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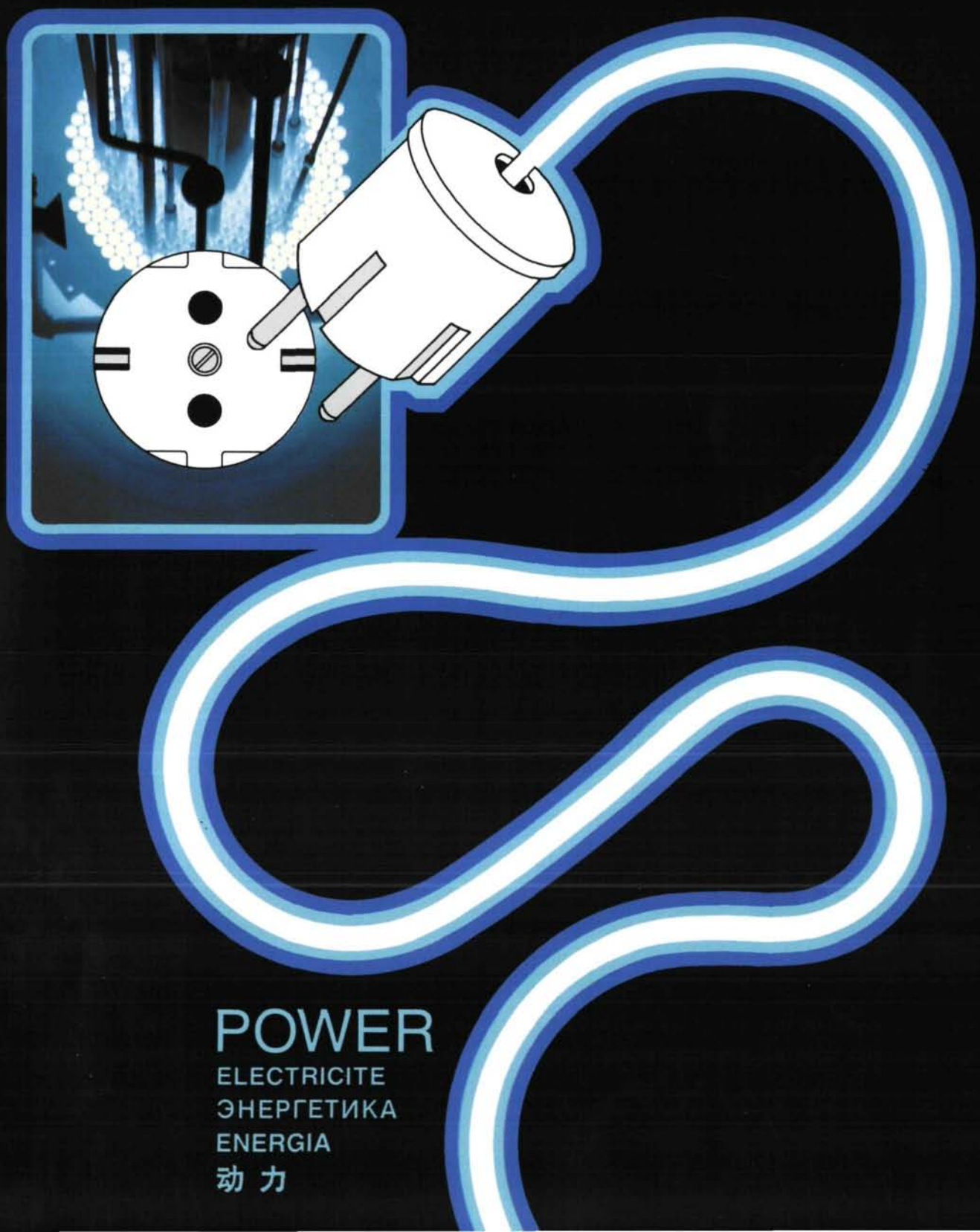

## POWER

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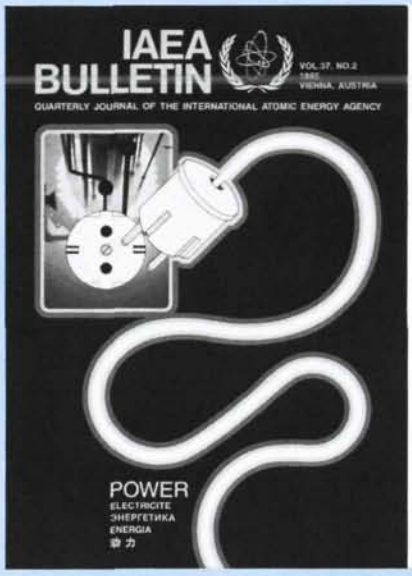


***Front cover:*** Electrical power remains the engine of economic development, yet much of the world cannot depend on reliable sources of fuel. As populations grow, and electricity needs rise, the situation may become more acute as we head into the next century. Many countries today are taking closer looks at their electricity options and strategies in a changing and more competitive marketplace. In many cases, the IAEA is working with national and international experts to help countries comparatively plan for and assess their energy futures. Several articles in this edition report on aspects of this work, and at the roles nuclear power can play to ensure sustainable electricity generation. In October 1995, a major international conference on electricity options sponsored by the IAEA in Vienna will examine many of the issues in more depth. *(Cover design: Ms. Hannelore Wilczek, IAEA)*

***Facing page:*** Flags await the wind in Vienna, Austria, at the headquarters of the International Atomic Energy Agency. *(Credit: Pavlicek, IAEA)*

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# Electricity, health, and the environment: The DECADES project

*An update of an inter-agency project providing a framework for comparatively assessing electricity options and strategies*

by
**Evelyne Bertel**

Environmental and health-related impacts of different energy systems, including those associated with the production of electricity, have become significant national and global issues. Current debates, for example, centre on the health effects of pollution, environmental damage due to acidification of forests and lakes, the safety of nuclear power plants and radioactive waste management, and the potential risks of global climate change induced by increasing atmospheric concentrations of carbon dioxide and other greenhouse gases.

All fuel chains within the electricity generation system involve some health risks and lead to some environmental impacts. This fact — together with the needs of many countries to define their energy and electricity programmes for the coming decades — stands behind a growing interest in the application of improved data, tools, and techniques for comparative assessment of different electricity generation options, particularly from environmental and human health viewpoints.

At the international level, the need to design and implement sustainable strategies in the electricity sector has been stressed throughout the 1990s at major global meetings. This was the case in 1991 at the Senior Expert Symposium on Electricity and the Environment (Helsinki), in 1992 at the United Nations Conference on Environment and Development (UNCED, Rio de Janeiro), and at the 15th Conference of the World Energy Council (Madrid). The Agenda 21, adopted by UNCED, emphasizes that environmental and development concerns should be integrated into the decision-making process. The Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), prepared in 1993 and 1994, highlights that options for alleviating the risks of global climate change should be comprehensively assessed and that adequate policies should be implemented to promote the most efficient technologies for reducing greenhouse gas emissions.

In the electricity sector, the essential goal of sustainable strategies is to provide the energy services required for supporting economic growth and improving quality of life, especially in developing countries, while minimizing the health and environmental impacts of human activities.

In mid-1992, the IAEA and a number of other organizations initiated an inter-agency joint project on databases and methodologies for comparative assessment of different energy sources for electricity generation, known as DECADES. Its objective is to enhance capabilities for incorporating health and environmental issues into comparative assessments of different electricity generation chains and strategies in the process of energy planning and decision-making.

The project is carried out jointly by the IAEA, the European Commission (EC), the Economic and Social Commission for Asia and the Pacific (ESCAP), the International Bank for Reconstruction and Development (IBRD/World Bank), the International Institute for Applied Systems Analysis (IIASA), the Nuclear Energy Agency of the Organization for Economic Cooperation and Development (OECD/NEA), the Organization of Petroleum Exporting Countries (OPEC), the United Nations Industrial Development Organization (UNIDO), and the World Meteorological Organization (WMO). Several other international organizations, including the United Nations Environment Programme (UNEP) and the World Health Organization (WHO), are contributing to the project within their areas of expertise. The Project Secretariat, comprised of representatives of the four Vienna-

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**The Cruas nuclear power plant in France.** *(Credit: EDF, Henri Cazin)*

based organizations (IAEA, IIASA, OPEC, and UNIDO), co-ordinates activities within the scope and objectives defined by the project's Joint Steering Committee (JSC).

This article reviews the major elements of the DECADES project and reports on selected activities and results to date. It also looks at future developments, including the October 1995 international conference at which results will be more fully presented and reviewed.

## Major elements of DECADES

The DECADES project addresses some, but not all, of the issues involved in comparative assessments of different electricity generation options and strategies. The project principally aims toward providing comprehensive information about different energy chains for electricity generation — i.e., fossil fuels, nuclear power, and renewable sources — and user friendly tools for accessing, handling, and processing key information needed for planning and decision-making purposes.

The project's first phase, from mid-1992 to mid-1995, focuses on the development of databases and analytical tools for electricity system planning and decision support studies, and their concrete application in national case studies. Upon completion of this first phase, it is expected that the participating organizations will consider the feasibility of jointly undertaking further activities in this field in order to address certain issues more comprehensively. It is also expected that the exploratory national case studies will be extended with the objective of fully testing and demonstrating the use of the DECADES tools in planning and decision-making for the electricity sector.

The major components of the project are:

- establishment of databases, in particular of a comprehensive technology inventory, providing characteristics of energy chains for electricity generation, from fuel extraction to waste management, covering technical, economic, health and environmental aspects;
- development of an information system (computer software) for user-oriented access to electronic databases, allowing retrieval, display, and handling of the data;
- development of a software package integrating technical, economic, environmental, and health aspects into electricity system analysis and expansion planning;
- compilation and review of methodologies, analytical models, and computerized tools for comparative assessment, with emphasis on those tools that may be used in the planning and decision-making process for the electricity sector;
- carrying out of some case studies addressing

specific national or regional issues, with the primary objective of illustrating the applicability of the data bases and computerized tools in the planning and decision- making process.

## DECADES products

Products developed within the project's framework — i.e., computer tools, including databases and publications — are designed for use by energy analysts and planners in national institutes, in particular in developing countries and international organizations. However, they will also be relevant for use by a broader audience of individuals and groups interested in technical, economic, health, and environmental aspects of electricity generation options. In this connection, special emphasis has been given in the design of the products to ensure coherence, consistency, and transparency of the data and tools.

Since the DECADES products are developed and maintained by international organizations, they will be distributed upon request to non-profit international organizations and national institutes. Workshops and seminars will be organized to provide opportunities for exchange of information and experience between users and with the developers of the databases and computer tools.

The products are intended to be of particular relevance for planning and implementing electricity system expansion strategies in developing countries. These countries, which are experiencing the highest rates of growth in electricity demand and rapidly increasing environmental problems, need reliable information and easy-to-use tools to design and implement economically competitive and environmentally sound strategies for electricity supply. The generic data provided by the DECADES project, as well as the computer structure for collecting, storing, and processing specific national data, will be useful in the process of establishing a country-specific framework for electricity planning. The methodologies that will be reviewed and demonstrated could also serve as a basis for comprehensive and coherent approaches that could be adapted to each specific national context.

For international organizations, the products can be useful tools in that they reflect a broad consensus on reference data and methodological approaches which could be used for analysis and studies in different countries and regions. The tools could be applied within the framework of their technical assistance programmes to developing countries.

The transparency and user friendliness of the DECADES products are key aspects of their design. These features should facilitate their use by energy/electricity system analysts and senior executives, as well as by a broader public less familiar with technical issues. In this connection, the dissemination of the databases and reports is intended to lead to a better understanding of the implications of electricity generation choices and policies.

The products developed up to April 1995 and already distributed to a number of selected users include:

- a database management system (DBMS), distributed in electronic format for use on personal computers (PCs) together with a user's manual. The package includes: a Reference Technology Data Base (RTDB) containing information on different energy chains for electricity generation, including their technical and economic parameters, emissions, and other residuals at each level of the chains; a computer structure for establishing a user/country specific database; and a graphical user interface for accessing, displaying, and handling the information contained in the databases.
- a software package (DECPAC Phase I) for electricity system planning, which is provided as executable code with a user's manual. The package runs on PCs and includes the supporting databases developed within the project, i.e. the RTDB and Country Specific Data Bases (CSDBs) whenever they have been established by national scientific teams.
- a document on computer tools for comparative assessment of electricity generation options and strategies. It provides information on selected PC-based computer tools currently available or expected to be available in the near future;
- interim reports on case studies being carried out to assess and compare alternative strategies in the electricity sector, taking into account their technical, economic, health, and environmental aspects. The studies illustrate the use, in the planning and decision-making process, of the databases and computer tools developed and reviewed within the DECADES project.

## DECADES databases

The databases within the DECADES project cover not only currently available technologies but also advanced technologies expected to be commercially deployed within the next two or three decades. They are designed for use on personal computers with an accompanying database management system.

**Technology databases.** The technology inventory databases contain information on all levels of different energy chains, i.e., fossil fuels, nuclear power, and renewable energy sources, for electricity generation. Data on fuel characteristics and abatement technologies are included. Transmission and end-use of electricity are not covered in the first phase of the project, but the database structure and management system are flexible enough to allow for incorporating these levels at a later stage.

**Country Specific Data Bases (CSDBs).** CSDBs are being developed by national institutes mainly under research or scientific contracts with the IAEA. Data on electricity generation technologies in a given country or region are collected by national teams and stored in a computer structure identical to that of RTDB. Technical support and guidance are provided by the IAEA on the use of the DBMS for establishing country-specific databases. Furthermore, the information contained in RTDB can be used for complementing and checking the consistency of the data available in the country.

**Vendor database.** As part of the DECADES technology inventory, comprehensive information on state-of-the-art electricity generation chain facilities offered by manufacturers would be highly valuable for users. Recognizing this need, the JSC recommended to establish an Extended Vendor Specific Data Base providing quantitative and qualitative information on commercial equipment and facilities currently available from vendors. Its establishment will be considered during the second phase of the DECADES project.

**Toxicology database.** Data on toxicology profiles for pollutants released at different levels of energy chains for electricity generation are needed for assessing health impacts resulting from the emissions. Although the first phase of the project will not address comprehensively the issues of health impact assessment, the JSC recommended to collect and structure the data that will be required for this purpose at an early stage of the project. The prototype Toxicology Data Base (TOXDB) is based largely upon an existing one established by UNEP and WHO. It covers most chemical products emitted at all levels of the energy chains for electricity generation. Information on the toxicity of radiochemicals has been collected to complement this existing data and to cover dose-effect relationships for all significant pollutants. TOXDB will also contain textual information related to toxicology profiles, as well as standards and regulations in different countries on emission limits.

**Health and environmental database.** A database on Health and Environmental Impacts of Energy Systems for Electricity Generation (HEIES) also will be developed. It will be used for storing results from selected studies and measurements related to health and environmental impacts from different electricity generation chain facilities and systems.

**DECADES Computer Products and Documents**

***Documents completed, in preparation, and planned under the DECADES project include:***

- The DECADES Project – Outline and General Overview
- Computerized Tools for Comparative Assessment of Electricity Generation: Options and Strategies
- DECADES Databases: Overview and General Description (in preparation)
- Reference Technology Data Base (RTDB) Vol. 1: Overview and General Description (working paper)
- Reference Technology Data Base (RTDB) Vol. 2: User's Manual (in preparation)
- Reference Technology Data Base (RTDB) Vol. 3: Description of Computer Structure and Data Management System (working paper intended for data management specialists)
- DECADES Software Package (DECPAC) Vol. 1: Overview and General Description of Software Design and Functions
- DECADES Software Package (DECPAC) Vol. 2: User's Manual
- Case Studies on Comparative Assessment of Electricity Generation Options: Vol. 1: Executive Summary (working paper)
- Case Studies on Comparative Assessment of Electricity Generation Options: Vol. 2: Detailed Reports on Country Studies (working paper)
- Reference Book on Incorporating Economic, Social, Health and Environmental Concerns into Policy Making for the Power Sector (in preparation)
- Electricity, Health and the Environment: Comparative Assessment in Support of Decision Making, Proceedings of a Symposium to be held in October 1995 (subsequent publication by the IAEA)

***Electronic databases and software include:***

- Reference Technology Data Base and Data Base Management System (released)
- DECADES Software Package (DECPAC) Phase 1 (released)
- Toxicology Data Base (under development)
- Health and Environmental Impacts of Energy Systems for Electricity Generation Data Base (under development)

## Analytical tools

Although a number of methodologies, models, and tools exist or are under development for comparative assessment of energy/electricity supply options and strategies, no single methodology, model, or tool incorporates all the elements needed for a comprehensive approach. Potential users thus need information on the different approaches, and their capabilities and limitations. Under the DECADES project, a review

was carried out of methodologies and models for comparative assessment of analytical tools for use on personal computers that are available at little or no cost. A detailed project document that catalogues available tools has been prepared. Additionally, a group of international experts from the IAEA and World Bank is preparing a reference book focusing on the incorporation of economic, social, health, and environmental aspects into policy-making for the power sector.

Within the DECADES project, software was develped to provide an integrated tool for comparative assessment of electricity options and strategies in the process of system expansion planning. The software package (DECPAC Phase 1) implemented in the project's first phase is intended to be a screening tool for preliminary assessment and selection of options that might be investigated further. It includes analysis modules — covering electricity systems, primary energy supply, and the environment — that have been drawn from methodological approaches and computer codes developed by the IAEA in co-operation with the Argonne National Laboratory in the United States. These include the Wien Automatic System Planning model (WASP) and the Energy and Power Evaluation Program package (ENEP).

## Case studies

Within the DECADES framework, the scope and objective of the case studies were defined by national scientific teams. They are focusing on concrete issues that have to be addressed by analysts and planners in support of the decision-making process.

The IAEA has established two Co-ordinated Research Programmes (CRPs), which provide an organizational and support framework for national institutes from Member States wishing to undertake case studies in their respective countries. Other studies are supported by the IAEA through other mechanisms, while some are being carried out by other organizations participating in the DECADES project, e.g., ESCAP, IBRD, and UNIDO. These studies also will contribute to the overall set of DECADES case studies.

The two CRPs were initiated over the past 2 years. The first one, started in December 1993, focuses on case studies to assess and compare the potential role of nuclear power and other options in reducing emissions and residuals from electricity generation. Research contracts and agreements have been signed with 19 Member States. The second CRP, launched in April 1994, is directed at comparative health and environmental risks of nuclear and other energy systems. Eleven scientific teams are participating in this research. Reports from each case study will be prepared by national teams and published in the DECADES Project Document Series.

## Milestones and future directions

In October 1995, the IAEA and its DECADES partners will convene the International Symposium on Electricity, Health and the Environment: Comparative Assessment in Support of Decision Making. The meeting marks a major milestone of the DECADES project. Technical and panel sessions on various topics will draw upon results of the DECADES project, as well as other international and national studies. Computer tools available to decision makers for carrying out comparative assessment studies also will be demonstrated. The symposium thus offers to provide a valuable base of comprehensive information on issues related to assessing electricity options.

The results obtained within the DECADES project so far are encouraging. Many experts, in particular from developing countries, have expressed interest in the project. More than 15 national institutes are already using the RTDB computer structure. Moreover, many of the same countries have requested training on the use of DECPAC.

In 1995, work plans are placing emphasis on maintenance, enhancement, and dissemination of DECADES products and tools. The work includes a systematic expert review of data contained in RTDB and the preparation of more extensive numerical, textual, and pictorial information. More workshops also are being organized to assist national teams in establishing country-specific databases. Also under way is the final design and implementation of the databases covering toxicological and health and environmental information, and the further improvement of the DECADES software for electricity system planning, DECPAC.

Most tasks within DECADES draw upon ongoing programmes of the project's participating organizations. In this connection, the IAEA in years ahead is planning to continue its emphasis on DECADES-related activities through its programme on comparative assessment of nuclear power and other options. Important ingredients of the programme are national and regional technical co-operation projects designed to assist countries in applying computer tools and models for analyzing their electricity needs and for effectively assessing the risks and benefits of specific technologies. ❐

# Radiation in perspective: Improving comprehension of risks

*Report of an international conference that explored why radiation risks are so commonly misunderstood*

**by Franz-Nikolaus Flakus**

Over the past century, few nuclear issues have commanded as much public and scientific attention as those related to radiation. Based on the scientific record and public debate, one clear message has emerged: radiation's real and perceived risks are commonly misunderstood. There are significant gaps between what scientists have documented about radiation effects and what the public generally believes to be true. Communication of the facts has proved difficult at best.

At local and national levels, efforts to bridge communication gaps have been central ingredients of nuclear information programmes for many years. At the global level, the problems now are being more directly addressed. In late 1994, the IAEA co-sponsored the first major international meeting principally devoted to the comprehension of radiation risks.* More than 400 health and regulatory authorities, social scientists, radiation experts, journalists, and nuclear communicators from 50 countries and nine international organizations attended the week-long conference. Held at the Carrousel du Louvre in Paris, it was organized at the invitation of France and hosted by the Institut de Protection et de Sûreté Nucléaire (IPSN). *(See box, next page.)*

This article highlights selected issues discussed at the conference, and offers some insights into the challenge of improving the communication about, and the comprehension of, radiation and its associated risks.

## The scientific record and public perception

The conference featured technical sessions devoted to topics and case studies that have been particularly sensitive to misinterpretation in the past. Selected topics are briefly reviewed here.

**Assessment of radiation health effects.** According to our current knowledge, two main types of health effects induced by exposure to ionizing radiation are distinguished: effects mainly linked to cell killing (e.g. skin burns) called *deterministic effects*, and effects linked to cell modification (e.g. cancers or genetic disorders) called *stochastic* effects. Deterministic effects develop above a threshold and the severity of the effect increases with dose. For stochastic effects, the *probability* of occurrence increases with dose. Carcinogenesis involves a multistep process. A relatively long latency period is needed before clinical diagnosis can be made.

Stochastic effects of radiation are today not distinguishable from similar effects of other causative agents (e.g. tobacco, chemicals). Consequently, their occurrence can only be established in epidemiological studies comparing exposed and unexposed population groups. Effects of low radiation doses can be estimated only if a large number of persons is included in such studies. The most important epidemiological study in this context has been the one done over the past 40 years of the survivors of Hiroshima and Nagasaki. *(See box, page 10.)* Estimates of cancer risk from this survivors' study have been confirmed by other studies, including one on a large number of nuclear workers from Canada, the United States, and the United Kingdom.

Information on genetic disorders is based only on animal experiments and epidemiology could not demonstrate these effects. For the assessment of the risk represented by the carcinogenic effect of radiation, several assumptions have to be made and models have to be used. For

Mr. Flakus, who served as Scientific Secretary of the Paris Conference, is a senior staff member in the IAEA Department of Nuclear Safety.

*International Conference on Radiation and Society: Comprehending Radiation Risk, 24-28 October 1994, Paris, France. Proceedings are being published by the IAEA in three volumes, the first of which has been issued. See the *Keep Abreast* section in the *IAEA Bulletin* for ordering information.

most cancer localizations, the excess risk linked to radiation is proportional to the spontaneous cancer rate in the human population.

What late effects have been found on populations living in high altitude areas or where there are increased radiation levels, for example on monazite sands or in houses having high levels of radon? The findings of some studies reported at the conference indicate little risk of cancer induction in such groups.

Our scientific knowledge of radiation effects promises to expand in years ahead. Advances in modern molecular biology, for instance, might make it eventually possible to determine the sensitivity to ionizing radiation of an individual person and also to determine if a cancer or genetic disorder is caused by radiation or not.

