of: ● preventing accidents that may cause exposure; ● mitigating the consequences of any such accident, if it does occur; and ● restoring sources to safe conditions after any such accident.

Good engineering practice. As applicable, the siting or location, design, construction, assembly, commissioning, operation, maintenance, and decommissioning of sources within practices is to be based on sound engineering which shall, as appropriate: ● reflect approved codes and standards and other appropriately documented instruments; ● be supported by reliable managerial and organizational features, with the aim of ensuring protection and safety throughout the life of the sources; ● include sufficient safety margins for the design and construction of the sources and for operations involving the sources, such as to assure reliable performance during normal operation, taking into account quality, redundancy, and inspectability, with emphasis on preventing accidents, mitigating their consequences, and restricting any future exposures; and ● take account of relevant developments in technical criteria, as well as the results of any relevant research on protection or safety and lessons from experience.

BSS management requirements

The BSS has established a number of management requirements to ensure radiation safety. They address:

Safety culture. A safety culture is to be established and maintained which encourages a questioning and learning attitude to protection and safety and to discourage complacency, by ensuring that: ● policies and procedures be established that identify the protection and safety of the public and workers as being of the highest priority; ● problems affecting protection and safety be promptly identified and corrected, commensurate with their importance; ● each individual's responsibilities including those at senior management levels for protection and safety be clearly identified and that each individual be suitably trained and qualified; ● clear lines of authority for protection and safety decisions be established; and ● organizational arrangements and lines of communications be established that result in an appropriate flow of protection and safety information at and between the various levels of the organization.

Quality assurance (QA). QA programmes are to be established that provide, as appropriate: ● adequate assurance that the specified requirements related to protection and safety are satisfied; and ● quality control mechanisms and procedures to review and assess the overall effectiveness of protection and safety measures.

Human factors. Provisions are to be made for reducing as far as practicable the contribution of human error to accidents and other events that could give rise to exposures, by ensuring that: ● all personnel on whom protection and safety depend be appropriately trained and qualified such that they understand their responsibilities and perform their duties with appropriate judgement according to defined procedures; ● sound ergonomic principles be followed as appropriate in designing equipment and operating procedures, so as to facilitate the safe operation or use of equipment, to minimize the possibility that operating errors will lead to accidents, and to reduce the possibility of misinterpreting indications of normal and abnormal conditions; ● appropriate equipment, safety systems, procedural requirements, and other necessary provisions be provided to reduce, as far as practicable, the possibility that human error will lead to inadvertent or unintentional exposure of any person; ● means be provided for detecting human errors and for correcting or compensating for them; and ● intervention in the event of failure of safety systems or of other protective measures be facilitated.

Qualified experts. Qualified experts are to be identified and made available for providing advice regarding the observance of the BSS. Registrants and licensees have to inform the Regulatory Authority of the arrangements made to provide the expertise necessary for observance of the BSS. This information shall include the scope of the functions of any qualified experts identified.

Guidelines for intervention levels in emergency exposure situations

Urgent protective actions

Action	Avertable dose
Sheltering	10 mSv for a period of no more than 2 days
Iodine prophylaxis	100 mGy (committed absorbed dose to the thyroid)
Evacuation	50 mSv for a period of no more than 1 week

Withdrawal and substitution of foodstuffs
(From the CODEX Alimentarius Commission guideline levels for radionuclides in food moving in international trade following accidental contamination)

<table>
<tr><th>Radionuclides</th><th>Foods destined for general consumption (kBq/kg)</th><th>Milk, infant foods, and drinking water (kBq/kg)</th></tr>
<tr><td>Caesium-134, Caesium-137, Ruthenium-103, Ruthenium-106, Strontium-89</td><td rowspan="2">1</td><td>1</td></tr>
<tr><td>Iodine-131</td><td rowspan="2">0.1</td></tr>
<tr><td>Strontium-90</td><td>0.1</td></tr>
<tr><td>Americium-241, Plutonium-238, Plutonium-239</td><td>0.01</td><td>0.001</td></tr>
</table>

Long-term actions

Action	Avertable dose
Initiating temporary relocation	30 mSv in a month
Terminating temporary relocation	10 mSv in a month
Considering permanent resettlement	1 Sv in a lifetime

and requirements for classification of areas; local rules and supervision; personal protective equipment; co-operation between employers, registrants and licensees; individual monitoring and exposure assessment; monitoring of the workplace; health surveillance; records; and dose limitation in special circumstances.

For medical exposure: Responsibilities; justification of medical exposures; optimization of protection for medical exposures; guidance levels; dose constraints; maximum activity in therapy patients discharged from hospitals; investigation of accidental medical exposures; records.

For public exposure: Responsibilities; control of visitors; sources of external irradiation; radioactive contamination in enclosed spaces; radioactive waste; discharge of radioactive substances into the environment; radiation and environmental monitoring; consumer products.

For potential exposure — safety of sources: Responsibilities; safety assessment; requirements for design; requirements for operations; quality assurance.

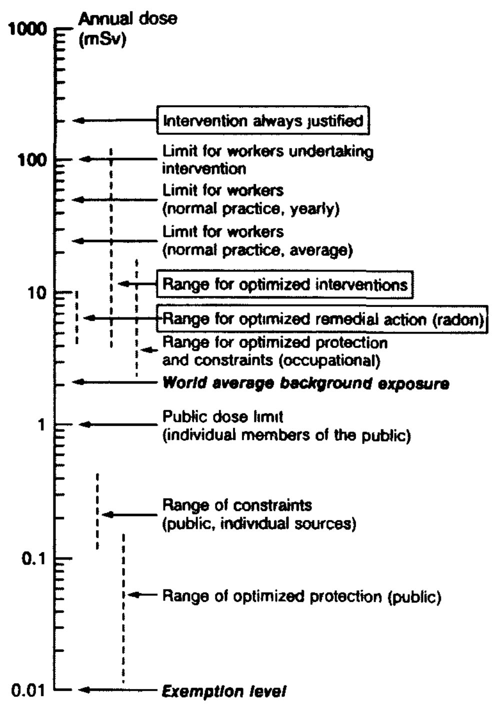
For emergency exposure situations: Responsibilities; emergency plans; intervention for emergency exposure situations; assessment and monitoring after accidents; cessation of intervention after an accident; protection of workers undertaking an intervention.

For chronic exposure situations: Responsibilities; remedial action plans; action levels for chronic exposure situations.

An international effort

The BSS establish a large number of interrelated requirements aimed at ensuring radiation protection and safety. *(See figure, next page.)* Although the majority of requirements are of a qualitative nature, the BSS also establish many quantitative requirements in terms of restrictions or guidance on the dose that may be incurred by people. The range of these doses is large, spreading over four orders of magnitude: from doses that are considered so minute as not to warrant

Implicit quantitative requirements and guidance for practices



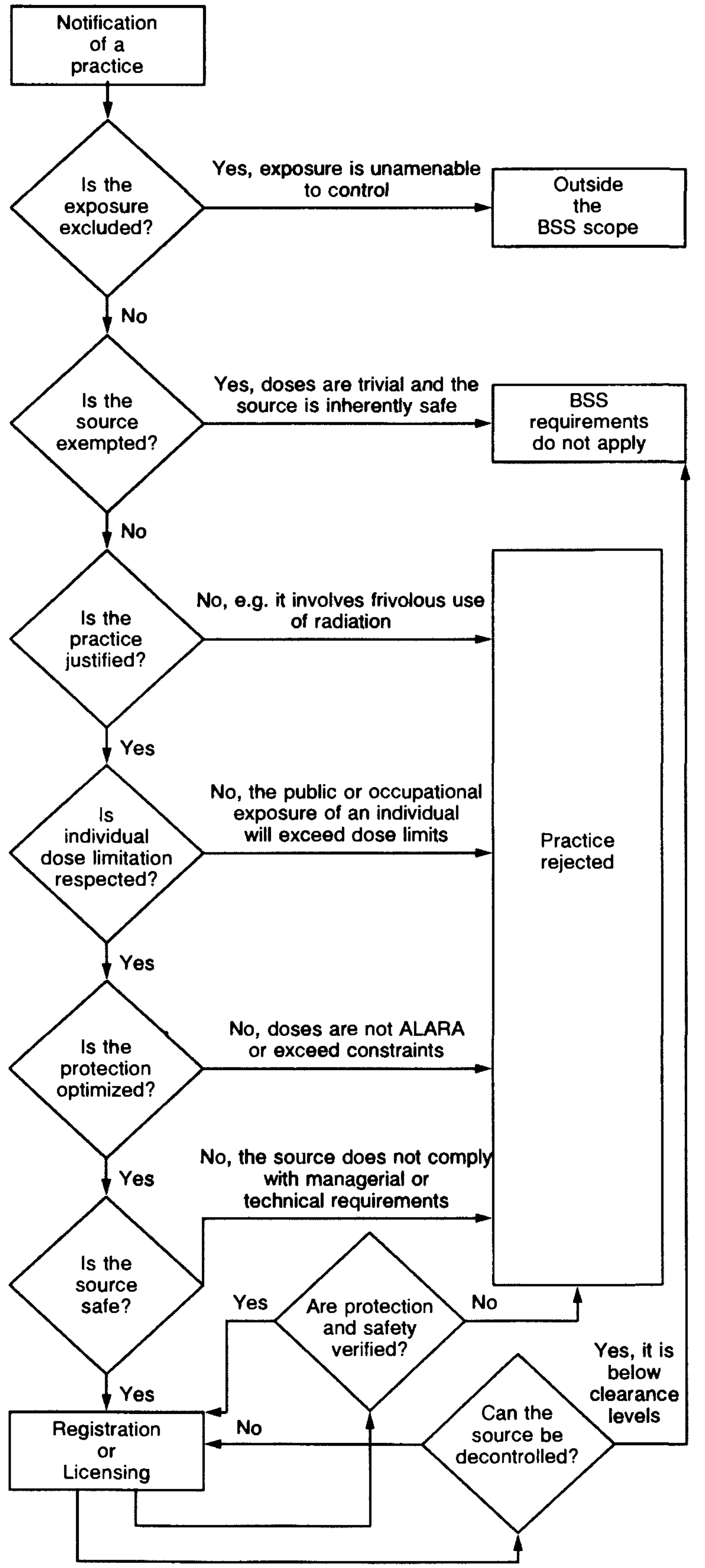
The BSS encompass a large number of interrelated requirements which, in their entirety, provide adequate protection and safety. It is therefore impossible to paraphrase these requirements without losing their essence. The figure at right, however, attempts to provide a simplified visual description on how the BSS work for practices. The chart presumes compliance with the administrative requirements for registration or licensing.

regulatory concern, but rather exemption from the requirements, to doses that are so large as to make intervention almost mandatory. *(See figure.)*

The BSS mark the culmination of attempts that have continued over the past several decades towards the harmonization of radiation protection and safety standards internationally. Following this unprecedented international effort to draft and review the Standards, the BSS were endorsed at a meeting of a Technical Committee held at IAEA headquarters in Vienna in December 1993. It was attended by 127 experts from 52 countries and 11 organizations.

The IAEA's Board of Governors is expected to approve the BSS soon. Thereafter, the IAEA will issue the BSS in an interim publication (in English only). Once the Standards have been formally endorsed by the other sponsoring organizations, they will be issued in the IAEA Safety Series as a final publication in Arabic, Chinese, English, French, Russian and Spanish. ❐

How the BSS work for practices



Sea disposal of radioactive wastes: The London Convention 1972

The IAEA's technical advisory role under the international convention is changing in response to global developments

by Kirsti-Liisa Sjöblom and Gordon Linsley

For many years the oceans were used for the disposal of industrial wastes, including radioactive wastes. In the 1970s, the practice became subject to an international convention which had the aim of regularizing procedures and preventing activities which could lead to marine pollution. As time went on, pressure mounted, especially from smaller countries not engaged in ocean disposal, for waste disposal activities to be further restricted. In November 1993, it was finally decided that the disposal of industrial and radioactive wastes at sea should be prohibited.

This article traces the history of radioactive waste disposal at sea from the time when it first came within the view of international organizations up to the present.

Law of the Sea

In 1958, the United Nations Conference on the Law of the Sea concluded that "every State shall take measures to prevent pollution of the sea from dumping of radioactive wastes, taking into account any standards and regulations which may be formulated by competent international organizations".

Pursuant to its responsibilities, the IAEA set up successive scientific panels to provide guidance and recommendations to ensure that the disposal of radioactive wastes in the sea would not result in unacceptable hazards to man. The first of these meetings was held in 1957 and resulted in the publication of IAEA Safety Series No. 5, *Radioactive Waste Disposal into the Sea* (1961).

Ms Sjöblom and Mr Linsley are staff members in the IAEA Division of Nuclear Fuel Cycle and Waste Management.

London Convention 1972

Following the United Nations Conference on the Human Environment, held in Stockholm in 1972, the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention 1972, formerly referred to as the London Dumping Convention) was established and entered into force in 1975.* For the regulation of materials to be disposed of in the marine environment, "black" and "grey" lists were established. The disposal of substances on the "black" list (Annex I to the Convention) was prohibited except in trace quantities. Substances on the "grey" list (Annex II to the Convention) were subject to "special care" measures to ensure that their disposal — which had to be carried out under the provisions of a "special permit" — would not have adverse effects on the marine environment.

High-level radioactive wastes (HLW) were included in the "black" list. The IAEA — which was recognized by the Contracting Parties to the London Convention as the competent international body in matters relating to radioactive waste disposal and radiation protection — was entrusted with the responsibility for defining HLW unsuitable for dumping at sea.

Radioactive wastes and other matter not on the "black" list (low- and intermediate-level wastes) were included in the "grey" list. In issuing the special permits for the dumping of these types of radioactive wastes, countries were ad-

*For the purposes of the Convention, "dumping" means (i) any deliberate disposal at sea of wastes or other matter from vessels, aircraft, platforms, or other man-made structures at sea; (ii) any deliberate disposal at sea of vessels, aircraft, platforms, or other man-made structures at sea; and "wastes" or "other matter" means materials and substances of any kind, form, and description. In this article, the word wastes is used alone in reference to this definition.

vised to take the recommendations of the IAEA fully into account.

Developments in regulating the sea disposal of radioactive wastes

In fulfillment of its obligations to the London Convention, the IAEA formulated and periodically reviewed its definition of HLW and recommendations for the use of national authorities on the issuance of "special permits" for the dumping of radioactive wastes other than HLW. In 1974, the IAEA presented the first provisional definition and recommendations to the London Convention. The most recent revision, published as IAEA Safety Series No. 78, was issued in 1986.

IAEA recommendations include, among other things, the requirement that the secretariat of the London Convention — the International Maritime Organization (IMO) headquartered in London — be notified prior to dumping and that records be kept during the dumping operations. Selection criteria for dump sites and guidance for performing the environmental assessments are also included. The revisions of the definition and recommendations between 1974 and 1986 were prepared to take into account improvements in the understanding of the dispersion and behaviour of radionuclides in the marine environment and of developments in radiation protection criteria.

The dumping of radioactive wastes at sea took place solely under national authority until 1977. At that time, the Organization for Economic Co-operation and Development (OECD) established a "Multilateral Consultation and Surveillance Mechanism" to co-ordinate the ocean disposal of its member states. Later, the OECD also established a Co-ordinated Research and Environmental Surveillance Programme (CRESP) to provide additional information for assessing the suitability of the Northeast Atlantic dumpsite, which was used by OECD member states.

The former Soviet Union, although becoming a Contracting Party to the London Convention in 1976, continued, within the context of its national regulations, to dump high-, intermediate-, and low-level radioactive wastes in the Arctic Seas and in the Northwest Pacific without informing the Contracting Parties. The dumping operations were carried out in zones of the oceans other than those approved by the IAEA and at lesser depths than recommended. After the disintegration of the Soviet Union in 1991, the Russian Federation continued to dump low-level radioactive wastes.

Regional conventions

After the institution of the London Convention, several regional conventions for the protection of the sea were established, either under the umbrella of the United Nations Environment Programme (UNEP) or independently.

Many of these, while promoting the objectives of the London Convention, adopted more restrictive approaches to the regulation of dumping. Thus, the sea disposal of radioactive waste was totally prohibited in the Baltic Sea (1974), Mediterranean Sea (1976), Black Sea (1992), and in certain areas of the South Pacific (1985) and Southeast Pacific (1989).

Temporary moratorium and inter-governmental review

By the early 1980s, there was increasing disquiet among many of the Contracting Parties to the London Convention over the continuing practice of sea dumping of low-level radioactive wastes. This led to a proposal being made at the Convention's 1983 Consultative Meeting to prohibit all sea dumping of radioactive wastes. After a vote, the meeting adopted a voluntary moratorium on the sea dumping of all types of radioactive waste pending a review of the safety of the practice which was to be carried out by an independent panel of scientific experts.

An "expanded panel" of experts concluded in 1985 that "no scientific or technical grounds could be found to treat the option of sea dumping differently from other available options when applying internationally accepted principles of radiation protection to radioactive waste disposal". At the ninth Consultative Meeting in 1985, it was generally agreed that the scientific report had not shown the dumping of low-level radioactive wastes at sea to be environmentally dangerous but neither had it shown that dumping was harmless. At this point, the Contracting Parties decided to take a broader view of the issue, recognizing that there were political, legal, social, and economic issues involved besides the purely technical aspects. Thus, the next Consultative Meeting (1986) established an Intergovernmental Panel of Experts on Radioactive Waste Disposal (IGPRAD) to consider the wider political, legal, economic, and social aspects of low-level radioactive waste dumping at sea. The voluntary moratorium on sea dumping of radioactive wastes was extended accordingly, pending the panel's final report.

IGPRAD was divided into two working groups, one to examine the political, legal, economic, and social aspects and the other to

Sea disposal of radioactive waste by different countries (TBq)

	Time of disposal	Totals
Atlantic sites		
Belgium	1960-1982	2120.0
France	1967-1969	353 0
Germany	1967	0.2
Italy	1969	0.2
Netherlands	1967-1982	336.0
Sweden	1969	3.2
Switzerland	1969-1982	4 419.0
United Kingdom	1949-1982	35 078.0
United States	1949-1967	2 942.0
Subtotal		45 252 0
Pacific sites		
Japan	1955-1969	15.0
Korea, Republic of	1968-1972	Not known
New Zealand	1954-1976	1 0
Russian Federation	1992-1993	1 4
Soviet Union (former)	1966-1991	707.0
United States	1946-1976	554.0
Subtotal		1 278.0
Arctic sites		
Soviet Union (former)	1960-1991	90 152.0
Subtotal		90 152.0
All sites		
Total		136 682 0

Distribution of radioactive waste disposal between the oceans (TBq)

	Atlantic	Pacific	Arctic	Totals
Reactors with and without fuel	1 000	4.3	88 800	89 804
Solid low-level waste	44 252	818.0	588	45 658
Liquid low-level waste	<0.001	456.0	764	1 220
Total	45 252	1278.3	90 152	136 682

examine scientific and technical issues. The IAEA prepared several documents in support of IGPRAD and submitted them to the working group on scientific and technical issues. The most important of those documents are *Estimation of Radiation Risk at Low Dose* (TECDOC-557, 1990), *Low-level Radioactive Waste Disposal: An Evaluation of Reports Comparing Ocean and Land Based Disposal Options* (TEC-DOC-562, 1990), and *Risk Comparisons Relevant to Sea Disposal of Low-Level Radioactive Waste* (TECDOC-725, 1993).

