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PROTECTING THE EARTH
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ОХРАНА ЗЕМНОЙ СРЕДЫ
PROTECCION DE LA TIERRA
حمايـــــــة الأرض
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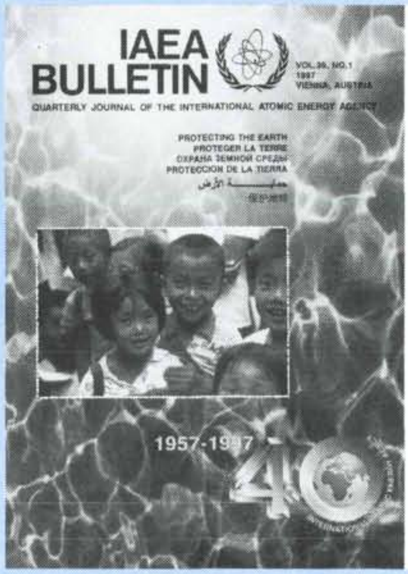
1957-1997

INTERNATIONAL ATOMIC ENERGY AGENCY



Front cover: The International Atomic Energy Agency marks its 40th year of service in 1997 as the world's "Atoms for Peace" organization. Its global work supporting safe and sustainable environmental development — from the use of radiation technologies in health care to the generation of clean electricity by nuclear power plants — has taken on added importance over the past decade. Countries are applying nuclear and related techniques to everyday problems, and they are drawing upon the IAEA's multi-faceted scientific and technical expertise. This edition of the *IAEA Bulletin* highlights some of the issues they are addressing, especially in areas of radiation and waste safety.

Cover design: Hannelore Wilczek, IAEA; Stefan Brodek, Vienna

Facing page: In the cold waters of the Kara Sea, biota are rare. As part of the International Arctic Seas Assessment Project, marine scientists from the IAEA's Marine Environment Laboratory in Monaco took part in a number of scientific investigations of the Kara Sea to collect samples for analysis and radiological assessments.

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Good signs for sustainable development: Nuclear energy's contributions

In many countries around the world, the goal of sustainable development is focusing attention on the benefits of nuclear-based technologies

by Arshad Khan, Lucille Langlois, and Marc Giroux

When radioactivity was discovered just over a hundred years ago, no one could foresee its far-reaching consequences. The discovery opened the door to a new and exciting branch of science and technology that has had a tremendous impact on the world, both terrifying and beneficial. Since its formation 40 years ago in 1957, the IAEA has been closely involved with both sides of nuclear energy and its peaceful international development. Its day-to-day work chiefly involves assisting countries in their collective efforts to prevent the terrifying uses of nuclear energy and to foster its safe application for the world's benefit.

Over the past four decades, important achievements have been registered in fields of energy and the environment, medicine, agriculture, and industry, among others, where nuclear and radiation technologies are widely applied. Their use allows us, for example, to detect, trace, image and measure what our own eyes cannot see, to destroy cancer cells and germs, to pinpoint water resources, and to generate large amounts of electricity in an environmentally clean and economically competitive way.

This article looks at the peaceful atom's contributions, especially within the context of the IAEA's activities for promoting sustainable development, and nuclear energy's versatile and varied applications. The beneficial applications of nuclear and radiation technologies have become valuable, and sometimes indispensable, tools for addressing a range of needs and problems in Latin America, Africa, Asia, and other regions of the world.

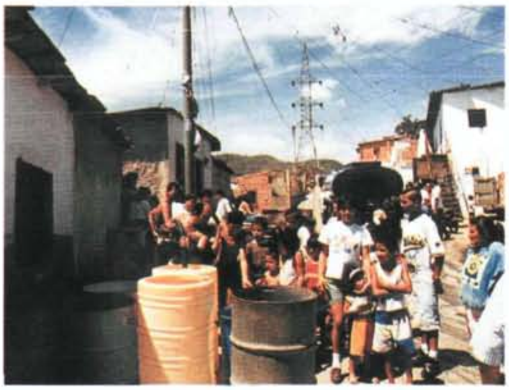
Mr. Khan, Ms. Langlois, and Mr. Giroux are staff members in the IAEA Department of Nuclear Energy's Planning and Economic Studies Section.

Medical and health care needs

Perhaps the most familiar and widely accepted use of nuclear techniques is in the medical fields of diagnosis, imaging, and cancer treatment. Modern medicine, in fact, would be unthinkable without diagnostic radiology and radiotherapy. These techniques have become so common, so reliable and so accurate that, in the Western industrialised world, about one patient in three undergoes some form of diagnostic or therapeutic radiological procedure.

The IAEA's nuclear medicine programme helps countries around the world to maintain a high degree of professional competence for all those who operate these installations, and to maintain the precision and the quality of the equipment they use in both diagnosis and radiation therapy. The Agency also provides assistance for advanced training of medical physicists who are currently working in radiology, radiotherapy, and nuclear medicine. Such assistance helps to assure the development of a high quality radiation diagnosis and treatment in various countries. With the World Health Organization (WHO), the IAEA further works to ensure conformity of radiation measurement in diagnosis and therapy through a global network of laboratories.

Human nutrition studies. Another specific application that is now drawing greater attention is the use of isotope techniques for evaluating human nutritional status and measuring the effects of nutrition programmes. It has many advantages over alternative procedures. It permits non-intrusive early and exact detection of nutritional deficiencies, and thus facilitates devising the proper remedies. The Agency is involved in some pioneering work using these techniques to evaluate vitamin-A



In many ways and forms, people are seeing good signs from uses of nuclear energy. *Clockwise from top left:* Gas emissions into the atmosphere from fossil fuels can be reduced by radiation techniques and avoided by nuclear plants that generate electricity without emitting carbon dioxide.*(Carnemark/World Bank)* Marine scientists use nuclear techniques to analyze samples for contamination from pesticides and other chemicals. *(IAEA-MEL)* In Africa, Latin America, and elsewhere, the nutritional health of children is being evaluated and improved using nuclear-based analytical methods. *(Carnemark/World Bank)* Greener fields are a practical goal of IAEA-supported projects that help farmers study and solve problems affecting food and agricultural production. *(IAEA)* In places where water is in short supply, the tools of isotope hydrology are helping countries to better understand and manage existing supplies, and to assess future sources of water. *(Marshall/IAEA)*

and iron deficiencies, bone disease, malnutrition, and the nutritional requirements of mothers and children. Right now, more than 800 million people around the world are chronically malnourished, and more than a billion are sick or disabled because of nutrient deficiencies.

To help improve this picture, the IAEA is developing and transferring nuclear-based evaluation tools that enable early detection and treatment. Such highly specialized techniques can become "sustainable solutions" in efforts to achieve a better nourished population and Agency-supported projects are helping to put programmes into place in countries of Latin America and elsewhere.

Food, water, and agricultural needs

Water resources. The world has enough water, but not always where it is most needed. Water deficits have become increasingly acute and isotopic techniques are often of great help to trace and measure the extent of underground water resources. Isotopic techniques provide important analytical tools in the management and husbanding of existing supplies of water and in the identification of new, replenishable and exploitable sources of water. The results permit informed recommendations for the planning and management of the sustainable use of these water resources.

The IAEA has a dedicated isotope hydrology laboratory that supports development activities. Projects provide assistance to countries with chronic water shortages such as Morocco, Senegal, and Ethiopia. Over the last decade, the Agency has supported almost 160 projects worth US $20 million to help countries develop national capabilities in hydrology isotope applications. Some 550 scientists in these countries have been trained in the relevant skills.

Agricultural applications. The use of nuclear techniques in the field of agriculture is of prime importance for the developing world. Radioisotopes and radiation techniques applied in this field can:

- induce mutations in plants to obtain desired agricultural crop varieties;
- determine conditions for optimizing fertilizer and water use, and biological nitrogen fixation;
- eradicate or control insect pests;
- increase genetic variability of plant species;
- reduce post-harvest losses by suppressing sprouting and contamination and extending shelf life of foodstuffs; and
- help identify the pathway of pesticides and agrochemicals in the environment and the food chain.

Measurement of nitrogen uptake in crops. In co-operation with the Food and Agriculture Organization (FAO) of the United Nations, the Agency has perfected the nitrogen-15 technique to measure how nitrogen is taken up by plants from the atmosphere, from the soil, and applied fertilizers. The technique provides an estimate of the total nitrogen fixed during the entire growing season. By this means, more efficient nitrogen fixing legumes with higher yield and protein content can be identified and selected for breeding. The FAO and IAEA jointly support some 30 projects worldwide on the production and use of biofertilizers for increasing biological nitrogen fixation and yield of grain legumes. Use of these bio-fertilizers has increased production by 25% in countries like Bangladesh, China, India, Malaysia, Pakistan, the Philippines, Sri Lanka, Thailand, and Viet Nam.

Eradication of insect pests. Sleeping sickness is a well known disease transmitted by the tsetse fly. The presence of this insect has prevented settlement and development of large areas of Africa. While some insect pests have been temporarily controlled in West Africa, eradication of tsetse has proved an elusive goal. Along with the FAO, the Agency is now effectively targeting one species that has caused sizeable losses of cattle on the island of Zanzibar, Tanzania, and authorities there are confident that eradication can be achieved.

A key component of efforts in Zanzibar is the Sterile Insect Technique (SIT), a radiation-based technology. It involves the sterilization of factory-reared male insects by irradiation before hatching and thereafter releasing millions of the sterile insects into infested areas. When they mate with flies in the wild, no offspring are produced, thereby gradually reducing and finally eradicating the insect population. The technique is particularly effective in a confined area such as the island of Zanzibar, where the risk of re-infestation from the outside is minimal.

The SIT has also been applied successfully against numerous other insect pests in recent years, including the costly Mediterranean fruitfly that alone attacks 260 varieties of fruits and vegetables in 82 countries and the New World Screwworm that endangers millions of livestock. In Mexico, sterile Medflies are reared in Tapachula at the largest such facility in the world. Mexico also has a large screwworm rearing facility at Tuxtla, which proved instrumental in its successful fight to eradicate the New World Screwworm in 1991. Over a 30-year period in Mexico, the cost-benefit ratio of the screwworm eradication is conservatively estimated at about 1 to 10. In monetary terms, this means that the benefits to the Mexican economy have been at least US $3 billion over that period of time. Drawing upon the base of SIT experience worldwide, the IAEA, FAO, and Libyan authorities several years ago succeeded in eradicating the screwworm in Libya where a large infestation had occurred. Huge quantities of sterile flies were flown from Mexico to Tripoli and released over the infested area in Libya. Mexico is presently providing sterile screwworm flies for an eradication campaign in Central America and will provide flies for similar campaigns in the Caribbean.

Eradication of such devastating pests by SIT is a major contribution to the ability of any country to feed itself and others in an environmentally sustainable way. The technique protects the quality and quantity of agricultural output without the additional extensive use of chemicals that otherwise would be released into the environment.

Enlarging the genetic variability of crops. Ionizing radiation in the field of plant breeding has been used for several decades as part of efforts to improve agricultural economic conditions in individual regions. Some of this research is done at the Agency's own research laboratories in Seibersdorf, Austria; region-specific or country-specific research is carried out through IAEA-supported agricultural research programmes around the world. By combining mutation with *in vitro* plant propagation strategies, this research has made possible the successful production of new genotypes/mutant lines of sorghum, garlic, wheat, bananas, beans, avocado and peppers, all of which more resistant to pests and more adaptable to harsh climatic conditions.

Preserving foodstuffs. The use of irradiation technology to preserve food is increasing around the world. In 37 countries, health and safety authorities have approved irradiation of over 40 kinds of food items, ranging from spices and grains, to deboned chicken, fruit, and vegetables. Today, consumers can safely enjoy irradiated strawberries as they can in France, or irradiated sausage, as is locally done in Thailand.

Here, too, rules and standards are needed to control the safe application of the technique. A worldwide standard for irradiated food was adopted as long ago as 1983 by the Codex Alimentarius Commission, which is a joint body of the FAO and WHO representing more than 130 countries. An expert committee further has reported to the Commission that the irradiation of any food commodity up to an overall average dose of 10,000 grays presented no toxicological hazard, required no further testing, and introduced no special nutritional or microbiological problems.*

Governmental interest in the process stems from a variety of reasons:

- high losses of food after harvesting (typically 25% of all food production) due to infestation, contamination, and spoilage;
- concern about foodborne diseases;
- growing international trade in foodstuffs that must meet stringent import standards of quality and quarantine.

While the Codex Alimentarius Commission exercises oversight regarding the foodstuffs themselves, international radiation protection regulations govern safe operation of installations where irradiation takes place. The IAEA helps in formulating such regulations, and it has frequently provided assistance to countries wishing to test or use this technology.

Livestock health, productivity, and disease control. Livestock are vital to sustainable agriculture in most developing countries but their productivity is often much lower than in the industrialized world. Livestock production can be improved if attention is given to animal nutrition, reproductive performance, and health, particularly the control and prevention of diseases. This can be done using nuclear and related techniques. Along with the FAO, the European Union, and other partners, the IAEA is helping countries in Africa and other regions to control, monitor, and ultimately eradicate rinderpest from their territories. In Africa, the campaign has been effective so far and the 34 countries engaged in the campaign now agree that eradication can be achieved over the next five years.

Energy and electricity needs

In the energy field, nuclear applications carry significant environmental benefits, and they go beyond the clean production of electricity.

Investigation of geothermal resources. Thanks to the analytical capabilities of the IAEA isotope hydrology laboratory in Vienna and its global partners, investigation of geot-

* 1 gray = 1 Joule per kilogram, the unit of measurement for the energy absorbed by the irradiated material.

Green sides of nuclear power

Using nuclear fuels, rather than burning fossil fuels, to power electricity plants may be part of the answer to the threat of global warming. Nuclear's role is already sizeable in helping countries to cut back or hold in check their emissions of carbon dioxide (CO_2), a gas linked to global climate changes. If the nuclear power plants in operation worldwide today were replaced by fossil-fired power plants, the CO_2 emissions from the energy sector would increase by more than 8%. This level almost equals the avoidance of CO_2 emissions by hydropower. Avoided CO_2 emissions are demonstrably greater in countries that have substantial nuclear shares in their electricity production — those like France, Sweden, Belgium, Spain, Switzerland, and the United States. In France, CO_2 emissions have been reduced by a factor of eight and sulphur dioxide emissions by a factor of ten between 1980 and 1993. During that time, France's total electricity generation roughly doubled, owing mainly to the increase of nuclear's share in electricity generation from some 25% to more than 75%. Similarly, in Sweden, a drastic reduction of atmospheric emissions was obtained mainly by substituting nuclear power for oil and other fossil fuels for electricity generation. Overall for industrialized countries of the Organization for Economic Co-operation and Development, it's been reported that nuclear power accounted for the greater part of the lowering of carbon intensity of the energy economies over the past 25 years.

Such achievements show that an objective comparison of different options for generating electricity is needed, and that the environmental advantages of nuclear power can be well documented. Given the interest of its Member States in such comprehensive comparisons for energy planning purposes, the IAEA has developed and distributed a package of computer tools and databases that comprise an analytical framework for analyzing the economic, health, environmental, and social aspects of all energy chains for electricity generation.

hermal systems can be improved and the use of their resources optimized. In some countries, like Costa Rica and Nicaragua, isotope techniques provided by the Agency have been used to map geothermal resources and to decide on the best location of installations.

Abatement of gaseous emissions. With the use of accelerator-generated electron beams in the chimney stacks of conventional coal-burning power plants, sulphur and nitrogen emissions to the environment can be virtually eliminated. Indeed, with the addition of ammonium, these potentially polluting flue gases are transformed into fertilizers — ammonium sulphate and ammonium nitrate — and water. This ingenious and original method is currently being demonstrated in a project which the IAEA is supporting near Warsaw in Poland. Where once the alchemists rosily dreamed of transforming lead into gold, today's energy planners are realistically seeing the transformation of polluting gases into useful food for crops.

Nuclear power. There is no doubt that global energy use will increase sharply, in part because the world population is increasing so much, in part because energy — and especially electricity use — is a vital part of the higher living standard that people seek. Bangladesh and Tanzania annually use less than 100 kWh electricity per capita. Sweden uses 15,000 kWh and Mexico uses about 1250. Given the inevitable growth in world population, a global striving for economic development, and growing trends towards urbanization, it is not surprising that the World Energy Council predicts that the world use of electricity will increase by 50% to 75% by the year 2020.

At present 63% of the world's electricity comes from thermal power (coal, oil and gas), 19% from hydro, 17% from nuclear, 0.5% from geothermal, and less than 0.1% from solar, wind power and biomass. This mix will clearly change as resources are developed and new technologies appear over time, and as environmental concerns become more effective. Rational energy production and use will necessarily be a major aspect of sustainable development. Based on experience so far, nuclear power should play an important part of any future energy mix.