***Impact of radiation on the environment.*** A central part of this conference session concerned the protection of plants and animals. The protection of people from radiation may not always provide adequate protection to plant or animal life. This can be the case when plants and animals live near potentially harmful sources of

**About the International Conference on Radiation and Society**

**The first of its kind at the global level, the International Conference on Radiation and Society in October 1994 attracted high governmental and media interest, and its format allowed for a free flow of discussion and viewpoints. Designed as a "discussion conference", the programme featured three distinct elements:**

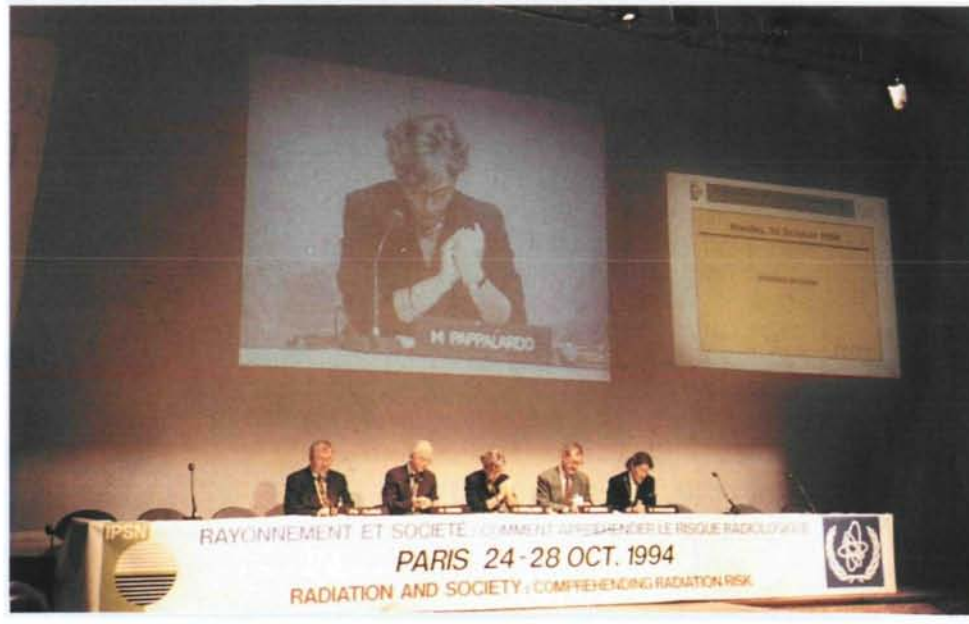
**• three "technical days", during which discussions focused on various topical issues grouped under five technical areas and five case study sessions;**

**• a "media day", which addressed topics related to the technical and case study sessions; radiation health effects in the context of environmental pollutants; communication of radiation risk; media analyses concerning controversial radiation case studies; and the media's influence on policy making,**

**• a "decision makers day", which served to explore economic, social, and political aspects in decisions involving radiation risk.**

**In parallel to the plenary sessions, more than 80 scientific posters were exhibited. Prior to the conference, a set of 12 background papers was prepared to serve as a basis for the discussions. Riskkollegiet, the Swedish Risk Academy, had prepared 10 papers on comprehending radiation risks, the concept of probability, risk perception, interpreting epidemiological results, problems in radiation risk assessment, cause structure of global mortality, radiation levels, problems in risk comparisons, risk communication, and risk and ethics. Two additional background papers addressing the impact of radiation on the environment and the management of radiation risks had been prepared by France's Institut de Protection et de Sûreté Nucléaire (IPSN).**

**Among the conference's distinguished speakers were Madame Michele Papalardo, Director of the French Cabinet of the Ministry of Environment; P. Vesseron, Director of IPSN ; Hans Blix, IAEA Director General; and Morris Rosen, the IAEA's Assistant Director General for Nuclear Safety. Shown below, from left to right, are F.N. Flakus, the IAEA's Scientific Secretary of the Conference; Mr. Rosen; Madame Papalardo; Mr. Vesseron; and Ms. N. Parmentier, Chairperson of the Conference Steering Committee.**



exposure that do not affect people living farther away. Experts at the conference pointed out that this situation is exceptional. For more common cases -- namely those where humans, plants, and animals live in the same location — measures to protect humans from potentially harmful radiation exposure will also ensure protection of other species.

Harm to the environment caused by radiation is almost entirely associated with accident conditions or the use of nuclear weapons. There is no evidence that the routine operation of nuclear facilities has caused environmental harm. In fact, participants urged that greater emphasis should be placed on the positive effects of nuclear power, including the role it is playing to reduce levels of emissions linked to environmental pollution and climate threatening processes.

In some countries proposals are being made for establishing environmental protection criteria for radiation. Conference participants noted that this could be seen as giving a misleading signal to non-radiation scientists and the public. While there may be ethical and other reasons for wishing to establish such criteria, the rules should be developed universally for all pollutants in the environment rather than for a single one.

**Perception of radiation risk.** The perception of risk depends on many factors, including the context in which the hazard occurs, the type of hazard, and the type of person who makes the judgments.

People are normally not especially concerned about circumstances which they believe they can control. Social debates and public outrage are easily triggered by scenarios of events that could have severe consequences but that are unlikely to occur — so-called high consequence/low probability events. There also seems to be a general tendency of people to respond more strongly to future threats than to future opportunities or benefits.

Some individuals reject nuclear activities because they do not accept additional risk in a society where there are already too many risks, while others are more favourable to nuclear development. Among most people, however, the most common attitude towards nuclear installations — or other types of major industrial projects — is "not in my backyard". Their emphasis is on the actual or perceived negative impacts that very often overshadow the positive sides of the industrial project or technology.

The reaction often reflects cultural, political, and ideological influences, as well as issues of credibility. Often, the main consequence of a large accident is the loss of people's confidence in the ability of authorities to manage the complex social and technological system. Confidence may return if authorities follow a policy of openness, take public demands into account, and become proficient in communicating both the risks and benefits.

Overall, perceptions of radiation risk can be more confounding than one might think. In the case of perceptions of health risks from exposure to radon in homes and buildings, the public generally believes the risks are *lower* than scientific estimates would substantiate. Several factors appear to contribute to this attitude: the voluntary nature of the risk, its connection with the home, the fact that there is no person or industry imposing this risk, and that it is not possible to say with certainty that a particular cancer victim has died from radon exposure.

**Cancer and leukaemia clusters**. The conference featured discussion of various studies on what are commonly called "cancer clusters". Discussions pointed out that it is almost impossible to distinguish a *post-hoc* cluster, which has arisen by chance, from one which is due to a locally caused excess risk. The correct scientific method is the *a priori* investigation of putative sources of risk. Such studies of childhood leukaemia around nuclear installations, for example, have been carried out. They reveal little, if any, evidence for an increased risk of childhood leukaemia.

Also discussed was the problem of media coverage and communication with the public. It was suggested that, when informing the public on these issues, scientists should not only point out that "the risk is low". They should try to look at the issue from the public's point of view, and take into consideration factors that may be influencing the perceptions of risk.

**Radioactive waste disposal and the environment**. Technical and philosophical aspects of high-level waste disposal — including the capa-

### Effects in perspective

About one-half of the global burden of diseases is caused by all types of substances or organisms that occur in excess amounts in our environment. Simple measures can alleviate these effects and it is possible to provide significant improvements in health at low cost. The effects of ionizing radiation represent around 1% of the global burden of disease. This small contribution is dominated by natural radiation, medical care of patients, and fallout from nuclear weapons tests. Industrial radiation sources contribute less than one-hundredth of 1%.

### The nuclear weapons legacy

The nuclear weapons legacy comprises essentially two components — their actual use, twice 50 years ago in August 1945 at Hiroshima and Nagasaki; and their potential use, in the form of nuclear weapons testing and environmental releases of radioactive materials from the nuclear weapons fuel cycle.

Among about 600,000 people living in Hiroshima and Nagasaki at the time of the bombings, approximately 180,000 immediate deaths were directly caused by the bombs, largely from blast and heat compounded by radiation. About 100,000 survivors in both cities, who experienced an average dose of 0.2 Gy, have been followed medically for more than 40 years. Through 1994, less than 50% of these survivors are deceased, including about 8000 deaths from cancer. About 5% of these cancer deaths have been attributed to radiation from the atomic bombs. In terms of loss of life expectancy, the average individual loss among the study group of survivors is less than one year. However, it is about 12 years on average for persons who died from radiation-induced solid cancer and 26 years for those who died of leukemia.

Studies of genetic effects are in progress on the offspring of the survivors. Since no demonstrable genetic effect has been found in the first generation, very little effect may be expected, if any, in later generations.

Risk data based on studies of A-bomb survivors have been used to establish radiation protection standards. Much effort has been made to publish and disseminate scientific data to the general public. However, the terminology used in this context is difficult to understand for lay people and more effort is needed to prepare and disseminate reports comprehensible to the general public.

One question raised at the conference was why the nuclear energy option seems to be better accepted in Japan than in other countries. Several reasons were offered. They included Japan's strict adherence, rooted in the law, to only peaceful uses of nuclear energy; the clear distinction between nuclear energy and nuclear bombs; strict regulation of nuclear safety; the involvement of local communities, including financial compensation schemes; and the political commitment to gaining a better understanding and acceptance of nuclear energy.

***Nuclear weapons testing.*** During the period 1945-80, a total of 520 nuclear weapons tests were conducted in the atmosphere, principally by the former Soviet Union and the United States but also by the United Kingdom, France, and China. The total energy released was equivalent to 545 Mt of TNT explosives. These tests were accompanied by substantial emissions of radionuclides into the atmosphere, resulting in worldwide environmental contamination. The highest radiation doses were received by populations living in the vicinity of nuclear weapons test sites.

In addition to atmospheric tests, more than 1000 tests have been conducted underground, resulting occasionally in small releases of radioactive materials to the atmosphere.

Several accidents have occurred at nuclear weapons facilities, the most serious being those in 1957 at Windscale in the United Kingdom and at Kyshtym in Russia. The radiation doses and health effects resulting from environmental releases in the early years of nuclear weapons production in the 1940s and 1950s are being investigated in the Russian Federation as well as in the United States.

bility for making safety predictions far into the future for radioactive waste repositories — were central features of discussion on this topic. Scientists acknowledged the inevitable uncertainties involved in making predictions over such extended time periods. At the same time, they emphasized that several different ways exist for providing assurance of safety. Confidence in long-term assessments is enhanced by comparisons with natural analogues in the environment.

Concerning waste transport between countries, discussions pointed to the importance of rules and practices that prevent movement of waste materials to countries without the resources and technology to handle them. A currently accepted position — determined more on political than on safety or economic grounds — is that each country should solve its own radioactive waste problems. A potentially beneficial approach, considering the number of small countries which have to deal with radioactive waste problems, would be regional repositories serving their needs.

## The media, scientists, and decision-makers

In three media fora, scientists, journalists, policy-makers, and other conference participants explored factors relating to perception and communication of radiation risk, and the influence of media and the public on policy making.

The scientific facts about radiation risk and media approaches to communicating risk need to be distinguished. Messages of scientists are necessarily based on statistics. The public essentially wants to know whether there is a risk or not. However, most people find the quantification of probability difficult to understand, and find it hard to accept that probabilities can never be zero. While the public generally regards the risk from natural radiation as inevitable, people do not want more risks and uncertainties added to their lives.

For scientists, the fora made some important points about effective communications. An important role of the scientist is to supply reliable information, without speculation, to build trust. Since openness is a prerequisite for credibility, scientists should provide simple information and make more detailed backup material available for further reference.

Communication should also be immediate. What comes out first strikes the public. Later messages seem to come from a defensive stance and are basically weak ones. In debate, scientists should be willing to discuss both bad and good news to gain credibility and build trust. Trust among scientists and journalists further could be strengthened through topical seminars and workshops.

The conference session on decision-making was directed at senior policy officials. Ministerial-level officials were invited to talk about the rationale and strategy for decision-making involving radiation issues. A number of points were addressed, including the question of how public perceptions, expert opinions, and persuasive types of communication influence the decision-making process.

The session emphasized that decision-makers should take into account some basic elements when dealing with radiation issues: they should acknowledgte the risk to be dealt with, state their commitment to protection, and then act upon that commitment. Overall, the aim must be to create a climate in which the public is convinced that all aspects, including bad news, are fully explored, and where varying views receive a complete and proper hearing. Toward that end, political structures and processes, as well as media channels, can be positively used. Additionally, the importance of having legislation in place that is clearly communicated to the public was stressed, so that the laws and principles upon which risks are controlled can be understood.

## A step forward

As a global pioneer in its field, the Paris conference marked a significant step forward in a process that undoubtedly will require far more time, attention, and resources. Better communication, and greater comprehension, of radiation risks will require a concerted effort among scientists, journalists, decision-makers, and the public.

One clear message of the conference is that difficulties in communication of radiation safety differ from country to country. Moreover, actions to ameliorate the situation need to be tailored to prevailing issues of national debate — for example, radon issues in the United States, or Chernobyl health effects in Ukraine and Belarus.

The conference also underlined the difficulty of expressing scientific facts of radiation effects in a form useful to non-specialists, and it helped illuminate the roadblocks to better comprehension. A clear message was that greater efforts are needed to place radiation issues in perspective, by improving communication of comparative studies about radiation risks and other hazards.

There seem to be no magic recipes for bringing about quick changes to the complex problem of comprehending radiation risks. Yet the Paris conference represented an important step forward by bringing together people closely involved in framing and communicating solutions. ❐

### The Chernobyl accident: Communicating the consequences

Although its size and consequences were apparent early, the Chernobyl accident in 1986 was characterized by communication gaps between the population, political decision makers, journalists, and experts.

The resultant confusion caused people to lose confidence in messages they received. Immediately after the accident, a report by the World Health Organization (WHO) gave reasonable conclusions and recommendations, especially pointing out differences in response measures that were taken by countries. Rather than trying to reconcile these differences, too many scientists indulged in speculation as to Chernobyl's potential effects. Consequently, the public was left with predictions ranging from 10,000 to 500,000 fatal cancers, numbers which the media in some cases wrongly reported as acute deaths.

Years after the accident, some articles in the media included descriptions of malformed plants and animals. A number of cows, other animals, and sensitive plants such as pine trees did die from exposure to high radiation doses. However, no evidence of fatal damage or malformations on a wide scale have been confirmed. The effects were seen mostly within the 10 kilometer exclusion zone that was set up around the Chernobyl site.

**International Chernobyl Project.** In 1991, the IAEA's International Chernobyl Project examined the radiological consequences of the accident, with the exception of certain aspects such as the health of the "liquidators", namely those who fought to get the accident under control. The general conclusions were that in 1990 there were no health consequences directly linked to radiation exposure but that some thyroid cancers in children should be expected. Post-accident traumatic stress disorders were seen whether people had actually been irradiated or not. Numerous people, however, rejected the conclusions, including politicians and some experts.

Now some new signs are starting to emerge, primarily an excess of thyroid cancer among children in the Russian Federation, Belarus, and Ukraine. These were at first met with skepticism in the scientific community because of the short latency period and comparisons with other studies. In several recent reports on this subject, the increased incidence of thyroid cancer in a number of specific regions and in particular age groups of children is confirmed. These cancers generally seem to be occurring among groups of children who were estimated to have received doses to the thyroid of 1 to 2 Gy.

**Other emerging effects.** Some data were also presented at the conference on diseases emerging among the Chernobyl liquidators that are not normally attributable to radiation exposure. They include illnesses of the nervous system, blood and circulatory systems, and psychic diseases. A number of experts at the conference felt that this phenomenon seems to be restricted to the region, with the common factor being some exposure to the Chernobyl accident. It was suggested that other populations previously exposed to high levels of radiation, such as survivors of the Hiroshima and Nagasaki bombings and the inhabitants near nuclear test sites on the Marshall Islands, should be examined for the same type of effects.

## Understanding radiation risks: Lessons from Paris

Comprehending radiation risk is a real and major problem confronting society today. Perhaps every professional working in this field has had experiences similar to one I will share with you. Frequently during my air travels, I enter into a conversation with my neighbour — generally, a well educated professional. In a few minutes he discovers that I am involved in nuclear safety and inevitably the conversation turns to questions about radiation and its health effects.

"What can you tell me about Hiroshima or about the vast environmental contamination caused by Chernobyl?" I usually begin my answers by explaining that as we speak we are being constantly bombarded by a broad range of radiation, not only from the cosmos, but also from the food we are consuming. That seemingly new and troublesome point is followed by my comments explaining that the many victims of Hiroshima were not killed directly by radiation, but by the explosion and the heat wave created from the nuclear detonation. Of the 80,000 survivors who received very high doses of radiation, less than 500 have incurred illnesses so far which are attributable to the radiation exposure — a statement that is also new and received with disbelief. But the figures are scientifically factual. About 8000 survivors have indeed died from solid cancer tumors, but epidemiological studies indicate that less than 500 can be attributed to radiation effects. The remainder are normal tumors of the type that will threaten all of us, whether survivors of Hiroshima or not. It seems that most of us, even the professionals, do not realize or want to acknowledge that cancer is a very common occurrence. Twenty five percent of us will incur a fatal cancer.

The answer to my neighbour's second question concerning Chernobyl elicits the same disbelief. Certainly the fact that the entire environmental contamination of Chernobyl has produced a global radiological impact equivalent to an additional world exposure to 20 days of natural background radiation is more difficult to comprehend, let alone understand. The same is true of the health effects to the surrounding population which, except for the apparent, expected, and regrettable increase in thyroid cancer in children, will be sufficiently small so as not to be discernible through epidemiological studies.

Why does my neighbour not believe me? Certainly, his perception of the facts is different from mine. Why? Many of us have been very pessimistic about our ability to deal with the public's comprehension of radiation risk. Radiation is mysterious; it is invisible, intangible, odourless, silent, and associated with warfare.

To explore this issue in more depth, the IAEA in October 1994 organized upon the invitation of France an International Conference on Radiation and Society: Comprehending Radiation Risk. It was the first major international meeting devoted to the subject, and attracted more than 400 participants from 50 countries and nine international organizations.

The conference sought to bring about a better comprehension of the risk attributed to the exposure to ionizing radiation. This is an important and serious subject for all of those concerned with the uses of atomic energy and ionizing radiation for health applications, improving the food supply, generating electricity, and producing consumer and industrial products. The large audience — a unique mixture of technical specialists, social scientists, decision makers, and media professionals — was an indication of the high level of interest in radiation and how individuals and society perceive its effects. The conference's goal was not a further elaboration of technical information, but a better comprehension of radiation risk. And by comprehension the Conference had certainly desired to promote not only an understanding of the scientific facts of radiation health effects, but also and more importantly an ability to express these facts in a form useful to the public and the decision makers.

The goal was ambitious, perhaps too ambitious. The conference had only limited success in satisfactorily dealing with the question of the comprehension of radiation risk. Yet the concerned specialists may have gained some better insights as to where the roadblocks to better comprehension lie. There are many.

Scientists too often speak to themselves and this pattern was very evident during many of the conference sessions. There could have been more efforts to present facts and conclusions in an understandable and communicative language. Some specific examples may be illuminating:

- It would have been useful to further discuss the implications of some remarkable facts among the 80,000 survivors of Hiroshima. Fewer than 500 have so far incurred a fatal cancer attributable to radiation exposure — and the average loss of life expectancy among the survivors is about 1 year while those that have incurred the fatal cancer had their life cut short by 10 years.
- It would also have been desirable to discuss the reported thyroid nodules cases in the

Marshall Islands and in Nevada by not only confirming that large exposures to radioactive iodine produces cancer nodules, but by also referring to the rather relatively small number of cases involved.

- As for the Chernobyl studies, speaking about a 2500% increase in thyroid cancers in children ignores the importance of the accuracy of the pre-Chernobyl reference value for these studies, which surely involves major uncertainties. It would have added more to the comprehension of health effects to have expressed the results as five cancers per 100,000 children and to refer more precisely to the total number of cancers to be expected in the various regions. An unemotional discussion of the clinical outlook for these children would also have been useful.
- There were a number of references to cardiovascular effects of radiation. This effect must be clearly qualified by indicating the many compounding factors and the more likely cause, which is other factors such as stress.
- In the discussion of cancer clusters, such as leukaemia clusters, it is necessary to repeatedly emphasize that clusters always exist in nature. They have been found long before nuclear power existed and are also found in locations remote from nuclear installations — and that in any case the number of excess cancers are few. Discussion of the Seascale cluster (reported in the 1980s in the United Kingdom) lingers on although most involved scientists believe it is not in any way connected with radiation. Why are the profound limitations of linking clusters to any cause not clearly and repeatedly stated? Furthermore, in much of the scientific community, epidemiology is recognized as an observational science with severe limitations. Epidemiological studies often involve small numbers of excess cancers with substantive compounding factors, such that for most situations positive as well as negative results must be taken with caution. The profound limitations of epidemiological studies should also be clearly and repeatedly stated.
- There was a need for further discussion in Paris of why there are so many differing national policies concerning radon control and the reasons for this.
- Finally, there was a very conspicuous limited use of comparison in most presentations. Comparisons could enable the radiation risk to be put into some perspective with other risks and at the same time also introduce the notion that life involves many risks along with benefits.

Dr. Rosen

- On the positive side, the conference format chosen for this meeting was helpful in conveying information and promoting audience participation. The use of a rapporteur and chairman to present information and lead discussions has proven successful in many recent IAEA meetings. Using this format, the conference systematically covered the technical aspects, followed this by some particularly relevant case studies, and then brought in the media and decision makers. The carefully chosen format thus facilitated meaningful discussion. As a whole, the sessions and the conference have been a significant step ahead in a process which undoubtedly will require additional time and attention.

The IAEA can help this process. One of its functions is to advise on how to develop standards and practices which adequately speak to the needs of constituents — the scientists, the social scientists, the decision makers, and the public. The deliberations at the conference will surely provide the Agency with insights into how to make this function more effective.

The IAEA, together with the European Commission and the World Health Organization, has also organized a major international meeting in April 1996 to further look at the health and environmental consequences of the Chernobyl accident — 10 years after the disaster. It is hoped that, after the meeting, there will be a better comprehension of the radiological consequences of Chernobyl. — ***Morris Rosen, Assistant Director General and Director of the IAEA Division of Nuclear Safety.*** ❐

# Nuclear power: Keeping the option open

*Though slowed in some countries, nuclear power development is rapid where the demand for electricity runs high*

by
**L.M.Davies and A.D.Boothroyd**

Generating electricity from nuclear power is a well-established technology. More than 30 countries were operating or building altogether more than 480 nuclear power plants at the end of 1994. Collectively over the past 40 years, the world has accumulated over 7200 operating years of experience with nuclear power, and the plants have generated about 20,000 terawatt-hours of electricity.

The increasing world population, the universal desire for an improved standard of living, and improving economic conditions will all lead to an increase in global demand for energy. The problems are compounded by the need to study and then reduce the emissions from burning fossil fuels. These factors inevitably mean an increase in demand for electricity. In the developing world, for example, electricity demand is increasing at a higher rate than either energy consumption or gross national product.

The choice of electric power sources in a country will depend upon many factors. They include existing capacity, availability and cost of fuel, capital funds, and political conditions. Many countries will adopt an approach which provides a balanced mix of fuel sources to guard against price and supply "shocks". Generating companies will also seek to stabilize the security of supplies and electricity prices to their customers. Diversity is seen as a key benefit for stabilizing the supply and cost of electricity. In this context, nuclear power will remain a viable option for future electricity generation.

In the industrialized world, the rate of demand for new nuclear power plants will be tempered by various factors. They include the magnitude of current excess generating capacity, the replacement rate of old and relatively inefficient conventional fossil burning plants, and the demands of meeting international agreements on the control of emissions. But in the developing world, the availability of money and other resources may be the controlling factor in the rate of implementation. The situation is not simple.

Currently, the demand for energy appears to have saturated in some regions of the world. However, this is thought to be mainly due to economic recession and the social changes in Central and Eastern Europe, rather than any underlying medium or long-term trend in energy usage. The demand in the rest of the world continues to increase inexorably and this is where the majority of the world's population lives.

In short, the global energy and electricity picture has changed over the past decade, with demand strongest in countries experiencing healthy economic growth. In September 1994, this changing picture and nuclear power's place within it were examined at an international conference at the IAEA in Vienna. About 150 participants from 37 countries and six international organizations attended. Recently, the IAEA published the Proceedings of the conference. This article reviews selected issues raised at the conference that are influencing nuclear power's future development.*

## National and regional nuclear growth

As they do today, various factors could impede the use of nuclear power in years ahead. They are related to issues of public acceptance, radioactive waste management, safety, economics, the environment, and legal liability.

In many countries developing nuclear power programmes, many of these factors have been

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* *Proceedings of the International Conference on the Nuclear Power Option*, held at the IAEA in Vienna, 5-8 September 1994.

addressed and overcome. National and regional reports at the conference from Eastern, Central and Western Europe, North and South America, and Asia indicated that nuclear power is well established, economic, and a significant source of electricity. Over the long term, continuing demand for electricity is expected to lead to greater nuclear development, as well as investment in other options. In these regions, nuclear power is seen to be competitive and environmentally advantageous.

The rate and timing of nuclear growth will vary between countries. Worldwide, nuclear power can be expected to continue to grow at the present level of three to eight gigawatts (GWe) per year, though increases of 10 GWe per year and higher are projected early in the next century.

At the national level, the prospects for growth are generally tied to economic and energy conditions, based on conference reports. In China and India, where energy demand surpasses supply, the limited availability of capital and other resources has served to constrain nuclear development though its growth is considered urgent. Russia, Ukraine, and other Eastern European countries also have urgent and continuing needs to improve and increase their generating capacity, but they face serious difficulties. In Latin America, countries generally have well-defined needs for electricity yet have a shortage of resources. In France, Japan, and the Republic of Korea, nuclear programmes are robust. In North America, where utilities currently have excess generating capacity, an expansion of nuclear power, as well as other sources, strongly depends on the pace of electricity demand.