Sea disposal operations

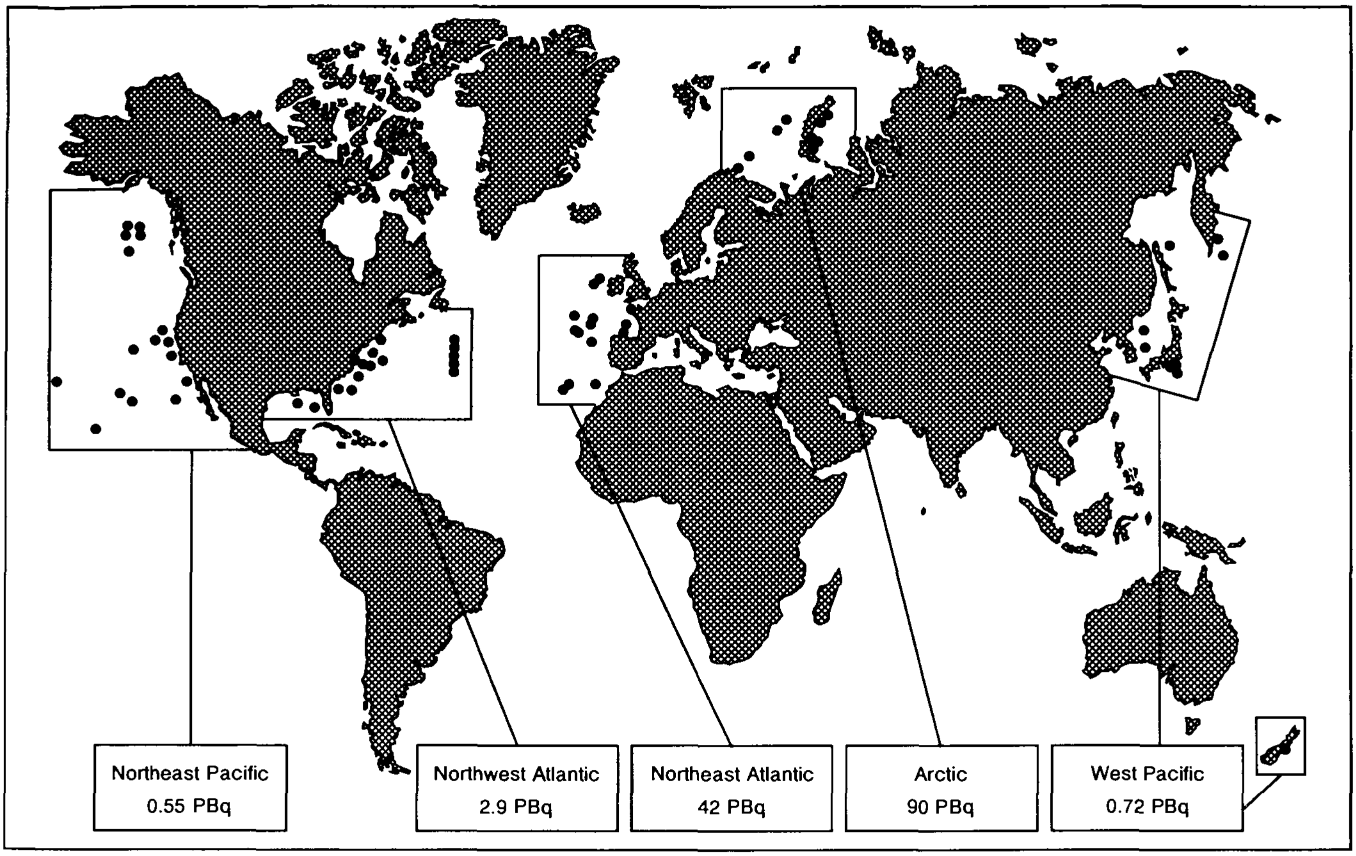
The first operations involving sea disposal of radioactive wastes took place in 1946 in the Northeast Pacific, about 80 km off the coast of California. During the 48-year history of sea disposal, 13 countries have disposed of approximately 140 PBq (140 x 10^{15} Bq) of radioactive wastes into the oceans. The wastes can be divided into three categories according to type: liquid low-level wastes; solid low-level wastes, either packaged in containers or large unpackaged objects; reactor vessels without nuclear fuel or containing damaged nuclear fuel.

The officially reported dumping operations of radioactive waste can be summarized broadly as follows: About two-thirds of the radioactivity of disposed waste is associated with six submarine reactors and the shielding assembly from a nuclear icebreaker reactor dumped together with damaged fuel by the former Soviet Union in the Kara Sea in the Arctic. The remaining one-third is associated with packaged solid low-level waste disposal at the Northeast Atlantic dumping sites, carried out by eight European States, predominantly the United Kingdom.

Of minor significance are, on the one hand, the dumping of liquid and solid low-level waste in the Arctic Ocean which makes up less than 1% of the total radioactivity dumped, and on the other hand, the entire dumping in the Pacific Ocean, also amounting to less than 1% of the worldwide total.

The dumping at the Northeast Atlantic site started on a very small scale in 1950, increased gradually, and reached a peak of 5 to 7 PBq per year in the early 1980s, before the voluntary moratorium of low-level radioactive waste disposal was adopted in 1983. The Arctic dumping sites were used from 1960 to 1992. High-level wastes were dumped predominantly before 1972, when the London Convention was introduced, but one submarine with two reactors containing nuclear fuel was dumped in 1981. The Pacific sites were used between 1946 and 1993.

Many of the States involved in the sea disposal operations only dumped small quantities on an occasional basis. For other countries, sea dumping was regularly used as an alternative to land-based waste disposal options.



Disposal at sea of radioactive wastes

Conclusions of expert panel

IGPRAD finalized its work in the summer of 1993. The conclusions on legal, political, social, and economic aspects referred to a growing awareness within the national and international communities that new and more effective measures were needed to protect the global marine environment, as evidenced by the results of the 1992 UN Conference on Environment and Development (UNCED) and spelled out in Agenda 21. (Chapter 22, para. 5b).

IGPRAD noted that there had been sustained development of international law in the previous 20 years. The trend was towards, firstly, restricting and controlling, and secondly, prohibiting sea disposal of radioactive wastes on a regional basis, and later challenging the legitimacy of States' use of the high seas and the ocean floors beyond their national jurisdiction for activities that might result in the pollution of the marine environment.

The work of the group on scientific and technical issues was fraught with difficulties throughout its meetings, largely because of the entrenched positions of many of the participants. The statement of its conclusions is ambiguous. In the discussion which followed the presentation of the IGPRAD report at the Consultative Meeting in November 1993, different Contracting Parties used the report to support opposing positions. In fact, none of the technical evidence presented to the IGPRAD working group in the seven years of its existence indicated that any significant radiological impact has resulted or would result from properly conducted sea disposal of solid low-level radioactive wastes in accordance with IAEA recommendations.

Prohibition of sea dumping of radioactive wastes

The Consultative Meeting of Contracting Parties in November 1993 was characterized by an extensive debate which was inflamed by reports of the illicit dumping of liquid radioactive waste by the Russian Federation in the Sea of Japan in October 1993. The meeting adopted, by a majority vote, the prohibition of dumping of all types of radioactive waste to come into effect on 20 February 1994. The meeting also adopted the prohibition of dumping of industrial wastes to come into effect by 1 January 1996.

The prohibitions were brought about by amending the Annexes to the Convention. As a result of the amendments, all types of radioactive wastes and radioactive matter are now included in the "black" list (Annex I).

The Russian Federation made a declaration not accepting the amendments associated with radioactive waste dumping, though stating that it will continue its endeavours to ensure that the sea is not polluted by the dumping of wastes and other matter. For it, the old Annexes of the Convention concerning this specific issue are still in force, and so too are the IAEA's definition and recommendations.

Coastal discharges

After the termination of solid industrial and radioactive waste disposal into the oceans, the only remaining route by which wastes can legally enter the marine environment is by effluent discharges to rivers and from coastal locations.

At the present time, the Montreal Guidelines for the Protection of the Marine Environment Against Pollution from Land-Based Sources (1985) is the main international document concerned with this subject, although it also comes within the scope of several regional conventions. Recognizing the potential sensitivity of coastal environments to pollutants, the Montreal Guidelines recommend that pollution, meaning the introduction by humans of substances to the marine environment which are likely to cause harm to living resources and marine ecosystems and hazards to human health, should be eliminated. Radioactive substances come within this categorization.

The guidelines do not attempt to eliminate discharges of small amounts of harmful substances but to eliminate the *pollution* caused by unrestricted releases of them. In addition, the guidelines do not have the status of an international convention, rather they are recommendations to countries. As a follow-up to the UNCED, an Intergovernmental Conference on Protection of the Marine Environment from Land-Based Activities will be organized in 1995.

Through various programmes, IAEA scientists are working to help protect the marine environment.

IAEA's current responsibilities to the London Convention 1972

As a result of the amendment of the Annexes, the mandate of the IAEA under the London Convention was also changed. While it continues to be identified by Contracting Parties as the competent international body in the field of radioactive waste management under the Convention, the IAEA's specific responsibilities, as stated in the revised Annexes to the Convention, are now limited to defining exempt or *de minimis* levels of radioactivity for the purposes of the Convention.The work related to this newly specified mandate is already under way. The principles for exemption are expressed in IAEA Safety Series No. 89, *Principles for the Exemption of Radiation Sources and Practices from Regulatory Control*, which was published in 1988.

In the case of marine disposal, the exemption principles are being applied to materials, such as sewage sludge and dredged material, the disposal of which is in principle not prohibited under the London Convention. These materials have not usually been subject to regulatory control. Nevertheless, they might contain radionuclides from anthropogenic sources on land or from coastal discharges. Now that the London Convention prohibits the sea disposal of all radioactive matter, it is seen as necessary to define quantitative exemption levels (expressed as becquerels per kilogram or becquerels per cubic meter), i.e. levels below which a material can be considered to be non-radioactive in the context of the Convention.

In addition, the IAEA continues to maintain other activities in support of the Convention. These include administering the International Arctic Seas Assessment Project (IASAP). Its objectives are to assess the potential risks to human health and to the environment associated with the radioactive wastes disposed of by the former Soviet Union in the Arctic Seas and to evaluate whether any remedial actions are necessary and justified. The IAEA is also developing and maintaining an inventory of radioactive material entering the marine environment from all anthropogenic sources.

Safety standards for radioactive waste management: Documenting international consensus

Under the IAEA's RADWASS programme, a special series of safety documents covering six key areas is being prepared

by Ernst Warnecke and Donald E. Saire

Radioactive waste is generated from the production of nuclear energy and from the use of radioactive materials in industry, research, medicine, and other fields. The importance of its safe management for the protection of human health and the environment has long been recognized and considerable experience has been gained.

Over the past several years, the IAEA has been working to provide evidence that radioactive waste can be managed safely and to help demonstrate a harmonization of approaches at the international level. A special series of safety documents devoted to radioactive waste management is being prepared within the framework of the IAEA's Radioactive Waste Safety Standards (RADWASS) programme, which covers all aspects of radioactive waste management.

The programme's purpose is to document existing international consensus in the approaches and methodologies for safe radioactive waste management; create a mechanism to establish consensus where it does not exist; and provide Member States with a comprehensive series of internationally agreed upon documents to complement national standards and criteria. This article presents an overview of the programme's structure and status.

Programme structure

RADWASS publications are organized in a hierarchical structure following the general framework of IAEA Safety Series documents. (Specifically, they will be published as advisory documents under IAEA Safety Series 111.) The top-level publication is a single Safety Fundamentals document which provides basic safety objectives and fundamental principles that should be followed in national waste management programmes.

Documents below this level — Safety Standards, Safety Guides, and Safety Practices — will be organized into six subject areas. The areas are planning; pre-disposal; near-surface disposal; geological disposal; waste from uranium/thorium mining and milling; and decommissioning and environmental restoration. Five Standing Technical Committees (STCs) have been established for these six areas to review the respective documents. (One STC covers both near-surface and geological disposal.) This will contribute to a consistent approach in the development of RADWASS documents and provide the national expertise of participating countries.

The entire RADWASS programme is overseen by the International Radioactive Waste Management Advisory Committee (INWAC), which consists of senior experts from selected IAEA Member States. With respect to RADWASS, the committee specifically provides advice on establishing the publication plan and schedules. It further reviews and approves the Safety Fundamentals and Safety Standards and the terms of reference for all other documents in the RADWASS series. The close and intensive co-operation among national senior experts thus is an important element in the elaboration of RADWASS documents.

Document preparation and review

Following its approval by the IAEA Board of Governors in September 1990, the RADWASS programme was established in 1991 to provide a series of documents incorporating international

Mr Saire is Head of the IAEA's Waste Management Section, Division of Nuclear Fuel Cycle and Waste Management, and Mr Warnecke is the RADWASS programme co-ordinator in the same Section.

Overview of RADWASS documents

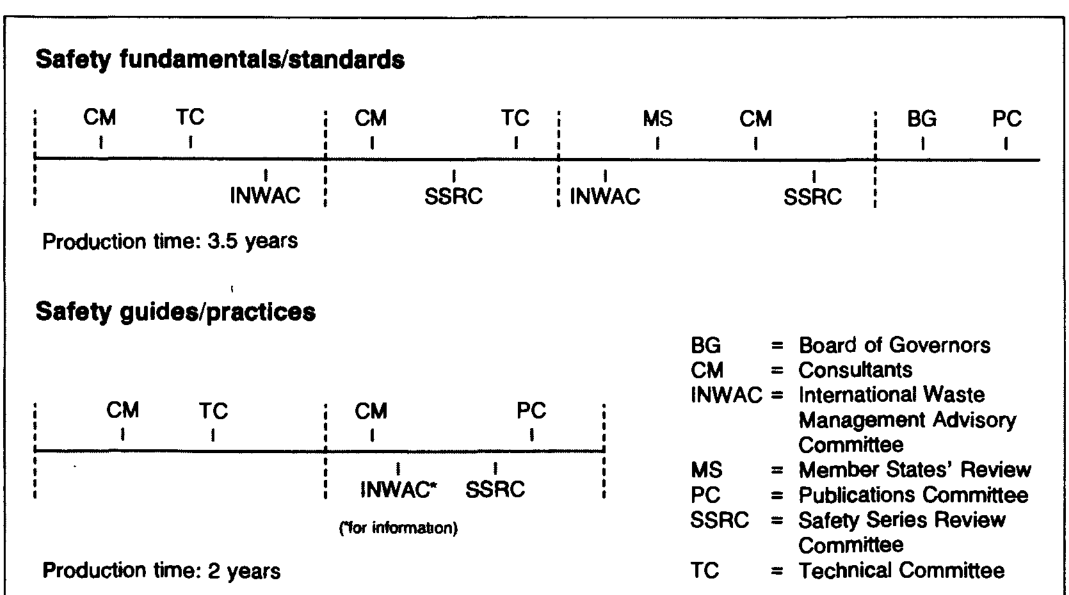
Safety fundamentals

Phase-1 Principles of radioactive waste management

Planning	Pre-disposal	Near-surface disposal	Geological disposal	Uranium/thorium mining and milling	Decommissioning/ Environmental restoration
Safety standards					
Phase-1 Establishing a national legal system for radioactive waste management	*Phase-1.* Pre-disposal management of radioactive waste	*Phase-1:* Near-surface disposal of radioactive waste	*Phase-2:* Geological disposal of radioactive waste	*Phase-2:* Management of waste from mining and milling of uranium and thorium ores	*Phases-2 & 3:* Decommissioning of nuclear facilities (to include environmental restoration)
Safety guides					
Phase-1 Classification of radioactive waste	*Phase-2:* Collection and treatment of low- and intermediate-level waste from nuclear fuel cycle facilities	*Phase-1:* Siting of near-surface disposal facilities	*Phase-1:* Siting of geological disposal facilities	*Phase-2:* Siting, design, construction, and operation of facilities for the management of wastes from mining and milling of uranium and thorium ores	*Phase-2:* Decommissioning of nuclear power and large research reactors
Phase-2: Planning and implementation of national radioactive waste management programmes	*Phase-1.* Pre-disposal management of radioactive waste from medicine, industry, and research	*Phase-2:* Design, construction, operation, and closure of near-surface repositories	*Phase-3:* Design, construction, operation, and closure of geological repositories	*Phase-2:* Decommissioning of surface facilities and closeout of mines, waste rock, and mill tailings from mining and milling of uranium and thorium ores	*Phase-2:* Decommissioning of medical, industrial, and small research facilities
Phase-2: Licensing of radioactive waste management facilities	*Phase-2:* Conditioning and storage of low- and intermediate-level waste from nuclear fuel cycle facilities	*Phase-2:* Safety assessment for near-surface disposal	*Phase-2:* Safety assessment for geological disposal	*Phase-3:* Safety assessment for the management of waste from mining and milling of uranium and thorium ores	*Phase-2:* Decommissioning of nuclear fuel cycle facilities
Phase-2. Quality assurance for the safe management of radioactive waste	*Phase-2:* Treatment, conditioning, and storage of high-level reprocessing waste				*Phase-2:* Safety assessment for the decommissioning of nuclear facilities
Phase-1 Clearance levels for radionuclides in solid materials: Application of exemption principles	*Phase-2:* Preparation of spent fuel for disposal				*Phase-2:* Environmental restoration of previously used or accidentally contaminated areas
Phase-3: Derivation of discharge limits for waste management facilities	*Phase-2:* Safety assessment for pre-disposal waste management facilities				*Phase-3:* Recommended cleanup levels for contaminated land areas
Phase-2 Radioactive waste management glossary					

Overview of RADWASS documents

Planning	Pre-disposal	Near-surface disposal	Geological disposal	Uranium/thorium mining and milling	Decommissioning
Safety practices					
Phase-1: Application of exemption principles to the recycle and reuse of materials from nuclear facilities	*Phase-3:* Off-gas treatment and air ventilation systems at nuclear facilities	*Phase-3:* Validation and verification of models for long-term safety assessment of radioactive waste disposal facilities		*Phase-3:* Procedures for closeout of mines, waste rock, and mill tailings	*Phase-3:* Techniques to achieve and maintain safe storage of nuclear facilities
Phase-1: Application of exemption principles to materials resulting from the use of radionuclides in medicine, industry, and research	*Phase-3:* Characterization of raw waste	*Phase-3:* Procedures for closure of radioactive waste disposal facilities		*Phase-3:* Operational and post-operational monitoring, surveillance, and maintenance of facilities for the management of waste from mining and milling of uranium and thorium ores	*Phase-3:* Procedures and techniques for the decommissioning of nuclear facilities
Phase-3: Data collection and record keeping in radioactive waste management	*Phase-3:* Control of waste conditioning processes	*Phase-2:* Waste acceptance requirements for near-surface disposal of radioactive waste	*Phase-3:* Waste acceptance requirements for geological disposal of radioactive waste		*Phase-2:* Methods for deriving cleanup levels for contaminated land areas
	Phase-3: Testing or radioactive packages	*Phase-3:* Selection of scenarios for safety assessment of near-surface disposal facilities	*Phase-3* Selection of scenarios for safety assessment of geological disposal facilities		*Phase-3:* Monitoring for compliance with cleanup levels
		Phase-3: Systems for operational and post-closure monitoring and surveillance of near-surface disposal facilities			



Process for the preparation of RADWASS documents

consensus on the safe management of radioactive waste. The first phase of the programme was developed to include 12 high priority documents to be published by the end of 1994. Phase 2 will be initiated with the development of additional documents in the post-1994 period.

At the time, it was already envisaged that a formal review of the programme would be undertaken in 1993 to define publication production rates and the resources needed for the post-1994 period. INWAC held this planned review in March 1993. It resulted in the completion and extension of the programme from 24 to 55 documents. *(See table.)* In particular, Safety Practices were defined for all six subject areas, and 11 Safety Guides were added, covering topics such as licensing, quality assurance, safety assessments, definitions, and environmental restoration. Additionally, some modifications were made in the area of decommissioning, which will include the subject of environmental restoration.

A standardized process is applied to the development of individual RADWASS documents. Additional steps may be added as necessary. A particularly elaborate process is applied in the preparation of the Safety Fundamentals and the Safety Standards, reflecting their high hierarchical level and the importance of achieving international consensus on the documents. Before these documents are submitted to the IAEA Board of Governors for approval, for example, they undergo three consultants' meetings, two STCs, two INWAC reviews, and finally are submitted to all IAEA Member States.

The RADWASS publication plan is split into three phases: the first phase extends to 1994; the second covers 1995-98; and the third covers the post-1998 timeframe.

Status of RADWASS documents

A number of RADWASS documents have been prepared, with many now in the review process.

In December 1992, the first document issued under the programme — *Application of Exemption Principles to the Recycle and Reuse of Materials from Nuclear Facilities* — was published as a Safety Practice. It assesses various scenarios for exposures of people to radionuclides from such nuclear materials.

During 1994, the revised draft of the Safety Fundamentals document is expected to be ready for submission to the IAEA Board of Governors. It has been reviewed by Member States and by consultants at meetings in late 1993 and early 1994 and was resubmitted to Member States in February 1994.