Nuclear prospects. In the 1970s there was great enthusiasm for nuclear power and expectations for rapid growth, not least to reduce dependence on oil. With high inflation and slower economic growth in the following decade, energy demand grew more slowly than expected and became more price sensitive. The large construction programmes contemplated in some countries, such as Mexico and Brazil, for instance, were not realized. With the many safety related changes required after Three

Mile Island, nuclear power also lost some of its economic competitive edge.

These economic factors, along with growing political opposition to nuclear power, slowed the expansion of the industry. Concerns over safety and waste disposal, part of a larger environmental movement, have stymied further nuclear investments in a number of countries. There is at present a stagnation in the construction of further nuclear plants in Western Europe and in the Americas, where slow economic growth and over-capacity in the generating industry have resulted in very little major baseload construction of any kind in recent years. Construction of nuclear plants is continuing vigorously only in East Asia, specifically in Japan, Republic of Korea, and China.

Nonetheless, nuclear power remains a viable part of our energy future for several reasons:

Economic competitiveness. The economic competitiveness of energy options remains important to countries, utilities and the consumers. From the economic point of view nuclear power is at present roughly on par with coal, and in some cases, gas. However, nuclear plants require larger up front investments, which is a drawback in capital starved developing countries. As nuclear technology is relatively young there should be scope for rationalisation, standardisation, modular construction, higher burnup, simplification — all resulting in greater efficiency and lower cost. Moreover, relative fuel prices are likely to change over time. Nuclear generation should remain an attractive option especially for countries lacking domestic fuel resources.

Safety. The objections advanced to nuclear power on the grounds of safety may gradually be answered by positive experience. No accidents in the world have had more publicity than those at Three Mile Island and at Chernobyl. This has tended to overshadow the fact that by now the world has the experience of some 7700 reactor years of operation without any other major accidents. Through national regulatory organizations, through the World Association of Nuclear Operators and through the Agency these many years of experience are made available for all to learn from. The Three Mile Island accident in 1979, even though it released little radioactivity into the environment, triggered extensive safety reviews, strengthening nuclear safety in the non-communist world. And the Chernobyl accident, which occurred 10 years ago, similarly led to reviews and new safety measures in Russia and Eastern Europe. Thus these two major nuclear accidents, which provoked so much opposition to nuclear power, also set in motion determined and extensive action in the field of safety. Nuclear power safety became even more of an important international concern and the Agency became a central instrument through which governments co-operate to establish important elements of what is now termed an "international nuclear safety culture". The impact of this effort can be seen in the improved production figures for nuclear power plants around the world, lower doses to their personnel and fewer unplanned stoppages. New types of advanced reactors, some of them available in the market today, have new safety features and can be expected to have even better records on reliability and safety than the current dominant reactor types.

Energy security. Energy independence is an important factor. Not all countries have abundant energy resources — hydrocarbons or waterfalls. To France, Japan, the Republic of Korea, Sweden and Finland, all without oil and gas, the measure of self-reliance and the measure of immunity against international crises which nuclear power offers, has been and remains important.

Environmental protection. Another important factor for a nuclear revival will be the environment. Nuclear power may be viewed as the least damaging, most emissions-free of the realistic energy options. Indeed, it is not nuclear power plants — but an excessive burning of fossil fuels — that have caused acid rains, dead forests and a threat of global climate change. Nuclear power does not generate airborne emissions, and helps fight global air pollution. Indeed, if the world's 437 nuclear power reactors were to be replaced by coal plants of equivalent capacity, some 2600 million tons of CO_2, and millions of tons of associated sulfur and nitrous oxides, would be added to the world's atmosphere each year.

Minimizing the impact of possible global climate change has become one of the principal goals of the sustainable development movement. There is much talk about the need to reduce CO_2 emissions, though scientists are not yet certain or agreed that there will indeed be an irreversible global warming as early as 50 years from now as a result of CO_2 emissions from fossil fuels such as oil, gas, and coal. Questions remain about global warming trends, and the uncertainty leads many observers to advocate that the world should pursue so-called "no regret" policies. By this they mean energy policies which we would not regret even if the fear of global warming were to prove unfounded. The nuclear power option fits the requirement of a no regret policy,

Comparing energy sources: The Decades programme

The IAEA and other international, regional, and national organizations are working together through a co-operative programme to assist energy planners in assessing electricity options.

Known as "Decades", the programme features a set of tools for comparative assessment of electricity generating sources throughout the entire energy chain. It includes databases with health, economic, and environmental aspects to support comparative assessments; integrated software packages for electricity system planning and analysis; and training and support services. The programme is carried out jointly by the IAEA and eight international organizations: the European Union, the Economic and Social Council for Asia and the Pacific, the Nuclear Energy Agency of the Organization for Economic Co-operation and Development, the International Institute of Applied Systems Analysis, the Organization of Petroleum Exporting Countries, the United Nations Industrial Development Organization, the World Health Organization, and the World Bank. The programme is under the supervision of a Joint Steering Committee composed of representatives of all nine participating organizations and co-ordinated by the IAEA's Planning and Economic Studies Section at the Agency's headquarters in Vienna.

as it does not contribute to global warming and is roughly competitive with the fossil fuels.

By contrast, renewable energy from solar, wind and biomass sources will not become commercially competitive on a wide scale in the foreseeable future. They are forecast to play only a minor role in the decades to come, though their development is certainly and appropriately being encouraged. Great strides in energy efficiency, meaning both a more efficient generation and use of energy, have been made and they remain very important to restrain demand. However, even as we become more efficient in our electricity generation and use, the world's total energy demand is increasing. This is not to suggest that nuclear power, alone, is a solution to the threat of global warming. Many different approaches may be used as needed, including renewable and conservation. But nuclear power can certainly be a viable and promising component of sustainable development in the response policies which need to be worked out.

Waste management. When it comes to nuclear power, concern is usually focused on the highly toxic and radioactive spent fuel and nuclear waste. What is characteristic of these, however, in addition to their toxicity and radioactivity, is that they are so limited in volume, which facilitates waste disposal. This contrasts sharply with the waste disposal problem for fossil fuelled plants, whose emissions are voluminous and directly enter the environment. When the problems of safely disposing of long-lived nuclear wastes are put into context, the comparative picture becomes clearer. Due to its limited volume, nuclear waste can technically and economically be safely taken care of and be put into the crust of the earth from where the uranium originally came. Not everyone, however, shares this confidence in "high tech" solutions. The "not-in-my-backyard" attitude has affected nuclear waste management programmes in every major nuclear country, just as it has the siting of almost every industrial and energy-related facility. The siting of such facilities is a major part of sustainable development. Blocking the disposal of waste does not make it go away or stop its generation: it just prolongs direct environmental exposure unnecessarily.

Comparative assessments of nuclear power and other forms of electricity generation highlight some of these interesting waste generation and disposal issues. Consider, for example, the case of a country that decides not to operate a nuclear plant and builds instead two coal-fired units of about the same capacity. The nuclear plant would consume about 30 tons of low-enriched uranium *per year*, while the coal plant would consume about five train loads of coal *per day*. The limited volume of nuclear waste from the uranium can be isolated in its entirety. The coal plant will produce huge quantities of CO_2 and ashes containing heavy metals which remain toxic forever. The disposal site for all this waste from burned coal — as from other fossil fuels — is our atmosphere and the surface of the earth.

Achieving sustainable solutions

The international goal of sustainable development requires the co-ordinated actions of people around the world, and all the scientific and technological tools at their disposal. In various fields, nuclear energy and its diverse applications have proved to be important components of steps to achieve sustainable solutions to practical problems affecting our social, economic, and environmental development.

To make the right choices in the months and years ahead, governments will need an objective record of experience and facts with which to evaluate their options, set priorities, and marshal the needed resources. Through its range of services and projects, the IAEA will be assisting countries in their efforts to constructively and safely apply nuclear and radiation technologies where they can be most beneficial, and to plan their energy and electricity development. ❐

Marine science: Joining forces for the environment

At the international level, inter-agency initiatives involving scientists worldwide are targetting environmental threats to our oceans and seas

by Murdoch S. Baxter, Fernando Carvalho, Iolanda Osvath, and David Kinley III

More than 70 percent of the earth's surface is covered with water — and fully 97% of that water is contained in saline seas. Marine ecosystems are vital to global food supplies: roughly one billion people, most of them in developing countries, depend on fish for their sole source of protein. And more than half the people on earth live in coastal zones.

The importance of the oceans and seas to economic well-being and environmental balance is acknowledged. But in a rapidly industrializing world with a population of roughly 6 billion people, what is being done to preserve this unique resource for generations to come?

For most of its 40 years, the IAEA has supported the only marine laboratory in the United Nations system, the Marine Environment Laboratory (MEL) in Monaco. Today, MEL is among the foremost specialized marine science establishments in the world, at the forefront of international efforts to understand, preserve, and protect the marine environment. In addition to the Government of Monaco, principal funders of MEL are the IAEA and United Nations Environment Programme (UNEP). Partners in research and field activities include the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO), Japan, Sweden, Germany, France, the European Commission, and a number of other governments and non-governmental organizations.

Over the past decade, MEL's expertise has been applied to many pressing international environmental challenges:

- Tracking the effects of ocean disposal of nuclear wastes;
- Assessing and mitigating the marine impacts of the Gulf War;
- Investigating the radiological consequences of nuclear weapons testing in the Pacific;
- Analyzing the "greenhouse effect" and the potential for "global warming;" and
- Studying the impacts of industrial and agrochemical pollution on marine ecosystems. *(See box, page 11.)*

This article offers a global perspective on inter-agency co-operation concerning pollution of the marine environment. Included are overviews of the MEL's work, and highlights of specific activities related to environmental assessment of the Black Sea, pesticides in the marine environment, and the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities.

Special environmental initiatives

Working with a range of partners, MEL is playing a key role in a number of special international scientific investigations related to marine radioactivity and ecosystems:

Nuclear wastes in Arctic Seas. Together with experts from Russia, Norway, and USA, MEL has been undertaking five expeditions to and laboratory analysis of samples collected in the Kara and Barents Seas to determine potential hazards to humans and the marine environment from dumped wastes, including reactors. Computer models have also been developed to predict the dispersion of any future leakage, and laboratory studies of concentration factors and distribution coefficients in Arctic conditions

Mr. Baxter is Director of the IAEA's Marine Environment Laboratory in Monaco. Mr. Carvalho is Head of MEL's Marine Environmental Studies Laboratory, and Ms. Osvath is a staff member in MEL's Radiometrics Laboratory. Portions of the article have been issued as a booklet, *Guarding the Seas*, prepared by David Kinley III of the IAEA Division of Public Information. The booklet is available from the Division and accessible over the IAEA's *WorldAtom* Internet site at http://www.iaea.org/worldatom.

IAEA's Marine Environment Laboratory in Monaco: Yesterday and today

A strong commitment to guarding the integrity of the seas comes naturally for the people of Monaco, given the Principality's location and economic reliance on the Mediterranean. But it was with considerable foresight that, back in 1959, Prince Rainier III hosted the first world-wide scientific conference on the disposal of radioactive wastes on land and at sea. Two years later, Monaco's government and the IAEA formalized their partnership by establishing MEL's predecessor, the International Laboratory of Marine Radioactivity, dedicated to improving knowledge about the behaviour of radionuclides in the seas and promoting use of nuclear and isotopic techniques in protecting the marine environment. With the continuing support of the IAEA and the Principality, the Laboratory expanded the scope of scientific research and field activities over the decades into many related fields and established itself as a valuable source of technical assistance for IAEA Member States. In 1991, it was renamed the "Marine Environment Laboratory" to convey more accurately the broad scope of responsibilities it had assumed in providing scientific expertise and technical support internationally. Today MEL operates on a modest regular annual budget of about US $5 million and has a full time staff of about 50 scientists, technicians and administrative personnel. Extrabudgetary resources for specialized research and services from a variety of governments and international bodies total some US $3 million annually. MEL activities concentrate on five principal areas:

- Understanding marine radioactivity;
- Improving knowledge about oceans using isotopic techniques
- Training staff and extending capabilities of IAEA Member States;
- Providing analytical quality control services;
- Promoting inter-agency efforts to protect the seas.

At left: SAS Prince Rainer III and Dr. Blix in January 1996. ***(Gaetan LUCI)***

have been carried out. *(See the article beginning on page 21.)*

Nuclear weapons tests in the South Pacific. At the request of the French Government, MEL is participating in an in-depth analysis of the radiological consequences of several decades of weapons testing on the Mururoa and Fangataufa Atolls in French Polynesia. The study is being directed by a special International Advisory Committee convened by IAEA's Director General, and will assess not only the current radiological situation but also the long-term ecological impacts.

Rising waters of the Caspian Sea. In collaboration with the IAEA's Isotope Hydrology Section at the Agency's headquarters in Vienna, the UNEP, and governments from the affected zones, MEL is conducting studies to understand better the causes of the dramatically rising levels of the Caspian Sea. By employing isotopic techniques to study the water cycle, the investigation will provide a new platform for the affected countries to co-operate in solving this environmental challenge.

Pollution of the Black Sea. In collaboration with UNDP and the IAEA's own Department of Technical Co-operation, MEL is at the centre of a combined research and capacity building initiative that addresses the rapidly deteriorating condition of Black Sea waters. Isotope tracers are being used to investigate water circulation and pollutant behaviour. Equipment and training activities also are being provided to ensure an improved regional ability to monitor and control the quality of the marine environment. *(See box, page 13.)*

Promoting inter-agency initiatives to protect the seas

The importance of global actions to protect the seas was stressed in Agenda 21, the document adopted at the UN Conference on Environment and Development in 1992. Chapter 17 of Agenda 21 calls for "new approaches to marine and coastal area management and development at the national, sub-regional, regional and global levels" and the strengthening of inter-agency cooperation in this regard. Emphasis was also placed on building the capacities of national and regional institutions (especially in developing countries) for making environmental assessments and controlling marine pollution.

Pesticides in the marine environment

Agrochemicals, and in particular pesticides, have become an integral part of modern agriculture systems contributing significantly to improved crop yields and enhanced production of food. Nevertheless, the lack of specificity of some pesticides, their persistence in the environment and their irresponsible use in certain regions have produced undesirable side effects. Besides the direct exposure of humans, pesticide residues introduced in aquatic ecosystems have been reported to cause massive fish and shrimp kills, to reduce the reproductive success of species and to contribute to the death of coral reefs so that ultimately they may have a major impact on fishery resources, biological diversity and the functional equilibrium of ecosystems.

An assessment of the ecological risk posed by pesticide residues in marine ecosystems is, for the most part, yet to be undertaken. Environmental risk assessment and introduction of measures to manage or counteract the risk of pesticide residues require expanded knowledge of the environmental behaviour and effects of pesticides. To this end, enhanced laboratory capacities in the countries are needed in order to implement ample marine monitoring programmes. Furthermore, experimental research is also required to generate the necessary data on the cycling, fate and effects of pesticides in marine ecosystems.

In the study of the environmental fate of pesticides, the use of carbon-14 labelled molecules has for some years provided an invaluable tool for research in both terrestrial and aquatic environments. They allow a compound to be followed in experimental systems and for the unambiguous identification and quantification of transformation products at very low concentrations. Because only the radioactive carbon is measured, for many purposes sample clean-up is less rigorous than that required by other techniques such as chromatography. Consequently, a large number of samples can be processed rapidly and measured with standard liquid scintillation equipment at low cost.

To develop relevant studies, MEL organized a coordinated research programme on the Distribution, Fate and Effects of Pesticides in Biota in the Tropical Environment, with support provided by Sweden. The programme currently includes participants from 17 Member States in Asia, Africa and America where pesticide research exists or is being developed. The results should be instrumental in expanding the present knowledge of environmental contamination by pesticide residues in tropical coastal regions and in the assessment of the potential consequences.

Recommendations for improving the management of the sensitive ecosystems of tropical coastal areas will be formulated to help Member States implement practical measures to harmonize the interests of agriculture with the preservation of their aquatic resources. The other specialized agencies of the UN family operate other programmes in this area. For example, the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities which aims, namely, to assess the severity and impact of persistent organic pollutants. The IAEA's project is complementary and illustrates how nuclear techniques can uniquely fill existing gaps in knowledge and methodology.

The IAEA and other organizations are leading efforts to strengthen the capabilities of laboratories to analyze biological samples as part of marine monitoring programmes. ***(IAEA-MEL)***

Thus, in addition to carrying out an IAEA-focused work programme, MEL responds regularly to requests for technical assistance from many other United Nations agencies, international organizations, and governments. Within the UN, co-operative activities are formally established with UNEP and IOC-UNESCO. There is also extensive collaboration with the World Meteorological Organization, the World Health Organization, the World Bank, the UNDP, the UN Food and Agriculture Organization, and the International Union for the Conservation of Nature in programmes of assistance for developing countries.