## Plant management and performance

Among the conference's key topics was the management and performance of nuclear power plants.

In many countries, lessons have been learned from problems encountered during plant construction and operation. Equipment, operating, and maintenance procedures, as well as training programmes, have been upgraded. In some countries, the need to improve project management skills was identified as especially important, particularly for countries moving from a centrally planned to a market driven economy.

Greater cooperation and communication between operators of nuclear plants have resulted in improved performance. The World Association of Nuclear Operators (WANO) reported that the operational availability of plants has increased while the number and severity of reportable incidents has decreased. A report from Nuclear Electric in the United Kingdom described a remarkable improvement in the performance of their advanced gas-reactors over the past 4 years, with load factors increasing from 40% to 79%. By taking a broad approach to safety culture, Nuclear Electric has been able to take advantage of lessons to be learned from a wide range of industries. Through research programmes, for example, a study of the management and organizational factors behind recent severe accidents in nuclear, chemical, transport, space, and petroleum industries has been conducted with the aim of determining organizational characteristics that would prevent such accidents. These studies and other national and international programmes have led to considerable progress over the last 5 years in efforts to improve safety culture and hence the safe performance of plants.

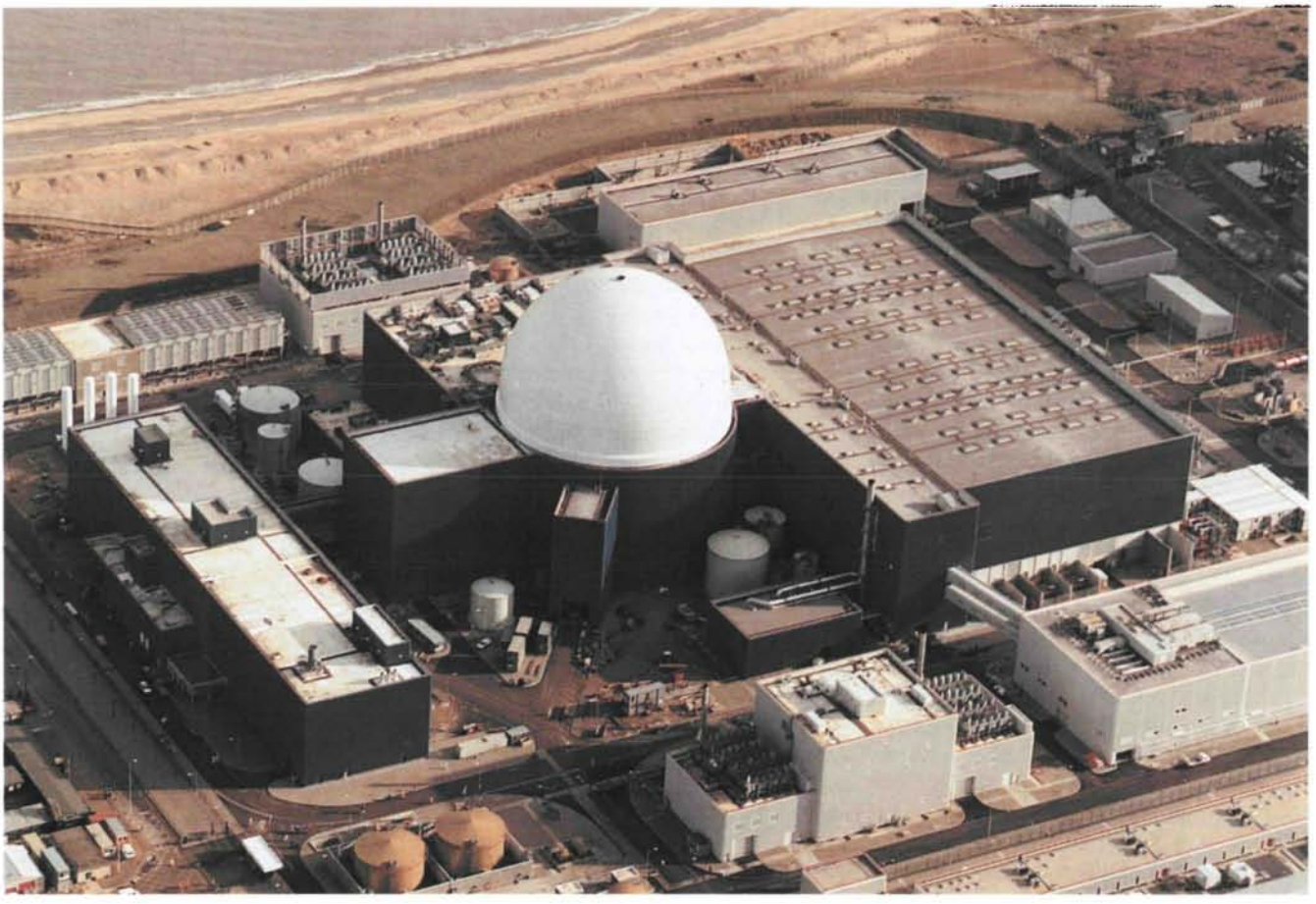
A number of reports emphasized the value of opening plants to outside international safety reviews and publishing performance data in the IAEA's Power Reactor Information System (PRIS), particularly from the standpoint of public perceptions. One report analyzed the good production record of WWER-440/230 plants, a fact that contrasted with safety concerns expressed about these plants. The performance of the successor design, the WWER-440/213, has been generally better, whereas that of the larger WWER-1000 has not been quite as good as expected.

## Economic and related issues

With regard to the economic viability of nuclear power, studies carried out by the IAEA, Nuclear Energy Agency (NEA), International Energy Agency (IEA), and Union of International Producers and Distributors of Electricity (UNIPEDE) show that electricity generation costs for nuclear plants are closely competitive with those for coal and gas-fired plants. However, the economic margin in favour of nuclear generation has declined in recent years, primarily because of increases in operation and maintenance costs for nuclear plants, at least in several countries.

Projected costs for plants that could enter service around the year 2000 or shortly thereafter show that nuclear power should be able to continue to compete with fossil plants. Whether nuclear is the cheapest option will differ from country to country, and will be strongly influenced by the price of fossil fuels and by the costs and duration of construction.

It is essential, if the nuclear option is to be



Sizewell "B", the UK's most recent nuclear power plant.

competitive, that nuclear projects be well managed during construction and operation. New nuclear plant designs, drawing upon the lessons learned from existing plants, should lead to plants that are simpler and cheaper to construct, while maintaining high safety levels. Improvements in fuel performance, including higher burnup, together with the trends towards lower prices for uranium and fuel cycle services, will lead to stable or declining nuclear fuel cycle costs.

In addition to being economically competitive, nuclear plants are beneficial from the environmental viewpoint, since they do not emit any greenhouse gases or other damaging air pollutants, such as sulphur dioxide and nitrogen oxides. Thus, nuclear power can play an important role in strategies aiming towards limited or reduced levels of greenhouse gas emissions.

**Quality assurance.** The management of quality in nuclear power organizations and equipment suppliers varies quite widely across the industry. The efforts that have been made to produce documented systems and to audit compliance with those systems has often resulted in little benefit in quality terms. The IAEA and several regional organizations have long since recognized the problems. Highly pragmatic solutions are now emerging in line with and in many cases ahead of developments in the broader industrial scene. The evolution of quality management into a "culture" which promotes improved performance of all staff, not just addressing the production of "quality" documentation, was described. Performance-based quality management, which focuses on processes, provides a refreshing approach to the assurance of quality. The approach is described in a recently revised IAEA code and supporting guides prepared for publication in 1995.

**Siting and plant life.** Other topics receiving close attention at the conference related to the siting and operational lifetimes of nuclear plants. A number of participants emphasized the importance of retaining existing sites, and of maximizing the operational lifetimes of plants for economic reasons.

Extending the lifetimes of existing plants reduces the demand for new ones and defers decommissioning and its associated waste disposal requirements. Although there seems to be no technical impediment to the construction of a large number of new plants, the limiting factor could be associated with choice of new sites.

With the time approaching for decisions about the construction of new plants, whether or not such decisions are made, plant lifetimes are extremely relevant to keeping the nuclear option open. How long a nuclear plant operates is predominantly a business decision of the owner, even though associated regulatory requirements are mandatory. For building new plants, given the 10-year lead time for licensing, construction, and commissioning, participants stressed the importance of taking decisions now to meet needs early in the next century.

**Public attitudes.** On the matter of public attitudes toward nuclear power, both Japan and France commended the advantages of the "good neighbour" approach by utilities. The importance of creating "symbiosis" between plants and the community was emphasized. Building trust comes from listening to the issues raised by the community and from an open approach to communication. This technique is also employed in other countries, with communities near power stations in particular. The Russian public, during the current crisis of the national economy, was said to perceive nuclear power as an "island of stability".

It was also noted that, in the United States, public support was often underestimated, which leads to hesitation by government officials and others to speak out and take strong action in support of nuclear energy. New approaches are being taken to improve the industry's understanding of public concerns.

## Waste and nuclear safety issues

Presentations covering the management of spent fuel and radioactive waste all emphasized that safety was the paramount consideration. France described the development of a complete inventory of all radioactive waste in the country and reported that media coverage of that activity had been generally favourable, again demonstrating the value of openness in gaining public confidence. Several speakers noted that technical solutions for waste disposal existed, but more progress in establishing sites and demonstrating the reliable operation of operational waste disposal facilities in the near term was vital to public acceptance of the nuclear power option.

The session on safety included topics related to safety assessment methods and implementation of a safety culture. Some speakers emphasized the need for cost effectiveness of safety improvements, a view not shared by the regulatory community. Concern was expressed about a proposed feature of some new plant safety requirements, namely that no accident should require off-site emergency planning. This would cause much difficulty if it was intended to be applied retroactively to existing plants. There was strong general agreement and support for the need to keep demonstrating the safe and productive operation of current plants, a fact that would help sustain public confidence.

**Nuclear liability.** Based on discussion surrounding a joint IAEA and NEA paper, there is disagreement between East and West on the question of liability for accidents. Participants from Eastern countries generally expressed the view that suppliers should remain responsible in the event of equipment malfunction, while those from Western countries generally endorse the concept of limited liability and place responsibility with the operator of the plant.

**Human resources and training.** The need to attract and train more qualified staff was noted with some concern. Again, public perceptions about nuclear's prospects were noted. They were generally seen as a factor behind the lack of interest in nuclear-related studies at high school and university levels. The contraction and diversification of nuclear research and development institutes also has led to a serious reduction of available qualified staff, which will take many years to rebuild. Governments were urged to take action soon to ensure that this trend is reversed if they wish to preserve the nuclear power option.

## A mixed picture

The demand for and interest in nuclear power are seen to be increasing but it is not homogenous. In his closing remarks, Dr. Boris Semenov, the IAEA's Deputy Director General for Nuclear Energy and Safety, noted that the conference had reached consensus on the continued viability of the nuclear power option, and that in many countries, it was the preferred option as a proven, economically competitive, and environmentally sound technology. However, he pointed to a number of prerequisites for expanding nuclear development. They include the safe and reliable operation of existing nuclear power plants; the need for convincing solutions to waste storage and disposal problems; and a predictable licensing process. These provisions, together with a supportive and consistent government policy, are needed to achieve greater public acceptance of nuclear power, which he said constitutes probably the most important prerequisite.

He concluded by noting that these tasks cannot all be accomplished at once. However, steps must be taken soon to sustain the nuclear power option in the best interests of meeting the world's electricity and environmental needs. ❐

# Nuclear power: Training for safety and reliability

*The best international practices are being emphasized to help countries strengthen nuclear plant training programmes*

by F. Mautner-Markhof and K.V. Mahadeva Rao

A central challenge for industries anywhere is to maintain safe and reliable operation of their plants and facilities. These objectives cannot be achieved solely by improvements in equipment and hardware. They critically depend upon the qualifications, experience, and competence of people carrying out various tasks and holding different levels of responsibility.

In the nuclear power industry, training has assumed increasingly greater importance over the past 15 years. During this period, several studies have shown that human error has been a major contributing factor to incidents at nuclear power plants. In turn, these errors often can be traced back to deficiencies related to training.

Over the years, the IAEA has established a range of services directed at helping countries strengthen their training practices, approaches, and facilities for nuclear power personnel. This article reports on Agency programmes in the context of international developments in the field.

## Key elements of evolving approaches

A strong emphasis on safety has characterized the development of nuclear power technology. In the early years, personnel involved in plant design, construction, and operation were pioneers in nuclear technology and the strength of their base of knowledge was able to offset any weaknesses in training, which was evolving simultaneously. Training techniques used for staff of conventional power plants were first adapted to suit the requirements of nuclear plant operations personnel. In the 1970s, as nuclear technology entered its commercial industrial phase, the tendency was to develop more specific operating procedures in increasing detail. Training programmes were designed accordingly, this time for a new generation of operators having different educational and professional qualifications.

In 1979, the Three Mile Island (TMI) accident in the United States jolted the industry. It challenged the belief that such an accident could not happen, particularly in the Western industrialized world, given the emphasis on safety and the defense-in-depth strategy adopted in the design, construction, and operation of nuclear power plants. The accident's root cause was traced to human errors, and inadequate training and qualification. In prompt response, the US nuclear industry voluntarily formed the Institute of Nuclear Power Operations (INPO) and subjected the prevailing training methodology to a critical review. Borrowing from techniques used in military training, a systematic approach to training (SAT) was developed and an industry-wide commitment to SAT was made in 1981. In addition, training programmes of nuclear utilities were reviewed by INPO accreditation teams to promote a uniform standard of training across the board. At the same time, the US Nuclear Regulatory Commission strongly urged that SAT be used as the basis for training nuclear power plant personnel, and it mandated full-scope simulator training. As a result of these and other measures, US nuclear utilities have achieved a sustained improvement in all plant performance indicators.

Following TMI, other countries with operating nuclear power plants also conducted detailed analyses of their plant designs, as well as operations and maintenance procedures. They made necessary modifications, and in most cases, they strongly recommended the use of SAT. Most countries with significant nuclear power programmes now use SAT as the basis for developing, implementing, and evaluating their training programmes for nuclear power personnel. Although many countries

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do not have systems for formal accreditation of training programmes, important elements of SAT and of an accreditation process have been incorporated in their training programmes.

The critical role of operations personnel has been rightly emphasized by every country with a nuclear power programme. Maintenance training, however, has received far less attention and there is widespread agreement that it must be improved. The competence of maintenance personnel is essential for reducing events connected with equipment failure or malfunctioning systems.

## Training techniques and methods

Personnel who are properly trained and qualified for jobs and responsibilities at nuclear power plants are not available directly from university-level institutions or technical colleges. New recruits therefore have to be trained in areas going beyond their academic or vocational qualifications. Existing staff also require continuous training to maintain and upgrade their skills and knowledge.

These diverse types of training can be provided at a dedicated training centre at a nuclear power plant; at a centralized training facility serving the needs of a number of similar nuclear plants; or at a national training facility. External training organizations also can provide specific types of training. Whichever approach is followed, the training site must have facilities for classroom teaching, workshops with mock-ups and models for maintenance training, and simulators for operations personnel with attendant workshops and laboratories. Training on full-scope or partial nuclear plant simulators serves the goals of both safety and reliability, and these two cannot be treated separately. Simulator training has become one of the most effective and important means for upgrading the skills and attitudes of operations personnel.

Another important component is on-the-job training (OJT). The trainee performs the required work under the close supervision and with the assistance of the responsible supervisor. Thus, he or she becomes an integral part of a team that subsequently has to function well. Although the effectiveness of OJT is enhanced by educational qualifications and classroom training, it cannot be replaced by theoretical training.

Simulator, OJT, and other types of training should be based on SAT. It is also important to emphasize the need for top-quality trainers with good teaching skills. They should have practical and up-to-date experience, as opposed to only academic experience and qualifications.

**An overview of SAT.** The Systematic Approach to Training (SAT) is a process which encompasses the analysis of training needs and the competencies required to perform a given job; the design of training to meet these needs, which involves converting the competence requirements into training objectives including identification of appropriate training tools and settings; the development of training materials and tools such that all objectives can be met, as well as the training of trainers; the implementation of training according to the procedures and materials developed (training can be implemented in the classroom, workshop, simulator, and by self-study and OJT); the evaluation of training performance during and at the conclusion of training; and feedback of evaluation results into the relevant phases and parts of the training process and programmme, as well as to other needed plant improvments. SAT is thus a logical and self-improving system. It goes from identifying tasks and competencies required for performing a job to the implementation and evaluation of training for those competencies.

The use of SAT offers significant advantages over more conventional training approaches. In essence, it is a quality assurance process for ensuring the competence of nuclear power plant personnel, and for helping management more effectively monitor and improve training policies and practices.

SAT is now recognized as the international best practice for training nuclear power plant personnel. The approach can be adapted to suit the specific requirements and conditions of individual nuclear power plants, utilizing and building upon existing capabilities. It also incorporates aspects that promote a safety culture among staff and management. Regulatory bodies in a number of countries mandate or strongly recommend the use of SAT-based training for nuclear personnel.

## IAEA assistance and support

IAEA programmes in nuclear power training are helping countries to apply the best international practices in their efforts to improve the qualifications and competence of their operations, maintenance, management, and technical support personnel. Toward this end, an International Working Group on Nuclear Power Plant Personnel Training and Qualification has been set up. Its objectives are to:

- provide advice and comments on the IAEA's current and future activities related to a broad integrated SAT-based approach to training and qualification of nuclear power plant personnel;
- establish mechanisms through the IAEA to provide countries with information, recommendations, and advice on nuclear power plant personnel training and qualification;

## IAEA activities in support of training for nuclear power plant personnel, 1995-96

### IAEA Division of Nuclear Power

- preparation of a technical report on nuclear power plant personnel training and evaluation
- preparation of a technical document on training performance indicators
- preparation of a reference manual on training centres in the world
- preparation of a technical document on measures to implement more effective on-the-job training
- provision of technical officers and training experts in support of technical cooperation projects and for transferring information on the systematic approach to training (SAT)
- organization of training advisory missions
- preparation of a technical document on training for maintenance personnel
- preparation of a technical document on the design of nuclear power plant training simulators and related assessment methodology
- organization of training courses

### IAEA Division of Nuclear Safety

- organization and implementation of safety review missions to nuclear power plants (OSART and ASSET missions)
- preparation of a technical document on training personnel for the management of accidents
- preparation of a technical document on the use of operating experience to identify operational safety issues in the field of human factors
- preparation of a technical report on organizational factors influencing human performance in nuclear power plants
- interregional education and training courses on optimized maintenance of nuclear power plants

### IAEA technical cooperation projects

- Training in Nuclear Engineering, Algeria
- Manpower Development for Safe Operation of Nuclear Power Plants, China
- Upgrading University Training in Reactor Physics, Czech Republic
- Strengthening Training for Operational Safety at Paks Nuclear Plant, Hungary
- Establishing University Courses in Nuclear Engineering, Hungary
- Introduction of SAT in the Training Centre of BATAN and Support for the First Nuclear Power Plant, Indonesia
- Infrastructure including Training for Implementation of Nuclear Power Programme, Iran
- Nuclear Power and Safety Technology, Republic of Korea
- National Nuclear Training Centre, Mexico
- Upgrading of Training Facilities at Karachi Nuclear Power Plant Training Centre, Pakistan
- Development of Basic Principal Simulator for Karachi Nuclear Power Plant, Pakistan
- Support of Cernavoda Training Centre, Romania
- Upgrading Nuclear Power Plant Personnel Training Programmes, Slovak Republic
- Enhancement of Availability and Safety of WWER-type Reactors, Slovak Republic
- Enhancement of Operational Safety at Krsko Nuclear Power Plant, Slovenia
- Education and Training in Radiation Protection, Ukraine
- Training for Safe Operation and Management of Nuclear Power Plant, Ukraine
- Improving Nuclear Power Plant Operation Management, Regional Project for Eastern Europe

- promote exchange of information on national programmes, new developments, and experience from operating nuclear power plants and training centres;
- promote the effective implementation of relevant IAEA standards, guides, and other documents at the nuclear power plant level through training programmes and related activities.

The IAEA has recently prepared a new *Guidebook on Nuclear Power Plant Personnel Training and its Evaluation*, a revision of an earlier technical document (TECDOC-525) that had become the widely used international standard reference on SAT. This new guidebook reflects the experience gained in SAT implementation over the past 6 years. It emphasizes a broader concept of competence which includes not only technical knowledge and skills but also knowledge, skills, and attitudes concerning human factors. It further covers the role and responsibilities of management; the training of maintenance and management personnel; more effective and efficient methods of SAT analysis; and evaluation of the overall training process.

Another document, *Simulators for Training Nuclear Power Plant Personnel* (TECDOC-685), provides guidance on the procurement, establishment, and utilization of a simulator training centre. Other IAEA activities include the preparation of guidelines for designing nuclear power plant training simulators, and for using related assessment methodologies; the organization of regional and national workshops on the use of simulators and on the application of SAT in designing simulator-based training programmes; and the development of training performance indicators to facilitate management's monitoring of programmes.

IAEA training advisory services are further provided at the request of countries. The services are technical in nature and are not an auditing mechanism. Rather, training experts provide practical advice and guidance on the best ways to meet the needs and priorities of a specific nuclear power plant or country.

In Hungary, the IAEA under its technical cooperation programme has started a model project to strengthen training for operating and maintenance personnel at the Paks nuclear plant. It specifically aims to introduce SAT-based training, to assist in establishing a training centre for maintenance personnel, and to enhance safety culture. The project is serving as an example for other nuclear power plants in countries of Central and Eastern Europe and the former Soviet Union. Its successful completion in Hungary can serve as a model for similar types of nuclear plants operating elsewhere in the region. ❐

# Nuclear energy for seawater desalination: Updating the record

*Results of IAEA-supported studies show a range of combinations and options for tapping the earth's seas and oceans*

by
**Juergen Kupitz**

Worldwide availability of potable water greatly exceeds the amounts needed and used, but resources are not evenly distributed. There are regions where water is scarce, and where the population is already at the mercy of inadequate supplies. Seawater constitutes a practically unlimited source of supply. When desalted, it can contribute to the solution of growing water problems, wherever the sea is accessible. Desalination, as all industrial processes, requires energy.

Fossil energy resources are limited, however, and their increasingly intensive use raises environmental concerns, including the threat of a gradual climate change with far-reaching consequences. At the same time, worldwide demand for energy is steadily growing, and adequate solutions are needed. Nuclear energy contributes significantly to the world's existing supply of energy, and it has the potential to do even more. Realizing this potential, however, is not an easy challenge.

This article reviews the national and global interest in using nuclear energy in seawater desalination processes. It further reports on recent IAEA studies examining the possibilities and potential of nuclear desalination today.

## The early years

Combining the use of nuclear energy with the industrial process of supplying potable water by seawater desalination has been considered as far back as the 1960s. Indeed, it was characterized at that time by great optimism regarding the use of nuclear energy. Several studies were undertaken by individual countries, organizations, and nuclear industries. At the request of its Member States, the IAEA performed several technical and economic studies between 1964 and 1967, which were issued in the Technical Reports Series (Nos. 24, 51, 69 and 80).

At that time, there was considerable interest in promoting the use of nuclear energy for a variety of applications in addition to generating electricity. Applications included ship propulsion, district heating, energy supply to remote locations, industrial process steam supply, and seawater desalination. The idea of large agro-industrial-nuclear complexes was also pursued.

At a time of strong public and political support, these nuclear energy applications did not remain at the study stage, but proceeded to prototypes and demonstration projects. For seawater desalination, the design and construction of the Shevchenko complex (now Aktau in Kazakhstan) was launched by the former Soviet Union. The BN-350, a liquid-metal-cooled fast reactor, went into operation in 1973, and since then has provided both electricity and heat for the production of potable water.

What happened after the early efforts and achievements is now history. Developments in the nuclear field were concentrated in large power reactors for electricity generation, and the BN-350 is still the only power reactor in the world being used to supply heat for industrial-scale desalination. In Japan, several small-scale seawater desalination plants have been installed in large nuclear power stations for producing feedwater and miscellaneous services. There are also about 16 small desalination plants installed on Russian nuclear icebreakers and other nuclear-powered ships.

No further projects have been undertaken regarding the combination of nuclear energy and seawater desalination. Major developments, however, have taken place in both nuclear power and in desalination technologies, and several studies have been done.

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## Renewed interest

At the 1989 session of the IAEA General Conference, renewed interest was expressed in the potential of nuclear reactors for seawater desalination. The Conference adopted a resolution [GC(XXXIII)/RES/515] which requested the IAEA to assess the technical and economic potential of nuclear desalination. Since then, this subject, under the title "Plan for Producing Potable Water Economically", has remained on the agenda of every General Conference, and successive resolutions have directed the Agency to further pursue relevant activities.