A number of other documents have been or are being submitted to Member States for review shortly. They include four Safety Standards: *National Legal System for Radioactive Waste Management; Pre-disposal Management of Radioactive Waste; Near Surface Disposal of Radioactive Waste; and Decommissioning of Nuclear Facilities.*

Additionally, two Safety Guides — namely *Classification of Radioactive Waste* and *Siting of Geological Disposal Facilities* — have been submitted for publication. A third Safety Guide — *Siting of Near Surface Disposal Facilities* — has been approved internally, while another — *Clearance Levels for Radionuclides in Solid Materials* — presently is under internal review. Being prepared for completion by the end of 1994 is the Safety Guide entitled *Pre-disposal Management of Low and Intermediate Level Waste from Medicine, Industry and Research.*

Another document — the Safety Practice entitled *Application of Exemption Principles to Materials Resulting from the Use of Radionuclides in Medicine, Industry and Research* — now is being prepared for internal review. It previously has been separately reviewed by consultants and national specialists participating in technical meetings and advisory groups.

Convention on the safety of radioactive waste management

In October 1993, the IAEA General Conference, in adopting a resolution for strengthening nuclear safety through the early conclusion of a nuclear safety convention, *inter alia* requested the IAEA Director General to initiate preparations for a convention on the safety of radioactive waste management. The preparations were to begin as soon as broad international agreement was reached from the ongoing process of developing the Safety Fundamentals document for waste management.

Such a convention would be a "stand alone" document legally binding for signatory States. Its preparation has to be initiated and carried out with great care, with respect to its timing as well as its contents. IAEA Member States are expected to provide further guidance in these areas. It now seems to be agreeable that work on a waste management convention can be initiated once the RADWASS Safety Fundamentals, and possibly also the Safety Standard on the national waste management system, have gained the approval of the IAEA Board of Governors. A "bridging process" will be able to identify those elements of the RADWASS documents that should be used for the formulation of the convention.

Further impetus for the convention can be expected from an international seminar — "Requirements for the Safe Management of Radioactive Waste" — being organized by the IAEA from 28 August to 1 September 1995. It will provide a forum for discussion of results from the first phase of the RADWASS programme, as well as for updating national experience in the field of waste management.

Safety principles and requirements

Safe management of radioactive waste involves the application of technology and resources in an integrated and regulated manner. The objective is to control occupational and public exposure to ionizing radiation and to protect the environment in accordance with national regulations and international recommendations. In furtherance of these objectives, a number of safety principles, to be agreed upon internationally, have been defined in the latest draft version of the RADWASS Safety Fundamentals document entitled *The Principles of Radioactive Waste Management.* The principles are:

Principle 1: Protection of human health. Radioactive waste shall be managed in a way to secure an acceptable level of protection of human health.

Principle 2: Protection of the environment. Radioactive waste shall be managed in a way that provides protection of the environment.

Principle 3: Protection beyond national borders. Radioactive waste shall be managed in such a way as to assure that possible effects on human health and the environment beyond national borders will not be greater than what is acceptable within the country of origin.

Principle 4: Protection of future generations. Radioactive waste shall be managed in a way that predicted impacts on the health of future generations do not exceed relevant levels that are acceptable today.

Principle 5: Burdens on future generations. Radioactive waste shall be managed in a way that will not impose undue burdens on future generations.

Principle 6: Legal framework. Radioactive waste shall be managed within an appropriate legal framework including clear allocation of responsibilities and provision for independent regulatory functions.

Principle 7: Control of radioactive waste generation. Generation of radioactive waste shall be kept to the minimum practicable.

Principle 8: Radioactive waste generation and management interdependencies. Interdependencies among all steps in radioactive waste generation and management shall be appropriately taken into account.

Principle 9: Safety of facilities. Safety of facilities for radioactive waste management shall be appropriately assured during their lifetimes.

In order to put these principles into practice, countries must have an established national legal system for radioactive waste management. Such a system must specify the objectives and requirements of a national strategy for radioactive waste management and the responsibilities of the parties involved. It must also describe other essential features, such as licensing processes and safety and environmental assessments.

The elements of such a system are summarized in the latest draft version of the RADWASS Safety Standard, *Establishing a National Legal System for Radioactive Waste Management*, which is the leading publication in the subject area, "Planning". The document assigns 10 responsibilities to the State, the regulatory body, or the operators.

Responsibilities of the State are to 1) establish and implement a legal framework; 2) establish a regulatory body; 3) define responsibilities of waste generators and operators; and 4) provide for adequate resources.

Responsibilities of the regulatory body are to 1) apply and enforce legal requirements; 2) implement the licensing process; and 3) advise the government.

Responsibilities of the operators are to 1) identify an acceptable destination for the radioactive waste; 2) safely manage the radioactive waste; and 3) comply with legal requirements.

The IAEA also is working to formulate as Safety Standards the definition of technical safety requirements for each of the other five RADWASS subject areas. This additionally will assist countries in implementing the safety principles outlined in *The Principles of Radioactive Waste Management.* ❐

Extensive experience has been acquired for the safe management of radioactive wastes.
(Credit: BNFL)

The interface between nuclear safeguards and radioactive waste disposal: Emerging issues

Experts are examining requirements and policies for applying safeguards at geological waste repositories and related sites

by Gordon Linsley and Abdul Fattah

A number of questions arise in considering the application of safeguards measures to radioactive wastes, especially in the disposal phase.

The main concern from the waste management side is that safeguards should not disturb the arrangements made to ensure the long-term safety of radioactive wastes, including spent fuel, in a geological repository. The requirement to safeguard certain nuclear materials must be carried through the entire nuclear fuel cycle to the stage where the materials may be considered to be waste from an economic standpoint. Safeguards must be continued for materials still considered to represent a potential target for diversion for undeclared and non-peaceful uses. At this point, the need to continue safeguarding may conflict with the plans to ensure that waste is managed and disposed of in a way that ensures long-term safety.

In 1992, issues concerning the interface between nuclear safeguards and radioactive waste management were discussed at a meeting of the Standing Sub-Group of the International Waste Management Advisory Committee (INWAC) on "Principles and Criteria for Radioactive Waste Disposal". Discussion at that meeting suggested that the full implications of the need to apply nuclear safeguards are not well understood by the radioactive waste management community. The Sub-Group requested that a working paper be prepared to examine the current safeguards position with respect to radioactive wastes, including spent fuel, from a radioactive waste management perspective. This article is based on that working paper,* which should be seen as one input to a dialogue between the radioactive waste management and nuclear safeguards communities.

Mr Linsley is a staff member in the IAEA Division of Nuclear Fuel Cycle and Waste Management, Department of Nuclear Energy and Safety, and Mr Fattah is a staff member in the IAEA Division of Concepts and Planning, Department of Safeguards. The article is based on a paper — "The Interface Between Nuclear Safeguards and Radioactive Waste Disposal" — presented at the IAEA International Symposium on Safeguards in March 1994. Full references are available from the authors.

Safeguards policy for radioactive wastes and spent fuel

In recent years, the IAEA's Department of Safeguards has worked towards defining a safeguards policy on radioactive waste and spent fuel. A basic consideration in relation to radioactive wastes and spent fuel is whether conditions can be met for termination of safeguards or whether safeguards must be continued indefinitely. Agency documents INFCIRC/66/Rev. 2 and INFCIRC/153 state that safeguards can be terminated once the IAEA determines that the material has been consumed or diluted in such a way that it is no longer usable for any nuclear activities or has become practicably irrecoverable. (It is noted that some regional safeguards authorities, such as Euratom, do not allow for termination of safeguards at all.) It has been suggested that there should be more precisely defined technical criteria based on the "consumed", "diluted" or "practicably irrecoverable" attributes relevant to materials from the nuclear fuel cycle.

In 1988, an advisory group was convened to consider the subject of safeguards related to final disposal of nuclear material in waste and spent

*The participants in the working group were D. Gentsch from Germany; F. Gera from Italy; S. Wingefors from Sweden; and G. Linsley and A. Fattah from the IAEA.

fuel. It recommended that the IAEA should, in consultation with Member States, undertake to define specific criteria for the termination of safeguards on waste other than spent fuel. The criteria for making determinations of "practicably irrecoverable" should include waste material type, nuclear material composition, chemical and physical form, and waste quality (e.g. the presence or absence of fission products). Total quantity, facility-specific technical parameters, and the intended method of eventual disposal should also be considered.

In relation to spent fuel, the group concluded that it does not qualify as being practicably irrecoverable at any point prior to, or following, placement in a geological formation commonly described as a "permanent repository", and that safeguards should not be terminated on spent fuel. Since that meeting, work has continued in the safeguards department towards defining criteria for the termination of safeguards on wastes and on the development of methods for implementing safeguards for spent fuel in geological repositories.

Principles for radioactive waste management

The main objective of radioactive waste management is to design systems for the handling, treatment, and disposal of radioactive wastes which ensure the protection of human beings both now and in the future. The concern for the future arises because of the long-lived radioactive components present in some types of waste, particularly high-level waste and spent nuclear fuel.

This concern for the long-term has led to the IAEA's development of principles such as the following:

"Radioactive waste shall be managed in a way that predicted impacts on the health of future generations do not exceed levels that are acceptable today." This principle is derived from an ethical concern for the health of future generations. In order to achieve this, the wastes should be isolated from the human environment over extended timescales, and while it is not possible to ensure total containment indefinitely, the intent is that there will be no significant impacts when radionuclides enter the environment. In deep geological repositories, isolation will be achieved by a system of barriers surrounding the waste, some engineered (the waste canister, the backfill material) and some natural (the geosphere, the biosphere).

An additional principle is that:

"Radioactive waste shall be managed in a way that limits the burden on future generations." The ethical principle for this is the premise that the generation that produces waste should bear the responsibility for managing it. The responsibility of the present generation includes developing the technology, operating the facilities, and providing funds for the management of radioactive waste. This includes the means for disposal. Long-term management of radioactive waste should, as appropriate, rely on containment without reliance on long-term institutional arrangements as a necessary safety feature. This does not exclude the possible use of institutional control arrangements, such as, monitoring and recordkeeping, but, because of the timescales involved, the primary reliance for safety should not be on such measures.

Interface issues

The main concern from the waste management standpoint is that any intended safeguards measures should not impair the safety of waste management system. Other concerns, not dealt with here, might include consideration of any additional costs associated with the need to implement safeguards measures.

In the following sections, the concerns with respect to safeguards and waste management are discussed for radioactive waste and spent fuel at various stages to final disposal.

Termination of safeguards on wastes

Following the recommendations of the 1988 advisory group, work on the development of criteria for termination of safeguards on different waste types went on through meetings at the IAEA in the period 1989-90. A set of technical criteria was developed although there were divergent views on the quantity limits. Most of the waste which is generated in the nuclear fuel cycle will fall within the criteria but certain wastes do not meet the criteria. For wastes of this type, which have been conditioned to increase their resistance to leaching, it has been proposed that termination of safeguards could be considered on a case-by-case basis.

Depending on the type of waste, conditioning methods in use include bituminization, cementation, and vitrification. One view is that the waste material, being of low grade, would not be very attractive for diversion purposes and once conditioned using one of the above methods, it would be very difficult to use as a basis for generating significant quantities of nuclear material. When such conditioned waste is emplaced and sealed in a geological repository, the likelihood of it being used as a source of nuclear material is still further reduced. A common view among waste management experts is that safeguards should be terminated at this point or before. On the other hand, it can be pointed out that there is no physical form from which nuclear material cannot be recovered if cost is not important. Technological innovations might provide even easier and less costly means to recover material and potentially these could be applied to materials on which safeguards had been terminated at an earlier time.

At present, there is no established consensus on these latter issues and the formal position of the safeguards department is that safeguards would have to be maintained on certain waste types even after conditioning and disposal.

Conditioning of spent fuel

Conditioning of spent fuel involves immobilization or conditioning of the fuel assemblies either in plants located on the site or elsewhere. These operations are generally carried out under dry conditions. After arrival at the conditioning facility, spent fuel is transferred to a hot cell where it is disassembled. The disassembled components are then put into containers which meet final disposal requirements. In some cases it may be necessary to cut the components into pieces. The important concern here is the need to provide assurance that the fuel assemblies have retained their integrity on arrival at the conditioning facility. The major impact on safeguards is the loss of identity of the fuel assembly as a discrete item for accountancy. The material handling operation which changes the content of spent fuel due to such operations should be followed by measures to verify the nuclear material content. Effective safeguards depend on the accounting practices to verify the content and composition of the material placed into final disposal.

Various safeguards techniques have been proposed for application at a spent fuel conditioning facility; generally, they consist of developments of techniques already available. None of the proposed techniques are likely to cause significant problems from the safety point of view. No destructive verification techniques are foreseen. On the contrary, an effective safeguards system would require care in the handling of the fuel itself and of the resulting disposal packages. However, for certain containers, special attention may be needed to ensure that markings made for safeguards purposes do not cause any negative effect on their long-term corrosion resistance.

It is noted that anticipated safeguards will impose certain requirements on the design and layout of the conditioning facility. This issue needs to be considered by national authorities, the implementors, and the IAEA safeguards department.

Operational phase of a repository

A geologic repository is similar to a mine and consists of access corridors and disposal caverns, excavated deep within the geologic formation. Various supporting facilities are located on the surface over the repository. Shafts provide access to the disposal caverns (drifts). At least three separate types of shaft are envisaged to ensure optimum usage. These are a canister transportation shaft; a personnel and ventilation intake shaft; and a ventilation exhaust shaft. The underground facilities at the repository may be designed to allow further excavation of new caverns, receipt and transport of spent fuel, emplacement, and backfilling of the disposal caverns. Mining operations may be performed on a continuous basis. Following excavation of the caverns, vertical access and emplacement shafts would be opened. Spent fuel would arrive at the repository from the conditioning plant in containers which are prepared for final disposal in surface facilities. The containers would be lowered through a shaft to the disposal level, transported to the disposal cavern, and placed in the emplacement shafts. All operations are expected to be remotely controlled. After the canister has been emplaced, the void space would be backfilled with low permeability material.

When the repository has been filled to design capacity and the room has been backfilled, final decommissioning would begin with the backfilling of all corridors and mine level openings. All shafts would be sealed to restore the formation integrity.

The considerations important to safeguards of a repository are the identification of individual canisters that enter the repository and verification that they remain there until the drift is closed and the repository is sealed.

Since the long-term safety provided by the waste disposal system depends upon the multibarrier system surrounding the waste or spent-fuel operating as designed, it is important that none of the safeguards measures taken to identify, trace, and verify impairs the system. The development of safeguards methods suitable for this phase is still under way. The proposed methods place emphasis on identifying and accounting for the containers entering the repository, maintaining a constant check on movements at all accesses into the repository, and on maintaining a complete knowledge of the design of and changes to the geological repository. It has been pointed out that it is not important to know the exact location of emplaced containers within the repository but only to be able to verify that the disposal container has entered and remains within the confines of the repository.

Most of the proposed safeguards methods would not affect the integrity of the waste container and the surrounding material, although there have been suggestions that geophysical techniques could be used for locating packages within the repository. These methods must not be intrusive and must leave natural geological barriers to radionuclide migration undisturbed.

Post-closure phase of a repository

Geological repositories are designed to provide long-term isolation of radioactive waste. Waste isolation is ensured by a combination of engineered and natural barriers. Long-lived radioactive wastes, including spent fuel, require almost complete isolation for time periods of many thousands of years. Since it is not conceivable that human society will be able or willing to maintain controls on repository sites for many thousands of years, isolation systems are designed to be passive in nature. In other words, the safety of the systems depends on the intrinsic properties of the isolation barriers and not on the existence of surveillance and maintenance procedures.

On the other hand, it is admitted generally that public opinion will demand that some form of monitoring be maintained at repository sites for an undefined period of time. The purpose of such monitoring programmes could be to provide reassurance that the system behaves as assumed in the safety assessment and that no unforeseen events are taking place. Any such monitoring programme should not require activities potentially capable of decreasing the performance of the isolation barriers. Drilling to obtain deep samples or to install instruments within the barrier formations are obvious examples of unacceptable activities. Since monitoring activities are not required for technical reasons but can be justified only on social grounds, it is clearly impossible to make predictions on their duration. We can assume that, at some future time, as a result of a cost-benefit analysis, the monitoring programme will be intentionally discontinued or some major disruption of society will eliminate its justification. In the context of shallow land disposal of short-lived radioactive waste — a disposal option for which safe isolation depends on maintaining institutional control of the site — it is generally agreed that it would not be reasonable to expect institutional controls to last for more than a few hundred years.

On the question of safeguarding closed geological repositories containing spent fuel, the 1988 safeguards advisory group took the view that safeguards cannot be terminated even after closure of the repository. This position then poses certain questions, namely how to design an effective safeguards procedure that has no negative impact on the safety of the disposal system; and how long safeguards should last since the spent fuel will remain a potential source of nuclear material for hundreds of thousands of years.

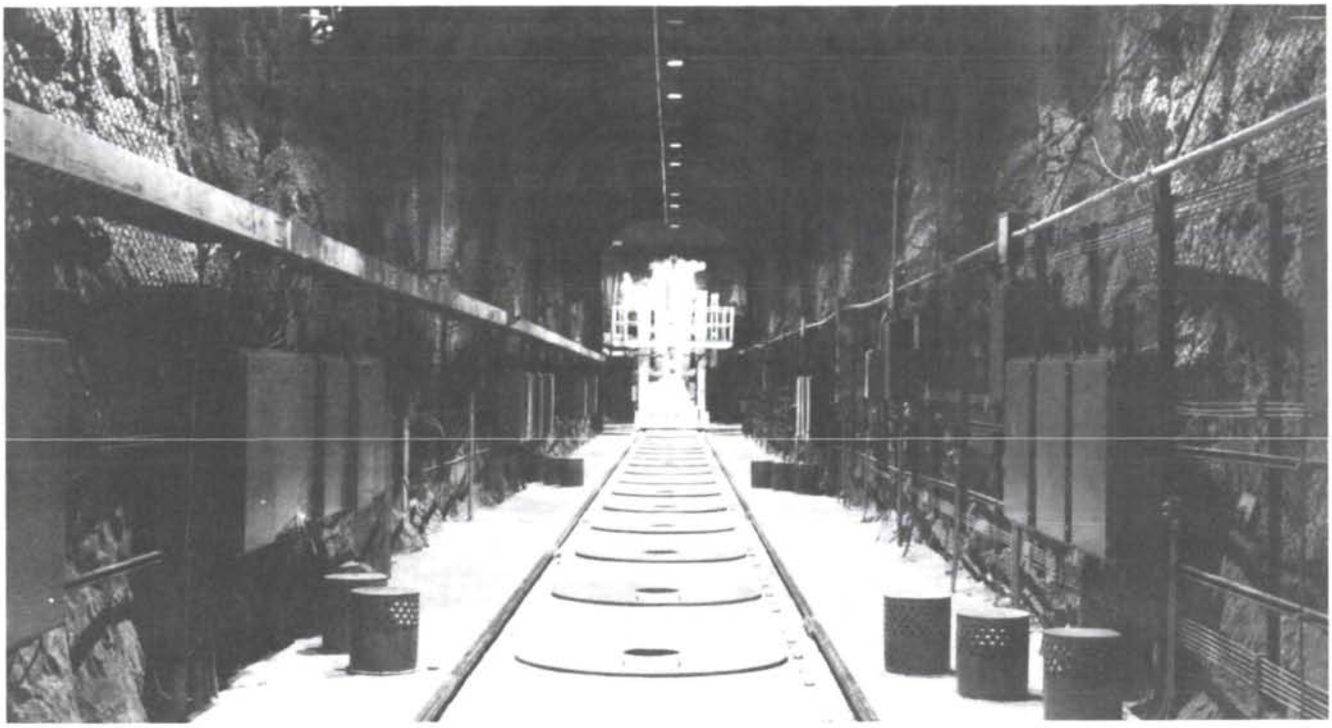
Tentative answers are the following: The repository should be safeguarded without compromising safety features. Since excavation of a sealed repository could not be carried out in a short time, nor made invisible, an obvious approach would be through the analysis of periodically obtained satellite images. Additionally, the above-ground site of the former repository could be subject to periodic inspection by international inspectors. It is also noted that such a safeguards surveillance mechanism would increase the safety of the repository, since it would reduce or remove the possibility of inadvertent intrusion into the repository by humans.

The safeguarding of nuclear material is an important issue for societies today and may continue to be in the future. However, the situation may change in a way which cannot be predicted. Scenarios can be imagined in which the evolution of society makes safeguards an irrelevant issue.