A focal point for this co-operation is being provided by the Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities, which has been requested and supported by Member States and requires MEL's services for analytical capacity building. *(See box, pages 14-15.)*

Understanding marine radioactivity

Since its beginnings, MEL has been engaged in deepening scientific understanding of marine radioactivity. Over the decades, moreover, research has broadened to include analysis of a wide range of non-radioactive pollutants in the marine environment, using nuclear and isotopic techniques.

MEL scientists examine the consequences of radioactive discharges and disposals by monitoring and assessing radionuclide levels and modelling their dispersion in the marine environment. The results then assist Member States in radiological assessments related to nuclear weapons test sites, nuclear waste disposal areas, and in emergency responses to accidents at sea. To facilitate this work, MEL has created a Global Marine Radioactivity Database (GLOMARD) to provide countries with radioactivity baseline data on seawater, sediment, and biota for undertaking assessments. In addition, a large-scale project on Worldwide Marine Radioactivity, supported by Japan, is being carried out with the aim of providing new data on present radionuclide levels in the oceans and seas.

Improving knowledge of oceans

Nuclear and isotopic techniques are being employed in a wide variety of research activities aimed at enhancing understanding and improving the management of marine ecosystems:

- Establishing the distributions of natural radionuclides in marine ecosystems and the resulting doses to humans through the food chain;
- Tracing the behaviour and fate of key radionuclides and natural analogue elements;
- Measuring the rates and ages of marine samples and processes using the unique timeclock of radioactive decay; and;
- Mapping the biological processes leading to the aggregation of particulate carbon.

As mentioned above, radiotracer methods are used to study agrochemical compounds, such as pesticides, and their accumulation and effects in marine systems. They are also used in establishing the pathways and accumulations of heavy metals and other toxic elements in the marine environment and their effects on people and ecosystems.

Training and capacity building

In co-operation with the IAEA Departments of Research and Isotopes and Technical Co-operation, MEL provides support to developing countries in obtaining high quality data on marine radioactivity and radioecology, while the non-nuclear contaminants are covered through close co-operation with other specialized agencies including UNEP, the IOC-UNESCO and the United Nations Development Programme (UNDP). The Laboratory also supports marine pollution monitoring and research in developing countries by conducting joint exercises and training courses as part of an integrated programme of quality assurance.

Each year approximately a dozen specialist training courses are conducted for participants from developing countries in subjects such as marine radioactivity and radioecology, radiochemistry, and various aspects of analytical chemistry. MEL also sponsors dozens of trainees from developing countries to work on research projects at Monaco and elsewhere to enhance their scientific skills. During 1996, MEL implemented 10 IAEA Technical Co-operation Projects, while providing advisory and technical assistance missions to 31 countries.

Providing analytical services

In order to produce reliable scientific results, monitoring laboratories need to follow a quality control system that includes regular

Environmental protection of the Black Sea: Assessing the picture

Late last year, the Global Environment Facility (GEF) Black Sea Environmental Programme (BSEP) offered an informative perspective on inter-agency efforts to protect the Sea from environmental pollution. An excerpt from the report, published in the September 1996 edition of the GEF newsletter *Saving the Black Sea*, follows:

A deadly soup? *"Three years ago a leading international newspaper described the Black Sea as a "Deadly Soup of Toxic Waste". At that time, there was little or no reliable information available to confirm or deny such an alarming statement. The sea certainly looked visibly dirty, judging by the green-brown colour of the water and the litter on the beaches, many of which were closed to tourists. The Black Sea ecosystem was also in a catastrophic state of decline. All of these visible signs, together with the knowledge that much of the waste of 17 countries drains to the Black Sea, could easily lead to a sense of hopelessness.*

"Science, however, does not depend upon anecdotes but seeks out hard facts. Much of the limited data available had not been obtained using the well-proven techniques and independent quality control procedures which are now demanded of those working in the marine environment. One of the key roles of the new Black Sea Environmental Programme (BSEP) with collaboration of its partners (IAEA, IOC, UNEP, EU) was thus to provide the missing equipment, techniques and quality control in order to obtain a better evaluation of the realities of the Black Sea pollution. Inevitably, despite the presence of excellent scientists already working in the region, it takes time and money to upgrade scientific institutions, and the process is far from complete. In view of the urgent need for reliable data, institutions in the Black Sea, western Europe and the U.S., and several UN Agencies decided to cooperate to undertake a series of pilot studies in representative areas of the sea. The areas studied included the continental shelf of Ukraine (the Activity Centre for Special Pollution Monitoring, Odessa, together with the IAEA Marine Environmental Studies Laboratory — MESL — in Monaco), the shelf off the entrance to the Bosphorus, (Middle East Technical University, Erdemli, with MESL), the coastal area near Sochi, Russia (the Hydromet Centre, Sochi, with MESL) and the north-western Black Sea shelf and Danube discharge. The result was the preparation of the first ever comprehensive pollution review, entitled "The State of Pollution of the Black Sea", which will be shortly published."

Following a comprehensive scientific assessment of the problems facing the Black Sea, on 31 October 1996, in Istanbul, the governments of the six Black Sea countries approved a Strategic Action Plan for the Rehabilitation and Protection of the Black Sea.

What will happen next? The Black Sea regional monitoring system is expected to be underway in 1997. It will include strong provisions for "biological effects" monitoring and an independent quality control system for much needed high quality analytical data on marine contaminants. More scientific research is also still required. Moreover, capacity building in laboratories of the region, training in analytical techniques and data quality assurance on marine contaminants continue to be a top priority for the IAEA and inter-agency support to the Black Sea countries.

IAEA programmes. The IAEA is supporting efforts in the Black Sea region through programmes related to both radioactive and non-radioactive pollutants. MEL's role is to provide technical and scientific backstopping. Significant progress in understanding the fate of contaminants in the Black Sea has been made through a co-ordinated research programme. It resulted in a comprehensive and up-to-date assessment of inputs, space-time distributions, inventories and radiological effects of anthropogenic and natural radionuclides in the Black Sea. It also demonstrated the unique potential of radioactive and stable isotopes to trace and quantify the key processes which control the behaviour of pollutants affecting the life-support capacity, and hence the productivity, of the Black Sea ecosystem. Finally, it clearly indicated the need to upgrade the regional analytical and monitoring capacities for radionuclides in the marine environment. This need is being addressed through a regional technical co-operation programme, "Marine Environmental Assessment of the Black Sea Region". It involves the six IAEA Member States bordering the Black Sea: Bulgaria, Georgia, Romania, Russian Federation, Turkey, and Ukraine. Its main components support developing a regionally co-ordinated marine radioactivity monitoring programme and enhancing capabilities to investigate the fate of contaminants by using radiotracers. Joint research is focused on issues and areas identified as critical for the current status and future trends of Black Sea pollution, such as sedimentary processes on the northwestern shelf, in the Danube and Dnieper estuaries, mixing of water masses at the Bosphorus Strait, and ventilation of the deep anoxic waters.

The assessment of non-radioactive pollutants has been targeted by an IAEA/UNDP-GEF Inter-Agency Agreement. Its main objective is to assist the region's countries to obtain high quality analytical data for special and routine monitoring in the context of the BSEP. To this end, MEL, through its MESL Section, provides comprehensive technical support including the production of reference methods, organization of intercomparison exercises, distribution of reference materials and standards, training, instrument maintenance, quality assurance missions, and organization of expert meetings. MEL will continue to provide this support in the framework of the new Strategic Action Plan for the Rehabilitation and Protection of the Black Sea.

Global Programme of Action for Protecting the Marine Environment

About 80% of all marine pollution is caused by human activities on land — activities such as sewage disposal in rivers and the coastal ecosystem; inadequately treated waters from industries; discharges of nutrients of phosphorus and nitrogen used in agriculture and finally; heavy metals and persistent organic pollutants.States adopted the Global Programme of Action (GPA) for the Protection of the Marine Environment from Land-based Activities in 1995, an action that US Vice-President Albert Gore has said "is the first programme that will lead to more sustainable interaction between mankind and the world's oceans." Highlighted here are key features of the GPA and associated background information leading up to the programme's adoption.

Global and regional conventions and events related to protection of the marine environment

1976 Regional Seas Conventions and related Protocols, which today govern 15 Regional Seas Programmes
1982 United Nations Convention on the Law of the Sea (UNCLOS)
1989 Basle Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal
1992 Convention on Biological Diversity
1992 United Nations Framework Convention on Climate Change
1992 United Nations Conference on Environment and Development (UNCED) and Agenda 21

In 1982, the United Nations Environment Programme (UNEP) started addressing issues related to impacts on the marine environment from land-based activities, resulting in the following conventions and decisions:

1985 Montreal Guidelines for the Protection of the Marine Environment Against Pollution from Land-based Sources
1995 UNEP Governing Council decisions 18/31 and 18/32 pertaining to the Washington Conference and Persistent Organic Pollutants (POPS)
1995 Conference to adopt a Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, Washington, DC, 23 October-3 November 1995

The Global Programme of Action

By adopting the Washington Declaration, more than 100 governments, and the European Commission, declared their commitment to protect and preserve the marine environment from the adverse environmental impacts of land-based activities. They called upon UNEP, the World Bank, the United Nations Development Programme (UNDP), the Regional Development Banks, and all agencies within the United Nations system, to support and strengthen the regional structures in place for the protection of the marine environment. They called upon UNEP, in close partnership with UNDP, the World Health Organization, Habitat, and other relevant organizations, to act as the Secretariat of the Global Programme of Action. The programme is designed to be a source of conceptual and practical guidance to be drawn upon by national and/or regional authorities in devising and implementing sustained action to prevent, reduce, control and/or eliminate marine degradation from land-based activities. It aims at preventing the degradation of the marine environment from land-based activities by facilitating the realization of the duty of States to preserve and protect the marine environment. More specifically, the GPA aims at:

- ***Identifying the nature and severity of problems caused by marine pollution.*** Analyzing the impact of marine pollution on (i) food security and poverty alleviation; (ii) public health, (iii) ecosystem health and biological diversity, and (iv) economic and social benefits and uses;
- ***Assessing the severity and impacts of contaminants.*** Includes sewage, persistent organic pollutants, radioactive substances, heavy metals, oils, nutrients, sediment mobilization and litter;
- ***Assessing the physical alteration, including habitat modification and destruction, in areas of concern;***
- ***Assessing the sources of degradation.*** They include (i) point sources, (e.g. waste-water treatment facilities or dredging operations); (ii) non-point sources, (e.g. urban or agricultural run-off); and (iii) atmospheric depositions caused by vehicle emissions, power plants and industrial facilities, incinerators and agricultural operations;
- ***Identifying areas which are affected or particularly vulnerable.*** Includes coastal watersheds, shorelines, estuaries and their drainage basins, and habitats of endangered species.
- ***Establishing priorities for action based on the identification and assessment of problems.***
- ***Defining specific management objectives, both with respect to source categories and areas affected, based on established priorities.***
- ***Identifying, evaluating and selecting strategies and measures.***
- ***Establishing criteria for evaluating the effectiveness of strategies and measures.***

What will the GPA do?

- Adapt existing regional and national action programmes, or promote and facilitate their development.
- Prepare a global review on the effects of land-based sources of pollution on the marine, coastal and associated freshwater environment. Identify "hot spots" for priority actions.
- Develop manuals and guidelines relevant to the implementation of the GPA.
- Organize and operate a clearinghouse prepared to respond to requests for assistance.
- Assist countries in (i) identification and formulation of project proposals; (ii) identification of potential donors; and (iii) negotiation with donors.
- Inform governments about problems related to land-based activities and the opportunities offered by the GPA. Support governments and non-governmental organizations alike, in the preparation and distribution of public awareness booklets and in setting up public awareness campaigns.

How will the GPA be implemented?

- Implementation will be addressed simultaneously at national, regional and global levels;
- Formulation of national, sub-regional and regional action programmes will be the cornerstone for successful implementation;
- Financial sources and mechanisms are to be addressed both at the State level (e.g. charging the polluter, revolving funds, private sector participation) and at the international level (e.g. multilateral loans and debt-for-equity swaps).

How can the IAEA contribute to the GPA?

The IAEA has followed the underlying principles of GPA for many decades. It has paid close attention to the quantification and reporting of inputs of radioactivity to the oceans and, through the Marine Environment Laboratory (MEL), to the monitoring and assessment of the consequences of these inputs. The Agency is therefore in an excellent position to contribute meaningfully to the GPA. From the IAEA Division of Radiation and Waste Safety, the following contributions have been proposed:

- Development of standards for controlling discharges of radioactive materials to the marine environment;
- Acquisition and dissemination of information on options, methods and technologies for the control of discharges;
- Development of inventories of worldwide discharges of radionuclides from nuclear installations and other, non-nuclear, facilities into the environment, including the marine environment;
- Assessment of the impact of discharges;
- Regular publication of data on discharges and their environmental impacts.

From MEL, the contributions combine the mainstream activities on marine radioactivity with inter-agency collaboration on a wide range of non-nuclear contaminants, as follows:

- Training and capacity building to extend the capabilities of Member States to monitor, understand and assess marine radioactivity;
- Provision of analytical quality control services by distributing a wide range of intercomparison and reference materials to laboratories worldwide;
- Maintenance of, and the provision of global access to, a comprehensive computer database on radioactivity in the marine environment, including intelligent functions to model dispersions from individual source-terms and to identify and explain spatial and temporal trends in marine radionuclide distributions;
- Quantification of the radiological (health-related) consequences of known inputs of radioactivity to the oceans by a combination of direct measurement, modelling and radiological assessment;
- Provision of an international emergency response function to assist on request with monitoring and evaluation of unplanned marine radioactivity inputs, including improvement of methodologies for continuous monitoring of marine radioactivity;
- The improvement of the understanding of the oceans, their circulation and the behaviour of pollutants by using the unique timing and tracing potentials of marine radionuclides and stable isotopes.

Building on the expertise available at MEL — and on the experience gained in more than 15 years of collaboration with UNEP and IOC-UNESCO on the assessment and monitoring of pollutants in the marine environment, including particularly the quality control of obtained data — the IAEA can assist in a number of activities relevant to the implementation of the GPA:

- Organization and implementation of data quality assurance programmes ensuring that assessments of major marine contaminants from land-based sources (including POPs, trace elements, oil) are reliable and intercomparable on regional and global levels;
- Preparation and testing of reference methods and guidelines for marine pollution assessment and monitoring;
- Design of national and regional marine pollution monitoring programmes;
- Training in analytical chemistry relevant to research and monitoring of marine pollutants; and
- Strengthening or establishment of regional technical support centres relevant to marine pollution research and monitoring.

measurements of contaminants in standard reference materials and participation in intercomparison and intercalibration exercises. MEL is a worldwide centre for quality assurance data for all types of chemical contaminants, both nuclear and non-nuclear. It also conducts regional exercises for quality assurance in the Mediterranean, the Persian Gulf area, the western and southeast Pacific, west and central Africa, east Africa, southeast Asia, the Caribbean, the southwest Atlantic, the Arctic, and the Baltic and Black Seas.

Scientific investigators associated with such intercalibration exercises have reported approximately 100,000 measurements since 1971 for specific contaminants in seawater, sediment, seaweed, plants, fish and other organisms. Participating laboratories have increased from approximately 50 in total in 1970 to 208 different laboratories now analyzing radionuclides, trace organics, and trace elements. Some 60 different intercomparison materials are available.

Reference materials. Samples of marine materials certified as reference materials for certain analytes (radionuclides, trace metals, chlorinated hydrocarbons, etc.) are used in quality control programmes. Together with UNEP and the IOC-UNESCO, the IAEA works closely with other producers of reference materials to assure a continuous supply of these vital elements of quality assurance procedures. A full catalogue of some 600 standards and reference materials are banked in Monaco.

Reference methods. One difficulty faced by many analysts starting studies in marine contamination is finding a reliable method that uses readily available, and serviceable, instruments. Working with several UN agencies, MEL edits and tests reference methods. The series now includes more than 70 volumes that are available around the world.

Improving quality of data. Despite progress so far in national laboratories to accurately measure marine contaminants, more needs to be done, for example, in the analysis of organic pollutants such as chlorinated pesticides and petroleum hydrocarbons. The needs include improved training of analysts, further advances in analytical techniques, and intensified production of intercomparison samples and marine reference materials.

All of the services provided by MEL have become essential to the operation of the UNEP and IOC-UNESCO regional and global pollution assessment programmes. They particularly provide relevant support to UNEP issues of integrated coastal area management and to the assessment of pollution from land-based sources. As importantly, they support the work of the IOC-UNESCO, UNEP, IAEA, and International Maritime Organization related to the programme for the Global Investigation of Pollution in the Marine Environment.