The importance of having adequate supplies of clean potable water for growing populations — coupled with the magnitude of problems involved in satisfying this need — is now globally recognized. Less known is that desalination, which during the 1960s constituted an emerging technology with a status comparable to nuclear reactors for electric power at that time, has become an established commercially available process, with further potential for improvements.

Nuclear reactors for electric power have also matured. Even though they have become a technically proven and economically competitive source of energy which supplies about 17% of worldwide electricity consumption, they have been plagued by problems of public and political acceptance in many countries. With reduced prospects for further penetration into the electricity supply market when compared to earlier expectations, interest in other applications, in particular seawater desalination, has reappeared.

A number of other factors are propelling the technology of nuclear desalination forward. They include growing concerns about the environmental effects of burning fossil fuels; recognition of the benefits of diversification of energy sources; the development of new advanced reactor concepts in the small- and medium-power range; and interest in achieving higher efficiency in energy consumption processes.

Since the renewal of the IAEA's activities concerning nuclear desalination, a growing number of countries and international organizations have expressed interest, participated in meetings, and provided information and support. The assistance and support, involving more than 20 countries, has included the provision of expert services and funds totalling US $570,000.

## Recent IAEA reviews and studies

Following the 1989 General Conference, the IAEA took steps to update its review of available information on desalination technologies and the coupling of nuclear reactors with desalination plants. Results were reported in a 1990 technical document (TECDOC-574), *Use of Nuclear Reactors for Seawater Desalination.*

After the status review, the IAEA prepared and issued a report in 1992 entitled *Technical and Economic Evaluation of Potable Water Production through Desalination of Seawater by Using Nuclear Energy and other Means* (TECDOC-666). This report contained an assessment of the need for desalination based on recent analysis of the world's potable water resources; information on the most promising desalination processes and energy sources; and a review of nuclear reactor systems proposed by potential suppliers. It specifically evaluated the economic viability of seawater desalination by using nuclear energy in comparison with fossil fuels. The study encompassed a broad range of both nuclear and fossil plant sizes and technologies in combination with various desalination processes. Other aspects, such as environmental and institutional issues, were also discussed. The IAEA is continuing to collect and analyse relevant information on suitable nuclear reactors, desalination processes, coupling aspects, and potable water demand.

In 1991, in response to a request for assistance submitted by five North African States (Algeria, Egypt, Libyan Arab Jamahiriya, Morocco, and Tunisia) a regional feasibility study on nuclear desalination was launched. This study was presented to the participating countries this year.

Saudi Arabia has also requested IAEA technical assistance for a feasibility study on nuclear desalination. Work on this study was started in 1993, and is expected to be concluded by 1996.

Other work is being carried out in response to a resolution of the 1993 General Conference concerning demonstration facilities of nuclear desalination. As a first step, a study is being perfomed to identify, define, and characterize a practical set of options from which one or more demonstration facilities might be chosen. Work on this "options identification programme" started in 1994, and is expected to be concluded by 1996.

These activities, studies, and reports are not isolated efforts. Rather, they have been performed in a combined way, following a logical sequence, and complementing each other. They illustrate the IAEA's roles of facilitating the exchange of information and the transfer of knowledge and experience. In this way, it can serve as a catalyzer, organizer, or co-ordinator of nuclear desalination projects, and as a provider of technical assistance. The IAEA cannot, however, take a leading role for practical applications of nuclear desalination, nor can it design, build, own, or operate nuclear desalination complexes.

## Combinations, options, and prospects

There are various regions in the world, and many specific locations in a number of countries, where water demand exceeds supply and where seawater desalination constitutes the only or the best available supply option. There are, however, no reliable databases which would permit global quantitative estimates of water deficits.

The IAEA's studies have found that the North African and Gulf regions are characterized by overall water scarcity. As an input to the North African feasibility study, the region's participating countries analyzed their respective water demand and supply situations and available options for increasing supply. They identified a series of specific locations, with production demands for seawater desalination ranging from 20,000 to 720,000 cubic meters per day by the year 2005. Indeed, the countries of the region already have had to use fossil-fueled energy for desalination to supply their growing needs for potable water. Presently, there is an installed desalination capacity of the order of a million cubic meters per day in the region. In Saudi Arabia, the water supply is even more dependent on seawater desalination; the currently installed capacity is around four million cubic meters per day.

Though better knowledge of the current situation and more precise forecasts of the evolution of demand and supply are needed in these regions, there is no doubt that desalination will be required in increasing amounts to complement surface and diminishing groundwater resources.

Due to the relatively high cost of seawater desalination independent of the energy source used, this option is currently only relevant for the supply of potable water for personal, domestic, and industrial use. For widespread irrigation in agriculture, the costs are still too high. This restriction is expected to prevail for at least several decades. Among available desalination processes, three have been selected for study. These are the RO (reverse osmosis) process, the MED (multi-effect distillation)

***More countries are interested in desalting water from the world's oceans.***

process, and the MSF (multi-stage flash distillation) process.

It has been found that there are no technical impediments to the use of nuclear reactors as an energy source for seawater desalination. Nuclear reactors could provide electricity or heat, or both, as required by the desalination processes. Regarding nuclear safety, the same principles, criteria, and measures would apply as to any nuclear power plant. An additional requirement is that the product water would have to be adequately protected against any conceivable contamination.

Practically any type of nuclear reactor could provide the energy needed for desalination. Technical, and in many cases also economic information, was collected on about 20 reactor concepts from potential vendors. These concepts correspond to different stages of design and are mostly in the small- and medium-power range. The amount of energy — either in the form of heat or electricity or both — that can be supplied by nuclear reactors in this power range is typically more than enough even for very large seawater desalination plants. For example, a desalination plant with a capacity of one million cubic meters per day could supply an urban concentration of three to four million people with sufficient potable water for domestic use. Such a desalination plant using the RO process would require a nuclear plant having an installed capacity of about 300 megawatts-electric. This same urban concentration of people also would require between 4000 to 6000 megawatts-electric of installed capacity to provide their corresponding electricity needs. Hence, nuclear power plants in the upper end of the small- and medium-size power range, and certainly the large-size nuclear power plants, would only constitute suitable choices when they are intended to supply electricity to consumers in addition to energy for seawater desalination. Thus, there is no reason why nuclear reactors could not supply both requirements simultaneously, and take advantage of the economic benefits accruing to large-size nuclear plants.

In the North African feasibility study, it was assumed that the nuclear reactors would be integrated into the electric grid system, and the size of the reactors would only be limited by the grid size, i.e. not larger then 10% of the interconnected capacity. With this assumption, the options considered were in the small- and medium-power range, except in Egypt, where even large-size reactors could be utilized.

With the methodology applied and the assumptions adopted, the economic assessment in the 1992 IAEA generic study has shown that the use of nuclear reactors as an alternative option to the use of fossil fuelled plants would in general be economically competitive for medium- and large-size nuclear plants supplying electricity only or electricity and heat that are integrated into the electric grid system. Water production costs would generally be between US $0.7 and $1.1 per cubic meter. Combinations with plants supplying only heat result in considerably higher water production costs.

The economic assessment performed within the scope of the North African feasibility study confirmed these earlier results. In this assessment, the economic data provided by the potential vendors were used, instead of the parametric values adopted in the generic study.

The results obtained in such assessments are considered suitable for indicating economic feasibility. However, firm prices as contained in formal tenders would be needed prior to investments.

The studies performed have shown that a very large number of possible combinations exist between the many different reactor concepts, the various desalination processes, and the different coupling schemes. The options identification programme now under way is expected to identify the most practical approaches, and determine the associated demonstration requirements.

The institutional issues regarding nuclear desalination are fundamentally those corresponding to any nuclear power project. In particular, the development of suitable local infrastructure constitutes a challenge to any country starting a nuclear programme. Experience has shown that this can be done, though it does involve major efforts sustained over a relatively long period of time.

The North African feasibility study has shown that it is possible to perform such a study in co-operation with countries on a regional level. It has also shown that there are mutual benefits, if a common approach and joint efforts are applied. Several subject areas appear to be of particular interest for regional co-operation. These include the development of databases, and activities related to technology transfer; nuclear safety; regulatory infrastructure; local participation; and the development of human resources .

The work done within the framework of the IAEA's nuclear desalination programme over the past 5 years has shown what can be achieved through cooperative approaches involving active national participation and related technical and financial support.

All the results so far illustrate that the application of nuclear energy to seawater desalination is a realistic option. The challenge ahead is to demonstrate its use by proceeding with effective development and practical applications. ❐

# The International Arctic Seas Assessment Project: Progress report

*Under an IAEA-supported study, experts are taking a close look at past radioactive waste dumping in the Kara and Barents seas*

**by Kirsti-Liisa Sjoeblom and Gordon S. Linsley**

In 1992 the news that the former Soviet Union for over three decades had dumped large amounts of high-level radioactive wastes in the shallow waters of the Arctic Seas caused widespread concern, especially in countries with Arctic coastlines.

The IAEA responded by making a proposal for an international study to assess the health and environmental implications of the dumping. The proposal received support from the Contracting Parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention 1972). The study became known as the International Arctic Seas Assessment Project (IASAP) and was launched at a meeting jointly organized with the Norwegian and Russian Governments in Oslo in February 1993.

This article provides some background information on wastes dumped into the Arctic Seas and describes the progress made within the framework of IASAP.

## International control of dumping

The first recorded sea disposal of radioactive wastes took place in 1946 at a site in the North-East Pacific Ocean, about 80 km off the coast of California. In subsequent years, as sea disposal became more widely used as a radioactive waste disposal option, the pressure for it to be controlled also increased. In response, the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter was established in 1972 and entered into force in 1975. (This convention became well-known as the London Dumping Convention but has recently been renamed the London Convention 1972.) The Convention is recognized as the main international mechanism for the control of waste dumping at sea.

The Convention in its original form prohibited, *inter alia*, the dumping of high-level radioactive wastes and required that low-level radioactive wastes were dumped only after a special permit was issued. The IAEA was requested to provide a definition of high-level wastes unsuitable for sea disposal and provide recommendations concerning disposal sites, packages etc. for low-level waste disposal. Three documents were prepared to address the request.*

In 1983, following the concerns of some of the Contracting Parties to the Convention over the possible health and environmental risks which could be produced by the radioactive waste disposal operations, a voluntary moratorium on radioactive waste dumping at sea was imposed pending a wide-ranging review of the issue. The IAEA provided technical input to aid this discussion. In 1993 Contracting Parties to the Convention reached the decision to prohibit the sea dumping of all types of radioactive waste. It was noted that the decision on total prohibition was not reached on the basis of scientific and technical considerations but rather on social, moral, and political grounds.

## Sea dumping by the former Soviet Union

Information on the sea dumping practices of the former Soviet Union was first made public by a Russian non-governmental environmental group, Towards a New Earth. Greenpeace International, as observer to the London Convention,

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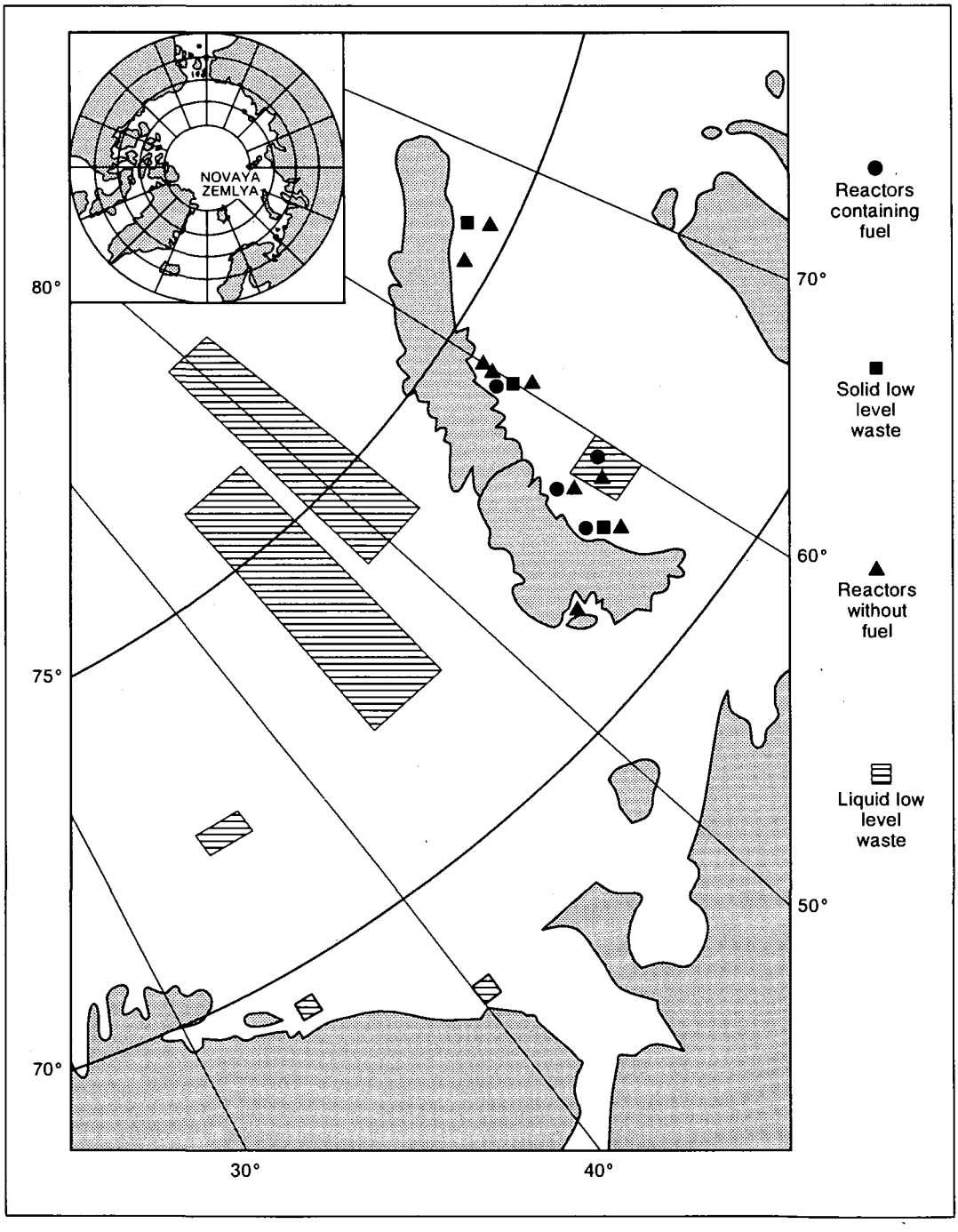
*For more information on sea disposal of radioactive wastes and the London Convention 1972, see articles in *IAEA Bulletin* editions Vol. 34, No.2 (1992) and Vol. 36, No. 2 (1994).

brought the issue to the attention of the Convention in 1991 and again in 1992. As a result, the Russian Federation was urged by Contracting Parties to the Convention to present complete information on the subject. The IAEA, in this period, developed plans to initiate a project for assessing the consequences of the dumping on human health and the environment and these were subsequently endorsed by the Contracting Parties to the Convention. The IAEA was requested to report the results of the assessment to the Convention.

In May 1993 the Russian Federation provided information to the IAEA about the high- and low-level radioactive waste dumped in the Arctic Seas and in the North-East Pacific during the years 1959-92. According to this report, the total amount of radioactivity dumped in the Arctic Seas was more than 90 PBq (90 x $10^{15}$ Bq or 2.4 x $10^{6}$ Ci). The items dumped included six nuclear submarine reactors and a shielding assembly from an icebreaker reactor containing spent fuel comprising a total of 85 PBq; ten reactors (without fuel) containing 3.7 PBq; liq-

**Sea disposal of radioactive waste in the Arctic Seas by the former Soviet Union and Russia**



uid low-level waste containing 0.9 PBq; and solid intermediate- and low-level waste containing 0.6 PBq. The packaged and unpackaged solid waste and the nuclear reactors were dumped in the Kara Sea, in the shallow bays of Novaya Zemlya. The depths of the dumping sites there range from 12 to 135 meters, and in the trough of Novaya Zemlya, 300 meters. The liquid low-level waste was discharged in the open Barents and Kara Seas. *(See table.)*

## Arctic Sea dumping in perspective

Until its amendment in 1993, the London Convention prohibited the disposal at sea of high-level radioactive waste but allowed, under special permit, the dumping of other types of radioactive waste. Much of the material dumped in the Kara Sea falls into the category of high-level waste. However, most of the spent fuel was dumped in the years before the London Convention came into being (1972) and before the USSR became a Contracting Party to the Convention (1976). The radioactive waste disposal continued in the Arctic Seas until 1991.

The IAEA's Safety Series No. 78 (issued in 1986) specifies locations and depths below which the dumping of low-level wastes can be permitted, when appropriate environmental assessment and notification to the Secretariat of the Convention have been made. The Arctic dumping sites do not fit within these specifications and, in particular, many of the dumping sites are in very shallow waters. It may be noted here that, prior to the entry into force of the London Convention, the dumping of radioactive wastes had also been carried out in shallow coastal waters in other parts of the world and by other countries.

In 1992, the Joint Norwegian-Russian Expert Group was established to investigate radioactive contamination due to dumped nuclear waste in the Barents and Kara Seas. It arranged exploratory cruises to the dumping areas, with the participation of a scientist from the IAEA's Marine Environment Laboratory (IAEA-MEL) in 1992, 1993, and 1994. All four sites where reactors containing nuclear fuel were dumped have been visited by the cruises of the expert group, but only some of the objects have been successfully located. The group has taken samples, made measurements and used a side scanning sonar and video camera in an attempt to identify and examine the wastes. The results obtained during the cruises have not indicated any significant radioactive contamination at the dumping sites, although the levels near some dumped objects are slightly elevated compared with elsewhere.

While it appears that there are no significant regional and global effects at present from the

**Data on the nuclear reactors dumped near Novaya Zemlya**

| Site | Year of dumping | Depth of dumping (meters) | Factory number | Dumped unit | Number of reactors | | Total activity (PBq) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Without spent nuclear fuel | Containing spent nuclear fuel | Initial data | Further studies | |
| | | | | | | | At the time of dumping | At the time of dumping | 1993/94 |
| Abrosimov Fjord | 1965 | 20 (10-15) | 285 | Reactor compartment | 1 | 1 | 29.6 | 11.6 | 0.655 |
| | | 20 (10-15) | 901 | Reactor compartment | - | 2 | 14.8 | 2.95 | 0.727 |
| | | 20 | 254 | Reactor compartment | 2 | - | * | 0.093 | 0.009 |
| | 1966 | 20 | 260 | Reactor compartment | 2 | - | * | 0.044 | 0.005 |
| Tsivolka Fjord | 1967 | 50 | OK-150 | Reactor compartment and a box containing fuel | 3 | 0.6 | * 3.7 | 19.5 | 2.2 |
| East Novaya Zemlya Trough | 1972 | 300 | 421 | Reactor | - | 1 | 29.6 | 1.05 | 0.293 |
| Stepovoy Fjord | 1981 | 50 (30) | 601 | Submarine | - | 2 | 7.4 | 1.72 | 0.838 |
| Techeniye Fjord | 1988 | 35-40 | 538 | Reactors | 2 | - | * | 0.006 | 0.005 |
| **Total** | | | | | 10 | 6.6 | 89 | 37 | 4.7 |

*Notes:* The initial data on total activity were provided to the IAEA in May 1993 by the Russian Federation; the data were revised following further studies within the framework of IASAP. The data on depths of dumping were provided in May 1993 by the Russian Federation; the data in parenthesis were obtained during joint Norwegian-Russian scientific cruises in 1993 and 1994.

* Reactors without spent fuel, not more than 3.7 PBq total.

dumped wastes, the gradual deterioration of the waste containments could lead to future impacts. These could occur through contamination of the marine food chain, possibly resulting in the radiation exposure of humans through the consumption of fish and other marine foodstuffs. Since the wastes are lying in shallow waters, the possibility of radiation exposure by other routes — such as the movement and transport of the waste packages by natural events (ice or storm action), or deliberate human action — cannot be ruled out. The time scales for consideration are very long (tens of thousands of years) and, therefore, the possible impact of climatic change has also to be taken into account. In order to provide answers to these questions, it is necessary to have a thorough understanding of the present and future physical, chemical, and biological characteristics of the environment surrounding the wastes and of the wastes themselves.

Preliminary assessments have indicated that even under the most pessimistic release conditions, the wastes would not cause a significant global radiological impact. However, it was evident then that to evaluate the possible risks at the local and regional scales considerably more information would be needed than was generally available in 1992. The International Arctic Seas Assessment Project (IASAP) was established to answer these and other related questions.

## Aims and implementation of IASAP

The objectives of IASAP take into account the requests of the Contracting Parties to the London Convention. They are to:

- assess the risks to human health and to the environment associated with the radioactive waste dumped in the Kara and Barents Seas; and
- examine possible remedial actions related to the dumped wastes and to advise on whether they are necessary and justified.

The results and conclusions of the project will be reported to the London Convention in 1996. The project is organized in five working areas: source terms; existing environmental concentrations; transfer mechanisms and models; impact assessment; and remedial measures.

The work is being carried out using normal IAEA mechanisms: consultants and advisory group meetings, a coordinated research programme, and research and technical contracts.

## Progress of IASAP activities

Progress in all IASAP working areas is reviewed each year by a group of senior scientists.

**Source term.** The aim of the Source Term Working Group is to determine the information needed about the waste for use in impact assessment calculations. This involves having knowledge of the waste form and of its likely behaviour with time in the marine environment. The efforts of the Group have been focused on the dumped reactors containing spent fuel which obviously pose the highest potential risk. At a later stage, consideration will be given to the packaged and unpackaged low- and intermediate-level waste.

The official information on the dumped waste provided by the Russian Federation in May 1993 did not include information on the radionuclide composition of the waste nor on the characteristics of the fuel in the different types of dumped reactors. To obtain more detailed information, it has been necessary to investigate the archives of the former Soviet Union and to reconstruct the history of the reactor fuel prior to dumping.

As the first step, in January 1994, a detailed inventory of radionuclide composition and information on the structure of the dumped reactor containment of the commercial nuclear icebreaker *Lenin* was obtained (OK-150 in the table on page 27). Later, in July 1994, the Russian authorities declassified essential details of the structure, operational history, and characteristics of the fuel of the dumped submarine reactors. As a consequence, the corresponding radionuclide inventories of the lead bismuth cooled submarine reactors (No. 601 in table) and the water cooled submarine reactors (numbers 254, 260, 285, 421, 538 and 901 in table) were made available to IASAP.

The total activity of the dumped reactors (with and without nuclear fuel) at the time of dumping is now estimated to be about 37 PBq. This may be compared with the first estimate of 89 PBq provided in May 1993 by the Russian Federation. The reason for lower actual figures is that most of the reactors met with an accident after a very short period of operation. This was not taken into account in making the original estimates. Due to the radioactive decay, the total activity of the dumped reactors at the present time is about 4.7 PBq.

For impact assessment purposes, it is also necessary to have information on the protective barriers provided for the dumped reactors either by the initial construction or through preparations prior to dumping. This information has also been obtained through contracts placed in the Russian institutes.

Fuel was removed from ten of the reactors prior to dumping. Those dumped with spent fuel (six reactors) had usually met with an accident prior to the dumping in which the fuel was dam-

aged. The dumping of the reactors took place by four principal means: 1) Most of the submarine reactors were dumped contained in their reactor compartments. The reactors were filled with a special polymer, furfural; 2) In some cases the reactors were taken out of the compartment and filled with furfural prior to dumping; 3) In the case of the lead-bismuth cooled reactors, the submarine compartment was filled with furfural and bitumen and the whole submarine was dumped (No. 601 in table). In this case the solidified liquid metal coolant forms an additional protective barrier; 4) The dumped component of the nuclear icebreaker *Lenin* includes a reactor compartment with three reactor vessels from which the fuel was removed and which were filled with furfural. 57% of the fuel from one of the reactors was dumped in a separate metal-lined concrete box also filled with the sealant furfural.

On the basis of an analysis of the weak points of the protective barriers, the Source Term Working Group has prepared sets of possible time patterns of radionuclide release and release rates.