Toward close co-operation

The main purpose of this analysis was to assess the implications of safeguards requirements on the management of radioactive waste and spent fuel. In particular, there was concern that a conflict might exist between safeguards requirements and the main objective of waste management, that is, ensuring that the radioactive substances in the waste are safely isolated from the biosphere as long as necessary to reduce the radiological impacts to acceptable levels.

Provided some conditions are met, the application of safeguards to the management of radioactive waste and spent fuel can be affected without negative impacts on safety. In the first place, it can be observed that the management



Experts are studying safeguards requirements for radioactive wastes destined for disposal in engineered geological repositories. *(Credit: US DOE)*

steps prior to disposal do not appear to present any problem since safeguards procedures are already in effect or could be introduced easily. With respect to disposal, the primary condition is that safeguards procedures must be designed keeping in mind that the safety of the isolation system is an absolute priority. In other words, neither the integrity of the engineered barriers within the repository can be endangered, due to surveillance and control measures during operation, backfilling, and sealing of the disposal zones, nor can the integrity of the natural barriers be threatened, due to surveillance and monitoring after repository closure.

It is assumed that deep geological repositories receiving safeguarded waste material have to be kept under safeguards during the operational phase. From the perspective of waste management, and assuming that the safety system of the planned repository remains intact, safeguarding based on surveillance and control at the surface accesses to the repository (shafts and/or ramps) would cause no difficulties. Similarly, visual inspections underground would be acceptable. However, use of geophysical techniques — which would endanger safety barriers — for locating waste packages inside the repository are to be avoided.

At the present time, no clear safeguards policy for closed repositories containing only wastes exists. Safeguards requirements for the waste-only repositories should therefore be evaluated, taking account of the relatively low concentrations of nuclear materials in the various categories of radioactive wastes and the difficulties of recovering conditioned waste from closed, deep disposal facilities, and then of extracting nuclear material.

For spent fuel in repositories, the IAEA safeguards department's policy is to continue safeguarding after repository closure. In the post-closure period, proposed surveillance techniques such as a combination of satellite imagery and inspections would ensure the continuing integrity of the repository and would not impair its safety system.

The expected duration of safeguards surveillance at the sites of deep geological repositories containing spent nuclear fuel cannot be defined, but, on the basis of spent fuel compositions, safeguarding requirements could last for thousands of years. The acceptance of a requirement for open-ended surveillance of spent fuel repositories raises two issues: 1) a contradiction with one of the objectives of radioactive waste management, that is not to impose a burden on future generations; and 2) the troubling aspect of making economic provisions for an activity of unknown duration and, therefore, with a cost that cannot be estimated reliably.

In order to ensure that safeguards requirements are developed in ways which are compatible with plans involving the long-term isolation of radioactive wastes, experts in safeguards and waste disposal should work in close cooperation. ❐

Education and training in radiation protection and nuclear safety: Bridging the gaps

The IAEA is placing added emphasis on helping national authorities to strengthen their development of human resources

by Karol Skornik

Education and training are indispensable to the development of human resources in industries around the world. In nuclear industries, efforts have intensified in these areas over recent years. In its programme plan to the year 2000, the IAEA has attached considerable importance to the development of human resources for nuclear and radiation safety, in keeping with its ongoing emphasis on providing technical assistance to strengthen national infrastructures and promote the safe use of nuclear technologies for peaceful applications in various fields.

In September 1993, the IAEA's General Conference approved the 1994-98 programme for education and training in radiation protection and nuclear safety. This article presents an overview of the programme within the context of global developments in the nuclear field, national priorities and needs, and policy directions.

The context of developments

The quest for excellence in nuclear and radiation safety calls for an integrated approach to education and training. Both radiation protection and nuclear safety are, by and large, multidisciplinary fields comprising interrelated parts of applied physics, chemistry, biology, nuclear technology, and other specialized areas. When it comes to the development of human resources, however, there are important differences and specific needs and problems. Some differences and problems stem from the wide variety and range of nuclear and radiation applications.

Today, radiation technologies and radioactive sources are widely used around the world, mostly in medicine (diagnostic radiology, radiotherapy, nuclear medicine) as well as in industry, agriculture, and research.

In medicine, for example, it is estimated that:

- more than 400 000 diagnostic X-ray machines are in use for about 1200 million medical X-ray tests annually,
- 320 million dental X-ray tests are carried out annually,
- 10 000 gamma cameras are installed worldwide, supporting a range of nuclear medicine procedures,
- 22 million *in-vivo* applications of radioisotopes (nuclear medicine) are performed per year,
- radiation therapy is applied to more than 4 million patients each year, and
- more than 60 countries have set up routine medical programmes involving the use of nuclear techniques.

There are indications that exposures of populations from the diagnostic and therapeutic uses of ionizing radiation are increasing worldwide. Much of this increase can be justified on clinical grounds, particularly in developing countries, where medical services are not yet sufficiently available. By the year 2000, the collective dose to the world's population from medical irradiation will probably increase by 50% and by the year 2025, it may more than double, according to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

Over the past two decades, radiation processing has grown at a steady rate of 10%-15% per year, based on the number and total power rating of installed radiation sources. More than 135 industrial gamma irradiators and some 400 electron beam machines are operational in 42 countries. Radiation-processed products include foodstuffs, hospital and medical supplies, synthetic and rubber items, and wire and cabling.

Mr Skornik is a staff member in the IAEA Division of Nuclear Safety.

The total value of these products is estimated at more than US $2 billion annually.

In industrial sectors, applications of ionizing radiation are widespread. They include radiotracer techniques for measurement of fluid flows or detection of leaks, for example. Gamma radiography, as part of non-destructive testing of materials, also is widely used in inspection of casting defects, detection of welding defects in pipes and vessels, and for optimization of casting methods prior to mass production. Radioisotopes are used on a routine basis in well logging by oil and gas industries, in natural resource prospecting, and geophysical investigations. A number of industrial gauges and consumer products are based on or involve the use of radiation sources.

In fields of agriculture, nearly 1000 crop varieties derived from radiation induced mutations are grown worldwide on several million hectares, yielding economic gains estimated to be in the billions of dollars. Moreover, the use of radiation techniques in pest control has helped to combat the loss of crops to insects and the loss of livestock from diseases spread by insects.

Perhaps the most visible of the benefits derived from ionizing radiation are the 430 nuclear power plants now in operation worldwide, together accounting for more than 16% of the world's total electricity production. Another 55 power reactors are under construction to meet demands for reliable electrical power. Cumulative worldwide operating experience from civil nuclear reactors at the end of 1993 surpassed 6500 years. At the end of 1993, there also were 301 research reactors operating in 59 countries to support analytical studies in many scientific fields, and to produce radioisotopes for medicine, industry, and agriculture. This includes 51 reactors in 18 countries which are used for training purposes.

Specialists at an IAEA training course on radiation protection.

Such extensive uses of ionizing radiation are indicative of the international scope of education and training needs in areas of radiation protection and nuclear safety. Such programmes need to address practices in a growing number of installations, facilities, laboratories, and work places involving the use of ionizing radiation, radiation sources, or nuclear techniques.

Infrastructural aspects. A large body of both radiation and nuclear safety standards, including international standards, exists. However, this is not a guarantee for good safety practices. A proper national infrastructure is required for the application of safety standards to achieve and maintain the desired degree of protection and safety. The infrastructure is understood to comprise essentially the following main elements:

- legislation and regulations for setting forth legal, technical, and administrative requirements;
- an enforcement system for legislation, through regulatory mechanisms, such as notification, registration, licensing, inspection, and advice on how to satisfy safety requirements;
- human resources and know-how at all levels ranging from highly qualified work, including policy making and research and development, to specialized areas of applications, to technical support for routine operations and services;
- a capable technical base for the provision of various safety services such as radiation monitoring (personnel dosimetry, calibration of instruments, environmental monitoring), maintenance of equipment and components, and emergency response capabilities; and
- resources for setting forth and implementing the national programme for radiation safety.

The extent of any national infrastructure needs to be commensurate with the degree and volume of nuclear technological activities requiring safety efforts, ranging from electricity production by nuclear power plants to other applications of ionizing radiation.

IAEA Member States differ in their commitments to nuclear technologies and related safety infrastructures. Hence, their requirements and capabilities to adequately educate and train their nationals also differ. The Agency's policy in education and training reflects these differences. Relevant programmes are adjusted for different groups of countries. Emphasis is placed on the specific areas in radiation protection and nuclear safety which are consistent with the needs and priorities of these countries in their national programmes for the development of human resources. In this context, a national programme for education and training is seen as an essential part of the country's system designed to teach professionals, technicians, and members of the general public about the benefits and risks associated with the use of ionizing radiation.

Analysis of needs

Radiation protection and nuclear safety are primarily a national responsibility. All countries using ionizing radiation or committed to nuclear power programmes are engaged in some education and training activities in these fields. Many developing countries still find it difficult, however, to set up and/or implement such programmes, due to budgetary constraints, shortage of qualified teachers, and other deficiencies in infrastructure. Hence, they have become increasingly aware of the benefits that can be derived in this connection from international co-operation and harmonization.

In analyzing the needs of its Member States, the IAEA has drawn upon insights and experience acquired through its technical co-operation programme (specifically in this case, safety services and interregional, regional, and national projects) and through its regular activities such as conferences, symposia, seminars, and other technical gatherings. IAEA safety services in both radiation protection and nuclear safety include Radiation Protection Advisory Teams (RAPAT); Operational Safety Review Teams (OSART); Assessment of Safety Significant Event Teams (ASSET); International Regulatory Review Teams (IRRT); Integrated Safety Assessment of Research Reactors (INSARR); and Engineering Safety Review Services (ESRS).

Radiation protection. An analysis of the RAPAT findings underscores the importance of strengthening international co-operation in the field of radiation protection. There is evidence that *radiation safety control mechanisms* today are inadequate in more than half of the IAEA's Member States. Many countries simply lack the necessary infrastructure for implementing a safety policy based on international recommendations. In some countries, national radiation protection facilities are inadequate; in others multiple institutions claim responsibility; and in several, including those relatively new IAEA Member States, national competent authorities have yet to be established. Too often, basic legislation and supporting up-to-date regulations are wanting.

Several radiological accidents outside the nuclear power field have underscored the importance of safety control mechanisms. For example, an international review conducted by the IAEA following a serious radiological accident at an industrial irradiation facility in San Salvador in 1989 revealed that this accident could have been avoided if a proper radiation protection system had been in place. Even in countries where appropriate national regulations exist, there is often a shortage of properly educated and trained nationals able to set up operative radiation safety systems, including licensing, inspection, and supporting technical services.

In 1991 the International Commission on Radiological Protection published its revised recommendations (ICRP 60) which constitute the basis for the revised *Basic Safety Standards for Protection Against Ionizing Radiation and the Safety of Radiation Sources*. These international standards are due to be issued jointly by the IAEA, International Labour Organization (ILO), Nuclear Energy Agency of the Organization for Economic Co-operation and Development (NEA/ OECD), World Health Organization (WHO), Pan-American Health Organization (PAHO), and Food and Agriculture Organization (FAO). Various types of assistance will have to be given to many developing countries. They will need help in incorporating international standards into detailed national regulations for radiation protection; in setting up authorities to supervise the implementation of such regulations; and in enhancing the performance of such authorities. IAEA assistance involving the use of radioactive materials and other radiation sources will necessarily involve the provision of education and training in radiation protection to groups of professionals.

An issue which will continue to receive emphasis is the enhancement of radiation safety for nuclear personnel in the workplace, an area in which training remains in high demand. Each category of workers has its own particular needs, depending on the occupation in question. Exposed workers or workers likely to be exposed can be grouped by various fields — the nuclear industry and transport of radioactive materials; hospitals and other medical institutions (radiotherapy, diagnostic radiology, nuclear medicine centres); industrial plants and projects using radiation sources; universities and research centres; institutions and groups involved in emergency operations (medical services, civil defense, local police, for example).

In industry, training must be accessible to the greatest number of workers and be based on a balance between the level of knowledge they require for the purposes of their occupation, and the level needed for radiation protection.

In medical teaching and research, training is needed for groups of professionals having a sound scientific education but inadequate knowledge of radiation protection. There is a particularly growing demand worldwide for training of radiation safety officers (health physicists) and medical personnel, including medical doctors, in departments of radiotherapy, diagnostic radiology, and nuclear medicine. Refresher courses for this group are needed on a regular basis to keep personnel abreast of radiation safety requirements. Attention must be accorded to nurses, a group having a very important impact on public perception of radiation risk.

Radiation protection training for members of emergency teams should be seen as part of the national plan for dealing with nuclear accidents and radiological emergencies. The need for such training at all levels is persistent for many countries in all regions. Training and re-training in radiation protection thus concerns a wide range of groups with different levels of knowledge. Harmonization as an objective must first be directed at decision-makers, teachers, and specialists and then extended to all occupationally exposed workers.

Regarding general education, it should be noted that there is common omission of radiation health and safety areas in most countries and radiation protection is rarely covered in secondary education. Training in this field often lacks a basis on which to build. Teaching, if any, varies greatly from country to country. For many countries, achieving a critical mass of local educators and trainers, both knowledgeable about radiation safety and able to transmit their knowledge, remains elusive.

Nuclear safety. In analyzing needs for education and training in nuclear safety, a detailed classification of countries is necessary. In the IAEA's programme, the focus is being placed on three groups: a) developing and/or restructuring countries with ongoing programmes involving operation/construction of nuclear power plants or research reactors; b) countries in which the nuclear option is considered as a means of meeting growing demands for electricity, with ongoing research/training reactor programmes; and c) countries with no nuclear power programme whose use of technology involving nuclear safety is limited to research/ training reactors.

There is an acknowledged need worldwide for general education in nuclear safety, including the safety of future reactors, in conjunction with radiation protection. A range of general subject areas and groups of personnel has been identified by IAEA safety teams as priority areas, a number of them dealing with the development, organization, and administration of training programmes for different groups of personnel.

The difficulties in ensuring consistent levels of safety standards are rather obvious. Economic strengths, industrial traditions, legislative frameworks, and commercial policies all vary widely. Regulatory organizations must enforce national standards in their own way and these standards play a part in developing good national safety cultures. IAEA guidance is incorporated in the Nuclear Safety Standards (NUSS) — a series of documents which give recommendations on licensing, organizational, and technical matters relating to the safety of nuclear power and research reactors. They are available for use in support of national activities and they form the basis of the Agency's safety assistance. Training for national regulators will continue to play an important part in this process.

Training activities also will play key roles in upgrading the safety levels of nuclear power plants, and to some extent research reactors, that were built according to early safety standards, as well as plants facing problems because of various ageing processes.

Some problems particularly apply to WWER 440/230 nuclear power reactors operating in the countries of the former USSR as well as in Central and Eastern Europe. Issues related to ageing of nuclear facilities are of worldwide significance, on the other hand, and the IAEA has seen a growing demand for training programmes. It stems from the realization that knowledge of the fundamental physical processes than can occur in a power plant or research reactor as it ages can improve the ability of operators to respond to plant transients and other events. Furthermore, as the understanding of ageing phenomena is translated to changes in operations at reactor facilities, plant personnel will need training in the new procedures.

IAEA policies and programmes

The IAEA's programme for education and training in radiation protection and nuclear safety is based on the following objectives:

- the achievement of national self-sufficiency in education and training programmes;
- the strengthening of national radiation protection and nuclear safety infrastructures; and
- the meeting of immediate national needs in States requesting assistance.

The programme emphasizes strategic planning over the near and long term, so as to ensure the highest possible standard of education and training programmes and to avoid the pitfalls of ad-hoc individualized approaches. The fundamental guidelines in planning comprise two independent features: concentration, which denotes co-operation with Member States in arranging for IAEA-supported training events on carefully selected subjects reflecting the most persistent needs, and standardization of efforts, which is understood as the IAEA's activities for preparing standard syllabi for general education and specialized training courses.

Overall, the programme is characterized by a number of modalities and mechanisms.

Education. Post-graduate educational courses are designed to meet the educational and initial training requirements of junior staff of graduate level, holding or earmarked for positions in radiation protection (including health physics) or nuclear safety. The target audience includes young professionals who need to acquire a sound basis in these areas in order to become — in the course of time — trainers in their home countries. In addition to the established post-graduate educational course in radiation protection and nuclear safety held in Spanish, new courses will be held in English and French (radiation protection), and possibly in Russian (radiation protection and nuclear safety), at an interregional or regional level, in selected educational/training centres. The relevant courses in radiation protection will be based on a standard syllabus prepared by the IAEA. The syllabus is planned for distribution to Member States so as to facilitate the integration of educational courses in radiation protection into the curricula of their leading educational institutions.

Specialized training courses. Training courses are available for those seeking specialization in specific areas of radiation protection and nuclear safety. Typically, a course spans 3 to 8 weeks during which participants are provided with the opportunity to update and upgrade both their theoretical and practical knowledge and skills.

Interregional courses reflect specialized training needs that are common to Member States in more than one region, and they require special facilities and expertise not generally available during practical training. Their primary objective is to train people who will subsequently fill senior managerial or operational positions with the additional task of training others. In this "train the trainers" approach, the IAEA will continue to encourage countries to nominate candidates who, following their own training, will be willing and able to contribute to national staff development programmes in their respective countries. Also offered are regional training courses, which cover a wide range of topics and involve a number of host institutions in Member States, and national courses, which countries organize as part of their national programmes for the development of human resources, often in connection with IAEA technical co-operation projects.

Training workshops. Shorter (1 to 2 weeks), intensive training takes place at workshops designed to enhance skills of people working in both major fields. The emphasis is always on practical elements of training and upgrading "hands-on" experience. Generally, there is extensive laboratory, computer-aided, or field work. Apart from provision of expert services, training material, and demonstration kits, the IAEA provides laboratory equipment or instruments to enhance national training capabilities.

Other mechanisms. Fellowships are used primarily as a means of providing on-the-job training to individuals from developing countries. The IAEA's programme puts emphasis on selecting candidates who, after their fellowship training, can themselves contribute to national programmes for development of human resources. Scientific visits also are arranged for decision-makers who may become involved in strengthening the radiation protection and nuclear safety infrastructures in their countries.

The 1994-98 programme further includes a series of regional seminars for promoting education and training in radiation protection and nuclear safety. Such meetings serve as a timely forum for exchange of information and educational discussions by selected groups of specialists with common interests. In general, they provide opportunities for the exchange of ideas and experience for those involved in similar work (e.g. educators, health physicists, reactor safety specialists). They also serve as a focal point for the IAEA to elaborate on a new activity or service for which the active participation of Member States is essential, such as the IAEA Emergency Response System.

All these types of activities are supported by reference materials. These basically include the IAEA's safety-related publications (standards, guides, training series, radiation safety manuals, etc.) and other information materials specifically developed for educational and training courses.

Bridging the gaps

Whereas problems are more pervasive in developing countries, even the more advanced countries face the need for specialists able to bridge crucial gaps that are delaying understanding and communication in areas of radiation protection and nuclear safety.

From the international perspective, the problem can be more readily tackled through an integrated approach to education in radiation protection and nuclear safety, harmonization of the contents of courses, and assistance in training the trainers. Priority can be placed on better dissemination of experience and knowledge that is already available, and improved co-ordination of support mechanisms. Through its programme over the coming years, the IAEA will be working to help countries address these challenges. ❑

Radon in the human environment: Assessing the picture

More than 50 countries are involved in an IAEA/CEC research programme on radon which is set to conclude later this year

by Jasimuddin U. Ahmed

Until the late 1970s, radon and its daughter products were regarded as radiation health hazards only encountered in the mining and milling of uranium. This notion has dramatically changed as a result of widespread indoor measurements of radon in many parts of the world. Increased radon concentrations in dwellings, for example, have been noted in countries in the temperate regions, where stringent energy conservation measures caused people to tightly seal doors and windows, particularly during the cold months. Radon problems also have been increasingly recognized in many non-uranium underground mines or in underground workplaces where ventilation is insufficient.

Attention to the problem of radon exposure and the associated health risks has thus been growing around the world. According to the assessments made by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), radon in the natural environment constitutes about 53% of the human exposure to natural radiation.