Moving into the 21st century

In 1998, MEL will enter a new stage in its development with the opening of purpose-designed laboratory premises, which will more than double floor space, consolidate three Lab Sections into one building and improve facilities substantially, including a new training centre. As a contribution to the UN's International Year of the Ocean to be marked in 1998, MEL will host an inter-agency symposium on marine pollution next year.

The new laboratories position MEL to play an even stronger leadership role in key areas of scientific interest to IAEA Member States. These include:

- ***Using isotope techniques to study non-nuclear contaminants.*** Particular attention will be devoted to understanding marine pollution by organic compounds such as oils, sewage and fossil fuel consumption products and delineating key processes in the transport of carbon to the ocean depths.
- ***Development of a marine information system.*** Using the latest information technology and working with other UN agencies, a comprehensive, computer-based system for mapping, analyzing and forecasting marine pollution will link GLOMARD to other major databases.
- ***Employing revolutionary methodologies.*** On-site radioactivity monitoring with satellite data transmission will allow continuous surveillance of remote study locations, while a new generation of submersible detectors mounted on remotely operated vehicles will permit detailed inspection of seabed radioactivity. MEL will also develop and use ultra low-level radioactivity counting techniques located in a new underground laboratory.
- ***Increasing training and capacity building.*** Using the new Training Centre in Monaco, and stimulated by the challenges of the new GPA, the IAEA's Marine Environment Laboratory will consolidate and extend its leading position as the United Nations' centre of training and analytical quality assurance for the assessment of marine pollution. ❐

Radiation & the environment: Assessing effects on plants and animals

An overview of a recent report issued by the United Nations Scientific Committee on the Effects of Atomic Radiation

by Gordon Linsley

The international body known as the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) periodically reviews the effects of ionizing radiation on the environment. Last year, the Committee, for the first time, issued a report that contained a review specifically focused on the effects of ionizing radiation on plants and animals.* While the review contained no surprising findings, it does serve to focus attention on the changing nature of the scientific community's assessment of radiation's potential environmental effects.

Previously, scientific assessments had considered plants, animals, and other living organisms as part of the environment in which radionuclides become dispersed. They were further seen as resources which, when contaminated,, may contribute to human radiation exposures since some plants and animals are elements of food chains and represent pathways for the transfer of radionuclides to humans. In brief, the assessments reflected the generally accepted position that priority should be given to evaluating the potential consequences for humans — which are among the most radiosensitive mammalian species — and to providing a sound basis for protecting human health.

This position, however, has been questioned recently. It has been shown that there is at least one situation — namely in deep-sea sediments, an environment very remote from humans — where the above accepted priority could be incorrect.** Detrimental effects on the environment also have been observed in localized areas as a consequence of plants and animals having received short-term, very high radiation doses following major accidental releases of radionuclides. This has been the case, for example, in areas affected by the 1957 accident in the southeastern Urals and by the Chernobyl accident in 1986.

UNSCEAR's latest review was done in response to such concerns, and to demonstrate explicitly that full account can be, and is being, taken of the potential effects of radiation on the environment. It recognizes that the world's plants, animals, and organisms are themselves exposed to internal irradiation from accumulated radionuclides and to external exposure from contamination of their respective environments. This article highlights the main conclusions of UNSCEAR's review.

The context of environmental impact assessments

The presence in our environment of cosmic radiation and natural and artificial radionuclides implies a consequential radiation exposure of the indigenous populations of all organisms. For humans, it is expected that the probability of adverse effects are greater where exposures are higher than the range of natural background radiation dose rates. This also is to be expected for other organisms.

However, there is a fundamental difference in the viewpoint adopted for the evaluation of the risk. For humans, ethical considerations make the *individual* the principle object of protection. In actual practice, this means that the incremental risk to a person arising from increased radiation

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*United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) *Sources and Effects of Ionizing Radiation*, UNSCEAR 1996 Report to the General Assembly, with Scientific Annex, United Nations sales publication E.96.IX.3 (1996).

***Assessing the impact of deep-sea disposal of low-level radioactive waste on living marine resources*, Technical Reports Series No. 288, IAEA, Vienna (1988).

exposure must be constrained below some level which society judges to be acceptable. This level of risk, although small, is not zero.

In the case of other organisms, the case is less clear. Humans display an enormous range of attitudes towards the other species that share this planet — consider, for example, a population of mosquitoes at one extreme and an individual giant panda at the other. For the vast majority of organisms, we consider the *population* to be important, and we set as an appropriate objective the protection of each population from any increased risk attributed to radiation. Exceptions might be populations of small size (rare species) or those reproducing slowly (long generation times and/or low fecundity) for which it might be more appropriate to target protective measures at the level of the individual organism.

Whether we are interested in the protection of one or many, the responses are likely to be significantly different when it comes to the assessment of environmental impacts. One point undoubtedly is self-evident — namely, that there cannot be any effect at the population level (or at the higher levels of community and ecosystem) if there are not effects in the individual organisms constituting the different populations. This does not mean, however, that detectable radiation-induced effects in some members of a population necessarily would have any significant consequences for the population as a whole.

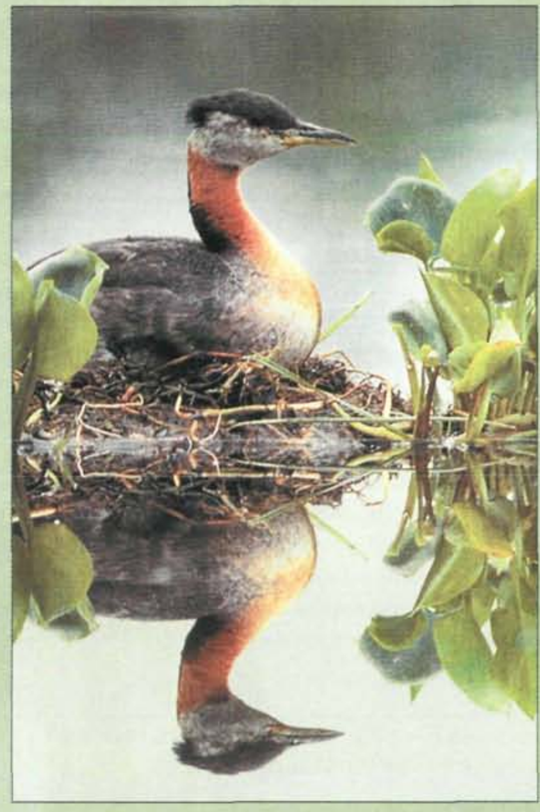
There are other factors to keep in mind as well when considering the assessment of environmental impacts. For one, natural populations of organisms exist in a state of dynamic equilibrium within their communities and environments and ionizing radiation is only one of the stresses that may influence this equilibrium. The incremental radiation exposure from human activities cannot, therefore, be considered in isolation from other sources of stress. This includes those that are either natural (e.g. climate, altitude, volcanic activity) or of human origin (e.g. synthetic chemical toxins, oil discharges, exploitation for food or sport, habitat destruction). When, as is not uncommon, ionizing radiation and chemicals, both from human activities, are acting together on a population, the difficult problem arises of correctly attributing any observed response to a specific cause.

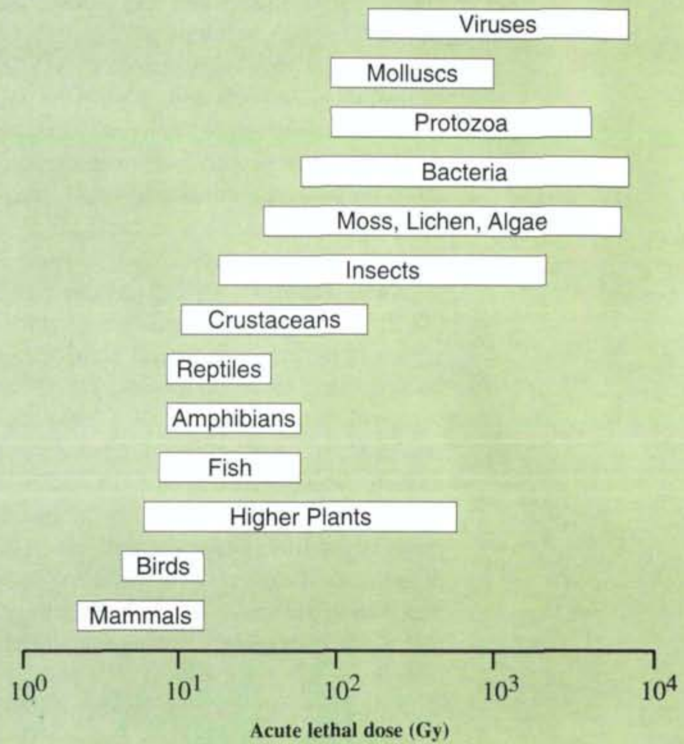
Conclusions of the UNSCEAR Review

All living organisms exist and survive in environments where they are subject, to a greater or lesser degree, to radiation from both natural and anthropogenic sources, including the contamination from global fallout which followed atmospheric nuclear weapons tests. At times, and generally in restricted areas, there are additional increments of radiation exposures either from authorized (controlled) discharges of radioactive wastes to the air, ground, or aquatic systems or from accidental releases. In the majority of cases there have been no apparent effects in wild plants and animals from these additional exposures. Following severe accidents, however, damage has been observed in individual organisms and populations, and long-term effects could develop in communities and ecosystems from the continuing increased chronic irradiation.

The available data on the exposure of wild organisms to radiation from the natural background and from contaminant radionuclides are relatively limited. They relate to a very restricted variety or organisms, although for the marine environment they do provide a reasonably representative picture of the range of dose-rate regimes likely to be experienced. Because the estimates are largely derived either from localized measurements of the concentrations of radionuclides within the organism and in its immediate external environment or from models that assume an equilibrium state, there is very little information on the temporal variation in dose rates to be expected from short-term fluctuations in discharge rates, differing stages in the life cycle, changes in behaviour and short-term environmental factors such as seasonality. It is thus very difficult to estimate from the available data the total doses that are likely to be accumulated over specific stages of the life cycle, e.g. during embryonic development or up to reproductive age.

For both terrestrial and aquatic environments, there appears to be a significant contribution to the natural background dose rate from alpha radiation. For the former the main source appears to be radon-222 and its short-lived decay products, and for the latter the main source is polonium-210. Owing to the short range of alpha particles, the absorbed dose rates are tissue-specific, and the results underline the crucial need for more detailed information on the distribution of the radionuclides relative to the biological targets that might be considered important (e.g. the developing embryo or the gonads) if accurate estimates of background radiation exposure are to be made. The usual range for the background radiation exposure is





The graphs show the approximate lethal dose ranges for various taxonomic groups, an indication of the comparative radiosensitivity.

Comparative radiosensitivity among organisms

up to a few microgray per hour, but in exceptional cases (e.g. the hepatopancreas of a small pelagic marine shrimp) the absorbed dose rate may be as high as 150 microgray per hour.

Radioactive wastes. It is accepted that the release of radioactive wastes to the environment is likely to increase the radiation exposure of wild organisms. For discharges to the atmosphere, to a landfill or to surface waters, the published assessments reviewed indicate that the radiation exposures to some (but not all) individuals in endemic wild populations could reach about 100 microgray per hour in general; in exceptional cases, depending on the quantities of specific radionuclides in the wastes, absorbed dose rates might reach several thousand micorgray per hour. In a very limited number of instances the dose rates estimated from measured concentrations of radionuclides in the contaminated environment have been broadly confirmed by *in situ* measurements employing dosimeters attached to the animals.

Accidental releases. The dose rates in the environment following an accidental release clearly depend on the quantities of specific radionuclides involved, the time-scale of the release, the initial dispersal and deposition patterns, and their subsequent redistribution by environmental processes over time. It is equally clear that these accidental releases have the potential to generate much higher dose rates and higher total doses in the environment than do normal operations. Such was the case following the accidents in the southeastern Urals and at Chernobyl, where numerous studies have indicated that trees (and, by reasonable extension, other organisms) close to the release points could have accumulated doses up to 2000 gray and 100 gray at the two accident sites, respectively, over relatively short periods of time. At both sites, longer-term chronic exposures from the deposit of longer-lived radionuclides have continued to be significantly higher than exposures from controlled waste disposal.

From these data it may be concluded that it is the responses of plants and animals to chronic radiation exposures up to a maximum absorbed dose rate of 1000 microgray per hour that are of interest from the viewpoint of providing a basis for assessing the environmental impact of controlled radioactive waste releases; in practice, information at lower dose rates, up to 100 microgray per hour would probably be sufficient in the great majority of cases.

For accident situations, experience has clearly demonstrated that initial dose rates can be high enough to allow accumulating lethal doses in relatively short periods (days). In light of this, data are needed to provide the basis for predicting the progress of environmental recovery at generally lower, long-term chronic dose rates, down to the upper end (1000 microgray per hour) of the range of interest for assessing waste disposal practices.

Radiosensitivity. There is a wide range over which organisms are sensitive to the lethal effects of radiation. A general classification has been devised based on the interphase chromosome volume of sensitive cells. These and other results of experimental irradiations show mammals to be most sensitive, followed by birds, fish, reptiles, and insects. Plants show a wide range of sensitivity that generally overlaps that of animals. Least sensitive to acute radiation exposures are mosses, lichens, algae and micro-organisms, such as bacteria and viruses. *(See figure, previous page.)*

Sensitivity of the organism to radiation depends on the life stage at exposure. Embryos and juvenile forms are more sensitive than adults. Fish embryos, for example, have been shown to be quite sensitive. The various developmental stages of insects are quite remarkable for the range of sensitivities they present. Overall, the available data indicate that the production of viable offspring through gametogenesis and reproduction is a more radiosensitive population attribute than the induction of individual mortality.

In the most sensitive plant species, the effects of chronic irradiation were noted at dose rates of 1000 to 3000 microgray per hour. It was suggested that chronic dose rates less than 400 microgray per hour (10 milligray per day) would have effects, although slight, in sensitive plants. They would be unlikely, however, to have significant deleterious effects in the wider range of plants present in natural plant communities.

For the most sensitive animal species, mammals, there is little indication that dose rates of 400 microgray per hour to the most exposed individual would seriously affect mortality in the population. For dose rates up to an order of magnitude less (40-100 microgray per hour), the same statement could be made with respect to reproductive effects. For aquatic organisms, the general conclusion was that maximum dose rates of 400 microgray per hour to a small proportion of the individuals and, therefore, a lower average rate to the remaining organisms would not have any detrimental effects at the population level. The radiation doses necessary to produce a significant deleterious effect are very difficult to estimate because of long-term recovery (including natural regeneration and the migration of individuals from surrounding areas that are less affected), compensatory behaviour, and the many confounding factors present in natural plant and animal communities in both terrestrial and aquatic environments.

IAEA activities and plans related to environmental protection

The results of the UNSCEAR review of the effects of radiation on the environment generally confirm the conclusions reached in an IAEA study issued in 1992. * They further support the general view of the International Commission on Radiological Protection (ICRP) that the "standard of environmental control needed to protect man to the degree currently thought desirable will ensure that other species are not put at risk".**

However, it is recognized in both the UNSCEAR and IAEA reviews that there are circumstances where this general conclusion may not be valid. Moreover, there is a view that the ICRP statement could be misinterpreted as indicating a lack of concern for the environment. For these and other reasons, there is a movement in some countries towards the establishment of specific standards for the protection of the environment. There were discussions on this theme at an IAEA symposium in 1996.*** In recognition of this ongoing debate, the Agency will hold a series of expert consultations during 1997 and 1998 with a view to determining the prevailing view in its Member States on these issues. Depending upon the outcome of these discussions, one possible objective is the development of a Safety Standard that incorporates international consensus on this important subject. ❐

* *Effects of ionizing radiation on plants and animals at levels implied by current radiation protection standards*, Technical Reports Series No. 332, IAEA, Vienna (1992).

**International Commission on Radiological Protection, 1990. *Recommendations of the International Commission on Radiological Protection, ICRP Publication 60*, Annals of the ICRP 21 (1-3) Pergamon Press, Oxford (1991).

***See "Environmental impact of radioactive releases: Addressing global issues", *IAEA Bulletin*, Vol. 38, No. 1 (1996).

Radiological assessment: Waste disposal in the Arctic Seas

Summary of results from an IAEA-supported study on the radiological impact of high-level radioactive waste dumping in the Arctic Seas

Almost five years ago, in 1992, international attention was focused on news reports that the former Soviet Union had, for over three decades, dumped radioactive wastes in the shallow waters of the Arctic Seas. The news caused widespread concern, especially in countries with Arctic coastlines.

At the global level, the IAEA responded by proposing an international study to assess the health and environmental implications of the dumping. The proposal received support from the Fifteenth Consultative Meeting of the Contracting Parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention 1972), which is under the auspices of the International Maritime Organization (IMO) in London. The Consultative Meeting requested that the study include consideration of possible remedial actions, such as the retrieval of the wastes for land storage.