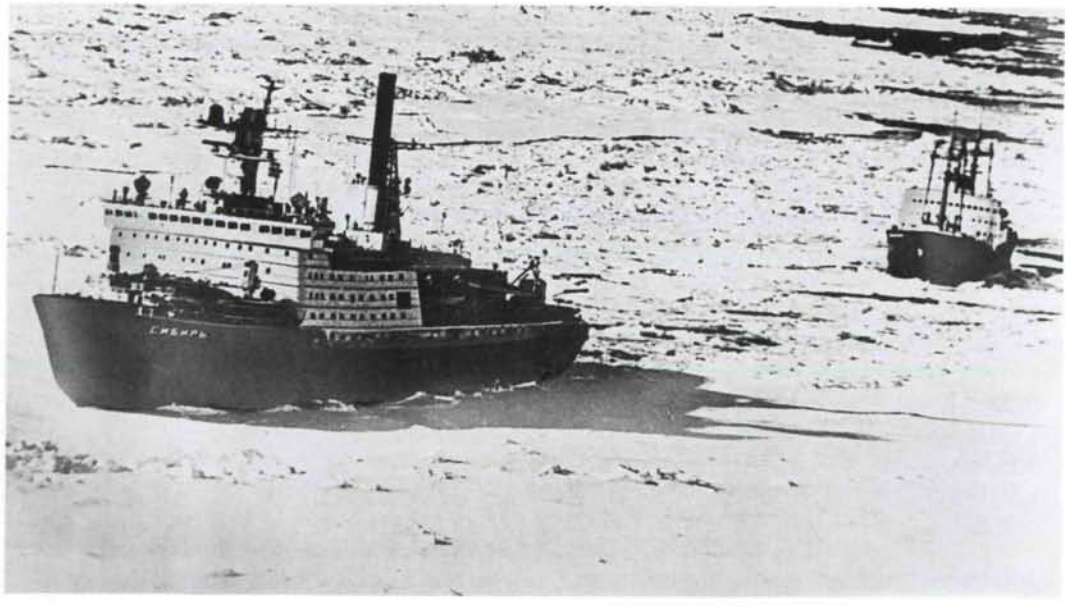
Further studies are expected to produce more accurate predictions of release. In this context, information on the physical and chemical characteristics of furfural and of its stability against radiation, heat, saline water, etc. would be valuable. In co-operation with IASAP, a study on the resistant properties of furfural was started early in 1995 as a Russian-US bilateral project.

The findings of the Norwegian-Russian exploratory cruises — for example, the results of visual investigation of reactors by means of underwater cameras; *in situ* radiometric measurements; and water and sediment sampling and analyses — are very important in the evaluation of the potential release rates. It is planned that the videotapes obtained during the exploratory cruises from the sunken objects will be carefully analyzed as a Norwegian-Russian co-operative project by experts on naval reactor and submarine design and on corrosion questions.

**Existing environmental concentrations.** Information on the levels of radioactive contamination in the target area and other areas of the Arctic seas is being collected as input to the Global Marine Radioactivity Data Base (GLOMARD) of IAEA-MEL. The database is designed to provide up-to-date information on radionuclide levels in seawater, sediment, and biota. It will enable the evaluation of nuclide ratios, identification of the different contributions to radioactivity in the region, the investigation of time trends, and the calculation of inventories. All available radionuclide data for the Arctic Seas have been entered into the database. The first report with a preliminary evaluation of existing radionuclide data will be available this year.

**Transfer mechanisms and models.** Laboratories in Denmark, Japan, the Netherlands, Russia, Switzerland, the United Kingdom, and IAEA-MEL are participating in the Co-ordinated Research Programme (CRP) entitled "Modelling of the Radiological Impact of Waste Dumping in the Arctic Seas". Its objective is to develop realistic and reliable assessment models for the Arctic Sea areas and to coordinate the efforts of different laboratories in the field. The final results of the modelling exercise will form the basis of the assessment for the London Convention.

A staged approach to the final modelling assessment is being taken. The participating modelling groups first analyzed scenarios based on assumed unit releases into a simplified environ-



**The waste dumped in the Arctic Seas includes reactor compartments from a nuclear icebreaker such as the one shown here.**

ment. At the first meeting of the CRP, the initial benchmark scenarios were supplemented with improved information on the oceanography and sedimentology of the Kara and Barents Seas, which was made available to the IASAP by Russian institutes. At the second meeting, fish and mammal catches from the target area and information on fish migration were included in the scenario.

At the same time, each modelling group participating in the CRP is in the process of developing and improving its models using the environmental information which is gradually becoming available from the target area. As the next step, release rates based on the results of the Source Term Working Group will be included in the scenario.

At the meetings of the CRP, the predictions of the different modelling groups for each benchmark scenario (i.e. concentrations of selected radionuclides in water and sediment in selected local and regional areas) are compared. This is done with a view to evaluating the sensitivity of the model results to the different modelling and transfer data assumptions.

**Impact assessment.** In 1995 and 1996, impact assessment calculations will be carried out on the basis of the concentration fields predicted by the Modelling Group and using appropriate environmental transfer factors and demographic data.

Radiation doses will be predicted at various times in the future for local, regional, and global populations. The predictions will take into account both the average consumers and those individuals whose diet consists of considerable amounts of seafood. The assessments will also include estimates of radiation dose to local fauna such as marine mammals.

Information on radionuclide concentration factors for biota and distribution factors between sediment and water relevant to the Arctic conditions is being acquired through projects of IAEA-MEL and other laboratories. The radiological, physical, and chemical measurements made on samples taken from the Arctic area are being analyzed and compiled and a literature review is being conducted. For nuclides and biological species on which appropriate local data is not available, the applicability of concentration and distribution factors derived at moderate latitudes will have to be considered. It is planned that the various sources of information will be evaluated by a small group of experts by the end of 1995.

**Remedial measures.** The Contracting Parties to the London Convention requested the IAEA to consider possible remedial actions in relation to the dumped wastes and to consider their feasibility. A group of technical experts was convened early in 1995 to consider possible remedial measures mainly from the standpoint of technical feasibility. While the findings of the group must be considered preliminary at this stage, certain general conclusions can be drawn:

- The objects which contain spent nuclear fuel should be considered as the prime potential subjects for remediation.
- Well-developed techniques are available for *in situ* remedial measures such as capping or underwater burial.
- If a remedial measure involving transport were to be chosen, underwater transport is a noteworthy option.

This subject will be discussed again at meetings in 1995 and the radiological impact of the various possible remedial options will be given special attention. One of the waste management options which has to be considered is leaving the wastes as they are without remediation. A decision to carry out remediation must be based, at least partly, on the judgment that potential future radiological risks from the dumped wastes are unacceptable.

## Coordinating global efforts

One of the basic ideas in establishing IASAP was to provide a mechanism for coordinating international efforts in the field. The cooperation with the Norwegian-Russian expert group on investigation of dumping of radioactive waste in the Barents and Kara Seas is recognized as being essential to the IASAP project. A small coordination body comprising one member from Norway, Russia, and the IAEA has met three times.

Exchange of information is maintained between IASAP and other groups working in the area of radioactive contamination of the Arctic, notably with the Arctic Nuclear Waste Assessment Programme of the United States.

It has also been agreed that the results of the IASAP project will be made available to the Arctic Monitoring and Assessment Programme (AMAP). AMAP is a component of the Arctic Environmental Protection Strategy (AEPS) as adopted in 1991by Ministers of eight Arctic Nations in their Declaration on the Protection of the Arctic Environment. AMAP is conducting an overall review of the impact of all types of pollution on the Arctic Seas. ❐

***See the following article for a report on the IASAP work of scientists from the IAEA's Marine Environment Laboratory in Monaco.***

# Marine scientists on the Arctic Seas: Documenting the radiological record

*The IAEA's Marine Environment Laboratory in Monaco is helping to assess the radiological picture in the Kara and Barents Seas*

**by Pavel Povinec, Iolanda Osvath, and Murdoch Baxter**

Before 1992, not much was known internationally about radioactivity levels from dumping operations in the Arctic Seas. That picture has changed over the past three years, largely due to the joint efforts of scientists from Russia, Norway, and the IAEA's Marine Environment Laboratory in Monaco

In 1992, the Agency's Marine Environment Laboratory (IAEA-MEL) responded to an invitation by the Russian and Norwegian governments to participate in investigatory cruises to the Kara Sea and to assist in the assessment programme related to the disposal of radioactive wastes in the Kara and Barents Seas. The IAEA-MEL programme, organized later in the framework of the Agency's IASAP project, included:

- participation on four expeditions to the Kara Sea organized by the joint Russian-Norwegian expert group and by the Russian Academy of Sciences during the period 1992-94;
- assistance with *in-situ* and laboratory-based radiometric measurements of radionuclide concentrations in the Kara Sea;
- organization of analytical quality assurance intercalibration exercises among the participating laboratories;
- provision of a central database facility for the IASAP project, including all available data on past and present radioactivity concentrations in the Arctic Seas; and
- contributing to the international programme of local, regional, and global scale computer modelling of the potential dispersal of radionuclides released from the dumped waste and the assessment of the associated radiological consequences.

Mr. Baxter is Director, Mr. Povinec is Head of the Radiometrics Section, and Ms. Osvath is a physicist at the IAEA's Marine Environment Laboratory in Monaco.

## Expeditions to the Kara Sea

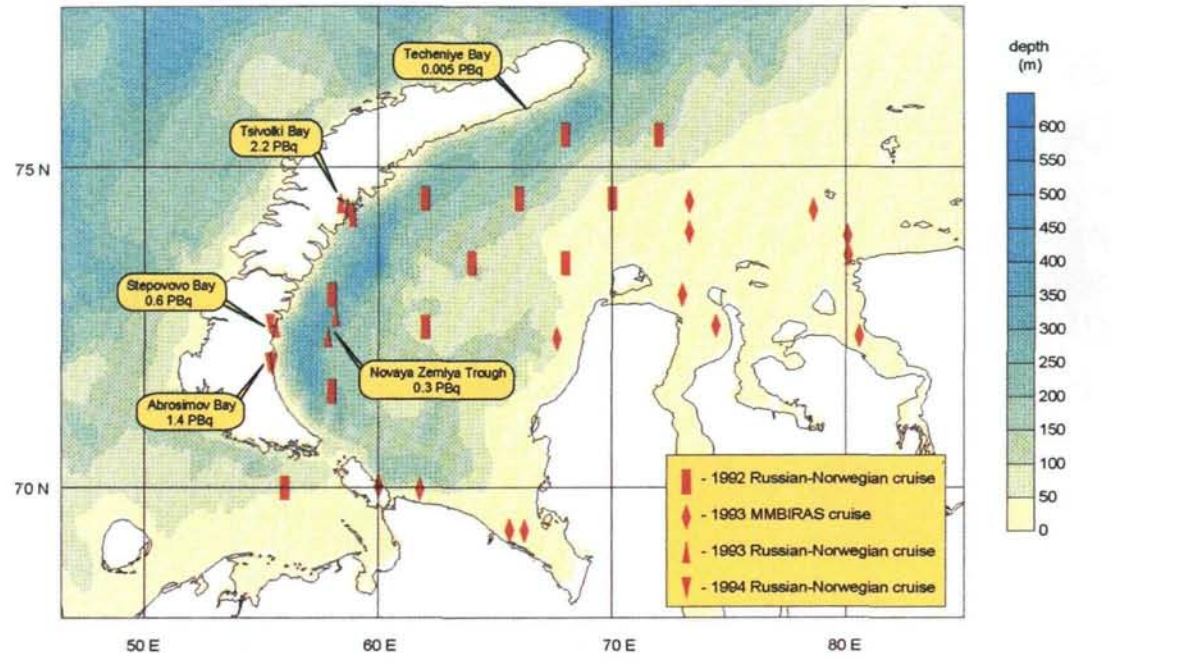
Few data exist in the open literature published before 1992 to document radioactivity levels in the Kara Sea. Those that exist are notably results of US and Russian surveys in the 1960s and 1980s. In 1992, following announcements about past dumping of radioactive wastes in the shallow waters off Novaya Zemlya, the Russian and Norwegian governments organized the first in a series of three joint expeditions to the Barents and Kara Seas and the IAEA was invited to participate in these. *(See map.)*

The scope of the first cruise was to investigate radioactive contamination of the marine environment in the open Kara Sea, with the aim of identifying and quantifying any contributions from local sources. In 1993, official information on the dumping was published, on the basis of which the 1993 and 1994 joint Russian-Norwegian expeditions were then planned. The objectives were to investigate the dump sites in the Tsivolki, Stepovovo, and Abrosimov bays and in the Novaya Zemlya trough in order to locate and identify the dumped objects, to document their state, and to measure the radioactivity levels in their environment. The sites were inspected using towed sonar systems, underwater spectrometers, and remotely operated vehicles.

The searches in the bays were successful. They yielded detailed information on dumped reactor compartments, cargo ships, and tankers with solid waste; the liquid metal-cooled submarine in Stepovovo Bay; and large numbers of containers with solid waste. All cruises performed *in situ* and on-board radiometric analyses and returned sets of environmental samples and data needed to allow an assessment of the environmental and health impacts of dumping.

The sampling strategy was aimed at (1) providing evidence of leakage, if any, from the dumped waste; (2) evaluating dispersal from the sources and mapping radionuclide distribution

**Sampling stations occupied during the 1992-94 Kara Sea cruises and estimated radionuclide inventories at sites**




*Note* The estimated inventories of radionuclides refer to 1994 and pertain to naval reactors disposed at major dump sites based on IASAP working documents

patterns in bottom sediments; (3) evaluating different contributions to the radionuclide inventories; (4) assessing contamination of biota, radionuclide transfer, and site-specific concentration factors; and (5) investigating the time evolution of radioactivity levels.

Water and bottom sediment profiles, marine biota and, from the 1994 cruise, samples of soil, fresh water, and vegetation from the shores of the bays were collected for further detailed radionuclide analyses. This was done mainly in Russian and Norwegian laboratories and at IAEA-MEL. To assure the quality of radioactivity data, IAEA-MEL organized intercomparison exercises for radionuclides in sediment, water, and seaweed for the laboratories involved in analytical work on cruise samples.

An important contribution to inventories of artificial radionuclides in the Kara Sea can be attributed to inputs from land-based sources in the catchment areas of the Ob and Yenisey rivers. Therefore, in 1993, the IAEA-MEL also joined an international expedition organized by the Russian Academy of Sciences to investigate radioactivity in the southern part of the Kara Sea.

At IAEA-MEL, the analytical work on approximately 300 samples brought back from these four expeditions is in progress. Laboratory experiments have also been initiated with materials returned from the Kara Sea on the biokinetics of radionuclides and their interaction with sediments in specific Arctic conditions.

## Radiometric investigations

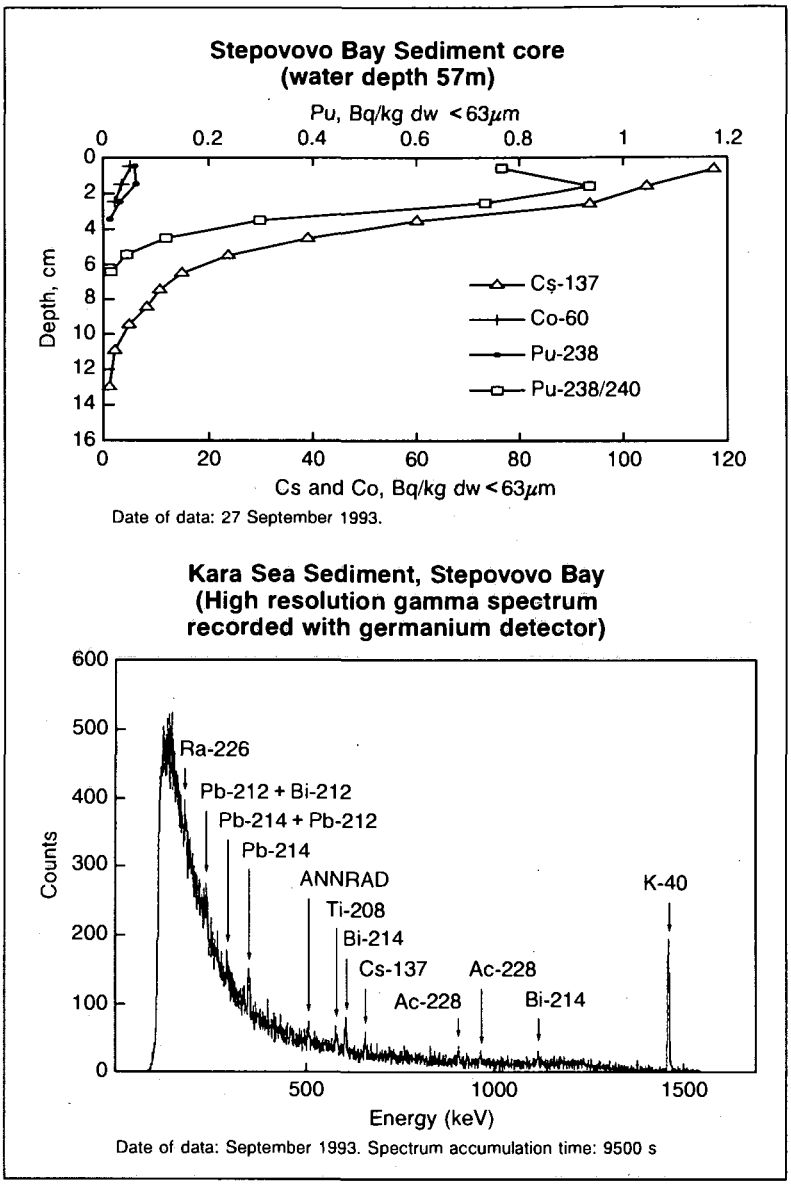
The results of radionuclide analyses of samples collected during expeditions to the Kara Sea show unambiguously that, as yet, there has been no major leakage from the disposed radioactive wastes. Perhaps the most persuasive piece of confirmatory evidence is IAEA-MEL's investigation of gamma-radiation at the sediment surface in the Stepovovo Bay dump site. The gamma-spectrum —obtained using IAEA-MEL's new underwater survey system which includes a cooled HPGe detector — is one of the first sets of high resolution marine gamma-spectra ever recorded *in-situ*. The system had first been tested successfully in the Irish Sea, near the Sellafield nuclear site, in summer 1993.

The spectrum shows at a glance the predominance of the gamma-ray lines from naturally occurring (background) radionuclides, namely from potassium-40 and the uranium and thorium decay series. The only identifiable anthropogenic radionuclide is caesium-137 at a concentration which is well below those of the natural radionuclides. Despite the vicinity to the dumped reactors and the sites of many past nuclear weap-

ons tests, the concentrations of anthropogenic radionuclides are low, less than in many other areas of the world's oceans. *(See graph.)*

Radiometric analyses of Kara Sea sediments in the laboratory have also shown clearly that the present anthropogenic radioactivity of Kara Sea sediments is low. It is predominantly due to direct deposition and catchment run-off of global fallout from nuclear weapons tests, discharges from the reprocessing plants in Western Europe and the former Soviet Union, Chernobyl fallout, and local fallout from nuclear tests performed at Novaya Zemlya. However, at the major dumping sites in Abrosimov, Stepovovo, and Tsivolki bays off Novaya Zemlya island, areas with elevated concentrations of caesium-137 and cobalt-60 have been found. *(See graph.)* These results indicate that local contamination due to leakage from dumped low-level wastes has occurred but that this is not detectable beyond the dump sites.

Our study, along with the work of Russian and Norwegian colleagues, shows that there is no evidence of major leakage from the reactor components and other wastes disposed of into the Kara Sea. Past and present radionuclide concentrations in seawater and sediments of the Kara Sea have generally been and still remain very low. The major residual issue regarding these disposals is therefore not what has happened so far but what could happen in future. The main scientific challenge is to predict the possible magnitude, nuclide composition, dispersal, transfer, and radiological consequences of any future leakage from the dumped reactors and other nuclear wastes.




**Results of radiometric investigations in the Kara Sea**

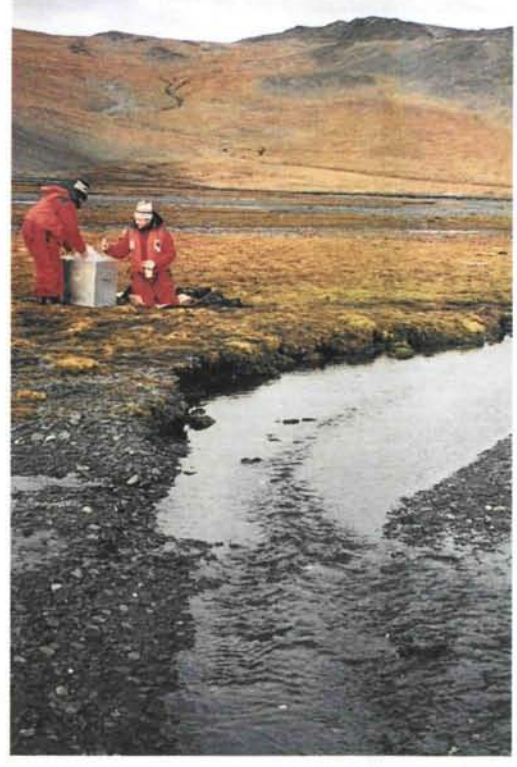
## Radioactivity database

A further contribution by IAEA-MEL within the framework of IASAP is via its Global Marine Radioactivity Database (GLOMARD) programme. The laboratory is acting as a central facility for the collection and synthesis of all data on marine radioactivity, i.e. in seawater, sediments, and biota. The database provides a scientific resource designed to serve several important functions, such as the provision of immediate and up-to-date information on radioactivity levels, the generation of snapshots of activities at given times and locations, the investigation of temporal changes, and the identification of gaps in available information.

The database has links to IAEA-MEL's in-house analytical quality control database. This allows immediate checks on laboratory practice. In the specific context of the Arctic Seas, the database will provide input to the evaluation of the environmental radioactivity levels of the region and to the assessment of the radiation doses to marine biota and local, regional, and global human populations. Some of the uses of the database within the Arctic assessment programme are immediate. They include the evaluation of nuclide ratios, investigation of time trends, inventory calculations, dose estimation, and model validation.

## Computer modelling and radiological assessment

Dispersion and radiological modelling has begun on three geographical scales, namely global, regional and local. This is being done in order to predict the possible consequences for the world at large and for those populations living near to the disposal sites. For modelling dispersal



**Scientists from IAEA-MEL have taken part in four expeditions to study the radiological situation in the Kara Sea, sometimes under difficult sea conditions. In addition to soil samples collected on the island, researchers collected biota and other samples in the waters of the Kara Sea.**

(*Credit: I. Osvath, IAEA-MEL*)

of radioactive pollutants on a global scale, IAEA-MEL has developed and implemented a number of compartmental models.

This class of models is particularly suited to long-range (greater than 100 years) assessments and has been previously used in other programmes (e.g. the Nuclear Energy Agency's CRESP and the European Commission's MARINA). The accuracy of results from such models is also well suited to the detail required for radiological assessments.

The work reported here is based on the 16-box ARCTIC-2 model, with enhanced structure in the Arctic region. The model provides a satisfactorily accurate prediction of Sellafield caesium-137 dispersion through the northern seas.

Doses to the world population (committed effective collective doses integrated over 300 years following release) and maximum individual dose rates for hypothetical critical groups were calculated based on the marine fish ingestion pathway. The oceanographic part of the model produces radionuclide concentration data as output. The radiological component translates radionuclide concentrations in water into corresponding concentrations in fish, using IAEA-recommended concentration factors. Catch values are derived from fishery statistics data of the Food and Agriculture Organization and ICES. Radionuclide intake by humans is quantified assuming that 50% of total fish catch is normally consumed, with the exception of the Arctic Seas where a consumption of 80% is assumed. Fish catch is taken as constant over the period of interest, and no delay between catch and consumption is considered. The final conversion to dose is achieved using dose conversion factors for adults based on those contained in ICRP-60 of the International Commission on Radiological Protection.

A range of source-term scenarios has been developed on the basis of available information on the nuclear wastes, including reactors, dumped in the Arctic. The calculations have been performed for 20 long-lived radionuclides both at time of dumping and 500 years thereafter.

For a gradual release of caesium-137 over 20 years following dumping from the naval reactors containing spent nuclear fuel disposed in the Kara Sea, the model predicts maximum concentrations of about 10 Bq per cubic meter averaged throughout the western Kara Sea bottom water compartment. This corresponds to less than 1% of the natural radioactivity of sea water. Local and regional models, with enhanced spatial resolution, will be used to localize and quantify smaller scale maxima.

A simple evaluation was made, on the basis of available information, of the radiological effects for a worst case scenario. Dose calculations based on estimated maximum inventories in reactors dumped in the Kara Sea indicate a committed collective effective dose in the order of 10 man Sv, if instantaneous release occurs at the time of dumping. More than 70% of this dose is delivered by caesium-137, and most of the remaining part is contributed by activation products (cobalt-60 and carbon-14). These computations are based on the assumption that the fish catch in the Kara Sea is about 20 kilotons per year.