In underground mining, mainly uranium mining, incidence of excess lung cancer has been observed in the United States (Colorado) the Czech Republic, and Canada (Ontario). This also has been the case among underground fluorspar miners and in iron ore miners in Sweden. Today, the scientific community agrees on the link between the incidence of excess lung cancer among underground miners and exposure to radon and its daughters.

Current knowledge of potential health effects from radon exposure in dwellings, on the other hand, is rather limited. The relationship between the incidence of excess lung cancer among underground miners and exposure to radon cannot be sensibly used to understand potential health risks to the public. This is because the level of exposure in dwellings is much lower than in mines. There are opinions that the incidence of excess lung cancer among early uranium miners may be explained by synergistic effects of heavy smoking, ore dust, toxic fumes, etc. and extremely high radon exposures. Nevertheless, the data on miners may be useful provided differences are kept in mind between the exposure implications for the two groups of populations under two different situations.

In the late 1980s, the IAEA and Commission of the European Communities initiated a 5-year co-ordinated research programme (CRP) on radon in the human environment. More than 50 countries now have ongoing projects, an indication of the high level of interest in this subject. The CRP concludes later this year. This article presents selective results from radon surveys in some countries and describes the international framework for continuing co-operative research in this field.

Origin of radon

Principally, soil is the source of radon-222. It is the daughter product of radium-226 which belongs to the uranium-238 decay chain. Thoron (radon-220) is produced by the alpha decay of radon-224 which belongs to the decay chain of thorium-232. Radon and thoron are noble gases which can migrate from the soil either by molecular diffusion or by convection and enter the atmosphere. The distribution of radon in the air depends on meteorological conditions. The daughter products of radon and thoron are isotopes of heavy metals and can easily attach themselves to aerosol particles in the air. They decay by alpha and/or beta/gamma emissions. Aerosols laden with radon and thoron daughters are removed from the air by dry deposition, or by rain and other precipitation processes.

Mr. Ahmed is a former senior staff member of the IAEA Division of Nuclear Safety. Full references for this article are available from the author.

Radon has a half-life of 3.8 days, while thoron is very short-lived with a half-life of only 55 seconds. Among the daughter products, some are short-lived, while some have long half-lives. The short-lived daughter products constitute the highest fraction of the radioactivity concentration at the ground level among all natural or man-made radioactive contaminants in the air. *(See table.)*

Building materials such as granite, Italian tuff, and alum shale lightweight concrete may contain significantly high concentrations of radon-226 which can be a source of radon migration into the indoor air. Outdoor air can play an important role for radon entry into the buildings through open doors and windows, mechanical ventilation and infiltration, and also uncontrolled leakage of air through cracks in the building. Additionally, radon contained in water and natural gas used at home can, to some extent, be transferred into the room air.

Selected major indoor radon studies

An avalanche of attention has been noted over the past decade among almost all countries of Europe and North America and many East European countries concerning radon in dwellings. Nationwide surveys have been undertaken to determine radon levels in homes and to assess consequent risks of lung cancer. Many countries in temperate zones, including China and Japan, have put into place large programmes on radon in dwellings and in workplaces. Among tropical countries, significant interest has been noted and radon survey programmes on varying scales have been undertaken.

The high level of interest in radon further can be noted from the scientific literature. At the International Symposium on the Natural Radiation Environment (NRE IV) held in Lisbon, Portugal, in 1987, 65% of the 110 published papers dealt with radon alone. Similarly, at NRE V held in Salzburg, Austria, in 1991, about 70% of the 163 papers dealt with radon issues.

Moreover, as previously noted, some 55 countries are participating in the IAEA/CEC coordinated research programme on radon. While it is not possible to present survey results from radon studies from so many countries, several are particularly worth noting.

United States. A survey carried out in the late 1980s by the United States Environmental Protection Agency (EPA) and announced by the US Public Health Service has indicated that indoor radon problems in the USA are more serious and widespread than previously suspected. According to the US Public Health Service, an estimated 5000 lung cancers among non-smokers each year are believed to be due entirely to indoor radon exposure; among smokers, indoor radon exposure played a role in 15 000 deaths from lung cancer. Some later estimates indicate even higher figures. The statistics indicate that indoor radon's human toll "probably exceeds by 10 times the problem of outdoor air pollution", the US Public Health Service said. EPA's recommendation for a further survey to test more houses was supported by the US Surgeon General, the American Medical Association, the American Lung Association, and other health organizations.

A national residential radon survey programme carried out by EPA from 1989 to 1991 estimated the frequency distribution of average annual radon concentrations in occupied housing units across 50 states. A 22-page questionnaire collected information on various factors. The results indicated that the arithmetical average annual radon concentration was 46 plus or minus 2 becquerels per m^3. It also indicated that about 6 million housing units exceeded the action level of 150 becquerels per m^3.

Another study in the USA compiled the results of measurements from available sources such as the EPA, the University of Pittsburgh, and agencies in various individual states. This study comprised radon measurements in homes for 1730 counties, well over half of all US coun-

Radionuclide		Half-life	Activity concentration (millibecquerel per cubic meter)
Natural	Tritium	12.3 years	≈ 20
	Carbon-14	5736 years	≈ 40
	Beryllium-7	53.6 days	1 -7
	Radon daughters*	164 µs - 26.8 minutes	1000 - 5000
	Lead-210	22.3 years	0.2 -1.0
	Polonium-210	138.4 days	0.03 - 0.3
	Lead-212	10.6 hours	20 - 1000
	Bismuth-212	60.6 minutes	10 - 700
Artificial	Iodine-131	8.04 days	< 0.0001 (4000**)
	Caesium-137	30.1 years	0.0005 - 0.005 (4000**)
	Ruthenium-106	386.2 days	0.0001 - 0.002 (2000**)

* Radon daughters are: polonium-218, lead-214, bismuth-214, and polonium-214.
** After the nuclear accident in Chernobyl, the highest value in Göttingen, Germany, 2-3 May 1986.
Source J Porstendorfer, Properties and Behaviour of Radon and Thoron and Their Decay Products in the Air, Proceedings of the Fifth International Symposium on the Natural Radiation Environment Tutonal Session, published by the Commission of European Communities, Luxembourg Office, 1993, ISBN92-826-5604-7

Concentration ranges of natural and artificial radionuclides in the air

The International Radon Metrology Programme

A system of reference, technical support, and regional co-ordinating laboratories has been established to assist in assuring comparability of radon measurements obtained by different institutions worldwide. It is called the International Radon Metrology Programme (IRMP). The programme is being co-ordinated by the IAEA and the Commission of the European Communities, with the University of Salzburg serving as the scientific secretariat. The laboratories assume the following responsibilities:

- Reference laboratories provide guidance on the scientific issues concerning the metrology of radon (radon-222), thoron (radon-220,) and their decay products, in particular in the areas of laboratory and field calibration of measurement devices, field sampling, and survey methods and analytical procedures. Such laboratories have been designated for three regions: Europe — the National Radiological Protection Board in the United Kingdom; North America — the US Department of Interior, Bureau of Mines, and the Environmental Measurements Laboratory; Asia and the Pacific — the Australian Radiation Laboratory.
- Technical support laboratories provide technical support in the form of calibrated exposure chambers, which are used to conduct intercomparison exercises for radon-222, thoron, and their decay products under defined laboratory conditions. Three technical support laboratories have been designated for the IRMP. These are two US Environmental Protection Agency offices in Montgomery and Las Vegas, USA, for radon-222; and CANMET in Elliot Lake, Canada, for thoron.
- Regional co-ordinating laboratories will provide logistical assistance in the co-ordination and conduct of regional activities related to quality assurance programmes concerning radon-222, thoron, and their decay products. These laboratories, which have been designated for four specific regions, are the Institute of Radiation Protection in Brazil for South America; the Australian Radiation Laboratory for Asia and the Pacific; the Atomic Energy Commission of Ghana for Africa; the Institute of Epidemiology in the Czech Republic for Europe and the Middle East; and the Institute of Uranium Mining in Hengyang, China, for Asia.

The operational programme functions in the following way. End users requiring calibration of passive detectors will pass them to their national laboratories. The national laboratories may calibrate the detectors or pass them to the regional co-ordinating laboratory for calibration by the technical support laboratory, which will run regular calibration exercizes and intercompare their measurement techniques with the reference laboratories. Laboratories at any level can calibrate their equipment using radon gas sources provided by national standards laboratories, such as the US National Institute of Science and Technology and the UK National Physical Laboratory.

ties and comprising about 90% of the US population.

An analysis of the health effects was carried out by Bernard Cohen on the health implications of exposure to indoor radon at the low levels observed. It strikingly found that the linear no-threshold theory of radiation carcinogenesis greatly overestimates the risk of low-level radiation. The analysis, which was reported in 1992, further concluded that even if the linear no-threshold theory is valid, the public fear of low-level radiation is grossly exaggerated.

United Kingdom. An estimate made by the National Radiological Protection Board (NRPB) in 1989 on the incidence of lung cancer from indoor radon exposure in the United Kingdom suggested that "radon may be responsible for anything up to 2500 or more lung cancers in a year out of the total of 4100". Indoor radon accounts for half of the average exposure of the UK population to ionizing radiation.

Up to the summer of 1991, measurements of radon in 58 000 homes were carried out in anticipation of follow-on epidemiological studies, plus implementation of remedial and preventive measures. Radon exposure in the home is now recognized by the government as a risk to health. Radon concentrations above the action level of 200 becquerels per m^3 have been discovered in so far in about 10% of homes in the UK. Despite this successful start, about 90% of potentially affected homes remain to be identified.

China. An epidemiological investigation was started in 1972 in areas having high levels of background radiation near Yangjang, China. A high background radiation area (HBRA) was chosen where natural radiation levels are three times higher than in a nearby control area. About 80 000 inhabitants in each area whose families have lived there for two or more generations were studied. The annual averaged effective dose equivalents in the HBRA were 5.4 mSv and 2 mSv in the control area from combined exposure to external gamma radiation and radon and its daughters. Environmental carcinogens and mutagens other than natural radiation, as well as host compounding factors, were studied. The investigation covered 1 million person years of observation to investigate cancer mortality in the two areas.

Results of the study found no increase of cancer mortality in the HBRA as compared to the control area. On the contrary, there was an observable trend of lower cancer mortality in the HBRA. The incidences of hereditary diseases and congenital defects were similar in both areas. The frequency of chromosomal aberrations in circulating lymphocytes was higher in the HBRA than in the control area.

National and international action levels

Over the years, governments and international bodies have set "action levels" for radon exposures. According to the International Commission on Radiological Protection (ICRP), they are meant for initiating intervention in order to help in deciding when to require or advise remedial action in existing dwellings. The choice of an action level is complex, depending not only on the level of exposure, but also on the likely scale of action, which has economic implications for the community and for individuals. The best choice of an action level may well be that level which defines a significant, but not unmanageable number of houses in need of remedial work. It is thus not to be expected that the same action level will be appropriate in all countries.

Action levels that have been adopted appear to differ. Similarly, the upper bound of radon concentrations for future new buildings differs from country to country. *(See table.)*

The IAEA, in its current revision of the Basic Safety Standards, recommends 200 becquerels of radon-222 per m^3 as the action level for dwellings and 1000 becquerels per m^3 for workplaces.

IAEA programme on radon

In the 1980s, the IAEA, in response to concerns among its Member States, decided to make an assessment of the situtation with regard to radon exposures in dwellings and work sites. One objective was to identify the types of guidance that would be needed for instituting any required control measures. In 1988, it initiated a co-ordinated research project (CRP) on radon in the human environment jointly with the CEC, and the programme took effect in late 1989. It attracted some 140 proposals from 55 countries, a rather overwhelming show of interest.

Following its review of the proposals, the IAEA awarded 14 research contracts and 37 research agreements, making a total of 51 projects. In addition, the CEC placed 25 research contracts, which it awarded to its Member States.

Subsequently, the former International Intercomparison and Intercalibration Programme (IIIP), which was run by a few specialized radon laboratories, became a part of the joint CRP at no cost to the IAEA. This gave an added dimension to the CRP by providing opportunities to many developing countries. It enabled them to take part in the intercomparison and intercalibration exercises at practically no cost to them and it afforded them access to all data. The IIIP recently was renamed as the International Radon Metrology Programme (IRPM). *(See box.)* It remains a part of the CRP.

Work through the CRP has progressed well, with a good number of projects now completed and others nearing completion. Results will be reported at the final research co-ordination meeting being scheduled for the fall of 1994. Thereafter, given the continuing high levels of interest, research through the IAEA's co-ordinated research programme likely will focus on the mitigation of radon exposures.

National and international values of action levels and upper bounds for radon in dwellings

	Action level (Bq per m^3)	Upper bound (Bq per m^3)	Year established
Australia	200	NR	NR
Canada	800	NR	1989
CSFR (former)	200	100	1991
China	200	100	NR
Germany	250	250	1988
Ireland	200	200	1991
Luxembourg	250	250	1988
Norway	200	< 60-70	1990
Sweden	200	70	1990
United Kingdom	200	200	1990
United States	150	NR	1988
USSR (former)	200	100	1990
CEC	400	200	1988
ICRP	200-600	—	1993
Nordic countries	400	100	1986
WHO	100	100	1985

CEC= Commission of the European Communities, ICRP = International Commission on Radiation Protection; Nordic countries = Sweden, Finland, Norway, and Denmark; WHO = World Health Organization, NR = Not yet reported to the IAEA.

Radioecological research of the Black Sea: Report from Romania

Marine scientists in Romania are involved in a range of national and international projects for monitoring the marine environment

by Alexandru Bologa

A semi-closed tideless basin bordering six countries, the Black Sea is considered a "unicum hydrobiologicum" because of its physical, chemical, and biological peculiarities. Unlike any other sea, the Black Sea is permanently deficient in oxygen, or anoxic, below a depth of 150-200 meters.

The Sea's radioactivity levels have been the subject of rigorous research in the riparian countries and among organizations participating in various international oceanographical cruises. After the Chernobyl accident in 1986, interest in radioecological research of the Black Sea increased in Romania, as it did in a number of other countries. Studies have included both radioactivity surveys on abiotic and biotic compounds and experiments on the biokinetics of radionuclides in the marine environment.

In Romania, such work has carried particular importance. The need for monitoring radioactivity levels is mainly explained by the continuing existence of fallout, by the Danube river's presence, and by the prospects for nuclear energy's use in electricity generation. The Danube is the main collector of radioactive wastes from seven riparian countries before flowing into the Black Sea; this important river flow (80% of the total input of fresh water to the Sea) could contribute to radiocontamination of the marine ecosystem as well. The utilization of nuclear energy in the future, following the completion of the nuclear power plant at Cernavoda in Romania, will be — despite all assurances — another possible source of radioactive wastes having an impact on the environment.

This article highlights Romanian research of the marine environment in the Black Sea, and the country's participation in related regional and international projects.

Mr Bologa is a biologist and the Scientific Deputy Director of the Romanian Marine Research Institute, B-dul Mamaia Nr. 300, Constantza 3, Romania RO-8700.

National research activities

Studies of radioactivity in some environmental components in the Romanian sector of the Black Sea have been carried out sporadically in various laboratories since 1962. Beginning in 1978, the Romanian Marine Research Institute (RMRI) initiated the country's systematic study of marine radioactivity using a network of permanent stations located between the Danube mouths, the southern extremity of the Romanian littoral, and occasionally offshore up to 90 nautical miles. Up to 1983, the work was carried out with the Fundeni Hospital/Laboratory of Radiobiology, and then in close co-operation with the Institute of Meteorology and Hydrology/Research Laboratory of Environmental Radioactivity. The monitoring programme has resulted in a fairly extensive database covering more than 10 years.

The monitoring is being done for a number of reasons. One objective is to define the levels of radioactivity in the marine environment as a baseline before the new nuclear power plant starts operation. Another objective is the identification of bioindicators for studying radiocontamination of the marine ecosystem, and experimentally determining possible levels of accumulation of critical radionuclides in marine biota and biological systems having direct or indirect influences on the environment and human health.

The main research tasks include completion of the database on marine radioactivity levels. Data will be used for a systematic study of distribution coefficients for marine sediments and seawater and of concentration factors for the relevant local species. Assessments also are being made of external and internal individual and collective doses from marine radioactivity due to immersion in seawater and/or food consumption.

Samples of sediments, seawater, and biota (macrophytes, mollusks, benthic and pelagic fish) have been continuously collected, at monthly, quarterly, and semi-annual intervals. For all seawater samples, some physical-chemical parameters such as temperature, salinity, pH, and O_2 concentration were also measured. From this work, researchers were able to determine the gross beta activity, the gamma radioactivity of sediment, seawater, and biota, the distribution coefficients of some radionuclides between seawater and sediment, and the concentration factors in marine biota.

The studies revealed significant radionuclide concentration factors for the uranium-radium and thorium series in some seaweeds. They further found fission product concentrations (originating from earlier atmospheric nuclear tests and post-Chernobyl environmental contamination) in different non-living and living marine components.

Given their importance, special attention was paid to caesium-134 and caesium-137, for which international organizations established maximum permissible limits for food products following the Chernobyl accident in 1986. Romanian studies thus particularly focused on computing the concentration of caesium-137 for sediment and seawater in the pre-Danubian sector of the Sea.

Environmental concentration factors for caesium-137 for different Black Sea biota were also estimated. In the Romanian Black sea sector, the maximum values of caesium-137 in seawater and fish were found in 1987, in macrophytes and mollusks in 1988, and in sediment in 1990 and 1991.

The isotopic ratio values of caesium-137/caesium-134 in sediments and seawater demonstrated that the Chernobyl accident was a source of radioactive contamination along the Romanian shore. Furthermore, the content of artificial gamma radionuclides there continually decreased in all components (sediment, sea water, biota) compared to 1986. This decrease was more gradual during 1990-91 than it was during the previous year. The relatively slow decrease of caesium-137 concentrations in sediment compared to seawater confirmed the ability of sediments to concentrate radionuclides.

The highest caesium-134 and caesium-137 concentration in edible marine biota (fish, mollusks) in this sector ranged below the maximum permissible level allowed for food by the United Nations Food and Agriculture Organization (FAO) in 1987 and the following years.

Analysis of the data that continue to be recorded on gamma radioactivity in the Romanian marine sector suggest the need for further surveys and monitoring of critical radionuclides in the Black Sea. The work will help in understanding the biogeochemical cycling of radionuclides and their radiological significance for human health.

The concentration factors for iron-54, cobalt-60, zinc-65, strontium-85 and strontium-89, iodine-131 and/or caesium-134 were experimentally derived for biota from the Romanian Black Sea littoral ecosystem. These biota proved to be potential bioindicators for marine pollution caused by one or several of these radionuclides: *Enteromorpha linza* for iron-59 and zinc-65, *Cystoseira barbata* for strontium-89 and iodine-131, *Mytilus galloprovincialis* and *Mya arenaria* for iron-59 and zinc-65. Low CFs are typical in the three bivalves for cobalt-60 contamination.

International involvement

In spite of extremely unfavourable conditions in Romania for maintaining international contacts especially during the last decade, the RMRI has kept close relationships with the IAEA in areas of marine science. Between 1987-92, the RMRI carried out work under an IAEA research contract on the monitoring of marine water, sediment, and biota radioactivity in samples from the Romanian sector of the Black Sea by means of gamma spectrometry. This contract enabled the international distribution of results on the concentration of some natural and artificial radionuclides in abiotic (sediment, seawater) and biotic (seaweeds, mollusks, fish) components from the western Black Sea.

In all samples that were collected, caesium-137 and, in most of them, caesium-134 persisted from 1987 until 1992. Thus, for example, it was possible to track the temporal changes in concentrations of caesium-137. *(See table.)*

Certain results from this work also contributed to Romania's participation in a co-ordinated research programme of the IAEA's Marine Environment Laboratory (IAEA-MEL)

Concentrations of caesium-137 in environmental samples from the Romanian sector of the Black Sea

	1987	1988	1989	1990	1991	1992
Emerged sediment	18.9	11.5	15.5	13.3	21.5	10.7
Submerged sediment	247 0	25.2	—	55.0	24.2	—
Seawater	0.13	0.10	0.09	0.07	0.08	0.06
Macrophytes	4.6	7.1	5.2	3.4	1.9	1.4
Mollusks	3.2	3.3	2.8	1.3	1.5	1.2
Fish	11.0	4.3	5.1	4 0	3.9	3 5

Notes: Values for sediment are expressed in becquerel per kilogram, dry; values for seawater are in becquerel per litre, and values for macrophytes, mollusks, and fish are expressed in becquerel per kilogram of fresh weight.

in Monaco. This programme focused on sources of radioactivity in the marine environment and their relative contributions to overall dose assessment from marine radioactivity. Data from Romania's monitoring of the annual concentrations of gamma emitting radionuclides in seawater and edible marine biota were used in this programme for external and internal individual and collective dose assessment arising from immersion in seawater and/or fish consumption in the Black Sea. Total external doses of no more than 2.5 micro-sievert per year (whole body) and 93.6 micro-sievert per year (skin) were received by seawater immersion (for 100 hours) in 1986. In 1987 and 1988, the corresponding values were one order of magnitude lower. Internal doses were estimated by direct and indirect methods; all internal doses were below IAEA recommended dose limits.