Shortly thereafter, in 1993, the IAEA launched the International Arctic Seas Assessment Project (IASAP).* Its main objectives were to assess the risks to human health and to the environment associated with the radioactive wastes dumped in the Kara and Barents Seas; and to examine possible remedial actions related to the dumped wastes and to advise on whether they are necessary and justified. The study, which involved more than 50 experts from 14 countries and was under the direction of an International Advisory Group, concluded in late 1996. Partially supported by extrabudgetary funding from the United States, the project was co-ordinated with the work of the Norwegian-Russian Expert Group for Investigation of Radioactive Contamination in the Northern Areas. This article summarizes the results and conclusions of IASAP, drawing upon the Executive Summary of the final report of the study.

What the study examined

Through a co-ordinated research programme, technical contracts, consultancies, and other mechanisms, the study brought together a wide range of expertise in various disciplines. The adopted approach specifically focused on:

- Examination of the current radiological situation in Arctic waters to assess evidence for releases from the dumped waste;
- Prediction of potential future releases from the dumped wastes concentrating on the solid high level waste objects which contain the majority of the radionuclide inventory of the wastes;
- Modelling of environmental transport of released nuclides and assessing the associated radiological impact on man and biota;
- Examination of the feasibility, costs, and benefits of possible remedial measures applied to a selected high-level waste object.

The total amount of radioactive waste dumped in Arctic Seas was estimated to be approximately 90 PBq (90 x 10^{15} Bq) at the time of dumping, based on information con-

This article is based on the Executive Summary of the IASAP study which was prepared by the project's Advisory Group. Ms. K.-L. Sjöblom of the IAEA's Waste Safety Section in the IAEA Division of Radiation and Waste Safety served as IASAP project officer..

*The background and early progress of the IASAP study was described in an article by K.-L. Sjöblom and G.S. Linsley in the *IAEA Bulletin*, Vol. 37, No. 2 (1995).

tained in the "White Book of the President of Russia" (Facts and Problems Related to Radioactive Waste Disposal in the Seas Adjacent to the Territory of the Russian Federation, 1993). The dumped items included six nuclear submarine reactors containing spent fuel; a shielding assembly from an icebreaker reactor containing spent fuel; ten nuclear reactors without fuel; and solid and liquid low level waste. Of the total estimated inventory, 89 PBq was contained in high-level wastes comprising reactors with and without spent fuel. The solid wastes, including the reactors mentioned above, were dumped in the Kara Sea, mainly in the shallow fjords of Novaya Zemlya, where the depths of the dumping sites range from 12 to 135 meters and in the Novaya Zemlya Trough at depths of up to 380 meters. Liquid low-level wastes were released in the open Barents and Kara Seas.

Additional information regarding the nature of the wastes was obtained through technical contracts placed in Russian institutes. There are, however, certain important gaps in the available information. For example, not all of the dumped high-level wastes referred to in Russian Federation documents have been located or unambiguously identified. Furthermore, some information related, for example, to the construction of the dumped submarine reactors and their fuel type remained classified. Thus, the conclusions of the IASAP study are valid only in the context of the information publicly available at the time it was completed.

The results of the IASAP study will be published in the report *Assessment of the Impact of Radioactive Waste Dumping in the Arctic Seas — Report of the International Arctic Seas Assessment Project (IASAP).* In addition, reports containing the findings of three different working groups will be published separately: (i) the environmental and radiological description of the Arctic Seas; (ii) the evaluation of the source term; and (iii) modelling and dose assessment. The study's Executive Summary has been provided to the Contracting Parties to the London Convention 1972 as agreed at the Fifteenth Consultative Meeting.

Current radiological situation

The current radiological situation in the Arctic Seas was examined by analyzing information acquired during a series of joint Norwegian-Russian cruises and other international expeditions to the Kara Sea. In addition, oceanographic and radiogeochemical surveys, many of them related to the IASAP study, provided new information on the physical, chemical, radiochemical, and biological conditions and processes in the Arctic Seas.* The open Kara Sea is relatively uncontaminated compared with some other marine areas, the main contributors to its artificial radionuclide content being direct atmospheric deposition and catchment runoff of global fallout from nuclear weapon tests, discharges from reprocessing plants in western Europe, and fallout from the Chernobyl accident.

The measurements of environmental materials suggest that annual individual doses from artificial radionuclides in the Kara and Barents Seas are only in the range of 1 to 20 microsieverts. In two of the fjords where both high- and low-level wastes were dumped, elevated levels of radionuclides were detected in sediments within a few meters of the low-level waste containers, suggesting that the containers have leaked. However, these leakages have not led to a measurable increase of radionuclides in the outer parts of the fjords or in the open Kara Sea. At the present time, therefore, the dumped wastes have a negligible radiological impact.

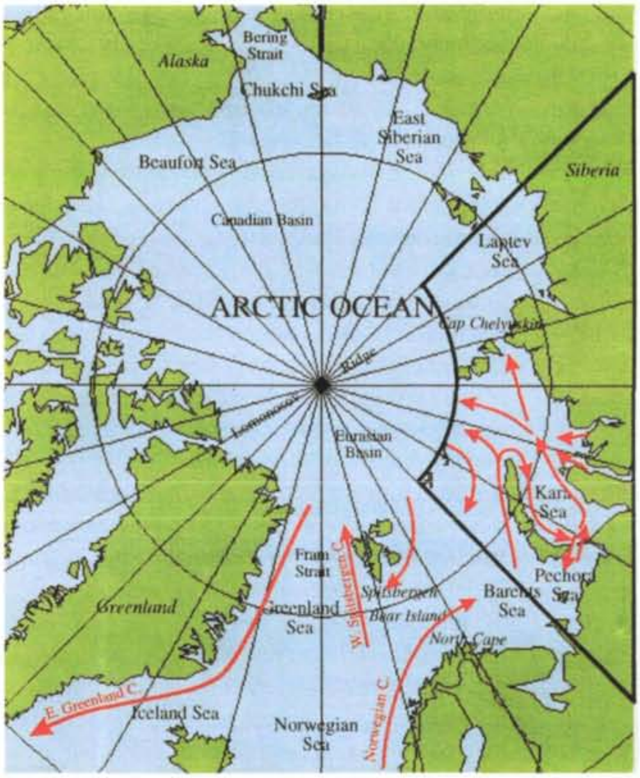
Future radiological situation

The assessment of the potential risks posed by possible future releases from the dumped wastes focused on the high-level waste objects containing the majority of the radioactive waste inventory. Release rates from these wastes were estimated and the corresponding radiation doses to man and biota were assessed using mathematical models for radionuclide transfer through the environment.

Source inventories and release rates. The characteristics of the dumped reactors and their operating histories were examined in considerable detail. This was done in order to provide appropriate release rate scenarios that can be used as input terms to the modelling of transport and exposure pathways leading to exposure estimates for humans and biota. This information, based on reactor operating histories and calculated neutron spectra, provided estimates of fission product, activation product, and

*For more information on Arctic environmental studies, see the article by P. Povinec, I. Osvath, and M. Baxter in the *IAEA Bulletin* Vol. 37, No. 2 (1995).

The Arctic Ocean, and the Kara and Barents Seas



The map at right shows the high-level waste dump sites on the east coast of Novaya Zemlya; the map at left shows the main sea currents relevant to the radiological assessment of the Arctic Seas. ***(IAEA-MEL)***

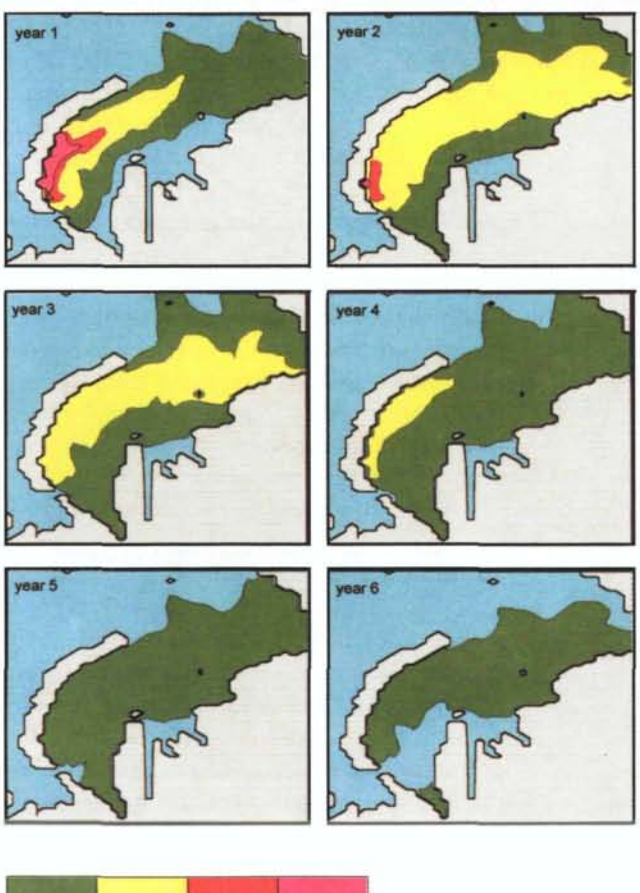


Photo: Marine scientists take water samples from the Arctic Seas. ***(IAEA-MEL)*** *Graphs:* Shown at left are predicted caesium-137 concentrations in seawater in the first six years after an instantaneous unit release from all dumping sites. These types of predictions were used for identification of potentially exposed populations. ***(Ingo Harms/IAEA-MEL)*** actinide inventories of the dumped reactors and fuel assemblies. It was concluded that the total radionuclide inventory of the high-level radioactive waste objects at the time of dumping was 37 PBq. The difference between this value and the preliminary estimate of 89 PBq given in the Russian White Book can be explained by the more accurate information on the actual operating history of the reactors provided to IASAP by the Russian authorities. The corresponding inventory of high-level dumped wastes in 1994 was estimated to be 4.7 PBq of which 86% are fission products, 12% activation products, and 2% actinides. The main radionuclides in these categories were strontium-90, caesium-137, nickel-63, and plutonium-241, respectively.

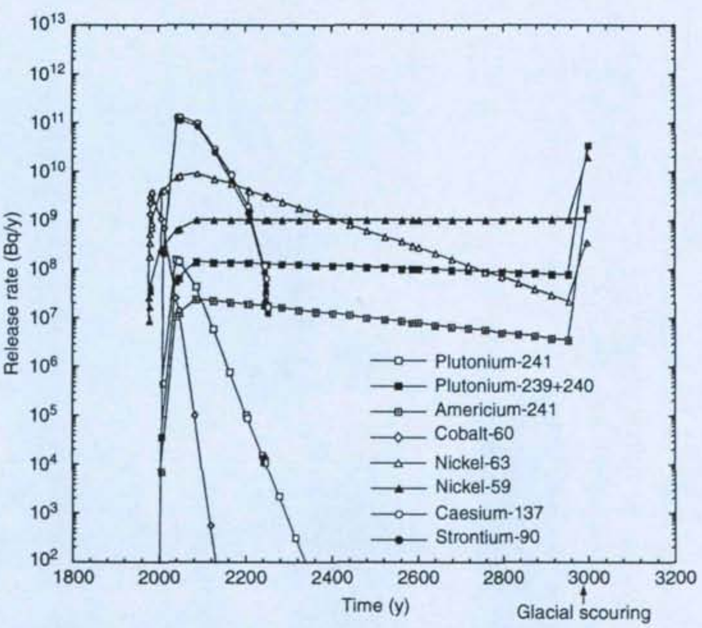
The rates of release of radionuclides to the environment will depend upon the integrity of materials forming the reactor structure, the barriers added prior to dumping, and the nuclear fuel itself. For each of the dumped high-level waste objects, the construction and composition of barriers were investigated in detail, weak points were identified, and the best estimates of the corrosion rates and barrier lifetimes were used in the calculation of release rates. External events, such as collision with ships or, more generally, global cooling following by glacial scouring of the fjords could damage the containment. This would lead to faster releases of radionuclides to the environment. In order to adequately represent the possible range of release rates to the environment, three release scenarios were considered:

- a *best estimate* scenario — release occurs via the gradual corrosion of the barriers, waste containers and the fuel itself;
- a *plausible worst case* scenario — normal gradual corrosion followed by a catastrophic disruption of two sources at a single dump site (the fuel container and the reactor compartment of the icebreaker) in the year 2050 followed by accelerated release of the remaining radionuclide inventory of these sources; and
- a *climate change* scenario — corrosion up to the year 3000 followed by instantaneous release, due to glacial scouring, of the radionuclide inventory remaining in all sources.

It should be noted that no attempt was made to assign probabilities to the events described in plausible worst case and climate change scenarios and the consequences have been assessed on the assumption that such events will occur in the years indicated.

For the *best estimate* scenario, the combined release rate from all sources peaks at about 3000 GBq/a (GBq = 10^9 Bq) within the next 100 years with a second peak of about 2100 GBq/a in about 300 years time. For most of the remaining time, total release rates lie between 2 and 20 GBq/a. The *plausible worst case* scenario results in a release "spike" of 110 000 GBq followed by releases of between 100 and 1000 GBq/a for the next few hundred years due to the accelerated release of radionuclides from the fuel container and reactor compartment of the nuclear icebreaker. In the *climate change* scenario, which assumes that glacial scouring causes an instantaneous release of the remaining inventory of all the wastes in 1000 years time, about 6600 GBq are released.

Examples of predicted release rates



Shown are examples of predicted release rates related to the climate change scenario applied to a single reactor dumped in the Novaya Zemlya Trough. The release of different radionuclides is assumed to be driven by corrosion until the year 3000 when, due to glacial scouring, the total disruption of all barriers and release of the whole remaining inventory is assumed to take place. ***(Neil Lynn, Royal Naval College, UK/Akira Wada, Nihon University, Japan)***

Modelling and assessment

The calculated release rates were used with mathematical models of the environmental behaviour of radionuclides to estimate radiation doses to people and biota. Different modelling approaches were adopted and experts from several countries and from the IAEA participated in the exercise. Substantial effort was devoted to a synthesis of existing information on marine ecology, oceanography, and sedimentology of the target area as a basis for model development.

Maximum total annual individual doses for selected population groups
(Doses in microsieverts)

Scenario	Annual doses to seafood consumers (Groups 1 and 3)	Annual doses to military personnel (Group 2)
Best estimate scenario	< 0.1	700
Plausible worst case scenario	< 1	4000
Climate change scenario	0.3	3000

Notes:
1 microsievert = 10^{-6} Sv.
For perspective, the annual doses to the critical Groups 1 and 3 from naturally occurring polonium-210 in seafood are 500 microsievert and 100 microsievert, respectively.
The worldwide total average annual dose from natural background radiation is 2400 microsievert.

Specific processes were identified as peculiar to the area and, thus, of potential importance for incorporation into models. Because of the need to provide predictions on very diverse space and time scales, a number of different models for the dispersal of radionuclides within and from the Arctic Ocean were developed.

Two main modelling approaches were adopted: compartmental or box models; and hydrodynamic circulation models. In addition, one hybrid model (using compartmental structure but at a finely-resolved spatial scale) was developed and applied. By modelling advective and diffusive dispersal, compartmental models provide long timescale, spatially-averaged, far-field predictions, while the hydrodynamic models provide locally resolved, short timescale results.

Separate attention was devoted to one of the most poorly-quantified transport pathways — sea-ice transport. A simple exemplar calculation, or scoping exercise, demonstrated that, for the radioactive waste sources considered here, sea-ice transport would make only a small contribution to individual dose compared with the transport of radionuclides in water.

For the estimation of doses to individuals, three population groups were considered. Calculations of individual doses were undertaken for time periods covering the peak individual dose rates for each of the three scenarios identified previously. Three groups were defined:

Group 1. A group living in the Ob and Yenisey estuaries and on the Taimyr and Yamal peninsulas whose subsistence is heavily dependent on the consumption of locally caught Kara Sea fish, marine mammals, seabirds and their eggs, and who spend 250 hours/year on the seashore. These habits are also typical of subsistence fishing communities in other countries bordering the Arctic.

Group 2. A hypothetical group of military personnel patrolling the foreshores of the fjords containing dumped radioactive materials, for assumed periods of 100 hours/year. The exposure pathways considered include external radiation and the inhalation of seaspray and re-suspended sediment.

Group 3. A group of seafood consumers considered representative of the Northern Russian population situated on the Kola peninsula eating fish, molluscs and crustaceans harvested from the Barents Sea. No consideration was given to the consumption of seaweed or marine mammals, nor to external radiation.