The assumption of instantaneous nuclide release is, however, an extremely unrealistic one. The mechanism of release for the bulk part of the inventory would normally be via corrosion, occurring over periods of up to hundreds or even thousands of years. In particular, the dissolution of cobalt-60 from steel and other structural components is unlikely to be quantitative within the short mean lifetime (about 7.6 years) of this nuclide. Thus, from a rapid release of reactor-derived radionuclides, caesium-137 is indeed the main deliverer of dose beyond the immediate disposal region. For a delayed release of radionuclides, e.g. after 500 years of containment, 99% of the fish ingestion dose commitment will arise from carbon-14.

To assess the impact on a regional scale, three-dimensional circulation and dispersion models developed at the University of Hamburg are now being employed. Preliminary calculations performed to test model predictions show that, for a continuous release of 1 TBq per year of caesium-137 in Abrosimov Bay, the average caesium-137 concentrations in the entrance of the bay could reach 2 kBq per cubic meter.

## Documenting the radiological situation

The IAEA-MEL's radiometric and preliminary modelling contributions to IASAP have yielded important results so far. They suggest that only radiological effects on regional and local scales may be of importance. The global radiological impact of past waste dumping in the Arctic Seas will be comparable to or less than those resulting from other anthropogenic and natural sources of radioactivity.

Scientists from IAEA-MEL will continue to be actively engaged in many facets of this important international project to investigate and document the health and environmental implications of past radioactive waste dumping practices in the Arctic Seas. ❐

# Atoms for sustainable agriculture: Enriching the farmer's field

*A look at how nuclear and isotope techniques help find ways to improve poor soils and sustain the world's crop production*

by
**Christian Hera**

Land represents a mere 29% of the world's total area, yet provides approximately 98% of its food. Most of this land is not very fertile: only 11% is of high fertility, 28% of moderate fertility, and 61% of low fertility.

At the same time, land, nutrient, crop, and water management practices in most developing countries are quite poor. Mining, for instance, causes soil deterioration which is no less dangerous than any other form of environmental degradation. This is one reason why the protection of nutrients and water is a major concern in many parts of the world, especially in developing countries.

Efforts to minimize soil losses and replenish nutrients are essential. Many organizations are paying increasing attention to the development of an integrated plant nutrition system. The basic underlying concept is the maintenance and possible increase of soil fertility for sustaining crop production through the best use of all possible sources of plant nutrients. This approach is ecologically, socially, and economically viable.

Nuclear and related isotope techniques are an important part of such agricultural solutions. They normally are used to compliment conventional or classical techniques in agricultural research, and they provide data that other methods cannot. This article looks at how nuclear techniques have been, and continue to be, used in soil and crop research. To a significant extent, their use has been stimulated by the combined efforts of the IAEA and Food and Agriculture Organization (FAO) of the United Nations. Since 1964, they have conducted programmes through the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, headquartered at the IAEA in Vienna.

Mr. Hera is Head of the Soil Fertility, Irrigation and Crop Production Section of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture.

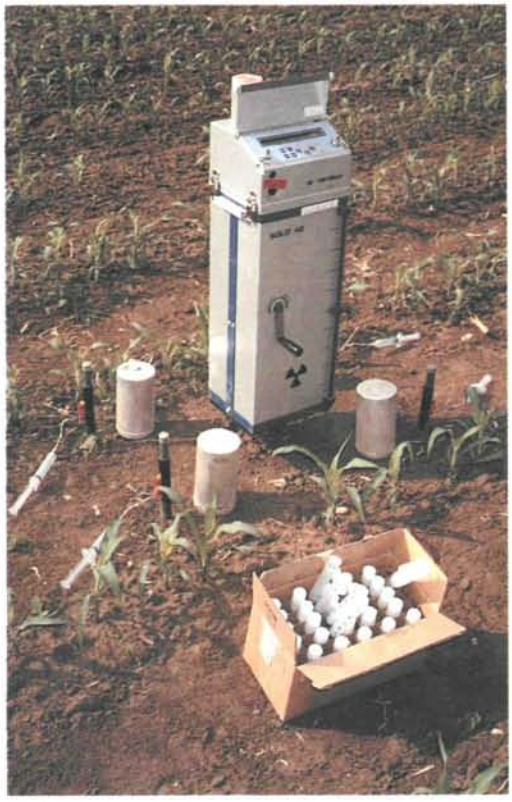
## The historical perspective

Research with isotopes dates back to 1923 and the work of G.V. Hevesy, which signified the start of isotope applications in soil and crop research. Some 35 years later, in 1959, the newly formed IAEA awarded its first research contracts to Japan and the Federal Republic of Germany to support studies on the efficiency of fertilizer use. Starting in 1962, research contractors from developing countries, and agreement holders from developed countries, were integrated through IAEA co-ordinated research programmes (CRP). The first two CRPs initiated by the IAEA were also in the area of soil fertility. They focused on the application of isotopes to rice fertilization (1962-68) and on plant nutrient supply and movement in soil systems (1962-68).

Since then, dozens of CRPs have been conducted. All told over the past three decades, the Joint Division's Soil Fertility, Irrigation and Crop Production Section has had the technical responsibility for 29 CRPs. Much of the research was inspired by some of the world's top soil scientists, including Mac Fried, who became the first Director of the Joint FAO/IAEA Division, and Hans Broeshard, who headed the Agricultural Laboratory at Seibersdorf. Their pioneering efforts left their mark on soil scientists all over the world.

From the very beginning, the use of isotopes and related techniques proved to be extremely valuable for increasing the efficiency of fertilizers and optimizing plant nutrition, among a wide range of other applications. Using an isotope to label a nutrient in fertilizer or in soil, for example, is an invaluable direct method to distinguish between the amount of the nutrient that plants take up from each source.

**Fertilizer studies.** Over the past 30 years through activities of the Joint Division, the use of isotope techniques has largely been directed



*Clockwise from above:* **A neutron moisture meter used for measurements of water content in soil; IAEA Director General Hans Blix (second from left) and FAO Director General J. Diouf (centre) head a group being briefed by the author at the IAEA General Conference on the use of nuclear and related techniques in soil and crop studies; Dr. Helga Axman of the FAO/IAEA Soil Science Unit with participants at a regional training course in Ghana; participants in a 1995 regional training course in Bangkok on the use of isotopes in soil/plant relationships.**

*(Credit: C. Hera, IAEA)*

at studies of fertilizer efficiency for major food grain crops, such as rice, maize, and wheat. The main objectives have been to achieve higher and more stable grain yields by maximizing the uptake of nutrients from applied fertilizers and other sources, and to simultaneously reduce potential harmful environmental effects. For instance, fertilizers labelled with nitrogen-15 have been applied to a crop in different ways (sources, timing, placement) to determine and measure its uptake. The research helped scientists identify the most efficient methods of fertilizer application for different soils and climatic conditions.

In the first rice fertilization programme (1962-68), one question was the relative efficiency of different sources of nitrogen when they were applied on the surface or incorporated in the top five centimeters of soil. Field experiments using ammonium nitrate, whose two main components were labelled with nitrogen-15, were carried out in five countries. The results clearly demonstrated which component was the most effective source of nitrogen to paddy rice, and how it should be applied. The highest uptake of nitrogen was obtained when ammonium was incorporated beneath the soil. Placement had no significant effect on the utilization of nitrate.

A highly successful CRP was on maize fertilization, in which eight countries participated. Studies sought to examine the best ways of applying fertilizer in the fields, compared with the classical application of broadcast spreading on the soil surface followed by ploughing. Fertilizers labelled with nitrogen-15 and phosphorus-32 were used. Results led to the conclusion that farmers should split the amounts of fertilizer they apply and spread them in different ways (called banding) and at different times in the growing cycle.

Results were put into practice in Romania. Seeders were equipped with special devices for applying fertilizer at seeding time, and cultivators for weed control were equipped with devices for applying fertilizer at the vegetation period. They were used during maize production on an area of two million hectares. Over a period of 6 years, an average yield increase was realized of 0.62 tonnes per hectare, as compared to yields obtained through the classical fertilizer method.

The investment for adapting to the new method represents only 5% of the total value of the yield increase that can be obtained every year. The method's advantages are even greater when taking into account that it eliminates the supplementary work, and possible associated negative soil effects, involved in classical fertilizer application.

## Nitrogen from the atmosphere

In spite of the abundance of nitrogen in the atmosphere (78% of all gases), it is one of the most limiting factors for crop growth. Only certain crops can directly use atmospheric nitrogen. Overcoming this limitation through the application of nitrogen fertilizer represents one of the major costs of crop production.

A process known as biological nitrogen fixation (BNF) has become a feasible alternative for farmers in both developing and developed countries. Legumes and a few other families in symbiosis with appropriate microorganisms are able to directly utilize atmospheric nitrogen through this process. It offers several advantages, including less expense, reduced pollution hazards, enhanced soil fertility, and greater protein content of crops. To realize these gains requires the proper management of nitrogen fixing systems. Nitrogen-15 isotopic techniques can provide quantitative and integrated values of nitrogen fixed in both natural and agricultural systems.

During the last two decades, several FAO/IAEA international research programmes have focused on measuring and enhancing BNF, especially symbiotic legume fixation in various systems. Current programmes emphasize the improvement of both yield and nitrogen fixation in grain legumes through an integrated multidisciplinary approach.

Results so far show large nitrogen fixation differences between the grain legumes species. For some, such as fababean, the process works rather effectively, while for others, such as common bean, it does not. These differences were persistent under a wide range of environmental conditions. Also considerable genotypic variations in nitrogen fixation between cultivars of common bean were found in different countries.

Of particular interest in BNF are nitrogen fixing trees. Studies show them to be an important component of agricultural systems. They play a significant role in restoring or increasing soil fertility and in decreasing soil erosion, and they grow well in nitrogen-deficient soils. Methods that can accurately measure factors affecting the growth of such trees under different conditions have been, and continue to be, studied.

Other studies have focused on the role played by blue-green algae and their association, particularly *Azolla,* in lowland rice fields.

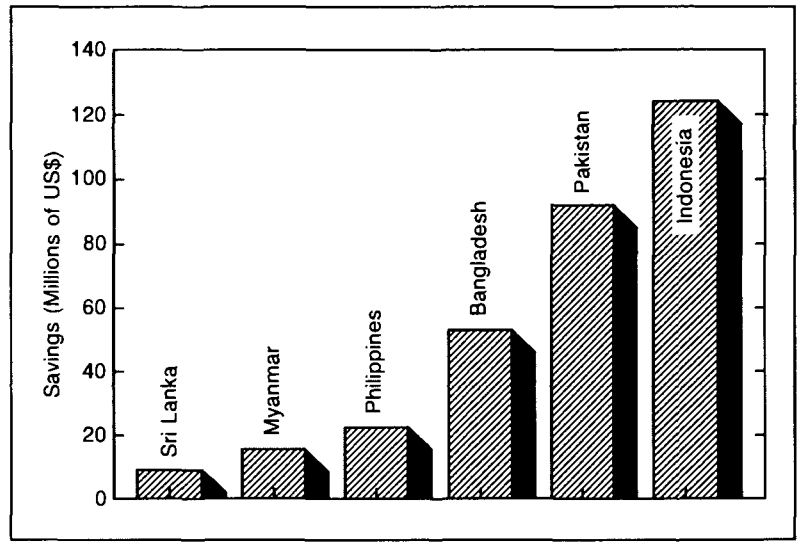
High yielding rice varieties linked to the "green revolution" require large amounts of expensive chemical nitrogen fertilizers. Scientists have long recognized that the aquatic nitrogen fixing *Azolla-Anabaena* symbiosis could replace at least part of the nitrogen requirement for rice. From 1984-89, a programme with financial sup-

port from the Swedish International Development Authority (SIDA) was coordinated by the Joint Division's Soil Fertility, Irrigation and Crop Production Section to investigate the benefits of using *Azolla* as a biofertilizer for rice. Scientists from nine rice producing countries — Bangladesh, Brazil, China, Hungary, Indonesia, Pakistan, Philippines, Sri Lanka, and Thailand — participated.

Although the *Azolla-Anabaena* symbiosis has been used for centuries as a green manure for rice in parts of China and Viet Nam, intensive scientific research only began after the 1973 oil shock dramatically increased the cost of nitrogen fertilizers. *Azolla* can grow very rapidly, doubling its weight in three to four days under optimal conditions. Yet before this programme began there was little evidence from field experiments to indicate whether the nitrogen accumulated by *Azolla* in the field was primarily drawn from the atmosphere or from the soil. Although there was substantial evidence to show that incorporating *Azolla* into the soil increased rice yields, only a few experiments had been done to explore the reasons for this.

With extensive use of the nitrogen-15 labelling technique, it was shown that 70% to 80% of the nitrogen in *Azolla* is derived from atmospheric fixation, and that there was no evidence of significant competition with rice for limited soil nitrogen. In fact, the most recent experiments have shown that a cover of *Azolla* floating on the surface of rice floodwater can even improve the efficiency of chemical nitrogen fertilizers. Urea is the most common nitrogen fertilizer used for rice. However, its efficiency is usually low and 50% or more can be lost to the atmosphere. Hydrolysis of urea in the water produces an alkaline reaction, and combined with the effects of algal photosynthesis, pH values over nine are commonly observed. At this pH level, ammonium is converted to the volatile gas ammonia. *Azolla* fortunately limits algal growth through shading of the floodwater. Following fertilizer applications, pH values one to two units lower were observed when *Azolla* was present.

The second effect is that *Azolla* takes up part of the nitrogen fertilizer from the water. If the *Azolla* is then incorporated into the soil, this nitrogen fertilizer becomes available to the rice along with the fixed nitrogen. In an experiment in Fuzhou, China, losses of nitrogen from a urea top dressing applied 2 weeks after transplanting were reduced from 50% without *Azolla* to 25% when the field was inoculated with *Azolla* at transplanting. Uptake of labelled fertilizer by rice was increased from 26% to 35%. In Thailand, application of urea at transplanting with and without inoculation with *Azolla* resulted in yield increases of 10% to 15% in plots with *Azolla*.




**Potential savings in rice production using *Azolla* as nitrogen fertilizer**

When *Azolla* was incorporated into the soil, it proved to be as good as urea as a nitrogen source for rice. Not only the uptake of nitrogen from *Azolla* was equal to that from urea but there was also the additional benefit that more of the nitrogen added as *Azolla* remained in the soil after harvest. In some of the tests, there was sufficient nitrogen available to the next crop to produce a yield increase of two to three times compared to urea, particularly when wheat followed the rice crop. Estimated savings from one crop of rice by the use of *Azolla* as a nitrogen fertilizer are substantial. *(See graph.)*

This successful programme demonstrated that a group of scientists from different parts of the world could work together, use the same critical methodology, and make rapid progress toward common goals. Since the studies were done in a wide range of environments, the results can be widely applied.

## Photosynthesis and water use

Isotope techniques are indispensable in studies of photosynthesis, plant metabolism, translocation, and nutrient uptake. By exposing plants to carbon dioxide labelled with carbon-14, photosynthesis and movement of metabolites throughout the plant can be monitored using techniques such as autoradiography. Recently, carbon-13 has been increasingly employed in tracer studies because of its greater availability and the ease with which it can be measured. Moreover, as a stable isotope, carbon-13 is environmentally friendly and therefore invaluable in studies of soil organic matter and greenhouse gases. However, plants discriminate against

carbon-13 during photosynthesis. Though it varies depending on the plant species, the discrimination is closely associated with a plant's ability to utilize water.

This technique can be useful for selecting cultivars of crop and tree species efficient in water use. Through one CRP, several genotypes of food crops and trees have been identified in poor soils that are highly efficient in the use of limited resources of water. In Morocco and Tunisia, genotypes of wheat have been found that are efficient in water use and produce high yields. In Sudan, provenances of the gum arabic tree *Acacia Senegal* have been identified which are highly efficient in growing in drought-prone regions. In Sri Lanka, the technique further has assisted scientists in identifying cultivars of coconut that are highly tolerant to drought and therefore eminently suitable for cultivation in the dry region of the country.

A recent research project, initiated in 1990, is investigating the effective use of scarce water resources to maximize plant productivity. The use of neutron moisture meters and other related techniques have helped assess irrigation practices and schedules. The meters were used successfully not only to measure the soil's water content but also to understand water dynamics under field conditions. Another CRP has examined the efficiency of water and fertilizer use in semi-arid farming systems. Since semi-arid zones, by definition, are deficient in rainfall, plant growth and crop yields are heavily dependent on the proper management and conservation of water. The research helped to identify measures for ensuring that crops receive an adequate amount of nutrients under such farming conditions.

## Environmental protection

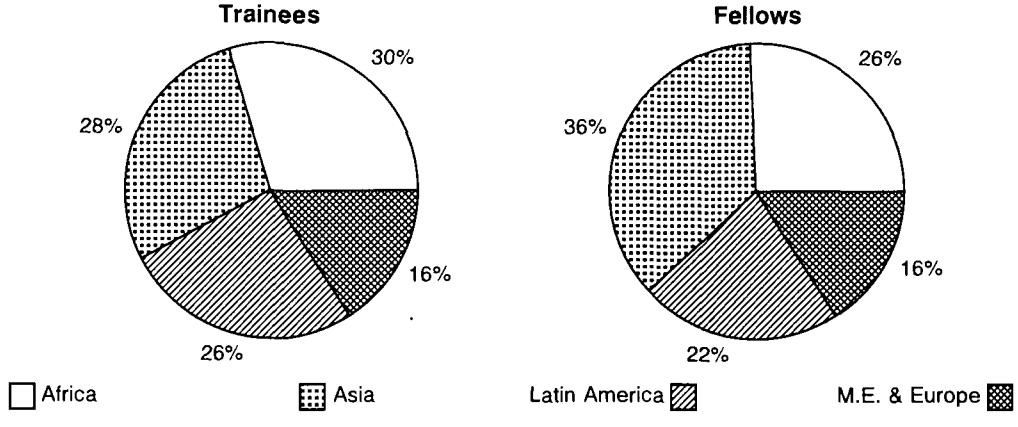
Alongside the need for improving agricultural productivity, many countries, mostly industrialized ones, share a problem of a different kind, namely the entry of nitrogen into groundwater and pollution of drinking water and lakes. In this case, there are simultaneous needs to protect existing and potential agricultural soils and nitrogen resources, and to meet the rising standards of environmental protection worldwide.

Nitrogen-15 provides a particularly powerful tool for studying the behavior of fertilizer nitrogen in the environment. With the support of Germany, the Soil Fertility Section of the Joint FAO/IAEA Division has carried out an international programme that provides key guidance for addressing problems. Based on the studies that were done, a number of conclusions were drawn. They include:

- Taking into account the prospects and time needed for developing alternative agricultural practices, conventional nitrogen fertilizer ap-

**FAO/IAEA-supported training activities in soil and crop science**

**Hundreds of scientists from around the world have been trained through courses and events organized by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. From 1978-94, eighteen training courses were held for 345 participants from 80 countries. Another 142 scientific fellows received training during the 1962-94 period. Shown below is the geographic distribution of trainees and fellows.**




Note: Data are for activities organized by the Soil Fertility, Irrigation and Crop Production Section and Soil Science unit at the IAEA Seibersdorf Laboratories

plications must continue to intensify and extend for the immediate decades ahead.

- As a result of this intensification, increasing amounts of nitrogen both in native soil and added as fertilizer will be lost from the soil-plant system and find their way into the environment. Soil-nitrogen levels and contingent productivity can nevertheless be maintained by developing improved soil-nitrogen management practices.
- In some situations, the nitrate levels in ground and drinking water are likely to continue rising. A proper diagnosis of the various sources responsible for this problem should be made.
- In developing countries, the losses of fertilizer nitrogen represent those having a relatively high cost input. In the more advanced industrialized countries, on the other hand, the higher amounts utilized represent an addition to the problems and costs of environmental quality and health protection. The data generated and the information reviewed suggest that these problems can be contained by improved soil and water management in agricultural systems. In particular there appears to be a huge scope for a better exploitation of alternative nitrogen sources, such as biological nitrogen fixation in legumes and non-legumes and/or biofertilizers.
- The United Nations agencies, such as the FAO, IAEA, United Nations Environment Programme, and World Health Organization, through improved collaboration with appropriate regional and national programmes, have a vital and urgent role in implementing the required improvements and short-term research needs, and accelerating the simultaneously needed education and training.

## Supporting services and activities

Several activities are simultaneously carried out to ensure the transfer of nuclear technologies for agricultural development. The Soil Science Unit at the FAO/IAEA Agriculture and Biotechnology Laboratory in Seibersdorf offers a range of research and training support.

**Training courses.** Annual interregional training courses on the use of isotopes and radiation techniques in studies of soil-plant relationships have been conducted at the Seibersdorf Laboratories since 1978. Each training course usually lasts 5 to 6 weeks and can be attended by 20 participants from all geographical regions. Additionally, national and regional training courses are supported.

**Fellowship training.** About 10 scientific fellows are trained at the Seibersdorf Soil Science Unit every year. There are two categories of fellows. Analytical fellows are accepted for a period of 2 to 3 months to learn isotope analytical techniques used in soil-plant research studies (for instance, nitrogen-15 assay techniques by optical emission spectrometry). This form of training includes technical tutoring and hands-on practical sessions. Research fellows are accepted for periods of 6 to 12 months to work on a topic within the FAO/IAEA's work programme. They receive guidance on experimental strategies and use of isotope and related techniques relevant to a particular area they will pursue upon return to their home country. They are expected to complete and write a piece of research work.

Additionally, the IAEA sponsors scientific visitors for short stays, typically for senior scientists. Other training-related opportunities for scientists of both developed and developing countries include selection as cost-free interns, cost-free experts, or associated professional officers.

**Research support.** Through CRPs and other mechanisms, extensive international and regional research networks have been built over the years. The FAO/IAEA Soil Science Unit provides a range of supporting services. They include the analysis of approximately 15,000 to 20,000 samples every year for projects in developing countries. Nitrogen-15 labelled fertilizers also are dispatched to participants in specific research projects. Analytical support further is provided to laboratories in developing countries receiving IAEA technical assistance and lacking suitable facilities.For routine purposes, the Unit plays a leading role in the development and transfer of nitrogen-15 assay technology used in IAEA technical assistance projects.

**Quality assurance service.** A recent initiative calls for establishing an international quality assurance service for nitrogen-15 analysis by optical emission spectrometry. The facilities of the Soil Science Unit will serve as the FAO/IAEA control "reference" laboratory. The service is expected to:

- ensure that the nitrogen-15 data generated by local laboratories are internationally acceptable;
- give confidence and encouragement to counterparts in their analytical procedures;
- promote regional cooperation and ensure an effective transfer of the nitrogen-15 technology to developing countries through FAO/IAEA programmes.

The service marks another step forward in global efforts to effectively transfer nuclear and isotope related techniques for beneficial purposes. It will enable developing countries to further build their expertise in applying these powerful tools for sustainable agricultural development. ❐

## IAEA General Conference opens in Vienna 18 September

The 39th regular session of the IAEA General Conference opens at the Austria Center in Vienna 18 September 1995. Sessions are scheduled throughout the week on the IAEA's policies, programmes, and budget.High-level governmental delegates from most of the Agency's 122 Member States are expected to attend.

The provisional agenda includes items related to strengthening technical cooperation activities; use of isotope hydrology for water resources management; measures to strengthen international cooperation in nuclear safety, radiological protection, and radioactive waste management; strengthening the effectiveness and improving the efficiency of the safeguards system; measures against illicit trafficking in nuclear materials and other radioactive sources; implementation of the safeguards agreement with the Democratic People's Republic of Korea (DPRK); implementation of United Nations Security resolutions relating to nuclear inspections in Iraq; an African nuclear-weapon-free zone; application of IAEA safeguards in the Middle East; and the IAEA's programme and budget for 1996.

In conjunction with the Conference, a number of events are being organized, including a special scientific programme as well as traditional meetings of senior officials on nuclear safety and group meetings in respect of IAEA regional cooperative programmes in Latin America, Asia and the Pacific, and Africa.

More information about the Conference may be obtained from the IAEA Division of Public Information.

## IAEA Board of Governors' meetings

At its meetings 12-16 June 1995 in Vienna, the IAEA Board of Governors *inter alia* examined specific proposals for achieving a strengthened and cost-effective safeguards system. The Board noted the Agency's plan to start implementing certain measures under its existing authority on the understanding that the IAEA would, for the benefit of Member States, elaborate implementation arrangements and hold further consultations with States to clarify some concerns that they had expressed.

**Safeguards proposals.** The proposals — developed at the Board's request and which pertain to IAEA verification in States having comprehensive safeguards agreements — were presented in two parts: Part 1 covers measures that the Agency could implement under existing authority and which would be both practical and useful to implement at an early date; Part 2 measures would need complementary legal authority. Board action in June focused only on Part 1 measures. These measures include, for example, broader access to information regarding sites and activities relevant to States' nuclear programmes, and environmental sampling at locations to which the IAEA has access. Part 2 measures are scheduled to be considered by the Board later this year.