Romania also is involved with a number of regional and international programmes. They include the Global Inventory on Radioactivity in the Mediterranean Sea (GIRMED) of the International Commission for the Scientific Exploration of the Mediterranean Sea (ICSEM). It was launched in 1988 and includes research on the Black Sea. Additionally, Romania is working with the Co-operative Marine Science Programme for the Black Sea (CoMSBlack), which was formed in 1991 as a non-governmental organization. Since all Black Sea riparian countries have a national programme of some magnitude, one major goal of CoMSBlack is to co-ordinate, where needed, these projects in order to stretch limited resources and to create common standards for such research. From this regional perspective, CoMSBlack will be able to design more effective monitoring arrays, with participation from all Black Sea countries without concern for maritime boundary restrictions.

Within the framework of this programme, Romanian marine scientists from RMRI participated in a research cruise in August 1992 aboard the R/V *Professor Vodyanitsky*. The cruise in the northwestern Black Sea was organized by the Institute of Biology of Southern Seas in Sevastopol, Ukraine; the Woods Hole Oceanographic Institution in the United States; and the US Environmental Protection Agency. The main objective was to conduct oceanographic and radioecological studies in the northwest Black Sea off the Dnieper and the Danube mouths. Researchers investigated the runoff of these rivers, the vertical migration of radionuclides, and the accumulation of long-lived radionuclides (mainly strontium-90 and caesium-137) in sediments and biota. Special attention was paid to intercalibration exercises between participating laboratories concerning the measurement of these radionuclides in sediment and water samples. Technical assistance and training were also provided.

Tracer techniques in Black Sea studies

The RMRI further is working with IAEA-MEL under a research programme addressing the application of tracer techniques in the study of processes and pollution in the Black Sea. The programme's scientific scope is to improve the general understanding of circulation in the Black Sea and of the various physical, chemical, and biological processes which influence the transport and fate of contaminants. It will also investigate how the measurement of environmental isotopes can be used to assess the sources, trends, and impacts of marine pollution in the Black Sea environment.

Nuclear techniques offer a unique method for studying physical circulation of water masses, for providing information on transport dynamics, and for monitoring environmental change. A range of radioactive tracers having different half-lives, chemical reactivities, and source functions are being incorporated in the work. Several different types of chemical tracers will be measured according to the availability of suitable instrumentation/expertise. Typical examples of chemical tracers that could be used in the Black Sea might include Chernobyl-derived radionuclides, naturally occurring uranium and thorium decay-series radionuclides, stable isotopes of carbon, hydrogen, and oxygen, chemical analogues of transuranic elements (e.g. rare earth elements), and other novel chemical tracers. The resultant data will provide a time-frame for assessing, modelling, and predicting the impact of marine pollution in the Black Sea. It will therefore form a basis for improving regional environmental management.

Such results could also be used within the framework of the planned international programme on Environmental Management and Protection of the Black Sea. The programme is under the auspices of the Global Environment Facility initiated by the United Nations Environment Programme, United Nations Development Programme, and the World Bank during a symposium held in Constantza, Romania, in 1992. It is intended to support analyses and activities within the framework of the integral management of the coastal zone, making direct reference to nature conservation, protection of human health, agriculture, fishing, and tourism.

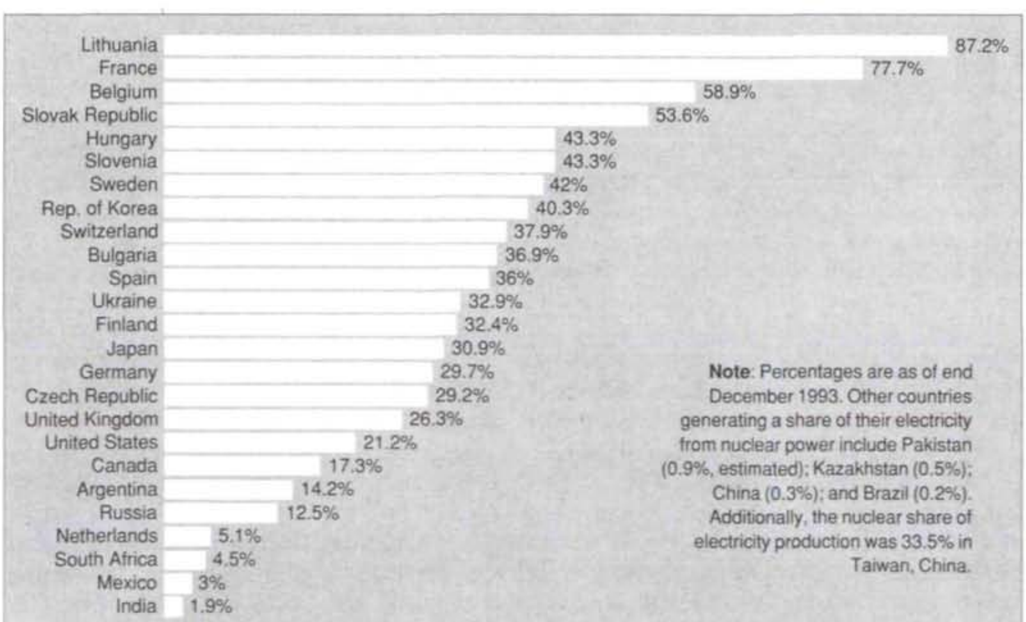
For Romania, and other riparian countries of the region, the project will add an important element to marine research of the Black Sea. ❐

Nuclear power status around the world

	In operation		Under construction	
	No. of units	Total net MWe	No. of units	Total net MWe
Argentina	2	935	1	692
Belgium	7	5 527		
Brazil	1	626	1	1245
Bulgaria	6	3 538		
Canada	22	15 755		
China	2	1 194	1	906
Cuba			2	816
Czech Republic	4	1 648	2	1 824
Finland	4	2 310		
France	57	59 033	4	5 815
Germany	21	22 559		
Hungary	4	1 729		
India	9	1 593	5	1 010
Iran			2	2 392
Japan	48	38 029	6	5 645
Kazakhstan	1	70		
Korea, Rep. of	9	7 220	7	5 770
Lithuania	2	2 370		
Mexico	1	654	1	654
Netherlands	2	504		
Pakistan	1	125	1	300
Romania			5	3 155
Russian Federation	29	19 843	4	3 375
South Africa	2	1 842		
Slovak Republic	4	1 632	4	1 552
Slovenia	1	632		
Spain	9	7 101		
Sweden	12	10 002		
Switzerland	5	2 985		
United Kingdom	35	11 909	1	1 188
Ukraine	15	12 679	6	5 700
USA	109	98 784	2	2 330
World total*	430	337 718	55	44 369

* The total includes Taiwan, China where six reactors totalling 4890 MWe are in operation.

Nuclear share of electricity generation in selected countries



IAEA Board of Governors

The conduct of the IAEA's safeguards inspections in the Democratic People's Republic of Korea (DPRK) was among matters before the Agency's Board of Governors at its meetings in June 1994 in Vienna. Other subjects on the Board's provisional agenda included items related to the IAEA's implementation of safeguards in 1993; measures to strengthen the effectiveness and efficiency of the safeguards system; the IAEA's technical assistance and co-operation activities; the draft *International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources;* global developments in nuclear safety and radiation protection; international radioactive waste management issues; the use of isotope hydrology for groundwater management; and matters related to the 38th regular session of the IAEA General Conference, which convenes in Vienna 19-23 September 1994.

In addition, the Board received a report from its Administrative and Budgetary Committee, which met in mid-May, on the Agency's programme and budget performance.

Concerning DPRK safeguards, IAEA Director General Hans Blix in June 1994 briefed the UN Security Council and the Agency's Board of Governors about recent safeguards developments. He *inter alia* reported that on the basis of reports from its safeguards inspections in the DPRK, the IAEA has drawn the conclusion that the discharge of spent fuel from a 5-megawatt experimental nuclear power plant has now made it impossible to select fuel rods for later measurements. Such measurements would show whether there has been any diversion of fuel from the reactor in the past years. He emphasized that for the IAEA to be able to verify non-diversion in the DPRK, it is essential for the Agency to have access to all safeguards relevant information and locations. To achieve that, he said, a paramount requirement is the full co-operation of the DPRK. *(See related item on page 49.)*

International nuclear safety convention

Governmental delegates met in Vienna 14-17 June at a Diplomatic Conference for the adoption of an international nuclear safety convention. The draft convention, which had been drawn up in a series of experts' meetings since 1991, covers land-based civil nuclear power plants. By setting international benchmarks to which States could subscribe, the convention is seen as a significant step forward in helping to maximize safety at nuclear power plants, of which 430 are currently in operation worldwide. *(See International Datafile in this edition.)*

The convention's objectives are to achieve and maintain a high level of nuclear safety worldwide through national measures and international co-operation; to establish and maintain effective defenses in nuclear installations against potential radiological hazards in order to protect individuals, society, and the environment from harmful effects of ionizing radiation from such installations; and to prevent accidents with radiological consequences and to mitigate such consequences should they occur.

The obligations placed upon Contracting Parties are based on fundamental nuclear safety principles that reflect an international consensus. They cover, for instance, siting, design, construction, operation, the availability of adequate financial and human resources, the assessment and verification of safety, quality assurance, and emergency preparedness. There is also an obligation for Contracting Parties to submit reports on implementation for "peer review" consideration at regular meetings of the Contracting Parties to be held at the IAEA.

Technical talks on long-term monitoring in Iraq

High-level technical talks between the IAEA and Iraq took place in Vienna 9-10 May 1994 on implementation of the IAEA plan for ongoing monitoring and verification in Iraq. Mr. Tariq Aziz, Deputy Prime Minister of Iraq, met with IAEA Director General Hans Blix and Prof. Maurizio Zifferero, Leader of the IAEA Action Team. The talks were a continuation of the process begun in July 1993 during the visit to Baghdad of the Executive Chairman of the United Nations Special Commission.

In a joint statement issued at the conclusion of the talks, the two sides made the following points:

"The actions taken to date in phasing in many elements of the IAEA's plan for ongoing monitoring and verification were reviewed. During the past several months, Iraq had provided to the IAEA extensive co-operation and both sides agreed that this had contributed significantly to the phasing in of these elements. Confidence was expressed that continued co-operation would contribute as well to the implementation of the remaining elements within the schedule envisaged during the March 1994 talks.

"The importance of the establishment in the Middle East of a zone free from weapons of mass destruction, as referred to in paragraph 14 of Security Council resolution 687 (1991) was stressed by both sides. The Director General stated that the IAEA was doing its very best to advise States which may negotiate such an agreement about the Agency's expertise in the field of verification and about the modes of verification which might be employed.

"Discussions took place on the status of technical co-operation in the areas of medical and agricultural applications of radioisotopes and radiation, and the IAEA undertook to reevaluate the extent of such technical co-operation that would be appropriate in the context of the relevant Security Council resolutions.

"More detailed follow-up discussions also were held with a view to resolving specific outstanding issues. The Iraqi side reiterated its readiness to assist the IAEA in such matters."

IAEA-MEL co-recipient of scientific award

A research programme being supported by the IAEA's Marine Environment Laboratory (IAEA-MEL) in Monaco has been awarded the 1994 Philip Morris Scientific Prize for biogeochemistry. Known as DYFAMED, the programme focuses on the biogeochemical cycle of carbon and associated elements in the Mediterranean Sea. The Philip Morris prize is awarded annually for research projects with applications to daily life.

The research programme began in 1986 and is part of the French contribution to a major international effort in marine sciences known as Joint Global Ocean Flux Studies. IAEA-MEL has contributed to the programme through its continuous measurement of the sedimenting flux of particles and carbon through the water column in the northwestern Mediterranean and by assessing the role marine organisms play in the carbon transport. It further has contributed to the assessment of natural and anthropogenic radionuclide fluxes and provided, in 1986, the first measurements of post-Chernobyl radioactivity in Mediterranean waters.

Knowledge of the carbon cycle is a key to comprehending the biosphere. Carbon dioxide makes up between 50% and 60% of the greenhouse gases, which trap solar energy and warm the global atmosphere. Because of the ocean's ability to serve as a potential sink of anthropogenic carbon dioxide, it may play an important role in modulating global climate. One major objective of DYFAMED is to see whether the variations observed in the environment (increase of atmospheric carbon dioxide) may be regulated by changes in oceanic primary production (called the "biological pump"). The Scientific Prize for the programme was awarded at a ceremony on 16 May in Paris.

Sea expedition of waste dumping site

Scientists at the IAEA's Marine Environment Laboratory (IAEA-MEL) in Monaco will be analyzing large samples of seawater from areas near the Republic of Korea and Japan where nuclear-related waste has been dumped by the former Soviet Union and the Russian Federation. The work is among follow-up analytical activities to the recently concluded joint sea expedition to assess radioactivity levels in these international waters. The mission, which took place from 18 March to 16 April 1994, was composed of scientists from Japan, Republic of Korea, the Russian Federation and IAEA-MEL. Samples of seawater, sediment, and biota were taken, and preliminary spectrometric measurements were carried out aboard the R/V "Okean", the vessel used for the mission.

During the expedition, intercomparison of techniques used by participating parties was performed. The results of these intercomparisons were satisfactory. Concentrations of caesium-137, one of the most important radionuclides in seawater and sediments, were found to be very low and do not differ from the global fallout background levels in the northwest Pacific Ocean. However, results of on board measurements are only preliminary. Detailed analysis of samples of seawater, bottom sediments, zooplankton, and benthos will be performed on land in the laboratories of

Japan, Republic of Korea, Russian Federation, and the IAEA, with subsequent data exchange, evaluation, and publication over the next year. About three tonnes of water samples are being shipped to the IAEA-MEL for detailed analysis. Further collaborative studies are planned for other sea areas where such dumping is known to have occurred.

Energy and ecology

Speaking at the annual conference of the Japan Atomic Industrial Forum in Hiroshima on 13 April, IAEA Director General Hans Blix said reality in the energy field appears to be moving in the opposite direction from rhetoric. Dr. Blix observed that despite the agreed aim of world governments at the 1992 UN Conference on Environment and Development to stabilize greenhouse gas concentrations at levels that will not interfere dangerously with our climate, even the most optimistic global energy projections up to 2020 show an increase in the use of fossil fuels with consequent increases in carbon dioxide emissions. By relying today on the burning of fossil fuels to provide over three-quarters of our energy needs, we are, he said, interfering with the earth's ecological balance.

Dr. Blix noted that nuclear power must first of all compete with other electrical power sources on its own economic, safety, and reliability merits. The rapid expansion of nuclear power in East Asia and the slow but continued growth in some other countries, like France, showed that competition on these grounds was possible. He added, however, that it is imperative today that the comparisons between different energy sources also take their respective health and environmental impacts into account. This necessity ought to lead to a renewed interest in nuclear power. Indeed, the global climate change that is presently foreseen as a result of the excessive emissions of so-called greenhouse gases, notably carbon dioxide and methane, would appear to make an early revival of nuclear power crucially important. He said it was curious that few of the many governments, international authorities, and non-governmental groups who are deeply engaged in the question of global warming have highlighted this point. Copies of the Director General's address may be obtained from the IAEA Division of Public Information.

Nuclear safety at Chernobyl

International experts meeting at the IAEA in April have described the safety situation at the Chernobyl nuclear power station in Ukraine as complex and difficult to solve in light of prevailing energy and economic conditions. The meeting was attended by representatives from the Ukraine and a dozen other countries to consider actions that could be taken to alleviate the current situation. It was convened following an IAEA expert mission in March 1994 that found serious safety deficiencies at the station, where two units remain operational and the reactor destroyed in the 1986 accident (unit-4) is enclosed in a deteriorating shelter. IAEA Director General Hans Blix subsequently informed the President of Ukraine that international levels of safety were not being met at the Chernobyl site.

In opening the meeting, Dr. Blix reminded the participants that national governments carry the responsibility for safety in nuclear installations in their territory. Yet, he said, there is legitimate international concern about maintaining safety of nuclear installations anywhere. Technical safety issues and actions would need to be considered in the context of other factors that influence the current situation, such as the overall energy and economic circumstances in the Ukraine. The Ukrainian Vice Prime Minister, Mr. Valeri Shmarov, and the Chairman of the State Committee on the Utilization of Nuclear Power, Mr. M.P. Umanets, discussed the energy and economic conditions and the current safety situation at Chernobyl. The meeting also heard views of the European Bank for Reconstruction and Development and was briefed on results of the IAEA safety mission.

Ukrainian officials made a number of points: energy use had dropped lately due to the temporary economic depression, but should rise substantially as the economy improves; *per capita* energy consumption is inordinately high, but reducing it would require complete overhaul of the infrastructure, lasting decades; the country is already heavily dependent on expensive external and potentially unreliable sources for gas and oil; coal is becoming harder to extract and, in any event, greater use depends on introducing, at high cost, modern combustion technology; and Ukraine must look to nuclear energy as a continuing major source to meet its energy requirements. In their view, the Chernobyl station could be upgraded to a level no less safe than other currently operating reactors of the same type (RBMKs). While Chernobyl is now behind in implementing the safety improvements undertaken at other RBMKs, they said the pace of implementation could be accelerated if sufficient resources were available. To date, however, no international financial assistance directed at improving the safety situation at Chernobyl has been provided by the international community.

There was consensus at the meeting that the many factors involved make the situation at Chernobyl complex and that there was no simple one-step solution. Some participants suggested continued technical assessment which could be undertaken in the framework of IAEA activities. A clear majority wished to see operation at Chernobyl discontinued as soon as conditions allow.

In concluding remarks, IAEA Assistant Director General for Nuclear Safety, Dr. Morris Rosen, characterized the situation at Chernobyl as unique and serious. The loss of many highly qualified staff, coupled with the scope of required safety improvements, mean that the Chernobyl plants would continue to operate at lower levels of safety than similar plants for several years to come. In addition, the shelter encasing the destroyed reactor is currently deteriorating and the remaining units would be operating in an environment of elevated radiation levels, he said.

Uranium supply and demand

The IAEA and the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (NEA/OECD) have issued their new 2-year joint study, *World Uranium Resources, Production and Demand.* Commonly known as the Red Book, the study points out that the most significant aspect of uranium supply and demand in the 1991-92 period was an over-saturated market, with a clear shortfall between fresh uranium production and uranium consumption.

The study's assessments are made from official data, maps of deposits, expert analyses, and forecasts of uranium supply and demand in over 50 countries, including new information presented on the Czech Republic, Kazakhstan, Lithuania, Mongolia, Russia, the Slovak Republic, Slovenia, Ukraine, and Uzbekistan.

Uranium demand over the short term is fairly predictable, the report states, while on the supply side uncertainties are chiefly related to where these supplies will come from and the amount of military uranium that may enter the commercial market. Continued downward pressure on prices, the expiration of high-priced long-term contracts, and the availability of new sources of supply are expected to continue through the mid-1990s, restricting the prospects for market recovery in the short term. For the longer term, it is generally believed that reactor requirements and uranium production will reach closer balance when inventories have been drawn down to desired levels. Beyond the turn of the century, the three factors that will have the greatest impact on the supply/demand balance are expected to be the rate of orders for new nuclear capacity, the rate of erosion of the existing base of reactors, and certain technological developments. More information may be obtained from NEA/OECD, Le Seine St-Germain, 12 boulevard des Iles, 92130 Issy-les-Moulineaux, France.

Isotopes in global climate studies

Representatives of 14 scientific teams from 13 countries participating in a new IAEA research project recently reviewed the key role that isotope methodologies can play in deciphering historical patterns of global climate change. The IAEA project, within the framework of its Co-ordinated Research Programme (CRP), focuses on the use of isotope and nuclear techniques in palaeoclimatology, specifically for reconstructions of climatic changes occurring on the continents over the last thousands of years.