Maximum total annual individual doses for selected population groups

The maximum annual individual doses in each critical group of seafood consumers (Groups 1 and 3) for all three scenarios are small and very much less than variations in natural background doses. *(See table.)* Doses to the hypothetical critical group of military personnel patrolling the fjords (Group 2) are higher but, nevertheless, comparable to natural background radiation doses.

Collective doses were estimated only for the *best estimate* release rate scenario. The collective dose to the world population arising from the dispersion of radionuclides in the world's oceans (nuclides other than carbon-14 and iodine-129) were calculated for two time periods: (i) up to the year 2050 to provide information on the collective dose to the current generation; and (ii) over the next 1000 years, a time period which covers the estimated peak releases.

Because of the increasing uncertainties in predicting future events, processes, and developments, it was not considered meaningful to

Main conclusions of the International Arctic Seas Assessment Project

● **Monitoring has shown that releases from identified dumped objects are small and localized to the immediate vicinity of the dumping sites.** Overall, the levels of artificial radionuclides in the Kara and Barents Seas are low and the associated radiation doses are negligible when compared with those from natural sources. Environmental measurements suggest that current annual individual doses from all artificial radionuclides in the Barents and Kara Seas are at most 1 to 20 microsievert. The main contributors are global fallout from nuclear weapons testing, discharges from nuclear fuel reprocessing plants in western Europe, and fallout from the Chernobyl nuclear accident.

● **Projected future doses to members of the public in typical local population groups arising from radioactive wastes dumped in the Kara Sea are very small, less than 1 microsievert.** Projected future doses to a hypothetical group of military personnel patrolling the foreshores of the fjords in which wastes have been dumped are higher, up to 4000 microsievert but still of the same order as the average natural background dose.

● **Doses to marine fauna are insignificant, orders of magnitude below those at which detrimental effects on fauna populations might be expected to occur.** Furthermore, these doses are delivered to only a small proportion of the local fauna populations.

● **On radiological grounds, remediation is not warranted.** Controls on the occupation of beaches and the use of coastal marine resources and amenities in the fjords of Novaya Zemlya used as dump sites must, however, be maintained. This condition is specified to take account of concerns regarding the possible inadvertent disturbance or recovery of high level waste objects and the radiological protection of the hypothetical group of individuals occupying the beaches adjacent to the fjords.

Recommendations of the International Arctic Seas Assessment Project

● Efforts should be made to locate and identify all high level waste objects.

● Institutional control should be maintained over access and activities in the terrestrial and marine environments in and around the fjords of Novaya Zemlya in which dumping has occurred.

● If at some time in the future, it is proposed to terminate institutional control over areas in and around these fjords, a prior assessment should be made of doses to any new groups of individuals who may be potentially at risk.

● In order to detect any changes in the condition of the dumped high level wastes a limited environmental monitoring programme at the dump sites should be considered.

extend the assessment beyond 1000 years. The estimated collective doses are 0.01 man·Sv and 1 man·Sv, respectively in the two time periods. The calculations provide some illustration of the temporal distribution of the dose.

Appropriate global circulation models were used to calculate collective doses from carbon-14 and iodine-129, which are long-lived and circulate globally in the aquatic, atmospheric and terrestrial environments. Assuming the entire carbon-14 inventory of the wastes released around the year 2000 and integrating the dose to the world's population over 1000 years into the future (i.e., to the year 3000) yields a collective dose of about 8 man·Sv. The corresponding value for iodine-129 is much lower at 0.0001 man·Sv. Thus, the total collective dose over the next 1000 years to the world's population from all radionuclides in the dumped radioactive waste is of the order of 10 man·Sv. In contrast, the annual collective dose to the world's population from natural occurring polonium-210 in the ocean is estimated in other studies to be about three orders of magnitude higher. It is also informative to compare the collective dose associated with wastes dumped in the Kara Sea with the collective dose estimated for low-level radioactive waste dumped in the Northeast Atlantic. The collective dose to the world population is 1 man·Sv over 50 years and 3000 man·Sv over 1000 years from the latter practice.

The radiation dose rates to a range of populations of wild organisms, from zooplankton to whales, were calculated and found to be very low. The peak dose rates predicted in this assessment are about 0.1 milligray per hour — a dose rate that is considered unlikely to entail any detrimental effects on morbidity, mortality, fertility, fecundity, and mutation rate that may influence the maintenance of healthy populations. It is also relevant to note that only a small proportion of the biota population in local ecosystems could be affected by the releases.

Remediation options

Feasibility and costs. A preliminary engineering feasibility and cost study was conducted for five remediation options for the container of spent fuel from the nuclear icebreaker. This source was chosen because it contains the largest radionuclide inventory among the dumped waste objects and is the best documented regarding construction and introduced container barriers.

The five specific options initially selected for evaluation were:

Option 1. Injection of material to reduce corrosion and to provide an additional release barrier.

Option 2. Capping *in situ* with concrete or other suitable material to encapsulate the object.

Option 3. Recovery to a land environment.

Option 4. Disposal into an underwater cavern on the coast of Novaya Zemlya.

Option 5. Recovery and underwater transport to a deep ocean site.

Further consideration of these options by salvage experts screened out options 1, 4 and 5. Option 1 was screened out on the grounds that the spent fuel package has been previously filled with a special polymer, Furfurol(F), which might make the injection of additional material difficult. Option 4 was omitted from further consideration because the creation of an underwater cavern would be too expensive a proposition for a single recovered source and would have to be justified in a larger context. Option 5 was discarded because first, it is doubtful whether special approval could be obtained from the London Convention 1972 for an operation that entailed re-dumping of a high-level waste object in the ocean, and second, underwater transport on the high seas would involve undue risks of losing the package during carriage to a new disposal site.

Further evaluation of remedial actions was therefore confined to the two remaining options, i.e., *in situ* capping and recovery for land treatment or disposal. Both options were deemed technically feasible. The costs of marine operations were estimated to be in the range US $6 million to $10 million. It should be appreciated that for the recovery option, there would be major additional costs to those considered here for subsequent land transport, treatment, storage, and/or disposal. Radiation exposures to the personnel involved in remedial actions were considered as was the likelihood of a criticality accident. It was concluded that, with the appropriate precautions and engineering surveys proposed as a basis for proceeding with remediation, the radiation risks to the personnel involved in remedial activities would not be significant.

Radiological protection considerations for the justification of remediation. The basic concepts of radiological protection relevant to this project are those recommended by the International Commission on Radiological Protection (ICRP) and incorporated into the *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources* (BSS) of the IAEA and other international organizations. These documents identify two classes of situation in which humans may be exposed to radiation — those in which protection measures can be planned prospectively, before sources of exposure are introduced, and other situations, where the sources of exposure are already present and protection measures have to be considered retrospectively. These are characterized respectively as practices and interventions.

The situation considered in the IASAP study falls within the category of interventions. In this case, intervention could in principle be applied at source or, following radionuclide release, to the environmental exposure pathways through which humans might be exposed. Intervention at source could include, for example, the introduction of additional protective barriers for the waste objects to prevent radionuclide release. Intervention applied to environmental exposure pathways could involve restricting consumption of contaminated food and/or limiting access to contaminated areas. In either case, it is required that remedial actions are justified on the basis that the intervention does more good than harm, i.e., the advantages of intervening, including the reduction in radiological detriment, outweigh the corresponding disadvantages, including the costs and detriment to those involved in the remedial action. Furthermore, the form and scale of any intervention should be optimized to produce the maximum net benefit.

There are a number of factors that require consideration in reaching a decision about the need for remedial actions. From a radiological protection perspective, the most important aspects are:

- The doses and risks to the most exposed individuals (the critical group) if action is not taken and the extent to which their situation can be improved by taking action; and
- The total health impact on exposed populations and how much of it can be avoided by taking remedial action. The total health impact is proportional to the collective dose, i.e., the sum of individual doses in an exposed population.

The dumped high-level radioactive wastes in the Kara Sea and adjoining fjords are in discrete packages that are expected to leak at some time in the future. They therefore constitute a potential chronic exposure situation where the concern relates to future increments of dose to exposed individuals resulting from releases of radionuclides from the dumped wastes. Depending on the physical condition of these sources, intervention (remediation) at source is the most viable course of action rather than intervention at some later time in environmental exposure pathways. The precondition for intervention is that it is both justified and optimized.

Currently, there are no internationally agreed criteria for invoking a requirement to remediate in chronic exposure situations except in the case of exposure of the public to radon, a naturally occurring radioactive gas, where international guidance suggests an action level at an incremental annual dose in the range 3 to 10 millisievert (3000 to 10 000 microsieverts). Both the ICRP and IAEA have under development guidance for applications to other types of intervention situation.

The radioactive waste sources in the Barents and Kara Seas are predicted to give rise to future annual doses of less than 1 microsievert to individuals in population groups bordering the Kara and Barents Seas. The risk of fatal cancer induction from a dose of 1 microsievert is estimated to be about 5×10^{-8} — a trivial risk. Therefore, members of local populations will not be exposed to significant risks from the dumped wastes. The predicted future doses to the members of the hypothetical group of military personnel patrolling the foreshores of the fjords of Novaya Zemlya are higher than those predicted for other members of the public and are comparable with doses from natural background radiation. (The average annual radiation dose due to natural background including radon exposure is 2400 microsieverts.) Taking into account that the doses to this hypothetical group could be controlled if required, none of the calculated individual doses indicates a need for remedial action.

Although the risks to each individual may be trivial, when summed over a population some health effects might be predicted to arise as a result of the additional exposure. These health effects are considered to be proportional to the collective dose arising from the dumped radioactive wastes. The collective dose to the world's population over the next 1000 years from the radioactive wastes dumped in the Barents and Kara Seas is of the order of 10 man·Sv. This calculated collective dose is small but can, nevertheless, be considered further in reaching a decision about the need for remediation. A simplified scoping approach to considering collective dose in a decision-making framework is to assign a monetary value to the health detriment that would be prevented if remedial action was implemented. If this scoping approach indicates that remedial action might be justified, a more detailed analysis in which the components of the collective dose are more closely examined would be warranted. Using the scoping approach it can be shown that remedial measures applied to the largest single source (the spent fuel package from the nuclear icebreaker) costing in excess of US $200 000 would not appear to offer sufficient benefit to be warranted. Since any of the proposed remedial actions would cost several million US dollars to implement it is clear that, on the basis of collective dose considerations, remediation is not justified.

Overall, from a radiological protection viewpoint, including consideration of the doses to biota, remedial action in relation to the dumped radioactive waste material is not warranted. However, to avoid the possible inadvertent disturbance or recovery of the dumped objects and because the potential doses to the hypothetical group of military personnel patrolling the Novaya Zemlya fjords used as dump sites are not trivial, this conclusion depends upon the maintenance of some form of institutional control over access and activities in the vicinity of those fjords.

Finally, it is noted that the discussion of the IASAP study was confined to the radiological aspects of decision-making regarding the need for remedial action. The political, economic, and social considerations that must form an important part of the decision-making process are not considered and are largely matters for the national government having jurisdiction and responsibility regarding the dumped radioactive wastes. ❐

Radiation and waste safety: Strengthening national capabilities

Through a technical co-operation model project, countries are following an integrated approach for upgrading their safety infrastructures

by Paulo Barretto, Geoffrey Webb, and Khammar Mrabit

For many years, the IAEA has been collecting information on national infrastructures for assuring safety in applications of nuclear and radiation technologies. For more than a decade, from 1984-95, information relevant to radiation safety particularly was obtained through more than 60 expert missions undertaken by Radiation Protection Advisory Teams (RAPATs) and follow-up technical visits and expert missions. The RAPAT programme documented major weaknesses and the reports provided useful background for preparation of national requests for IAEA technical assistance.

Building on this experience and subsequent policy reviews, the IAEA took steps to more systematically evaluate the needs for technical assistance in areas of nuclear and radiation safety. The outcome was the development of an integrated system designed to more closely assess national priorities and needs for upgrading their infrastructures for radiation and waste safety.

The work draws upon the Agency's long record of safety assistance through avenues of technical co-operation and assistance. By its Statute, the IAEA is authorized to establish or adopt safety standards for protection of health and minimization of danger to life and property, and to provide for the application of these standards to its own operations as well as to operations making use of materials, services, equipment, facilities, and information made available by the Agency or at its request or under its control or supervision. The safety standards which are being promoted are the *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS),* the latest revision of which was published in 1996. *(See box, page 32.)* Regarding technical assistance in this field, the IAEA's Statute further requires that the Agency's Board of Governors consider the "adequacy of proposed health and safety standards for handling and storing materials and for operating facilities" before giving approval to technical co-operation programmes.

With this perspective, this article reviews the IAEA's integrated management approach and establishment of a model technical co-operation project to upgrade radiation and waste safety infrastructures in its Member States. The project today involves more than 50 countries.

Project objectives. The concept for the model project was initiated in 1994; however its scope was adjusted and strengthened in management and financial resources for the 1996-97 technical co-operation programme cycle. The aim is to assist countries having an inadequate radiation and waste safety infrastructure so that they are able to comply with the IAEA's safety standards, i.e., the BSS. The project drew upon the findings of RAPAT missions to 64 countries, which had served to increase awareness of radiation safety issues, and upon numerous expert missions on radiation protection undertaken over the past five years.

One of the first actions to implement the project was to define more clearly what constituted an adequate radiation and waste safety infrastructure. This had to be done for different types of radiation applications, ranging from simple industrial and medical uses that exist in every country to the full nuclear fuel cycle that exists in relatively few developing coun-

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tries. The work led to the preparation of a document entitled "Guidance for the assessment of radiation protection and safety infrastructures in developing Member States and strategies for enhancement of infrastructure". It sets out the basic elements of radiation protection infrastructures. These elements include the legislative framework and regulatory structure; the compliance requirements on users; and the requirements for equipment and procedures. In the document, countries engaged in nuclear fuel cycle activities are considered to require a fully developed radiation protection and nuclear safety infrastructure, whereas the requirements for other countries vary with respect to the levels at which they use nuclear and radiation technologies.

During the document's development, consideration was also given to the necessary mechanisms for assessing the infrastructures in each participating country of the model project. Decisions were taken about what was needed to bring each country up to an adequate level, and about how to implement the provision of technical assistance and how to verify results.

The main components of this process, which are included in the document, were to assign officers from the Department of Nuclear Safety and project officers from the Department of Technical Co-operation with integrated responsibilities. Major aims are to collect and evaluate information on the existing safety infrastructure; establish and maintain country safety profiles; formulate and implement country safety action plans needed to rectify weak or non-existent infrastructure elements; monitor the development of improvements in safety infrastructure; and sustain an effective infrastructure and develop it for additional uses of radiation.

It was originally envisaged in 1994 that some five to six countries would benefit each year from the model project. However, material subsequently gathered indicated that more than 50 countries needed assistance. *(See table.)* Hence, programme and management adjustments had to be made, since achieving the objectives under an approach only concentrating on five to six countries per year would require more than a decade. An integrated management approach thus was developed with the aim to achieve adequate national radiation and waste safety infrastructures in most participating countries by the year 2000. In support of the new approach, the Department of Technical Co-operation appointed four "regional field managers" who are posted in Addis Ababa, Ethiopia (for the African group); Beirut, Lebanon (for the West and East Asian group); San José, Costa Rica (for the Latin American group); and Bratislava, Slovak Republic (for the European group).

For all participating countries, assessments have been made to identify their infrastructure weaknesses. These include, for example, inadequate information — or even a complete lack of information — on the radiation sources in the country, and deficiencies in radiation and waste safety regulations, personnel dosimetry services, and the calibration and state of repair of equipment. Shortcomings were discussed by the regional field managers with national authorities as part of steps to prepare detailed safety action plans. In essentially all of the participating countries, these plans have already been finalized and approved, with their implementation started.

Countries participating in the Model Project to Upgrade Radiation and Waste Safety Infrastructure

Africa	East Asia & the Pacific	Latin America	Europe	West Asia
Cameroon	Bangladesh	Bolivia	Albania	Afghanistan
Côte d'Ivoire	Mongolia	Costa Rica	Armenia	Kazakstan
Ethiopia	Myanamar	Dominican Republic	Belarus	Lebanon
Gabon	Sri Lanka	El Salvador	Bosnia & Herzegovina	Qatar
Ghana	Viet Nam	Guatemala	Cyprus	UnitedArab Emirates
Madagascar		Haiti	Estonia	Uzbekistan
Mali		Jamaica	Georgia	Yemen
Mauritius		Nicaragua	Latvia	Kyrgyzstan*
Namibia		Panama	Lithuania	
Niger		Paraguay	Moldova	
Nigeria			The Former Republic of Macedonia	
Senegal				
Sierra Leone				
Sudan				
Uganda				
Zaire				
Zimbabwe				

*Not a Member State of the Agency

Note: Colombia and Syria have recently requested the Agency to leave and join the Model Project, respectively.