In his statement to the Board, IAEA Director General Hans Blix highlighed the considerable efforts involved in the IAEA's ongoing safeguards development programme, known as "93+2", and commended Member States for their cooperation and support in developing specific proposals. "There is considerable international interest in the Agency's moves to strengthen its safeguards performance," he said, "and an expectation that the Board will maintain the momentum which it has created towards achieving a more credible and cost-effective safeguards system."

Other safeguards-related items discussed by the Board in June included the IAEA's Safeguards Implementation Report (SIR) for 1994, and the implementation of the safeguards agreement with the Democratic People's Republic of Korea (DPRK). Regarding safeguards in the DPRK, where the IAEA maintains a continuous inspector presence in Nyongbyon, Dr. Blix briefed the Board on developments since March and noted that the IAEA was continuing its efforts to schedule a further round of technical discussions regarding certain outstanding issues. The Board took note of the information and expressed its desire to see the technical talks take place soon.

A number of other items were before the Board in June. They included those related to:

**Technical cooperation.** The Board received a report on technical cooperation activities in 1994, and commended the IAEA for the record rate of implementation and the effective introduction of model projects. It noted with regret, however, the low level of pledges to the Technical Cooperation Fund, and highlighed the need for adequate, predictable, and assured resources for the Agency's technical cooperation activities. In regard to the proposed Standing Advisory Group on Technical Assistance and Cooperation, the Board welcomed the steps

that the Director General had taken to establish it. The Group will provide advice on the direction of the IAEA's technical cooperation programme and on measures for increasing its effectiveness and efficiency.

The Board further took note of a report describing the IAEA's intensified efforts to assist countries in the management of water resources. The work includes technical cooperation projects on the use of isotope techniques in hydrology; inter-agency activities designed to help countries tackle water-related problems; and research involving industrialized and developing countries under the Agency's coordinated research programme.

**Radiation safety.** The Board approved a document on Safety Fundamentals covering radiation protection and the safety of radiation sources, and authorized its publication in the IAEA's Safety Series. The document follows the Board's approval of similar documents covering the safety of nuclear installations (in 1992) and radioactive waste management (in March 1995).

**Radioactive waste management.** The Board authorized the submission to the General Conference of a report describing recent initiatives to resolve international radioactive waste management issues. The Director General also informed the Board that a group of technical and legal experts is scheduled to hold its first meeting 3-7 July 1995 concerning preparatory work for the Convention on the Safe Management of Radioactive Waste. The Group is expected to address the objectives, principles, and scope of the convention, as well as the obligations of the contracting parties and any institutional arrangements.

**Liability for Nuclear Damage.** The Board received a progress report on the work of the Standing Committee on Liability for Nuclear Damage, which has been examining the issue over the past several years. The Committee recently concluded that a diplomatic conference could be convened in 1996 to amend the Vienna Convention and to adopt a system of supplementary compensation. No date will be set until the completion of the preparatory work and the finalization of the Committee's report.

**Regular budget for 1996.** Upon the recommendation of its Administrative and Budget Committee, the Board approved the IAEA's regular budget for 1996, which calls for expenditures of US $219 million, at an exchange rate of 12.70 Austrian schillings to the dollar.

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## NPT Conference reaffirms support for IAEA roles

Parties to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) decided in May 1995 to extend the Treaty indefinitely and reaffirmed their support of the IAEA's roles in areas of verification and technology transfer.

In his statement to the IAEA Board of Governors in June, IAEA Director General Hans Blix made the following points:

- The Conference reconfirmed that the ultimate objective of the Treaty is a nuclear-weapon-free world. Under the NPT, non-nuclear weapon States commit themselves not to acquire such weapons and nuclear-weapon States commit themselves to nuclear disarmament. These commitments imply the increasing importance of verification and, in particular, that which is or may be carried out by the IAEA.
- The Conference expressed its support for the use and transfer of peaceful nuclear technology consistent with provisions of the NPT. The Atoms for Peace approach was thus maintained. For the IAEA, this points to the continued importance of its roles in the areas of nuclear safety, waste disposal, transfer of nuclear technology, and technical assistance.
- The Conference adopted a number of principles and objectives, some of which are directly relevant to the role and work of the IAEA. The IAEA was expressly recognized as the competent authority responsible to verify and assure compliance with safeguards agreements. The Conference stated that NPT Parties which have concerns regarding non-compliance with the safeguards agreements concluded pursuant to the Treaty should direct such concerns, along with supporting evidence and information, to the IAEA to consider, investigate, draw conclusions, and decide on necessary actions in accordance with its mandate. Also, the Conference in particular called for support of IAEA Board actions to strengthen safeguards, including the Agency's capability to detect any undeclared nuclear activities. It further recommended that nuclear material released

from military use should be placed under IAEA safeguards as soon as practicable.

● The Conference set 1996 as the target date for the conclusion of a comprehensive test ban agreement. It called for an early conclusion of a cut-off agreement (on the production of fissile materials for nuclear weapons and other nuclear explosive devices), and endorsed the creation of additional nuclear-weapon-free zones. The IAEA's specific role in relation to any of these measures has yet to be determined. The assumption remains that the proposed cut-off agreement would make use of IAEA safeguards as an essential element of the verification mechanism. In any new nuclear-weapon-free zone it could also be assumed — if existing models are an indication — that the IAEA will have some verification role. For a comprehensive test ban, it is relevant to note that the IAEA's comprehensive safeguards agreements already require verification by Agency inspectors of the commitment of non-nuclear-weapon States not to divert nuclear material for weapons or other nuclear explosive devices. What specific function the IAEA might be asked to assume under a comprehensive test ban are yet to be determined by the States negotiating this treaty.

● The Conference called for every effort to be made to ensure that the IAEA has the financial and human resources necessary to meet effectively its responsibilities in the areas of technical cooperation, safeguards, and nuclear safety.

The NPT Conference was held at the United Nations in New York 17 April to 12 May 1995. Altogether 175 States Parties participated. Dr. Blix addressed the Conference on its opening day *(see the following item)* and a team of IAEA senior officials attended continuously. The IAEA further contributed background reports on its activities relevant to the Treaty, particularly on matters related to safeguards and technical cooperation.

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**IAEA Director General addresses NPT Conference**

Addressing the opening session of the Review and Extension Conference of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), IAEA Director General Hans Blix underscored the key responsibilities that have been entrusted to the Agency under the Treaty, and the need for sufficient resources to reliably carry them out.

"The Agency must be enabled, through adequate resources, and strengthened and streamlined safeguards, effectively to verify that non-proliferation pledges are respected and, thereby, to create confidence among the Parties," he said. He noted that the IAEA has a central, statutory role both in supporting the peaceful development of nuclear energy and in helping to prevent its military use, thus serving as a vital instrument for the NPT's implementation. In this context, he pointed to proposals before the IAEA Board of Governors for a major safeguards development programme. These proposals would significantly increase the level of assurance about the absence of undeclared facilities, he said. In parallel, he noted, the IAEA would continue to serve as a principal intergovernmental channel for the transfer of peaceful nuclear technologies of assistance to countries in various fields.

Copies of the Director General's address — which was delivered 17 April 1995 at the United Nations in New York — are available from the IAEA Division of Public Information or through the IAEA's *World Atom* Internet services.

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**Nuclear waste management in Russia**

An international seminar convened by the IAEA in May 1995 could lay the groundwork for strengthening global cooperation with the Russian Federation in areas of radioactive waste management and environmental restoration. Attending were more than 30 representives from Russian ministries and organizations involved in waste management, as well as representatives of 15 other countries and one international organization. The meeting's main objectives were to review the existing situation and future plans of the Russian Federation in the field of radioactive waste management, to identify concerns, and to examine priorities for potential future cooperation. Toward this end, a comprehensive account was presented of Russia's waste management programmes, their structures, and problems. Detailed presentations also were made on programmes of bilateral cooperation with Russia in this field. The seminar was convened in response to a request of the Joint Council of the

Nordic countries and with the approval of the Russian authorities.

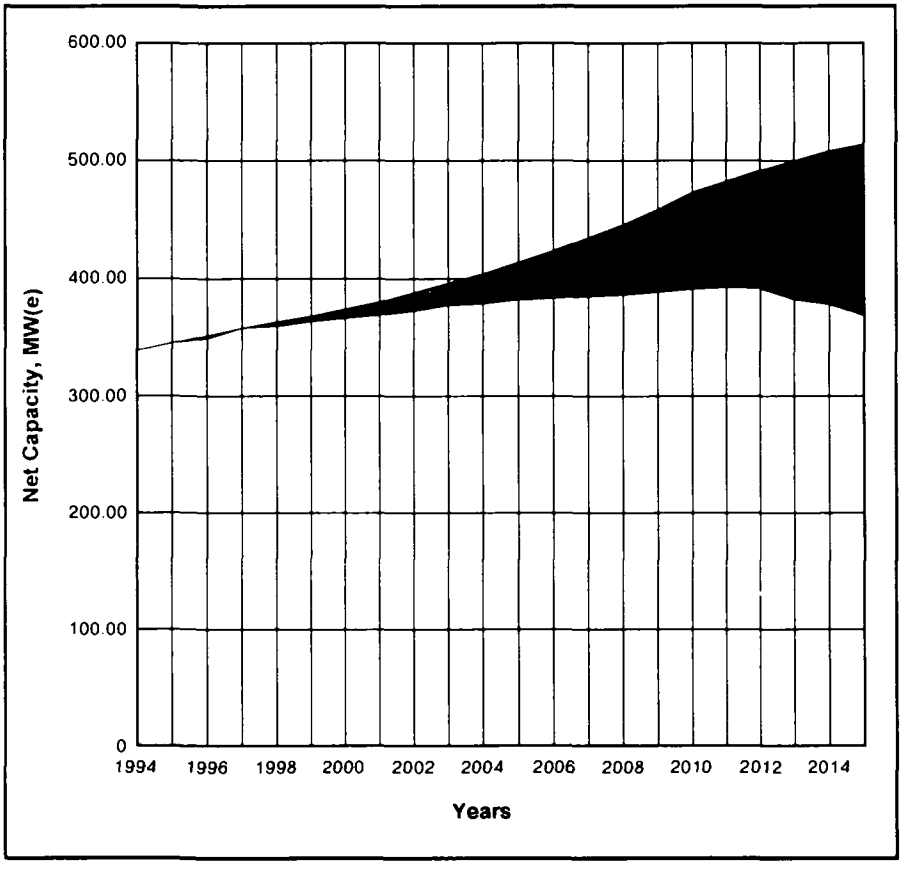
In addressing the seminar, IAEA Director General Hans Blix commended the Nordic initiative and the Russian Federation's positive response. He pointed out that "formidable tasks" are being faced regarding the treatment, storage, and disposal of radioactive waste, as well as in areas of environmental restoration, and he noted that the IAEA and its Member States could appropriately provide cooperation and assistance.

The IAEA is preparing a report and consolidation of data presented at the seminar. Also planned is a follow-up experts' meeting later this year to further elaborate and establish proposed cooperative activities and to specify the role that the IAEA might play.

## Nuclear power outlook

Nuclear power is expected to grow at a modest but steady pace over the next 15 years under prevailing restrictive conditions, based on recent estimates prepared by the IAEA's Planning and Economic Studies Section, Division of Nuclear Power. Growth could be much more robust if some obstacles—including financial contraints, low electricity demand in industrialized countries, and negative public attitudes in some countries—evolve in a positive direction. The graph below illustrates the range of projections.

| Year | Total Net Capacity MW(e) | |
|---|---|---|
| | Low | High |
| 1994 | 340,347 | 340,347 |
| 1995 | 345,153 | 346,103 |
| 1996 | 349,398 | 352,019 |
| 1997 | 355,936 | 359,186 |
| 1998 | 362,737 | 364,520 |
| 1999 | 364,760 | 368,396 |
| 2000 | 366,729 | 375,242 |
| 2001 | 368,844 | 381,803 |
| 2002 | 374,087 | 391,618 |
| 2003 | 377,362 | 399,606 |
| 2004 | 379,780 | 406,531 |
| 2005 | 382,444 | 415,888 |
| 2006 | 383,913 | 427,527 |
| 2007 | 385,586 | 438,759 |
| 2008 | 387,768 | 448,497 |
| 2009 | 389,460 | 459,525 |
| 2010 | 391,036 | 475,535 |
| 2011 | 394,159 | 483,337 |
| 2012 | 392,393 | 493,005 |
| 2013 | 383,273 | 502,447 |
| 2014 | 377,847 | 509,231 |
| 2015 | 368,671 | 515,539 |



### Cuba and Brazil: Nuclear information

Cuba and Brazil hosted public information seminars in May 1995 that brought together nuclear communicators, journalists, and government officials from countries throughout Latin America and neighbouring regions.

In Havana 17-19 May 1995, more than 80 participants from Cuba and eight other countries reviewed a range of topics in areas of public information and nuclear development, including progress reports on Cuba's nuclear research and development. The regional seminar, which the IAEA co-sponsored with the Nuclear Energy Agency of Cuba, was hosted by the Cuban Nuclear Energy Information Centre (CIEN).

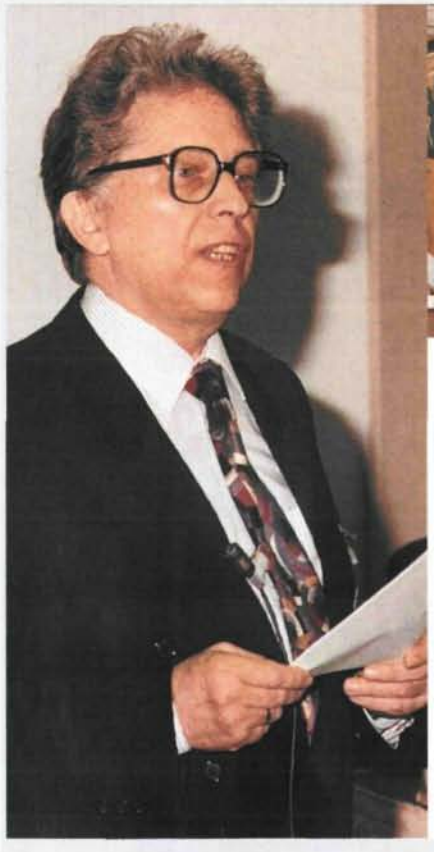
In Rio de Janeiro 24-26 May 1995, the seminar focused on topics related to energy and the environment, the Chernobyl legacy, waste management, and non-proliferation. More than 100 journalists, officials, and representatives of the nuclear and electric power industries attended, including delegates fromsix neighbouring countries. The meeting was co-sponsored by the IAEA, Brazilian Nuclear Energy Commission, and Brazilian Nuclear Industries.

The seminars were the latest in a series organized under an extrabudgetary public information programme funded by Japan. Upcoming seminars are planned in Viet Nam and in Japan.

### Japan, Romania & Poland: Nuclear safety convention

Japan, Romania, and Poland have become parties to the Convention on Nuclear Safety. Japan deposited its instrument of accession to the Convention 12 May 1995; Romania and Poland ratified the Convention on 1 June 1995 and 14 June 1995, respectively. Three other countries —Norway, the Slovak Republic, and Turkey— previously have become parties to the Convention, which through 15 June 1995 had been signed by 58 countries.

The Convention was adopted by a diplomatic conference under the aegis of the IAEA on 17 June 1994 and opened for signature on 20 September 1994. It will enter into force after ratification/accession by 22 States, 17 of which must have at least one nuclear installation that has achieved criticality in a reactor core. Japan is the first country with a large nuclear power




*Seminar scenes:* In Brazil, Mr. Boris Semenov, IAEA Deputy Director General for Nuclear Energy and Safety *(left photo)* and Mr. Abel González, Deputy Director of the Nuclear Safety Division *(left front, right photo)* were among Agency speakers; in Cuba, *(centre photo)* participants included Ms. Rosa Elena Simeon, Minister of Science, Technology, and Environment *(centre)*, Dr. Daniel Codorniù Pujals, President of Cuba's Nuclear Energy Agency *(left)*, Mr. Mohamed ElBaradei, IAEA Assistant Director General *(second from right)* and Mr. Dirk Schriefer, Director of an operations division in the IAEA's Department of Safeguards *(right)*. *(Credits: F. Diaz López, CIEN; Brazilian Nuclear Energy Commission)*

programme to join the Convention. Under the Convention; parties undertake to establish and maintain proper legislative and regulatory frameworks to govern safety of their land-based civil nuclear power plants. States further commit themselves to the application of fundamental safety principles for nuclear installations, and agree to submit periodic national reports on the implementation of their obligation and to participate in periodic peer review meetings.

### Barbados and Belarus: Safeguards

The IAEA Board of Governors has authorized the Agency to conclude a comprehensive safeguards agreement negotiated with Barbados earlier this year. The agreement is in relation to obligations that Barbados assumed under the Treaty of Tlatelolco and the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). Barbados has informed the IAEA that it has no nuclear material subject to safeguards as defined in the agreement.

**Belarus officially signs.** The Government of Belarus has officially notified the IAEA that it has signed the comprehensive safeguards agreement with the Agency. The agreement, concluded pursuant to the NPT which Belarus joined in July 1993, was signed at a ceremony in Belarus on 14 April 1995.

### France: DG addresses WANO meeting

Key strides that States have made for securing the safe and peaceful development of nuclear energy were welcomed by IAEA Director General Hans Blix in an address to the general meeting of the World Association of Nuclear Operators in Paris 24 April 1995. Dr. Blix emphasized that the global expansion of nuclear power has been accompanied by expanded commitments to non-proliferation. Contrary to some expectations, he said, nuclear power and nuclear weapons are not "Siamese twins", and it was not unrealistic today for the world to aim at nearly full nuclear disarmament and universal adherence to nuclear non-proliferation commitments. He further pointed to international progress in areas of nuclear safety and radioactive waste management, and underscored the environmentally beneficial role of nuclear power plants for electricity generation. Copies of the Director General's speech may be obtained from the

### India:
### Donation to IAEA Laboratories

India has donated instruments and related software to the IAEA's Laboratories at Seibersdorf for the training of scientists and technicians and for field applications of nuclear techniques. The equipment was presented to IAEA Director General Hans Blix by Dr. R. Chidambaram, Chairman of India's Atomic Energy Commission and currently the Chairman of the IAEA Board of Governors, at a ceremony at the Laboratories 19 June 1995. The instruments allow for *in situ* determination of many chemical elements of nuclear and environmental relevance, as well as for the on-line monitoring of low-level radioactivity of noble gases and elements such as iodine-131. The IAEA's Seibersdorf Laboratories play a leading role in the world's transfer of nuclear technologies for beneficial applications in fields of agriculture, medicine, industry, and science.

**Dr. Chidambaram (left) and Dr. Blix being briefed at the Agency's Seibersdorf Laboratories on uses of India's donated equipment.** *(Credit Pavlicek, IAEA)*

IAEA Division of Public Information or through the IAEA's Internet services.

### Georgia and Bosnia & Herzegovina: IAEA membership

The IAEA Board of Governors has endorsed the membership applications of Georgia and Bosnia and Herzegovina. At its June 1995 sessions, the 35-member Board recommended approval of the applications by the Agency's General Conference. The Conference opens in Vienna 18 September 1995.

Membership of the IAEA currently stands at 122 States.

### AFRA: Five more years

As of early June, ten African countries —Tunisia, Egypt, Madagascar, South Africa, Ethiopia, Algeria, Mauritius, Sudan, Tanzania, and Cameroon — had officially notified the IAEA that they accept the 5-year extension of a regional cooperative agreement called AFRA. The agreement, whose extension officially took effect 4 April 1995, focuses on research, development, and training related to nuclear science and technology.

Since its inception in 1990, AFRA has proved to be an important mechanism to promote regional cooperation, to coordinate expertise and resources, and to enhance capabilities in the diversified areas of nuclear technology. Projects are being carried out in fields of food and agriculture, human health, industrial applications, radiation protection and safety, and nuclear instrumentation, for example.

### Nova Scotia: G-7 Summit Statement

At their economic summit in Halifax, leaders of the Group-of-Seven industrial countries issued a communique on 16 June 1995 that included statements on nuclear safety. Excerpts from the statement:

"Each country is responsible for the safety of its nuclear facilities. We welcome progress to date in improving levels of nuclear safety in the countries of central and eastern Europe and the Newly Independent States. We congratulate President Kuchma of Ukraine on his decision to close the Chernobyl nuclear power plant by the year 2000....In order to assist the closure of Chernobyl, we will continue our efforts to mobilize international support for appropriate energy production, energy efficiency, and nuclear safety projects. Any assistance for replacement power for Chernobyl will be based on sound cost-effective and environmental criteria."

Among other topics, the statement also expressed support for global efforts promoting sustainable development and stressed the importance of meeting environmental commitments made at the 1992 Rio Earth Summit relating to climate change. The next G-7 economic summit is scheduled for 27-29 June 1996 in Lyon, France.

### Russia: Simulated emergency test

National and international teams, including the IAEA's emergency response unit, jointly responded in June 1995 to a simulated emergency at a nuclear power plant in northern Russia. The exercise, which was sponsored by the United Nations Department of Humanitarian Affairs (DHA), was designed to test international procedures and emergency communications channels for responding to such emergencies.

Besides emergency response units of Russia, the IAEA, and DHA, teams and experts from various countries participated. They included specialized military and civil defense teams from Austria, Finland, France, and Norway, and experts from Canada, Denmark, Germany, Italy, Lithuania, Sweden, Ukraine, United Kingdom, and United States. Also taking part in the test were experts from the European Commission, International Civil Defense Organization, and North Atlantic Treaty Organization. The exercise was organized within the framework of a DHA project on the use of military and civil defense assets in international emergency relief operations. More information may be obtained from DHA at the United Nations Office in Geneva, Switzerland.

### United States: Green nuclear energy

Electricity generation from nuclear power is being credited with helping the United States hold down emissions of carbon dioxide, and get closer to achieving its environmental targets for the next century. A survey by the Nuclear Energy Institute (NEI) reported in June 1995 that $CO_2$ emissions in the electric power sector would have been 32% higher in 1994 without nuclear power stations. More coal, oil, and natural gas would have been burned instead to generate nuclear's share of electricity, the survey assumed, leading to higher emissions of

carbon dioxide and other gases of environmental concern. In the United States, nuclear power — which provides just under 22% of all electrical energy without emitting carbon dioxide — is the country's single largest contributor to efforts for reducing emissions of greenhouse gases. More information may be obtained from NEI, 1776 Eye Street NW, Washington, DC 20006-3708.

### Morocco: Food irradiation seminar

Rabat is the scene of a planned regional seminar on food irradiation early in 1996.

The seminar is being convened by the Joint Division of the IAEA and Food and Agriculture Organization of the United Nations, and the United Nations Economic Commission for Africa, the International Institute for Refrigeration, the International Trade Centre, and the World Health Organization. Its emphasis will be on applications of food irradiation technology to reduce post-harvest food losses and foodborne diseases and to facilitate trade in certain food commodities within and from the African continent and neighbouring regions.

More information on the seminar, scheduled 26 February to 1 March 1996, may be obtained from the Joint FAO/IAEA Division at Agency headquarters in Vienna.

### Armenia: Safety of Medzamor

The IAEA has reaffirmed its readiness to assist Armenian regulators in efforts to resolve technical issues that might have implications for the safety of the Medzamor-2 nuclear power plant, which the Government plans to restart following its shutdown since 1989.

Over the past several months, Agency specialists have visited Armenia to review technical, seismic, and staff-related issues at the plant. In briefing the IAEA Board of Governors about the matter in June 1995, Director General Hans Blix reported that he has conveyed major findings of the expert reviews to Prime Minister Bagratian, who has extended his appreciation of the Agency's efforts. Dr. Blix noted that

although any decision to resume operation of the plant is entirely the responsibility of the Armenian Government, it would be essential in the event of such a decision that identified outstanding safety issues be resolved and that a competent and well-trained operating staff be available.

Based on their reviews, experts have recommended that safety modifications that were previously approved by the regulatory body be made at the plant; that comprehensive tests of safety systems be done before restarting the plant; that steps be taken to ensure sufficient numbers of qualified and licensed staff; that issues relating to the integrity of the unannealed reactor pressure vessel be resolved; that continuous efforts be made to assess and upgrade the seismic safety of the plant; and that additional steps be taken for emergency planning.

### China: Isotope conference

Global experts on the use of isotopes and radiation technologies for environmental, agricultural, industrial, and other purposes met in Beijing 7-12 May 1995 at the International Conference on Isotopes. The meeting reviewed applications, as well as topics related to radiation safety in the production and use of radioisotopes.