The project's first meeting took place at the IAEA 19-22 April. In addition to members of participating scientific teams, the meeting was attended by observers from Canada, Germany, Israel, Poland, Russia, Spain, and Switzerland. In an address to the meeting, Prof. Hans Oeschger, director of a project called PAGES (past global changes) of the International Geosphere Biosphere Programme, emphasized the scientific contribution that the IAEA could provide to PAGES through its Department of Research and Isotopes. The IAEA possesses a wide range of expertise in the application of isotope methodologies.

In the field of climate change studies, for example, high-resolution reconstruction of past climatic and environmental conditions can be obtained through isotope investigations of palaeowaters, lacustrine sediments, freshwater carbonates, ancient organic matter, continental glaciers, permafrost, and other continental archives. Such studies are seen as prerequisites to any meaningful prediction of future global warming due to greenhouse gas emissions.

Safeguards on Japanese nuclear material

In response to misleading media reports about safeguards in Japan, the IAEA issued the following statement on 25 May 1994:

"Recent reports have stated, incorrectly, that a sizable amount of nuclear material is unaccounted for in the Tokai Nuclear Fuel Fabrication Plant in Japan. The plant is a highly automated facility with the most advanced nuclear material accountancy system in existence. This system provides information to the IAEA on the movement and quantities of nuclear material on a near real-time basis. In addition, and as is the case with all nuclear facilities subject to IAEA safeguards, all nuclear material entering and leaving the facility is measured and verified.

"Since the beginning of operations of the plant 5 years ago, material in dust form has been accumulating on exposed surfaces of several areas of the glove boxes in which the nuclear material is processed. To minimize radiation exposure to its maintenance personnel, the operator has until now elected to leave the deposited material, referred to as 'hold-up', in place.

The IAEA has been well aware of the presence of this material throughout, which has been fully declared as hold-up by the operator and is measured by the IAEA on a monthly basis, using a specially designed system (glove box assay system). With a view to improving the quality of the assay measurements, the IAEA has on previous occasions pointed out to the operator the necessity of cleaning up the glove boxes and collecting the hold-up material. In this connection, a schedule for the recovery of hold-up has been proposed by the Japanese operator and is being discussed between the Japanese authorities and the IAEA.

"It will be clear from the above that the nuclear material held-up in the glove boxes of the Tokai Nuclear Fuel Fabrication Plant is not missing and remains under full safeguards and is declared."

Forthcoming IAEA meetings

Among the IAEA's upcoming international meetings are the following:

Isotopes and hydrology. Two scientific gatherings in this field will take place at the IAEA in August. From 15-19 August, the IAEA has organized an Interregional Seminar on Isotope Techniques in Arid and Semi-Arid Land Hydrology. Thereafter, from 22-26 August, the Agency is hosting the International Symposium on the Application of Tracers in Arid Zone Hydrology, which has been organized by the International Committee on Tracers of the International Association of Hydrological Sciences. It will address techniques and options in the application of natural and artifical tracers in hydrological investigations of arid regions, and will provide a forum for discussions on the results of experiments in which tracers are used to provide information for modelling in hydrological systems.

Conference on nuclear power option. The major thrust of this conference — from 5-9 September in Vienna, Austria — is on national nuclear power policies and programmes, in preparation for an expected renewed demand for nuclear-generated electricity. Worldwide electricity demand is expected to increase in the long term as populations grow and industrialization expands. Both fossil-fired and nuclear plants are expected to be built depending on local conditions. For its part, the nuclear industry has to be prepared to meet demand when the right economic, technical, and political conditions come together. The conference aims to prevent problems which will occur in the absence of proper preparation. It will also review collective experience in the current round of construction, licensing, and operation of nuclear power plants.

Nuclear fusion research. As part of efforts to encourage the exchange of scientific and technical information on fusion research between nations, the IAEA is hosting the 15th International Conference on Plasma Physics and Controlled Nuclear Fusion Research. To be held in Madrid, Spain, 29 September to 1 October 1994, the conference will review results from large experimental devices now in operation and under construction; the advances in the understanding of plasma physics; and the engineering design activities for fusion experimental devices which may lead to the demonstration of the "scientific breakeven" point soon.

Nuclear techniques in soil/plant studies. From 17-21 October 1994, the IAEA and Food and Agriculture Organization (FAO) of the United Nations, are jointly organizing an International Symposium on Nuclear and Related Techniques in Soil/Plant Studies on Sustainable Agriculture and Environmental Preservation. The symposium is intended to provide a forum for scientists to share results of their research on soil/plant studies. Its scope will include soil fertility, plant nutrition, water management, and crop production in sustainable agriculture where isotopes and related nuclear techniques have been used. Environmental aspects related to nutrient and water management in crop production will also be covered.

International conference on radiation and society: Comprehending radiation risk. Being convened in Paris, France, 24-28 October 1994, this conference seeks to bring about a better understanding of the risk attributed to the exposure to ionizing radiation. Sessions address a range of topics, including assessments of radiation exposure levels and radiation health effects; the impact of radiation on the environment; perceptions of radiation risk; management and communication aspects of radiation risks; radon in homes; radioactive waste disposal and the environment; and radiation case studies.

Nuclear fusion research project

Delegations from the four parties to the International Thermonuclear Experimental Reactor (ITER) met in Vienna on 21 March to sign Protocol 2 of the ITER engineering design activities (EDA). Under Protocol 2, the parties will develop an engineering design of the ITER with the aim of demonstrating the scientific and technological feasibility of fusion energy for peaceful purposes. Information developed in the course of the engineering design activities will provide the basis for future decisions on the construction of ITER. Protocol 2 specifically covers the parties' detailed technical work through the end of the agreement on 21 July 1998.

ITER parties are the European Community, Japan, Russia, and United States. The leaders of the delegations were: Ambassador Corrado

At the signing of the ITER Protocol (from left): Ambassador Pirzio-Biroli of the CEC; Dr. Cheverev of Russia; IAEA Director General Blix; Ambassador Kunisada Kume of Japan; and Ambassador Ritch III of the United States. *(Credit: Pavlicek, IAEA)*

Pirzio-Biroli, Head of the CEC's Delegation in Vienna; Ambassador Kunisada Kume, Japan's Resident Representative to the IAEA; Dr. Nicolai S. Cheverev, Administrative Director of Fusion Programmes in Russia's Ministry of Atomic Energy; and Ambassador John B. Ritch III, the US Resident Representative to the IAEA.

Director General Hans Blix conducted the signing ceremony.

International safeguards symposium

Technologies and approaches being developed and used for the verification of nuclear energy's peaceful uses were major topics of discussion at an IAEA International Symposium on Safeguards in mid-March 1994.

More than 400 safeguards specialists in government and industry from 42 countries participated in sessions covering a wide range of technical areas. They included, for example, presentations related to the application of safeguards in republics of the former USSR; the IAEA's verification experience in South Africa; the future implementation of safeguards in Brazil and Argentina; and measures being evaluated for further strengthening the IAEA's safeguards system, which over the past 30 years has become a central element of the world's nuclear non-proliferation regime. The week-long symposium included a panel discussion chaired by Dr. Bruno Pellaud, IAEA Deputy Director General for Safeguards, on the future directions of international safeguards. Panelists included IAEA Director General Hans Blix; Ambassador K. Bakshi of India; and Mr. David A.V. Fischer, an international expert on safeguards and nuclear non-proliferation who held a number of senior IAEA positions during his career. The discussions principally addressed the evolution of safeguards from legal, financial, and policy perspectives.

The symposium was organized by the IAEA in co-operation with the American Nuclear Society (ANS), the European Safeguards Research and Development Association (ESARDA), the Institute of Nuclear Materials Management (INMM), and the Russian Nuclear Society. Proceedings will be published by the IAEA.

NUCLEAR PLANT STATUS. Nine new nuclear power plants with a total capacity of 8988 megawatts went on line in 1993, based on data reported to the IAEA's Power Reactor Information System (PRIS). Countries which connected nuclear plants to their electricity grids were: Canada (1), China (1), France (1), Japan (4), Russia (1), and United States (1). Also in 1993, construction work on six plants started in Japan (1), Republic of Korea (2), Pakistan (1), and Russia (2). Worldwide, 430 nuclear reactors were operating at the end of 1993 and 55 more were being built. Nuclear power's share of electricity production stood at 21% or higher in 18 countries, with eight countries generating close to half or more of their electricity from nuclear power plants. (Also see the *International Datafile* section.)

South Africa: Gift to IAEA

South Africa has presented a sculpture to the IAEA as a symbol of its commitment to non-proliferation and as an encouragement to other States to pursue this path. The presentation was made to IAEA Director General Hans Blix on 7 April in Vienna by then South African Foreign Minister, Mr. R.F. "Pik" Botha.

The sculpture is a miniature metal ploughshare crafted from non-radioactive material belonging to one of South Africa's former nuclear devices. Its inscription reads: "This sculpture, made of non-nuclear material from a dismantled nuclear device, symbolizes the commitment of the Republic of South Africa to the non-proliferation of nuclear weapons." It ends with the words: "And they shall beat their swords into ploughshares, and their spears into pruning hooks. Nation shall not lift up sword against nation, neither shall they learn war any more."

In accepting the gift, Dr. Blix expressed the hope that more "weapons of war can be transformed into the tools of peace". He said that the number of countries committed to non-proliferation and accepting comprehensive verification of that commitment continues to grow. In singling out positive developments in South Africa, the Director General said that the "road should soon be open" for an early conclusion of an African nuclear-weapon-free zone treaty, in light of South Africa's membership of the Nuclear Non-Proliferation Treaty and its termination of the former nuclear-weapons programme.

At the presentation of South Africa's gift (from left): South African Ambassador Johannes P. Roux; Mr. Pik Botha; Mr. Godfrey Hetisani, member of the South African Transitional Executive Council; and Dr. Blix. *(Credit: Quevenco, IAEA)*

Finland: WATRP review

Experts from Canada, Germany, Belgium, Switzerland, and the IAEA have concluded a year-long review of Finland's radioactive waste management programme. The review was conducted under the Agency's radioactive waste management assessment and technical review programme (WATRP) in response to a request of the Finnish Government. It covered work being done toward siting and building a conditioning facility for spent nuclear fuel; siting and construction of a repository; and the plans and activities for the conditioning and disposal of waste from decommissioning Finland's reactors when that becomes necessary in the future.

The review team noted that although the Finnish nuclear power programme is quite young, in comparison with that of many countries, Finland has had notable success in developing its radioactive waste management technologies and its capabilities to achieve a complete and sound storage and diposal programme. It pointed out that Finnish scientists participate in many international working groups and committees, both contributing to the international understanding of the subject and obtaining knowledge that they can apply to their own national programme. Overall, the experts were impressed with the high standard of work being done. Their recommendations addressed a number of technical areas: the manufacture and testing of full-scale copper canisters for use in the repository for spent fuel, so that any potential difficulties can be identified as early as possible in the programme; full-scale testing of the proposed microbiological method of treatment of organic waste at the Loviisa nuclear plant; maintaining and possibly increasing the resources of the regulatory body; and continued work to produce detailed guidance on the criteria that would be applied for granting approvals of spent fuel disposal.

The Czech Republic and the Slovak Republic also have requested WATRP services; the Czech review is almost finished and the Slovak review has been initiated. WATRP is a peer review service on radioactive waste management offered by the IAEA in response to specific requests from Member States. Such peer reviews provide the requesting Member State or organization with independent opinions and advice from recognized international experts, thus enhancing confidence in the system planned or in operation.

Iran: NWFZ concept discussed

IAEA Director General Hans Blix and a senior adviser visited Tehran in mid-April principally to discuss the concept of a nuclear-weapon-free-zone in the Middle East and the question of verification and safeguards in such a zone. Dr. Blix has a mandate to explore this subject from the IAEA's General Conference and has already visited other countries in the region to gather their views. The Director General also discussed technical co-operation matters including the possible use of radioisotope techniques to investigate the rise in the level of the Caspian Sea.

During the visit, Dr. Blix had talks with the Iranian Foreign Minister, Dr. Ali A. Velayati; the Chairman of the Atomic Energy Commission, Dr. Reza Amrollahi; the first Deputy to the President of the Islamic Republic of Iran, Dr. Hassan Habibi; the Deputy to the Speaker of the Majlis, Dr. Hassan Rouhani; and a number of members of parliament.

China: Nuclear regulatory review

The national regulatory process governing nuclear power activities in China was reviewed in May under the IAEA's International Regulatory Review Team (IRRT) programme. The 7-member team of safety experts from the IAEA and five countries found a regulatory system corresponding to those in use worldwide, with an independent regulatory body divorced from nuclear power promotional activities.

The basis for China's national regulations are safety codes and guides developed by the IAEA, thus assuring consistency with commonly accepted international practices.

The review team conducted its mission at the request of the Chinese government and its National Nuclear Safety Administration (NNSA), an indication of the importance the country is giving to international co-operation in matters of nuclear safety. China has three nuclear power plants in operation, two of French design at Daya Bay near Hong Kong and one of indigenous design at Qinshan near Shanghai. Additional plants are planned at both sites.

The team made a number of observations and recommendations at the conclusion of its mission, which was carried out from 23 April to 10 May 1994. It was impressed by the overall competence of the NNSA staff, which although lacking extensive practical experience, displayed the desire to learn and implement international practices. Headquarters staff are supported by the affiliated technical support organization, the Beijing Nuclear Safety Center. There are regional offices in Shanghai and Guangdong, as well as one in Chengdu which deals with research reactors and fuel cycle facilities.

The team noted that the licensing and review process employed for the Daya Bay unit conforms with good international practices.

The team's recommendations were directed at improving the effectiveness of the regulatory process. An area which has not yet received sufficient attention by the NNSA is the analysis of feedback from operational experience for accident prevention. The use of it, now common worldwide, identifies precursors to operational events and allows preventive measures to be taken.

A number of other recommendations were made concerning emergency planning and response and inspection procedures during nuclear plant operation and refuelling outages. Another important area in need of development is a strong safety culture at the NNSA and throughout the Chinese nuclear community.

Speaking at the conclusion of the mission, Dr. Morris Rosen IAEA Assistant Director General for Nuclear Safety, cited the participation of China in major international safety agreements and systems developed at the IAEA, including the forthcoming International Nuclear Safety Convention. China has been instrumental in the convention's development and the review team's findings show that it is ready to fulfill all obligations.

United Kingdom: OSART mission

A team of experts under the IAEA's Operational Safety Review Team (OSART) programme visited the Hunterston-B nuclear power station in the United Kingdom from 11-29 April 1994. The team included experts from Belgium, France, Germany, Hungary, Japan, Sweden, and the United States, as well as observers from India, Slovenia, and Ukraine.

The team found the plant's overall performance and safety to be of high standard, and made a number of proposals to management for further enhancing operational safety. The OSART was the third such mission to a UK nuclear plant. Others have been to Oldbury and Sizewell-B.

DPRK: Safeguards developments

In June 1994, IAEA Director General Hans Blix briefed the United Nations Security Council and the Agency's Board of Governors about safeguards developments in the Democratic People's Republic of Korea (DPRK) in connection with the refuelling of the DPRK's 5-megawatt (MWe) nuclear power reactor. On the basis of reports from its safeguards inspectors in the DPRK, the IAEA concluded in early June that the discharge of spent fuel from a 5-megawatt experimental nuclear power reactor has now made it impossible to select fuel rods for later measurements, which would show whether there has been any diversion of fuel from the reactor in the past years.

The action followed a number of developments in May, which are referenced in recent statements issued by the IAEA.

In a press release issued on 21 May, the IAEA stated:

" On 19 April, the DPRK notified the IAEA of its intention to carry out 'at an early date' the refuelling of the 5-MWe Experimental Nuclear Reactor. The Agency has made clear to the DPRK that specific safeguards activities — related to the selection, segregation, and securing of certain fuel rods — are indispensable at the time of the refuelling. This is to enable the Agency to verify through measurement at a later date that no fuel in the reactor has been diverted in the past. The Agency needs to verify that the fuel discharged is the first core of the reactor, as the DPRK has declared to be the case.

"The Agency has made clear to the DPRK that if these inspection activities do not take place during the core discharge campaign, then any subsequent measurements would be of no value, and the information necessary for the Agency to verify that, in the past, there has been non-diversion of nuclear material would be irretrievably lost. The Agency, therefore, urged the DPRK not to initiate the core discharge campaign without enabling Agency inspectors to take the proposed measures.

"On 12 May the DPRK informed the IAEA that it had already started the refuelling campaign. An Agency inspection team currently in the DPRK has confirmed that core discharge has indeed started and has reported on the extent of that discharge. The Agency has concluded that further discharge of fuel rods would jeopardize the possibility of the Agency applying the safeguards measures necessary to verify whether any fuel has been diverted in the past.

"The IAEA has confirmed to the DPRK by a telex of 19 May that the discharge of fuel without the safeguards measures requested by the IAEA constitutes a serious violation of the safeguards agreement and is being reported as such to the IAEA Board of Governors and to the Security Council of the United Nations. The Agency has asked the DPRK to make arrangements promptly for the requisite safeguards measures and has urged that until these are in place, further discharge be deferred.

"As of today (19 May 1994), it still seems possible to implement the required safeguards measures. Should the DPRK continue the discharge operation without these measures, it would result in irreparable loss of the Agency's ability to verify whether all nuclear material subject to safeguards in the DPRK is in fact under safeguards and that no such material has been diverted.

"In view of the above, the Agency has proposed sending a team of officials immediately to the DPRK to discuss arrangements necessary for the implementation of the safeguards measures required in connection with the discharge operation."

On 21 May, the IAEA received a telex from the DPRK which expressed readiness to receive an IAEA consultation team. An IAEA team of senior safeguards officials arrived in the DPRK for talks on 24 May 1994.

In a press release issued on 28 May, the IAEA stated:

"On 27 May 1994, a team of officials of the IAEA concluded its consultations in the DPRK on how to proceed with the implementation of the safeguards measures required during the refuelling of the Experimental Nuclear Power Reactor.

"Unfortunately, no agreement was reached. The DPRK rejected all IAEA proposals put forward with the aim of maintaining the IAEA's ability to select, segregate, and secure fuel rods for later measurements so as to be able to verify the history of the reactor core. The DPRK continued to maintain that in view of its 'unique status', it could not accept the IAEA verification measures proposed. A proposal presented by the DPRK could not be accepted because it would not enable the IAEA to verify the history of the reactor core.

"The team is returning to Vienna today (28 May). Two inspectors remain in the DPRK to report on further developments. The IAEA Secretariat has reported the outcome of the discussions to its Board of Governors and to the Security Council."

NEW IAEA APPOINTMENTS. A number of new appointments have been announced at the IAEA. Mr. Abraham Espino from Panama has been appointed Director of the Division of Budget and Finance, succeeding Mr. André Gue of France. Mr. Slimane Cherif from Algeria and Mr. David Sinden from Canada have been appointed Special Assistants in the Office of the Director General.

ELECTRIC POWER GROWTH: LOOK TO ASIA. Projected additions to the world's electrical power capacity are estimated to be around 550 gigawatts, of which 45% is in Asia, the US-based Utility Data Institute (UDI) has reported. Over the 1993-2002 time period, UDI estimates that the new capacity will be distributed as follows: 25% coal-fired; 21% gas-fired; 22% hydroelectric; 13% nuclear; and 8% oil-fired. About half of the projected new capacity is not yet under construction. UDI is a directory and database publishing unit of McGraw-Hill, Inc. Its recent estimates are published in its *World Directory of New Electric Power Plants.* More information may be obtained from UDI, 1200 G Street NW, Suite 250, Washington, DC 20005 USA.

ENERGY USE AND CO_2. A comprehensive overview of the world's energy use and associated emissions of carbon has been issued by the Energy Information Administration (EIA) of the US Department of Energy. Entitled *Energy Use and Carbon Emissions: Some International Comparisons,* the study examines international energy use patterns, trends, and energy-related carbon emissions since 1970. Among its key conclusions: the world share of *noncarbon-emitting* energy sources increased over the past two decades, particularly in the industrialized countries where the share grew to 17% in 1991 compared to 7% in 1970. Most of this increase was due to growth in nuclear power generation. More information may be obtained from the EIA, National Energy Information Center, Forrestal Building, Room 1F-048, Washington, DC 20585 USA.