National obligations

It should be noted that the model project presumes that governments and national authorities are prepared to comply with their obligations as described in the Preamble of the BSS. This includes the obligation for the government to establish a national infrastructure which shall include *inter alia*:

- an appropriate national legislation and/or regulations (the type of regulatory system will depend on the size, complexity and safety implications of the regulated practices and sources as well as on the regulatory traditions in the country);
- a regulatory body empowered and authorized to inspect radiation users and to enforce the legislation and/or regulations;
- sufficient resources, and
- adequate numbers of trained persons.

The first milestone to be achieved under the model project in 1997 is the establishment of a system of notification and authorization as required by the BSS. The regional field managers are expected to monitor and report on each country's compliance, and in December this year, the IAEA is scheduled to submit a comprehensive report on the progress achieved to its Board of Governors.

Safety profiles of countries

The intention of the country safety profile information system is to maintain and keep updated all the data known to the Agency on the radiation and waste safety infrastructure of the country. Although the system includes a database which will be made available to all concerned, it is not limited to the database alone. It also includes the assembly of hard-copy information including laws and regulations, mission reports, papers describing the situation, and other material and relevant safety action plans. The essential structure of the system is provided by a questionnaire, the answers to which are the basic inputs for the computerized database. This questionnaire was completed initially as much as possible within the Agency before it was sent to the counterpart in the country for final completion.

The questionnaire and derived database cover the following main sections:

- organizational infrastructure;
- legal and regulatory status, including training;
- extent of practices involving ionizing radiation;
- provisions for individual dosimetry;
- public exposure control;
- radiation protection and safety of patients in medical diagnosis and therapy;
- transport of radioactive material;
- planning and preparedness for radiation emergencies; and
- quality assurance.

There is provision within the database for insertion of the answer to the questionnaire given by the country and an appraisal of those answers to determine the infrastructure status of the country. The country safety profile will only be fully effective if it is kept continually updated. The provision of the information to do this is one of the responsibilities of the regional field managers and designated country safety officers. Responsibility for maintaining the database is assigned to the Nuclear Safety-Technical Co-operation Co-ordinator.

Safety action plans for countries

Implementation plans are developed from an analysis of the completed questionnaires, within the framework of requirements for an adequate infrastructure. Missing or deficient items are determined and documented for preparation of a safety action plan specific to each country. The plan includes actions that are needed for the country to achieve a full and adequate infrastructure, commensurate with its existing and planned applications of ionizing radiation.

Safety systems must be able to prevent accidents such as this, where an operator tried to free a jammed package in an irradiation facility with the source exposed.

Once the Department of Technical Co-operation receives the agreement by the government on the action plan, it will start implementation of the scheduled activities. As of the beginning of 1997, more than 90% of participating countries have officially endorsed the action plans, which were prepared by the Agency in consultation with them.

The plans include both generic and specific activities. Generic activities apply to all countries, and as a first priority cover notification, authorization, and subsequent control of all radiation sources, whatever their use, within the country. Later steps will cover protection of workers, patients receiving medical treatment and the public from environmental releases; emergency plans; transport arrangements; and other areas. Specific activities are tailored to each country's particular needs, such as personnel training or the provision of necessary equipment.

The development of human resources through training is an important component of the model project. It involves not only training in nuclear technologies but covers the training of administrators, regulators, radiation protection specialists, and medical personnel. The establishment and sustainability of a sound infrastructure for assuring radiation and waste safety depends upon national capabilities in these areas.

Better basis for improvements

The complete system in support of the model project is targeted for implementation by the end of 1997. It will provide the IAEA with a fully documented on-line system for assessing the current status of any country with respect to its radiation and waste safety infrastructure and a prioritized and agreed set of needs that should form the basis of future technical assistance projects. There will also be enough data to assess the capacity of the country to assure the safety of other developments of technology or requested items of equipment that could pose radiation hazards.

Over time, the system should provide a firmer basis for the IAEA's co-operative work with its Member States and provision of technical assistance in areas of radiation and waste safety. Efforts can be better directed towards achieving a situation in which no Member State that actively co-operates with the IAEA has an inadequate radiation and waste safety infrastructure. Under an agreed action plan, this work will encompass measures for improving the identification of needs and requirements; and enhancing the use of resources to further strengthen national capabilities for ensuring safety in the peaceful applications of nuclear and radiation technologies. ❐

Radiation Safety Standards

Regardless of their own stage of nuclear technological development, every country has a stake and role to play in ensuring the safe use of radiation applications and the disposal of radioactive waste. To control the radiation exposure of workers, medical patients, and the public, many countries have laws and rules in place that are supported by administrative measures and enforced by inspectors. Just as important are internationally agreed standards for radiation safety. In co-operation with the World Health Organization, International Labour Organization, Food and Agriculture Organization, Nuclear Energy Agency of the Organization for Economic Co-operation and Development, and Pan American Health Organization, the IAEA has worked to develop the *International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources* (BSS). An updated edition was issued in 1996.

Protection under the BSS is based on principles of the International Commission on Radiological Protection, which can be summed up as follows:

Justification of the practice. No practice involving exposure to radiation should be adopted unless it produces a benefit that outweighs the harm it causes or could cause.

Optimization of protection. Radiation doses and risks should be kept as low as reasonably achievable, economic and social factors being taken into account. Constraints should be applied to dose or risk to prevent an unfair distribution of exposure or risk.

Limitation of individual risk. Exposure of individuals should not exceed specified dose limits above which the dose or risk would be deemed unacceptable.

Radioactive waste disposal: Global experience and challenges

With extensive experience in disposal of low- and intermediate-level radioactive wastes, countries are addressing some new challenges

by Kyong Won Han, Jorma Heinonen, and Arnold Bonne

Since the world's first disposal of radioactive waste in Oak Ridge, Tennessee, in 1944, considerable experience has been acquired in the field. The first disposal site — intended for "actively contaminated broken glassware or materials not sufficiently clean to be used in other work" — was a simple trench filled with unconditioned waste located on the Oak Ridge site. Similar approaches were adopted by other nuclear facilities and waste generators in the United States and other countries during the early phases of nuclear power's development.

Today, the world's disposal sites for low- and intermediate-level radioactive wastes (LILW) range from near-surface facilities to engineered geological repositories. More than one hundred LILW disposal facilities are, or have been, operating, and more than 42 repositories are under some stage of development in the IAEA's Member States. *(See the table on pages 38 and 39.)*

Accompanying the progress, a number of issues and challenges have arisen in countries pursuing radioactive waste disposal options. At the global level, the IAEA has been working to assist them in these efforts by promoting the transfer of technologies, particularly to developing countries. The work entails the collection, summary, and dissemination of updated technical information and support for co-ordinated research programmes on specific technical aspects. Within that context, this article presents an overview of international experience in land-based LILW disposal systems, and addresses the emerging issues and challenges now facing countries in this field.

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Practices and trends

Site selection. Siting a radioactive waste disposal facility refers to the process of selecting a suitable location that must take into account technical and other considerations. Technical factors cover a long list: geology, hydrogeology, geochemistry, tectonics and seismicity, surface processes, meteorology, human-induced events, transportation of waste, land use, population distribution, and environmental protection. Another key factor today is public acceptance, particularly in industrialized countries where a locality's "not-in-my-backyard" attitude can hinder the siting of all types of industrial waste facilities, not just radioactive waste sites. This has caused planners to focus greater attention on societal factors during early phases of the siting process. In some cases, repositories are being co-located at sites where nuclear facilities already exist; for example, Drigg (UK), Centre de la Manche (France), Rokkasho (Japan), and Olkiluoto (Finland). Some countries also have talked about the concept of siting a regional-multinational repository (discussed in more detail later). However, political factors and public concerns have kept any regional repositories from being developed in the world.

Currently in countries around the world, at least 17 sites have been selected for new LILW repositories, some of which already are licensed or under construction, while more than 25 sites are being investigated in 17 countries. They include China, which is planning to develop four LILW repositories, and has selected two sites for its northwest and southern regions. The northwest disposal site is located in an arid and sparsely populated area of the Gobi Desert. In the United States, no new commercial repository for low-level wastes has been constructed since the passage of the Low Level Radioactive Waste Policy Act of 1980. In eight US states, the site selection process is in some stage of progress. Four sites already have been selected by Nebraska (Central Interstate Compact), North Carolina (Southeast Compact), California (Southwest Compact) and Texas (pending the Texas Compact), and are now in the licensing process.

In addressing public acceptance issues, countries are taking several kinds of steps. In Australia, a comprehensive public consultation process characterizes the process of selecting the site of an engineered LILW repository. In Canada, where community opposition delayed the siting of a disposal facility for waste from radium and uranium refining activities, the Government halted the first site selection process and established a co-operative five-phase programme implemented by an independent siting task force. The task force works closely with municipal councils of the participating communities and with community liaison groups set up as information conduits with the general public. In Hungary, after two siting attempts stalled, a national siting project for LILW disposal was initiated by the Hungarian Atomic Energy Commission in 1992. Following a volunteer approach, the AEC found communities that volunteered to host sites, and in those that did, six sites have been selected. The communities now will be involved in detailed site investigations. In the United States, similar approaches also have been initiated. For instance, in Connecticut, where public resistance initially was met, the process was adapted to allow for greater public involvement on two aspects — "choice and control" — that may significantly influence the way the siting process is perceived and received.

Design factors. The type of repositories ultimately selected depend upon each country's geological conditions, specific disposal requirements, and regulatory approaches. All of these factors are tied to the facility's design. In general, the design aims to limit the release of contaminants or radionuclides to the biosphere; minimize exposure of workers and the public; and minimize maintenance during the post-closure phase. The aims can be achieved through technical components such as the waste package, engineered structures, the site itself, or a combination of these.

Some noticeable trends in design are related to technological advances in the field of waste disposal and public concerns over safety. One general tendency is that more reliance is being placed on a system of multiple engineered barriers to contain the waste. Such a system includes concrete vaults, backfilling materials, chemical barriers, and measures for gas venting, drainage, and buffer zones.

Worldwide, several different types of LILW facilities have been designed. About 62% of LILW repositories are engineered near-surface facilities within about 10 meters of the earth's surface, 18% are more simplifed near-surface facilities, 7% are mined cavities, and 4% are geological repositories. The type of facility ultimately selected and designed depends on the characteristics of the waste itself, as well as the site, and on national strategies and social and economic factors. Following are brief overviews of the different designs:

Simple near-surface facilities. Examples of these types of facilities include Barnwell (USA), and Vaalputs (South Africa), both of which benefit from the low permeable clay layer and/or low precipitation rate at the site. At Barnwell, the disposal system consists of trenches with a slightly sloped floor covered with a layer of sand to facilitate collection of infiltrating water in a trench drain. The trench drain ends in a sump which is monitored. Waste, packaged in boxes, drums and casks, is stacked in the trenches. Higher activity wastes are conditioned with concrete, bitumen, or other low leachability materials or placed in high integrity containers for structural stability. The space between the waste containers is filled with dry soil, and the trench is then covered with clay and soil. In Vaalputs, long and wide trenches, nearly eight meters deep, are covered by several layers of compacted clay and indigenous sand and vegetation.

Engineered near-surface disposal facilities. Examples here include the Drigg (UK) facility, where a simple trench concept was phased out in favour of engineered vaults. It is designed to accept LLW waste packages in containers of highly compacted waste in steel overpacks that forklifts then place into concrete vaults. The vaults, set on or below ground level, consist of a concrete base and walls with an underlying drainage layer. Any drainage from within or below the vault can be independently monitored and routed to an on-site water management system before discharge via a marine pipeline.

Concrete vaults in a box design are being used at sites including the Centre de la Manche and l'Aube (France), El Cabril (Spain), Trombay (India), and Rokkasho (Japan). Each one has unique design features. At la Manche, drums containing more active short-lived LILW are built into concrete walled monoliths at the base, with drums of lower activity stacked on top and then covered. The second French repository, l'Aube, takes advantage of the experience. There, all waste is isolated within reinforced concrete vaults (30 meters wide, 30 meters long, 8.5 meters high, with 30-centimeter thick walls). Vaults are built above the highest level of the groundwater table, and have additional design features to guard against rainwater infiltration. Also developed was a waste package handling system that workers operate remotely, which reduces their exposure to radiation. Based on earlier experience, a highly automated record management system was created.

In Spain, El Cabril follows a similar disposal concept, and incorporates the potential retrievability of waste packages; it also has waste conditioning and characterization facilities. In India, where six LILW repositories are operating, the design features reinforced concrete trenches and tile holes for different types of waste. At Trombay, the reinforced concrete trenches are waterproofed and covered with reinforced concrete; additional water repellants are used to prevent any ingress of monsoon water. Circular tile holes some four meters deep are designed to accommodate waste with activity higher than permissible for reinforced concrete trenches and for storage/disposal of alpha contaminated waste.

In countries of the former Soviet Union, LILW disposal facilities typically were built in the 1960s and 1970s and have been used for waste containing various radionuclides. Similar types of repositories were built in Eastern European countries. The standard design called for them to be located at least four meters above the water table. At the Sergiev Posad repository (Russia), concrete vaults were built just below ground surface. They are made of double-layered concrete walls containing bitumen layers. Waste packages are placed in individual compartments that are filled in with mortar made of cement and low-level liquid waste. When a compartment is full, the waste is covered by a concrete layer as well as a re-enforced concrete plate, two layers of bitumen, and a clay soil cap.

In Japan, at Rokkasho-mura, concrete pits are used between which a drainage system is installed as an engineered barrier in view of the fact that the repository is located under the groundwater table. One pit can accommodate approximately 5000 drums. Once full, the disposal pits will be backfilled and covered with at least four meters of soil.

In Canada, waste disposal engineers have designed what is called the "intrusion resistant underground structure", or IRUS. Its features include a concrete module with a thick concrete cap and permeable bottom that will be built above the water table in a sand formation. The permeable floor is designed to minimize the contact of water with the waste. Since the waste will contain small concentrations of very long-lived radionuclides, engineers have planned for the eventual infiltration of water as the concrete deteriorates over the long term: any water is channeled to readily drain through the floor, which is formed of two mixed layers of sand, clay, and natural zeolite. The adsorptive properties of the layers will limit the release of radionuclides with the draining water.

Mined cavities. This concept is followed in the Czech Republic, Sweden, Finland, and Norway, for example. In the Czech Republic, part of Richard II mine cavern, 70 to 80 meters underground, is used as a repository for institutional radioactive waste (mostly short-lived). Currently, the mine is dry and its geological environment is marly limestone and marlstone. In Sweden, the Swedish Final Repository (SFR) is built in crystalline rock about 60 meters under the sea bottom with access from land. The layout of the rock chambers have been adapted to the different types of short-lived LILW, their radioactivity content, composition, and handling requirements. Silo-shaped caverns 50 meters high with concrete walls, a bentonite clay buffer, and gas venting system house the waste packages containing the highest levels of activity. In Finland, Olkiluoto is similar to the SFR but it has only two silos — one for low-level wastes and the other for heatgenerating intermediate-level wastes — constructed 60 to 100 meters underground. Crushed and ground host rock is used as backfill, and major water-bearing fracture zones will be sealed with concrete plugs.

Geological repositories. The Morsleben and Konrad (Germany) sites, as well as the planned NIREX repository (UK), are examples of geological repositories for LILW. Morsleben is located in a very dry and stable salt mine roughly 500 meters underground, and has a capacity of 40,000 cubic meters of waste. ILW are disposed of in a large cavity which is then backfilled in layers for shielding; LLW is stacked in excavated chambers. The Konrad site is an exceptionally dry former iron mine which is easy to mine, stable, confined by other layers, and covered by about 400 meters of thick clay. According to the safety assessment, the time for water to travel from the repository to the surface would be 380,000 years. Horizontal repository tunnels are to be built at a depth of about 800 meters for disposal of non-heat generating wastes, while two shafts and tunnels will be used for transportation.

Licensing. Because of different legal and regulatory structures and requirements, the licensing process differs among countries. For instance, in Germany a single licensing process covers construction, operation, and closure of a repository, whereas several licensing steps are required in other countries. In general, the license application is based on site-specific repository design and safety assessments which must demonstrate compliance of the proposed facility with regulatory requirements. Licensing typically involves complex legal and political procedures, intensive technical reviews by the regulatory body, and interaction with the public.

In Switzerland, the site of Wellenberg in Canton Nidwalden was announced in June 1993 as a suitable potential site for LILW disposal after extended investigations. The Swiss licensing procedure includes federal, cantonal, and community licenses for the construction and later for the operation of the repository. In addition, a special mining concession must be granted by the Canton. The general license was submitted to the Swiss Federal Government in June 1994, whose decision is subject to ratification by the Federal Parliament. In the meantime, the siting community of Wolfensehiessen and the community assembly voted in favour of the project in 1994. However, the cantonal vote in June 1995 regarding the mining concession was slightly negative.