Among the group of invited speakers were Mr. David Waller, IAEA Deputy Director General for Administration, and Dr. Pier Danesi, Director of the IAEA's Laboratories at Seibersdorf. Mr. Waller reviewed the global nuclear scene and the influence of developments on the IAEA's activities and programmes. Dr. Danesi addressed the role of nuclear and isotope techniques in the context of environmental challenges and the work of the Seibersdorf Laboratories. The meeting was sponsored by the Chinese Nuclear Society and Isotope Society of China, with the co-sponsorship of 12 associations worldwide and in cooperation with the IAEA. More information may be obtained from Prof. Lin Qiongfang, P.O. Box 275-12, Beijing 102413 China.

### Italy & India: ICTP Prize awarded

The International Centre for Theoretical Physics (ICTP) in Trieste has announced that its 1995 ICTP Prize in the field of high energy physics has been awarded to Prof. Spenta Wadia of the Tata Institute for Fundamental Research in Bombay, India. The Prize consists of a medal, a diploma, and US $1000. Prof. Wadia, whose research work in theoretical high energy physics has earned international acclaim, received the award at a ceremony 14 June 1995. Annual ICTP Prizes were created in 1982 in recognition of outstanding and original contributions within mathematics and physics. More information may be obtained from Ms. Anna Triolo, Scientific Information Office, ICTP, Strada Costiera 11, Trieste, Italy 34014.

### Austria: Electricity, Health, & Environment Symposium

Vienna is the site of a major international symposium in October 1995 focusing on key issues related to assessing the options for safe, efficient, and clean generation of electricity. The International Symposium on Electricity, Health and the Environment: Comparative Assessment in Support of Decision-Making is being organized by the IAEA and nine partner organizations: the European Commission (EC); the Economic and Social Commission for Asia and the Pacific (ESCAP), the International Institute for Applied Systems Analysis (IIASA), the Nuclear Energy Agency of the Organization for Economic Cooperation and Development (OECD/NEA); the Organization of Petroleum Exporting Countries (OPEC); the United Nations Environment Programme (UNEP); the United Nations Industrial Development Organization (UNIDO); the International Bank for Reconstruction and Development (IBRD) of the World Bank; and the World Meteorological Organization (WMO). These organizations are participating in a project, called DECADES (Databases and Methodologies for Comparative Assessment of Different Energy Sources for electricity generation). The symposium will feature results from DECADES projects, as well as others being conducted internationally, and report on national case studies in a number of countries. IAEA Director General Hans Blix is scheduled to open the meeting, and senior officials of co-sponsoring organizations will deliver keynote addresses.

**NWFZ FOR AFRICA.** Agreement was reached in May 1995 on the proposed treaty establishing a nuclear-weapon-free zone (NWFZ) in Africa. The treaty *inter alia* envisages that the IAEA will verify compliance with the non-proliferation obligations that States assume under it. The draft treaty now goes for approval to the Council of Ministers of the Organization of African Unity.

**NEW HEAD OF ICTP.** Prof. Miguel A. Virasoro, of Argentina, has been appointed the new Director of the International Centre for Theoretical Physics (ICTP) in Trieste, Italy. The appointment was made in May 1995 by IAEA Director General Hans Blix in consultation with Prof. Frederico Mayor, Director General of the United Nations Educational, Scientific, and Cultural Organization (UNESCO). Prof. Virasoro's distinguished international scientific career includes positions in four countries and at CERN in Geneva. He succeeds Prof. Abdul Salam of Pakistan, who will continue to serve as President of the Centre.

**NUCLEAR NON-PROLIFERATION.** An informative guide to global developments in the field of nuclear non-proliferation has been issued by the Carnegie Endowment for International Peace. Called *Tracking Nuclear Proliferation*, the book features maps, charts, tables, and graphs to help readers visualize the rapidly changing and increasingly diverse international nuclear environment. It includes national as well as international overviews, briefly summarizes global trends and the nuclear non-proliferation regime, including the IAEA's role, and provides assessments of major developments. The book was produced under the direction of Leonard S. Spector with editors Mark G. McDonough and Evan Medeiros. More information may be obtained from the Carnegie Endowment for International Peace, 2400 N Street NW, Washington, DC 20037 USA.

**NEW ELECTRIC POWER PLANTS.** Countries around the world are projected to increase their electric generating capacity by about 629 gigawatts by the year 2003, a new report by the Utility Data Institute (UDI) estimates. The projections represent an annual increase of 2.1% over the 1994-2003 timeframe. About 2925 gigawatts of electric generating capacity are in worldwide service today. Most of the projected growth reflects plans to increase the use of fossil fuels, particularly coal and gas, for electricity generation. These two fuels account for 49% of the estimated increase, with coal alone accounting for 31%. Nuclear power's share of the projected capacity additions is about 10%. The data are reported in the *World Directory of New Electric Power Plants*, published in May 1995. More information may be obtained from UDI, 1200 G Street NW, Suite 250, Washington, DC 20005.

**NUCLEAR SAFETY REVIEWS.** In coming months, teams of international specialists are scheduled to review the operational safety of nuclear power plants in Lithuania, Argentina, Ukraine, Czech Republic, Switzerland, and the United Kingdom under the IAEA's Operational Safety Review Team (OSART) programme. Missions are done at the request of countries and address safety practices in specific areas of nuclear plant safety regulation. The schedule includes the Ignalina plant in Lithuania in September 1995; the Embalse plant in Argentina in October 1995; the Rovno, Khmelnitski, and Zaporozhe plants in Ukraine in October 1995; the Hunterston B plant in the United Kingdom in October 1995; the Temelin plant in the Czech Republic in November 1995; and the Beznau plant in Switzerland in November 1995. Six countries already have requested OSART missions for next year.

**ENERGY OVERVIEWS.** Profiles of major energy producers, consumers, and transport centres are featured in a new report by the US Energy Information Administration (EIA), an arm of the Department of Energy. The report, *Country Analysis Briefs: 1994*, includes topical overviews, maps, and background information about 25 countries, focusing on key energy, economic, and environmental topics. Also recently issued by the EIA is the *International Energy Annual*, an overview of energy trends for production, consumption, imports, and exports of primary energy commodities, and *International Energy Outlook 1995*. The reports are available in hard copy; data from them also are accessible through the Internet-World Wide Web system. More information may be obtained from the EIA, US Department of Energy, Washington, DC 20585 USA.

**OPERATIONAL SAFETY OF NUCLEAR POWER PLANTS.** The best international practices for maintaining and improving the operational safety of nuclear power plants will be highlighted at an international symposium at the IAEA in Vienna 4-8 September 1995. Presentations from nuclear plant operators and safety officials will especially address recent advances and new methods for enhancing the safe operation of nuclear plants, which worldwide supply more than 17% of total electricity. In particular, case studies will review recent achievements in national nuclear programmes, as well as through international cooperative projects, and a panel discussion will address ways to monitor plant performance and operational safety, as well as how to communicate the findings to the public. More information about the symposium may be obtained from the IAEA Department of Nuclear Energy and Safety or the Agency's Conference Services.

**CELEBRATING DISCOVERY.** In its latest edition, *World Health* — the magazine of the World Health Organization (WHO) — features articles and factual overviews about the discovery and development of X-rays and radioactivity. X-rays were discovered in 1895 by the German scientist Roentgen and radioactivity in 1896 by the French scientist Becquerel. WHO notes that radiological sciences have become an indispensable part of medicine, applied in the care and treatment of millions of patients. More information may be obtained from *World Health*, the Editor, World Health Organization, 1211 Geneva 27, Switzerland.

**INIS: HAPPY ANNIVERSARY.** The IAEA's International Nuclear Information System (INIS) officially marked its 25th anniversary of worldwide service in May 1995. From the production of its first products in 1970, INIS has grown to include more than 1.8 million items of nuclear literature and is growing at a rate of about 85,000 records per year. INIS is a bibliographic database providing access to information about nuclear energy's peaceful development, ranging from nuclear safety and radiation protection to nuclear and radiation applications and the verification of nuclear materials through safeguards. Currently 90 IAEA Member States and 17 international organizations are cooperating in the development of INIS. With the advent of international networking, many countries have established database host computers that offer access to INIS. Additionally, the total database is available on a set of compact disks that enable full local searching of references. The system also enables users to find full texts of documents that are difficult to obtain through normal commercial channels, items that are typically called non-conventional literature. Main users of the system over the past quarter century have included scientists, engineers, industry planners and policy-makers, members of academic and research institutes, students, and governmental officials.

**ENVIRONMENTAL GOALS.** Goals to stabilize carbon dioxide emissions in industrialized countries at 1990 levels are not attainable by the year 2000 under "business-as-usual" conditions. That view comes from more than 100 energy experts polled recently at an International Energy Workshop sponsored by the International Institute for Applied Systems Analysis (IIASA) in Austria. The experts pointed out that significant policy measures — which are not yet in place — will be required to meet the aspirations formulated in the United Nations Framework Convention on Climate Change. Established in 1981 by IIASA and Stanford University in the United States, the International Energy Workshop draws on a network of analysts concerned with global energy issues. Its aims are to compare energy projections and to understand the reasons for diverging views about future developments. More information may be obtained from IIASA, A-2361 Laxenburg, Austria, or through the Institute's Internet services.

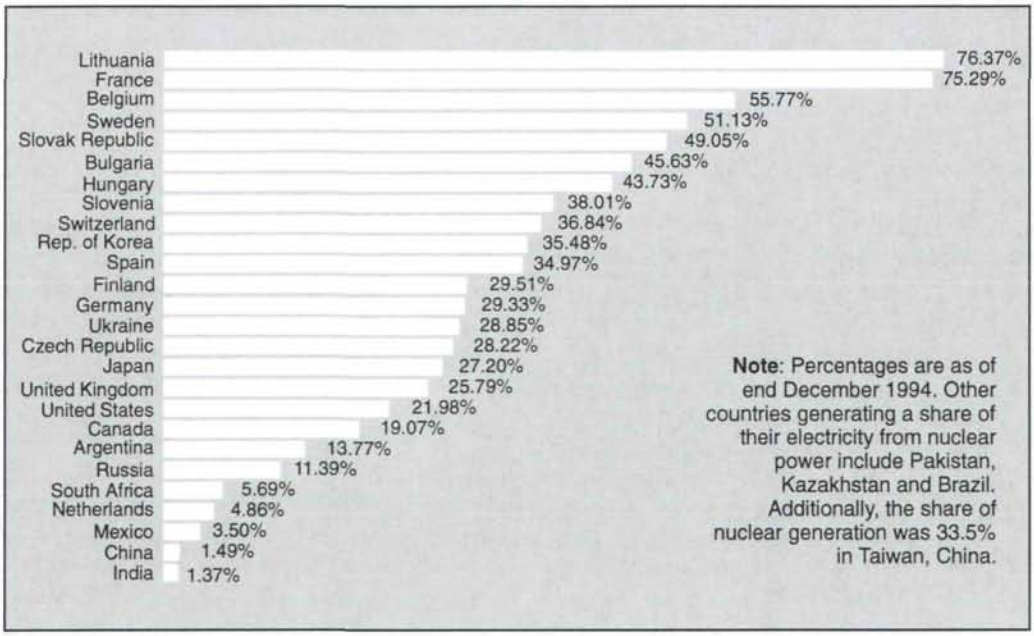
**CLIMATE CHANGE POLICIES.** The politics of climate change are the main focus of this year's *Green Globe Yearbook*, an annual reference on international cooperation in areas of environment and development. The book includes topical articles and key data on most important international agreements in the field, and major organizations playing active roles. It aims to demonstrate where the international community stands with regard to solving problems, what the main obstacles are to effective international solutions, and what must be done to overcome them. More information may be obtained from the Fridtjoj Nansen Institute, P.O. Box 326, N-1324 Lysaker, Norway, or through the Institute's Internet services.

## 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 | 3 | 2 100 | | |
| Czech Republic | 4 | 1 648 | 2 | 1 824 |
| Finland | 4 | 2 310 | | |
| France | 56 | 58 493 | 4 | 5 810 |
| Germany | 21 | 22 657 | | |
| Hungary | 4 | 1 729 | | |
| India | 9 | 1 493 | 5 | 1 010 |
| Iran | | | 2 | 2 392 |
| Japan | 49 | 38 875 | 5 | 4 799 |
| Kazakhstan | 1 | 70 | | |
| Korea, Rep. of | 10 | 8 170 | 6 | 4 820 |
| Lithuania | 2 | 2 370 | | |
| Mexico | 2 | 1 308 | 1 | 654 |
| Netherlands | 2 | 504 | | |
| Pakistan | 1 | 125 | 1 | 300 |
| Romania | | | 5 | 3 250 |
| 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 | 7 105 | | |
| Sweden | 12 | 10 002 | | |
| Switzerland | 5 | 2 985 | | |
| United Kingdom | 34 | 11 720 | 1 | 1 188 |
| Ukraine | 15 | 12 679 | 6 | 5 700 |
| USA | 109 | 98 784 | 1 | 1 165 |
| World total* | 432 | 340 347 | 48 | 38 876 |

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

## Nuclear share of electricity generation in selected countries



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# POSTS ANNOUNCED BY THE IAEA

**ATOMIC PHYSICIST** (95-039), Department of Research and Isotopes. This P-3 post requires an advanced degree in atomic physics followed by at least 6 years research experience in atomic collision physics and computer programming (FORTRAN and C languages in UNIX environment). *Closing date: 29 September 1995*

**HEAD, CHEMISTRY UNIT** (95-040), Department of Research and Isotopes. This P-4 post requires a Ph.D. in radiochemistry, analytical chemistry or inorganic chemistry (or equivalent advanced degree) with at least 10 years of practical experience in nuclear and non-nuclear modern analytical chemistry with emphasis on trace element analysis, environmental radioactivity, and quality assurance of such measurements. Also required is experience in management and supervising technical and scientific staff in analytical chemistry and good working knowledge of statistical methods. Demonstrated interpersonal communication skills. *Closing date. 29 September 1995.*

**COMPUTER SYSTEMS PROGRAMMER** (95-706), Department of Research and Isotopes. This P-3 post requires a university degree in computer sciences or engineering with at least 6 years of working experience in computing and networking. Also required is practical experience in computing and networking and in the running and maintenance of local area networks. Specific knowledge of LAN operating systems, Ethernet, PATHWORKS, WINDOWS NT and LAN administration. *Closing date: 29 September 1995*

**SAFEGUARDS ANALYST-UNIT HEAD** (95-038), Department of Safeguards. This P-4 post requires a university degree in physics, nuclear science or engineering. Also required is at least 10 years of experience, including at the international level in safeguards, and knowledge of the principles of human resources management and ability to apply this knowledge in managing multinational staff. Demonstrated interpersonal communication skills. *Closing date: 18 September 1995.*

**SAFEGUARDS ANALYST** (95-037), Department of Safeguards. This P-4 post requires a university degree in physics, nuclear science or engineering. Also required is at least 10 years of experience of which 3 years have been at the international level in safeguards. *Closing date: 18 September 1995.*

**DATABASE ADMINISTRATOR** (95-036), Department of Nuclear Energy and Safety. This P-3 post requires an advanced university degree in computer science or related field and 6 years of practical experience in database administration, database design and in the design and implementation of modern computer systems involving client/server architecture. Also required is broad knowledge of, and in-depth practical experience in, a modern relational database management system, such as Sybase. *Closing date: 18 September 1995*

**RADIATION THERAPY SPECIALIST** (94-033), Department of Research and Isotopes. This P-4 post requires a medical doctor degree, with speciality in radiation oncology. Also required is 10 years of recent scientific experience in the field of radiation therapy, working in a cancer hospital and teaching institution, recent publication in the speciality and familiarity with the needs and conditions of developing countries in the field. *Closing date 11 August 1995.*

**SECTION HEAD** (95/032), Department of Research and Isotopes. This P-5 post requires a Ph.D. or equivalent advanced degree in nuclear sciences or nuclear engineering followed by at least 15 years of professional experience in the measurement, computation and/or evaluation of nuclear data and related nuclear physics research. Also required is proven ability to effectively manage and utilize resources for the achievement of organizational objectives and familiarity with the application of nuclear and atomic and molecular data. *Closing date: 11 August 1995.*

**SECTION HEAD** (95/031), Department of Safeguards. This P-5 post requires an advanced university degree (or equivalent) in science, engineering or education and formal training in instructional design technology. Also required is a minimum of 15 years experience in research, industry or the nuclear field with substantial experience in directing or conducting training programmes. *Closing date 11 August 1995.*

**LEGAL OFFICER** (95/030), Department of Administration. This P-3 post requires a law degree with good academic record and at least 6 years of relevant experience in an international or national organization. Also required is the ability to draft legal documents in English. *Closing date: 11 August 1995.*

**SYSTEMS ANALYST** (95/029), Department of Safeguards. This P-3 post requires a university degree in computer science or related field and 6 years of working experience in the field of data base administration on large mainframes. Also required is a specific knowledge of ADABAS and related products, working knowledge of MS SQL servers and computer networking principles. *Closing date: 11 August 1995.*

**RADIATION PROTECTION LABORATORY SPECIALIST** (95/028), Department of Nuclear Energy and Safety. This P-3 post requires a university degree or equivalent in radiation protection. Also required is at least 6 years of experience in operational radiation protection, oriented to university scale laboratory activities and practical laboratory experience in dosimetry methods, as well as good knowledge of radiation protection instrumentation. *Closing date: 11 August 1995.*

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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 suitable 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 identification. 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. Please note that applications for posts cannot be forwarded through the computerized network, since they must be received in writing by the IAEA Division of Personnel.

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*Telephone: 01621 783282.*
*Fax: 01621 783132.*

mini-I

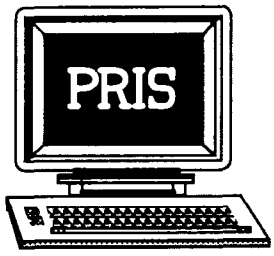
MINI-INSTRUMENTS LTD

# RAD/CON

**RADIATION AND CONTAMINATION INSTRUMENTATION**

# ON LINE DATABASES

## OF THE INTERNATIONAL ATOMIC ENERGY AGENCY




***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***

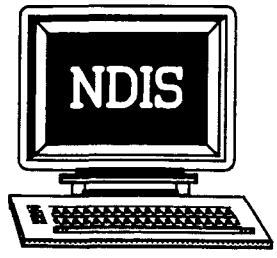
more than 130 000

***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

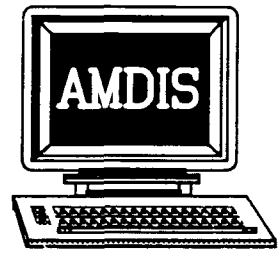
***Scope***

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***

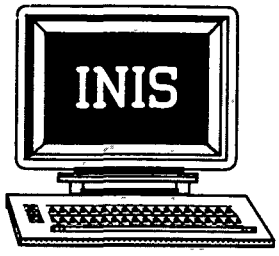
Data on atomic, molecular, plasma-surface interaction, and material properties of interest to fusion research and technology

***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 90 IAEA Member States and 17 other international member organizations

***IAEA contact***
IAEA, INIS 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: ATIEH@IAEA1.IAEA.OR.AT

***Number of records on line from January 1976 to date***
more than 1.8 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.

# INIS ON CD-ROM

**The IAEA's nuclear science and technology database on CD-ROM**

5000 JOURNALS

1.8 MILLION RECORDS

6 COMPACT DISCS

*INIS (the International Nuclear Information System) is a multi-disciplinary, bibliographic database covering all aspects of the peaceful uses of nuclear science and technology. INIS on CD-ROM combines the worldwide coverage of the nuclear literature with all the advantages of compact disc technology.*

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## IAEA UPCOMING CO-ORDINATED RESEARCH PROGRAMMES

**Applied research on air pollution using nuclear-related analytical techniques in Asia and the Pacific Region ( RCA)**
*To use nuclear-related analytical techniques for air pollution studies in the Asia and Pacific region through the assessment of toxic heavy metal pollution and other trace elements in air particulate matter.*

**Analysis of research reactor transients**
*To identify and evaluate the limitations of available methods and computer codes and, by improving them, establish adequate models to calculate research reactor transients. This research programme will be useful for scientists who are involved in the operation of research reactors and who have interest and experience in transient calculations.*

**Development of reference charged particle cross section database for medical radioisotope production**
*To develop a file and a handbook of recommended cross sections for monitoring beam currents and for production of major medical radioisotopes used primarily for diagnostic purposes. The nuclear reactions under consideration are those induced by light charged particles using small and medium cyclotrons.*

**Regional personal dosimetry intercomparison (ARCAL)**
*To provide participating personal dosimetry service organizations an assessment of their ability to measure relevant external dosimetry quantities with sufficient accuracy for radiation protection purposes.*

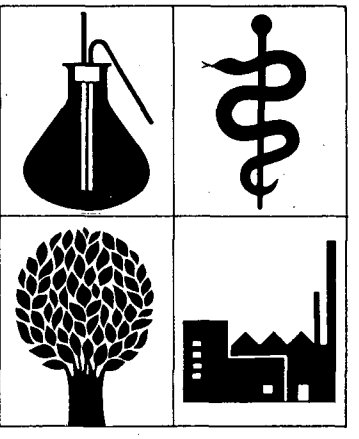
**Site characterization techniques used in environmental restoration activities**
*To encourage the development and improvement of site characterization technology, reduce the duplication of efforts by various parties, and provide useful results and tools for Member States planning activities in areas of environmental restoration.*

**Application of heavy charged particles in cancer radiotherapy**
*To promote the application of heavy charged particles in radiotherapy (protons and heavy ions) by evaluating their potential benefit as well as by identifying the mechanisms through which this benefit can be achieved.*

**Irradiation treatment of water, waste-water and sludges**
*To develop technology for decontamination of water, waste-water and sewage sludge based on the utilization of ionizing radiation as such, or in combination with other agents.*

**Isotope-aided studies of atmospheric carbon dioxide and other greenhouse gases — Phase 2**
*To improve the present understanding of the behaviour and the role of major greenhouse gases in the global ecosystem through observations of temporal and spatial variability of their isotopic composition in selected locations, combined with relevant modelling work.*

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 1995**

Symposium on Tomography in Nuclear Medicine, Present Status and Future Prospects, ***Vienna, Austria*** (21-25 August)

Seminar on the Requirements for the Safe Management of Radioactive Waste, ***Vienna, Austria*** (28 August - 1 September)

**SEPTEMBER 1995**

International Conference on Advances in Operational Safety of Nuclear Power Plants, ***Vienna, Austria*** (4-8 September)

IAEA General Conference, 39th Regular Session ***Vienna, Austria,*** (18-22 September)

**OCTOBER 1995**

International Symposium on Electricity, Health and the Environment: Comparative Assessment in Support of Decision Making, ***Vienna, Austria,*** (16-19 October)

**NOVEMBER 1995**

Regional (Asia & the Pacific) Seminar on Education and Training in Radiation Protection and Nuclear Safety, ***Melbourne, Australia*** (27 November - 1 December)

Regional Seminar for Asia and the Pacific on Radiotherapy Dosimetry: Radiation Dose in Radiotherapy from Prescription to Delivery, ***Bangkok, Thailand*** (28 November - 1 December)

**DECEMBER 1995**

Second FAO/IAEA Seminar for Africa on Animal Trypanosomiasis: Vector and Disease Control Using Nuclear Techniques, ***Zanzibar, Tanzania*** (dates to be confirmed)

**FEBRUARY 1996**

FAO/IAEA/IIR/ITC/WHO Interregional Seminar on Food Irradiation to Control Food Losses and Food-Borne Diseases in Africa and Near East Regions, ***Rabat, Morocco*** (26 February - 2 March)

**MARCH 1996**

International Seminar on Enhanced Utilization of Research and Test Reactors, ***Bombay, India*** (dates to be confirmed)

# IAEA BULLETIN

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## 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**
Mauritius

**1976**
Qatar
United Arab Emirates
United Republic of Tanzania

**1977**
Nicaragua

**1983**
Namibia

**1984**
China

**1986**
Zimbabwe

**1991**
*Latvia*
Lithuania

**1992**
Croatia
Estonia
Slovenia

**1993**
Armenia
Czech Republic
Slovakia

**1994**
Former Yugoslav Republic of Macedonia
Kazakhstan
Marshall Islands
Uzbekistan
Yemen

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.**

Until now, one of the biggest problems with reading personal exposure doses has been the size of the monitoring equipment. Which is precisely why we're introducing the Electronic Pocket Dosimeter (EPD) "MY DOSE mini™" PDM-Series.

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

But the big news is how very small and lightweight they've become. Able to fit into any pocket and weighing just 50~90 grams, the Aloka EPDs can go anywhere you go. Which may prove to be quite a sizable improvement, indeed.

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|---|---|---|---|
| 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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