RADIATION PROTECTION. Reports on radiation risks and controls recently have been issued by radiation protection bodies in the United States and the United Kingdom. In the USA, the National Council on Radiation Protection and Measurements (NCRP) has issued *Risk Estimates for Radiation Protection,* a critical examination of the information about risks from exposure to ionizing radiation. The principal focus is on stochastic effects, namely cancer and genetic effects. In the United Kingdom, the National Radiological Protection Board (NRPB) has issued *Guidance on Restrictions on Food and Water Following a Radiological Accident.* It provides revised advice in light of recommendations from the International Commission on Radiological Protection and the Council of the European Community Regulations on the subject. More information may be obtained, respectively, from the NCRP, 7910 Woodmont Ave., Suite 800, Bethesda, Maryland 20814-3095 USA; and the NRPB, Chilton, Didcot, Oxon OX11 ORQ, United Kingdom.

RADIOACTIVE MATERIALS AND THE ECONOMY. The use of radioactive materials in medicine and other fields in the United States contributes millions of jobs and dollars to the economy, according to a recent study reported by the Nuclear Energy Institute (NEI). The study shows that in 1991 radioactive materials were responsible for $257 billion in total industry gross sales; 3.7 million jobs; $11 billion in corporate profits; and $45 billion in tax revenues to local, state, and federal governments. The figures do not include the use of nuclear energy to generate electricity. This produces about $73 billion in annual gross domestic product and 417 000 jobs in the United States. More information may be obtained from NEI, 1776 Eye Street NW, Washington, DC 20006-3708 USA.

NON-PROLIFERATION, SAFEGUARDS, AND THE NPT. Mr. David A.V. Fischer, an expert in the field of safeguards and nuclear non-proliferation, has written an authoritative and comprehensive book on the world's attempts to control the spread of nuclear weapons. Entitled *Towards 1995: The Prospects for Ending the Proliferation of Nuclear Weapons,* the book examines the spread of nuclear weapons, the steps that have been taken to control this spread, and the prospects of containing it during the remainder of the century. Its focus is on the 1995 conference of the parties to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) which will decide the future of the Treaty. The book is published by Dartmouth Publishing Company Ltd., Gower House, Croft Road, Aldershot, Hants GU11 3HR, United Kingdom.

Reports and Proceedings

Use of Irradiation to Control Infectivity of Food-borne Parasites, *Panel Proceedings Series No. 933, 400 Austrian schillings, ISBN 92-0-103193-9*

Measurement Assurance in Dosimetry, *Proceedings Series No 930, 1900 Austrian schillings, ISBN 92-0-100194-0*

Compliance Assurance for the Safe Transport of Radioactive Material, *Safety Series No. 112, 360 Austrian schillings, ISBN 92-0-100394-3*

Uranium Extraction Technology, *Technical Reports Series No. 359, 1100 Austrian schillings, ISBN 92-0-103593-4*

Status of Technology for Volume Reduction and Treatment of Low and Intermediate Level Solid Radioactive Waste, *Technical Reports Series No. 360, 360 Austrian schillings, ISBN 92-0-100494-X*

Plasma Physics and Controlled Nuclear Fusion Research 1992, *Vols. 1, 2, 3 and 4; ISBN 92-0-101093-1, 2200 Austrian Schillings, ISBN 92-0-101193-8, 1900 Austrian schillings; ISBN 92-0-101293-4, 1560 Austrian schillings, ISBN 92-0-101393-0, 240 Austrian schillings*

Management of Insect Pests: Nuclear and Related Molecular and Genetic Techniques, *Proceeding Series, 1900 Austrian schillings, ISBN 92-0-000293-5*

Strengthening Radiation and Nuclear Safety Infrastructures in Countries of the Former USSR, *300 Austrian schillings, ISBN 92-0-102793-1*

Reference books/statistics

IAEA Yearbook 1993, *500 Austrian schillings, ISBN 92-0-102493-2*

Energy, Electricity and Nuclear Power Estimates up to 2010, *Reference Data Series No. 1, ISBN 92-0-102193-3 (IAEA-RDS-1/13)*

Nuclear Power Reactors in the World, *Reference Data Series No. 2, ISBN 92-0-101593-3 (IAEA-RDS-2/13))*

Nuclear Research Reactors in the World, *Reference Data Series No. 3, ISBN 92-0-103793-7*

Radioactive Waste Management Glossary, *200 Austrian schillings, ISBN 92-0-103493-8*

The Law and Practices of the International Atomic Energy Agency 1970-1980, Supplement 1 to the 1970 edition of Legal Series No. 7, *Legal Series No. 7-S1, 2000 Austrian schillings, ISBN 92-0-103693-0*

Agreements Registered with the International Atomic Energy Agency, 11th edition, *STI/PUB No. 954, 800 Austrian schillings, ISBN 92-0-100994-1*

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Scindia House, New Delhi-110 001

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Jugoslovenska Knjiga, Terazije 27,
P.O. Box 36, YU-11001 Belgrade

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International Atomic Energy Agency
Wagramerstrasse 5, P.O. Box 100,
A-1400 Vienna, Austria

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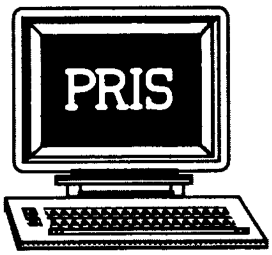


Database name
Power Reactor Information System (PRIS)

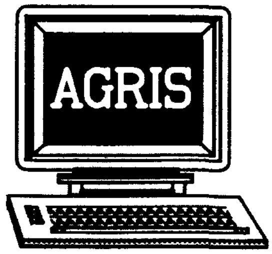
Type of database
Factual

Producer
International Atomic Energy Agency in co-operation with 29 IAEA Member States

IAEA contact
IAEA, Nuclear Power Engineering Section, P.O. Box 100
A-1400 Vienna, Austria
Telephone (43) (1) 2360
Telex (1)-12645
Facsimile +43 1 234564
Electronic mail via BITNET/INTERNET to ID: NES@IAEA1.IAEA.OR.AT

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

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



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

Type of database
Bibliographic

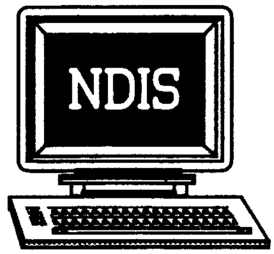
Producer
Food and Agriculture Organization of the United Nations (FAO) in co-operation with 172 national, regional, and international AGRIS centres

IAEA contact
AGRIS Processing Unit
c/o IAEA, P.O. Box 100
A-1400 Vienna, Austria
Telephone (43) (1) 2360
Telex (1)-12645
Facsimile +43 1 234564
Electronic mail via BITNET/INTERNET to ID: FAS@IAEA1.IAEA.OR.AT

Number of records on line from January 1993 to date
more than 130 000

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

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



Database name
Nuclear Data Information System (NDIS)

Type of database
Numerical and bibliographic

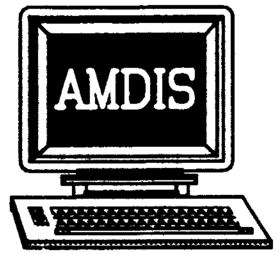
Producer
International Atomic Energy Agency in co-operation with the United States National Nuclear Data Centre at the Brookhaven National Laboratory, the Nuclear Data Bank of the Nuclear Energy Agency, Organisation for Economic Co-operation and Development in Paris, France, and a network of 22 other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

IAEA contact
IAEA Nuclear Data Section, P.O. Box 100
A-1400 Vienna, Austria
Telephone (43) (1) 2360
Telex (1)-12645
Facsimile +43 1 234564
Electronic mail via BITNET/INTERNET to ID: RNDS@IAEA1.IAEA.OR.AT

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

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

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



Database name
Atomic and Molecular Data Information System (AMDIS)

Type of database
Numerical and bibliographic

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

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

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

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

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

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

Database name
International Nuclear Information System (INIS)

Type of database
Bibliographic

Producer
International Atomic Energy Agency in co-operation with 87 IAEA Member States and 16 other international organizations

IAEA contact
IAEA, INIS Section, P.O. Box 100,
A-1400 Vienna, Austria
Telephone (43) (1) 2360 2842
Telex (1)-12645
Facsimile +43 1 234564
Electronic mail via
BITNET/INTERNET to ID:
ATIEH@NEP01.IAEA.OR.AT

Number of records on line from January 1976 to date
more than 1.5 million

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

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

POSTS ANNOUNCED BY THE IAEA

SENIOR TRANSLATOR (94-014), Department of Administration. This P-4 post requires a university degree or equivalent. Applicants must have Spanish as their mother-tongue or principal language of education and be able to write clearly and concisely. Also required is 10 years of experience, and acquired mastery of the terminology of several areas in the atomic energy field and demonstrated soundness of judgment on translation questions. *Closing date: 29 July 1994.*

LOCAL AREA NETWORK (LAN) SUPPORT SPECIALIST (94-016) Department of Nuclear Energy and Safety. This P-1/P-2 post requires a university degree in a computer related field of study, 2 years of relevant practical experience in providing technical and training support for users of local area networks and personal computers. *Closing date. 29 July 1994.*

CHEMIST (94-019), Department of Research and Isotopes. This P-4 post requires a Ph. D. or equivalent in nuclear/radiochemistry, industrial chemistry or applied nuclear physics with at least 10 years of relevant research/technical experience in nuclear analytical methods and their applications in science, technology and industry, preferably with additional field application experience in the use of nucleonic control systems in industry. *Closing date: 19 August 1994*

PERSONNEL DEVELOPMENT SPECIALIST (94-020), Department of Administration. This P-3 post requires a university degree in the arts or sciences in a field such as management, public administration, education or psychology, and at least 6 years of experience in personnel administration, including the design and presentation of training courses, and management training in particular. *Closing date: 19 August 1994.*

SYSTEMS ANALYST/PROGRAMMER (94-021), Department of Safeguards. This P-3 post requires a university degree, preferably in computer science and at least 6 years of relevant experience. Also required is experience with the design and development of DOS and Windows-based applications using high-level languages and application packages, and with relational DBMS. *Closing date: 19 August 1994.*

SYSTEMS PROGRAMMER (94-022), Department of Nuclear Energy and Safety. This P-3 post requires a university degree in computer science, related field or equivalent, and at least 6 years of relevant practical experience in systems programming techniques. Extensive experience with advanced PC technology utilized in an OS/2 and Windows software environment. Detailed knowledge of LAN operating systems and related products, LAN server technology (Windows NT and UNIX), network protocols, system interconnection and related hardware platforms. *Closing date: 19 August 1994.*

SYSTEMS ANALYST (94-023), Department of Nuclear Energy and Safety. This P-3 post requires a university degree in computer science or related field, and at least 6 years of relevant experience in development of computerized systems using modern techniques and tools, according to recognized methods and standards. Also required is experience with a relational database management system, Windows development tools, knowledge of SQL and structured development techniques, and experience in project management. *Closing date: 19 August 1994.*

TRAINING OFFICER (94-701), Department of Research and Isotopes. This P-3 post requires an advanced university degree in environmental science, and at least 6 years of experience in research and training at both national and international levels. *Closing date: 5 September 1994.*

RESEARCH SCIENTIST (94/702), Department of Research and Isotopes. This P-2 post requires an advanced university degree, preferably a Ph.D. in a relevant discipline with at least 2 years of working and research experience with the ICPMS technique. Also required is practical experience in the field of marine radioactivity or trace element studies. *Closing date: 5 September 1994.*

SECTION HEAD (94/025) Department of Safeguards. This P-5 post requires an advanced university degree in nuclear science or engineering, chemistry, chemical engineering or equivalent. Also required is at least 15 years of experience in the nuclear industry with particular emphasis on chemical reprocessing, plutonium conversion and mixed oxide fuel manufacturing of which at least 5 years were involved with safeguards. *Closing date: 9 September 1994.*

PLANT BREEDER/GENETICIST (94/024) Department of Research and Isotopes. This P-4 post requires a Ph.D. or equivalent with specialization in plant breeding and genetics, with sound training in agronomy, plant biotechnology, plant physiology, and a minimum of 10 years of professional experience after Ph.D. including application of nuclear techniques. Also required is the ability to use a personal computer. *Closing date: 9 September 1994.*

IAEA SAFEGUARDS INSPECTOR (94/SGO-4), Department of Safeguards. This P-4 post requires a university degree in chemistry, physics, engineering or electronics/instrumentation or equivalent with at least 10 years of relevant experience with the nuclear fuel cycle, processing of nuclear materials, material accounting or non-destructive analysis, preferably under plant operation conditions. Also required is national or international safeguards experience, demonstrated experience in the use of personal computers, and proven supervisory ability. *Closing date: 31 December 1994.*

IAEA SAFEGUARDS INSPECTOR (several positions) (94/SGO-3), Department of Safeguards. These P-3 posts require a university degree or equivalent with emphasis in a nuclear discipline, and at least 6 years of relevant experience in the nuclear field, preferably in the operation of nuclear facilities. Also required is demonstrated experience in the use of personal computers. *Closing date: 31 December 1994.*

READER'S NOTE:

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

ON-LINE COMPUTER SERVICES. IAEA vacancy notices for professional positions, as well as application forms, now are available through a global computerized network that can be accessed directly. Access is through the Internet Services. The vacancy notices are located in a public directory accessible via the normal Internet file transfer services. To use the service, connect to the IAEA's Internet address NESIRS01.IAEA.OR.AT (161.5.64.10), and then log on using the identification *anonymous* and your user password. The vacancy notices are in the directory called *pub/vacancy_posts*. A *README* file contains general information, and an *INDEX* file contains a short description of each vacancy notice. Other information, in the form of files that may be copied, includes an application form and conditions of employment.

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ENC '94 ENS – ANS – FORATOM

International Nuclear Congress + World Exhibition Atoms for Energy

A dialogue with the industry's young generation on nuclear's future

Lyon, France, October 2–6, 1994

ENC '94 – the unique combination of the world's major nuclear science & industry Expo with the largest international nuclear congress.

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CH-3001 Berne / Switzerland, Telefax ++41 31 382 44 66

Collection and classification of human reliability data for use in probabilistic safety assessments
To provide an exchange of operating experience in investigating and analyzing the root causes of human performance-related events to prevent their re-occurrence, thus improving plant safety and stimulating the exchange of methods and experience regarding collection and classification of human performance data for inclusion in probabilistic safety assessments.

Characterization and evaluation of high-dose dosimetry techniques for quality assurance in radiation processing
To understand the effect of various parameters on the performance of several routine dosimeters presently in use. To facilitate the extension of the Agency's International Dose Assurance Service (IDAS) to low energy (<4 MeV) electron beams and X-ray sources.

The standardization of iodine-131 treatment for hyperthyroidism with an intent to optimize radiation dose and treatment response
To standardize iodine-131 treatment for hyperthyroidism (diffuse toxic goitre) with the objective of optimizing radiation dose and treatment response, and identifying important factors which influence the outcome of the treatment.

Nuclear techniques for diagnosis of bacterial and viral infections (African region)
To develop expertise in the African region in the use of DNA probe hybridization and polymerase chain reaction amplification methods in diagnosis of diseases such as AIDS, viral hepatitis, and tuberculosis and evaluate different primers and probes which work best for the pathogen strains in the region.

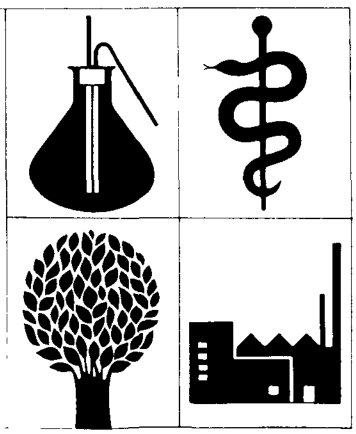
Clinical application of radiosensitizers in cancer radiotherapy
To enhance radiation-induced therapeutic gain by introducing the effective hypoxic cell radiosensitizer in treatment management.

Development of reference input parameter library for nuclear model calculations of nuclear data (Phase I: Starter file)
To develop a starter file of the input parameter library. The file is designed to provide necessary input for nuclear reaction model calculations of nuclear data for incident energies up to about 30 MeV

Radiative cooling rates of fusion plasma impurities
To establish a comprehensive recommended database for the radiative power losses of the most important plasma impurities in the range of plasma parameters relevant for presently operating and next generation fusion devices.

Validation of accident and safety analysis methodology
To promote research and the exchange of information on validation of accident and safety analysis methodology covering the aspects of design basis accidents (DBAs) and beyond DBAs (so-called severe accidents).

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



IAEA SYMPOSIA & SEMINARS

AUGUST 1994

Interregional Seminar on Isotope Techniques in Arid and Semi-Arid Land Hydrology, ***Vienna, Austria*** (15-26 August)

Interregional Seminar on Radiotherapy Dosimetry: Radiation Dose in Radiotherapy from Prescription to Delivery, ***Brazil*** (27-30 August)

SEPTEMBER 1994

Conference on Nuclear Power Option, ***Vienna, Austria*** (5-8 September)

15th International Conference on Plasma Physics and Controlled Nuclear Fusion Research, ***Seville, Spain*** (26 September-1 October)

OCTOBER 1994

Seminar on Radioactive Waste Management Practices and Issues in Developing Countries, ***Beijing, China*** (10-14 October)

International Symposium on Spent Fuel Storage — Safety, Engineering and Environmental Aspects, ***Vienna, Austria*** (10-14 October)

FAO/IAEA International Symposium on Nuclear and Related Techniques in Soil/Plant Studies on Sustainable Agriculture and Environmental Preservation, ***Vienna, Austria*** (17-21 October)

International Conference on Radiation, Health and Society Comprehending Radiation Risks, ***Paris, France*** (24-28 October)

JANUARY 1995

Symposium on Electricity, Health and Environment Data Bases and Methodologies for Comparative Assessment, ***Vienna, Austria***
(Preliminary)

FEBRUARY 1995

Symposium on Isotope Techniques in Water Resources Development, ***Vienna, Austria*** (20-24 March)

MAY 1995

Seminar on Management of Ageing Research Reactors, ***Hamburg, Germany*** (8-12 May)

GENERAL CONFERENCE

IAEA General Conference, Thirty-eighth Regular Session, ***Vienna, Austria***, (19-23 September 1994)

94-01257

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Tel: (43-1) 2360-1270
Facsimile: (43-1) 234564

IAEA MEMBER STATES

1957

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

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

1959
Iraq

1960
Chile
Colombia
Ghana
Senegal

1961
Lebanon
Mali
Zaire

1962
Liberia
Saudi Arabia

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

1964
Cameroon
Gabon
Kuwait
Nigeria

1965
Costa Rica
Cyprus
Jamaica
Kenya
Madagascar

1966
Jordan
Panama

1967
Sierra Leone
Singapore
Uganda

1968
Liechtenstein

1969
Malaysia
Niger
Zambia

1970
Ireland

1972
Bangladesh

1973
Mongolia

1974
Democratic People's Republic of Korea
Mauritius

1976
Qatar
United Arab Emirates
United Republic of Tanzania

1977
Nicaragua

1983
Namibia

1984
China

1986
Zimbabwe

1991
Latvia
Lithuania
Yemen, Republic of

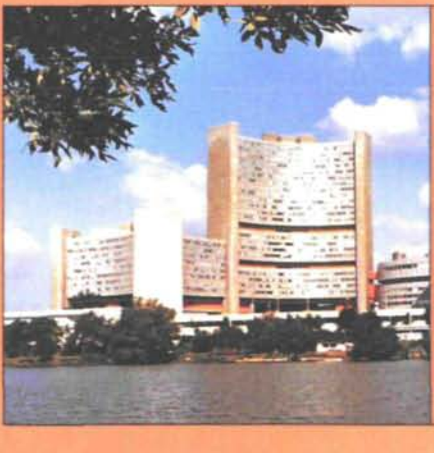
1992
Croatia
Estonia
Slovenia
Uzbekistan

1993
Armenia
Czech Republic
Kazakhstan
Marshall Islands
Slovakia
Former Yugoslav Republic of Macedonia

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

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

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



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

IAEA headquarters, at the Vienna International Centre.

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

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

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ALOKA CO., LTD.
6-22-1 Mure, Mitaka-shi, Tokyo 181, Japan
Telephone: (0422) 45-5111
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