In Germany, the Konrad mine in Lower Saxony was investigated from 1976 to 1982 to determine its suitability as a radioactive waste repository. When the investigations were completed, application was made for a license to begin repository construction. While all hurdles have been passed at the federal level, the regional government has not rendered its decision on the license application. In the United States, four states (California, Nebraska, North Carolina, Texas) submitted license applications in late 1989, July 1990, December 1993, and March 1992, respectively. Up to now only California has obtained a license, issued by the California Department of Health Services (DHS) on 16 September 1993. However, the license was conditioned on DHS ownership of the land. On 1 June 1994, the Superior Court of the State of California ordered DHS to reconsider its approval of the license. DHS is appealing the court's order. In Nebraska, US Ecology, which has responsibility for siting, submitted the eighth and final revision of the Safety Analysis Report plus various other documents relating to the license application on 15 June 1995. In North Carolina, due to political reasons, the application will not be approved before February 2000 by the state's Division of Radiation Protection in the Department of Environment, Health and Natural Resources.

Closure. Once a disposal facility is full, or disposal operations are stopped for other reasons, the process known as "closure" and "post-closure" begins. The closure process include steps to secure the facility, such as covering or sealing the disposal areas, compiling documents, and performing safety assessments. In many countries, several hundreds of years are foreseen for post-closure institutional control. This may include access control, maintenance, site monitoring, recordkeeping and corrective actions, if required.

In France, the Centre de la Manche received its last waste package in June 1994 and steps now are being taken in preparation for closure. The facility operator, the French National Radioactive Waste Management Agency (ANDRA), has applied for a license concerning the institutional control phase. Once the licence is granted, the site will continue to be under ANDRA responsibility. The license is expected to be granted in 1997, following a second public hearing that will provide guidance on institutional control activities including active and passive surveillance.

Emerging issues and challenges

A number of issues have emerged that are drawing close attention at the national and global levels. They include those concerning:

Naturally occurring radioactive materials (NORM). The earth's environment includes naturally occurring radionuclides, including potassium-40 and carbon-14, and radioactive heavy elements originating from the uranium and thorium decay series. They can be contained in residues, or wastes, resulting from any activities that involve removing natural materials from the earth or processing those materials (e.g. mining or oil and gas production). Also coal combustion results in concentration of radionuclides in the ash as well as significant airborne release of radioactivity. The radiological hazard due to NORM in waste products is mainly from radium and its progeny. Associated radiation doses may not be insignificant and indeed will often be higher than radiological standards set for the control of radiation from practices involving the use and application of radioactive materials.

The concerns have prompted regulators to consider the potential hazards associated with disposal of NORM wastes. In some countries, some of these wastes are now managed like radioactive waste although the level of control varies widely. A recent survey has shown that radionuclide concentrations in oil/gas processing pipelines can approach levels above which it would be deemed unacceptable for near-surface disposal of radioactive waste. In some countries, some byproducts of oil/gas production and processing are already managed as low-level radioactive waste, while in other countries it remains uncontrolled.

Very low-level waste (VLLW). This type of waste sometimes is generated in large volumes but carries low potential hazards. It creates a problem because it is neither practical to dispose of it in LILW repositories nor acceptable to dispose of it as industrial waste. Presently, there is no internationally agreed definition of VLLW, and the issue's resolution depends upon the development of regulatory criteria, among other factors.

In Sweden, several earthen mound facilities are in operation at each nuclear power plant site to dispose of VLLW. Such disposal can only be exercised for the waste requiring less than 100 years of radiological control. In France a large portion of VLLW is sent to the L'Aube repository while the remaining portion is kept at the sites. All told, French industry officials estimate the total amount of VLLW to be about 15 million metric tons, and efforts have intensified to find a more satisfactory solution to its disposal. A recent study by an industrial working group considered four types of disposal facilities for VLLW, three in tumulus structures and one underground. These designs are under review by the licensing authority. In Japan, the Japan Atomic Energy Research Institute (JAERI) has launched a programme to demonstrate the safety of near-surface disposal for VLLW. The type of waste for disposal in the demonstration project is mainly concrete chunks of reactor shields and contaminated structures from the country's Demonstration Power Reactor containing radionuclides several orders lower than the legal limits. Having obtained approval for building the test facility, a pit has been excavated at the reactor site, which accommodated 1700 tons of the waste from November 1995 to March 1996. The disposal pit has been covered by a thick landfill with grass on top and the site will be controlled for about 30 years.

Spent sealed radiation sources (SRS). More than half a million sealed radiation sources are widely used in medicine, research, agriculture, and other fields. Once used, or spent, they require careful management before their safe disposal. Experience has been acquired for all steps in the management of spent SRS, except for the disposal of long-lived sources. However, not all countries have the resources to implement existing methods.

Provided a near-surface facility is properly sited, constructed and operated, it may safely be used for the disposal of most spent SRS, with the exception of americium-241 and radium-226 and the large sources used in teletherapy or radiation facilities. The acceptability of waste at a given repository is subject to criteria which include a concentration limit for the different radionuclides or groups of radionuclides in a waste package and the total activity.

Many countries generate only small amounts of radioactive waste including spent SRS, up to a few cubic meters per year. These countries could benefit from establishing regional-multinational repositories. Other countries with operational repositories are facing different types of concerns with spent SRS. For example, in Russia, long-lived spent SRS (e.g. radium sources) are stored for future geological disposal and others are disposed of in concrete vaults or in boreholes built in shallow ground. The borehole concept, developed from the end of 1950s to the beginning of 1960s by the former USSR, involves dropping spent SRS through a spiral loading channel into a five meter deep stainless vessel situated in a concrete-lined bore-

Status of low and intermediate level waste disposal facilities in various countries in 1996

Country	Repository (date opened/closed)	Repository Concept
In the process of site selection		
Australia		ENSF
Belgium		ENSF
Brazil		ENSF
Bulgaria		ENSF
Canada (historic LLW)		-
China (East)		-
(Southwest)		-
Croatia		-
Cuba		MC
Ecuador		ENSF
Hungary		-
Indonesia		ENSF
Korea, Republic of		-
Pakistan		-
Slovenia		-
Turkey		ENSF
United Kingdom		GR
United States (Connecticut)		-
(Illinois)		ENSF
(Massachusetts)		-
(Ohio)		ENSF
(Michigan)		ENSF
(New Jersey)		-
(New York State)		ENSF
(Pensylvania)		ENSF
Site selected		
China	Guangdong Daya Bay	ENSF
Cyprus	Ari Farm	SNSF
Egypt	Inshas	ENSF
Mexico	Laguna Verde	ENSF
Peru	RASCO	ENSF
Romania	Cernavoda	ENSF
Swizerland	Wellenberg	MC
Under licensing		
Canada	Chalk River	ENSF
Germany	Konrad	GR
Norway	Himdalen	MC
Slovak Republic	Mohovce	ENSF
United States	Ward Valley, California	ENSF
	Boyd County, Nebraska	ENSF
	Wake County, North Carolina	ENSF
	Fackin Ranch, Texas	ENSF
Under construction		
China	Gobi, Gansa	ENSF
Finland	Loviisa	MC
In operation		
Argentina	Ezeiza (1970-)	ENSF
Azerbaijan	Baku (1960s-)	ENSF
Australia	Mt. Walton East (1992-)	ENSF
Belarus[1]	Ekores, Minsk reg.(1964-)	ENSF
Brazil	Abadia de Goias (1996-)	ENSF
Czech Republic	Richard II (1964-)	MC
	Bratrstvi (1974-)	MC
	Dukovany (1994-)	ENSF
Finland	Olkiluoto (1992-)	MC
France	Centre de l'Aube (1992-)	ENSF
Germany	Morsleben (1981-)	GR
Georgia	Tabilisi (1960s-)	ENSF

Country	Repository (date opened/closed)	Repository Concept
Hungary	RHFT Puspokszilagy (1976-)	ENSF
India	Trombay (1954-)	S/ENSF
	Tarapur (1968-)	ENSF
	Rajasthan (1972-)	ENSF
	Kalpakkam (1974-)	ENSF
	Narora (1991-)	ENSF
	Kakrapar (1993-)	ENSF
Iran	Kavir Ghom-desert (1984-)	SNSF
Israel	Negev Desert	SNSF
Japan	Rokkasho (1992-)	ENSF
Kazakstan	Almaty	ENSF
	Kurchatov (1996-)	ENSF
	Ulba (1996-)	ENSF
Kyrgyzstan	Tschuj (1965-)	ENSF
Latvia	Baldone (1961-)	ENSF
Mexico	Maquixco (1972-)	SNSF
Moldova	Kishinev (1960-)	ENSF
Pakistan	Kanupp (1971-)	SNSF
	PINSTECH (1969-)	SNSF
Poland	Rozan (1961-)	ENSF
Romania	Baita-Bihor (1985-)	GR
Russia[2]	Sergiev Posad, Moscow reg. (1961-)	ENSF
	Sosnovyi Bor, Leningrad reg.	ENSF
	Kazan, Tatarstan	ENSF
	Volgograd	ENSF
	Nijnyi Novgorod	ENSF
	Irkutsk	ENSF
	Samara	ENSF
	Novosibirsk	ENSF
	Rostov	ENSF
	Saratov	ENSF
	Ekaterinburg	ENS
	Ufa, Bashkortostan	ENSF
	Cheliabinsk	ENSF
	Habarovsk	ENSF
South Africa	Pelindaba (1969-)	SNSF
	Vaalputs (1986-)	SNSF
Spain	El Cabril (1992-)	ENSF
Sweden	SFR (1988-)	MC
	Oskarshamn NPP (1986-)	SNSF
	Studsvik (1988-)	SNSF
	Forsmark NPP(1988-)	SNSF
	Ringhals NPP (1993-)	SNSF
United Kingdom	Dounreay (1957-)	SNSF
	Drigg (1959-)	S/ENSF
Ukraine	Dnepropetrovsk center	ENSF
	L'vov center	ENSF
	Odessa center	ENSF
	Kharkov center	ENSF
	Donetsk center	ENSF
United States	RWMC, INEEL (1952-)	S/ENSF
	SWSA 6, ORNL (1973-)	S/ENSF
	Disposal Area G, LANL (1957-)	SNSF
	Barnwell, South Carolina (1971-)	SNSF
	200 East Area Burial Ground, Hanford (1940s-)	SNSF
	200 West Area Burial Ground, Hanford (1996-)	SNSF
	Richland, Washington (1965-)	SNSF
	Savanah River Plant site (1953-)	SNSF

Country	Repository (date opened/closed)	Repository Concept
Uzbekistan	Tashkent (1960s-)	ENSF
Viet Nam	Dalat (1986-)	ENSF
Operation stopped or under closure		
Armenia	Erevan	ENSF
Bulgaria	Novi Han (1964-1994)	ENSF
Estonia	Tammiku (f. Saku) (1964-1996)	ENSF
France	Centre de la Manche (1969-1994)	ENSF
Germany	Asse (1967-1978)	GR
Russian Federation[2]	Murmansk	ENSF
	Groznyi, Chechnya	ENSF
Tajikistan	Beshkek	ENSF
Ukraine	Kiev center (-1992)	ENSF
Closed		
Czech Republic	Hostim (1953-1965)	MC
Hungary	Solymar (1960-1976)[3]	ENSF
Japan	JAERI, Tokai (1995-1996)	SNSF
Mexico	La Piedrera (1983-1984)	ENSF
Norway	Kjeller (1970-1970)[4]	ENSF
Lithuania	Maishiogala (1970s-1989)	ENSF
United States	Beatty, Nevada (1962-1992)	ENSF
	Maxey Flats, Kentucky (1963-1978)	SNSF
	ORNL SWSA 1 (1944-1944)[3]	SNSF
	ORNL SWSA 2 (1944- 1946)	SNSF
	Shefield, Illinois (1967-1978)	SNSF
	West Valley, New York (1963-1975)	SNSF

Notes on the table

Abbreviations: SNSF = Simple Near Surface Facility MC = Mined Cavity ENSF = Engineered Near Surface Facility GR = Geological Repository S/ENSF = SNSF and ENSF

[1] There are 77 repositories built to accommodate waste from Chernobyl accident.

[2] Repositories in Russian Federation started operation from 1961 to 1967.

[3] Waste was moved to another repository (respectively, from Solymar to RHFT Puspokszilagy; and from ORNL SWSA-1 to ORNL SWSA-2).

[4] Waste will be moved to a new repository (Himdalen) when constructed.

Definitions of selected terms

Low- and intermediate-level waste (LILW) is defined by the IAEA as radioactive wastes in which the concentration of or quantity of radionuclides is above clearance levels established by the regulatory body, but with a radionuclide content and thermal power below those of high-level waste (i.e. about 2 kW/m^3). LILW is often separated into short-lived and long-lived wastes. LILW arises from the operation of nuclear power plants (~500 m^3/GWe year) and other fuel cycle facilities (~90 m^3/GWe year from reprocessing, ~60 000 m^3/GWe year from uranium mining and milling), decommissioning of those facilities (5000 to 10 000 m^3 from a one megawatt-electric station), and applications of radioisotopes. These wastes require proper management through treatment and conditioning and ultimately through disposal.

Disposal is defined as the emplacement of waste in an approved, specified facility without the intention of retrieval. It may also include the approved direct discharge of effluents into the environment with subsequent dispersion (this article does not consider this aspect). Again, the disposal by confinement and isolation includes land disposal, sea dumping (which was implemented by some countries before it was banned by the London Dumping Convention), and others. (This article focuses on land disposal which is the prevailing current common practice.) In this context, the objective of disposal is to provide sufficient isolation of waste to protect humans and the environment and not to impose any undue burden on future generations. This can be fulfilled by applying multiple protective measures to the disposal system taking into account interdependencies among elements involved in the system (i.e. systems approach). The protective measures require several levels of protection and multiple barriers to isolate the waste and to limit releases of radioactive materials, and to ensure that failures or combinations of failures that might lead to significant radiological consequences are of a very low likelihood.

Near-surface facility is a nuclear facility for waste disposal located at or within a few tens of meters from the Earth's surface. These types of facilities include trenches and engineered vaults.

Mined cavities are near-surface facilities constructed inside mines and caverns.

Geological repository is a nuclear facility for waste disposal located underground (usually more than several hundred meters below the surface) in a stable geological formation to provide long-term isolation of radionuclides from the biosphere.

hole. Beginning in 1986 for safety reasons, the free space inside the vessels was filled with metal matrix or polymeric composite materials depending on the activity level and half-life of the spent SRS. Since 1995, the bore holes have been monitored to assess their performance. In the United States, spent SRS is categorized into different classes, and not all of them are acceptable for near-surface disposal. Consequently, more conservative disposal options, such as a geological repository or deep-augured holes are under consideration. Regardless of the technology used, the volume of spent SRS for this type of disposal may not be large enough to justify the economic or institutional costs associated with developing such a separate facility.

Improving existing disposal facilities. Some countries with existing disposal systems are improving the operation of or remediating their disposal facilities to enhance their protective capabilities or to meet new regulations. Remediation can involve the retrieval of waste, *in-situ* immobilization of waste, *in-situ* decontamination, and *in-situ* containment, such as installing cap, cutoff walls, or floor barriers. In a number of countries, including Germany, India, Bulgaria, and other countries in eastern Europe, safety assessments have been or will be done as part of overall reviews of the performance of existing disposal facilities.

At the Morsleben repository in Germany, for example, a safety assessment was done that resulted in the formulation of new waste acceptance requirements and quality-assurance procedures. In Hungary, the Puspokszilagy repository, which had been accepting some unconditioned waste together with packaged waste, has established a guideline to accept only waste packaged in 200-liter steel drums beginning in 1997. In the UK, the Drigg repository underwent major improvements in the late 1980s. Leaving the old simple trenches closed, a concrete vault was built for new types of waste packages. Cutoff walls also were installed to limit water flow in and out of the existing disposal trenches. In Norway, the remedial action plan at an old near-surface disposal facility for long-lived wastes involves digging out all waste packages, and storing them at an interim surface facility. They will be moved to a rock cavern storage and disposal facility to be built at Himdalen.

Long-term storage. In some countries, the option of long-term storage of radioactive wastes is beginning to emerge. The option delays a decision on the wastes' ultimate disposal, in efforts to gain public confidence for implementing disposal operations. However, the approach may require further considerations of regulatory and technical aspects.

At Norway's planned Himdalen site, horizontal tunnels are foreseen for disposal of short-lived LILW, as well as a separate tunnel for storage of wastes containing plutonium for an operational period of about 30 years during which the stored waste will not be retrieved. When the repository is closed, a decision will be made about the waste's disposal at the site, based on operational experience. A similar approach is seen in Switzerland where there is public concern over the irretrievability of waste to be disposed of at the planned Wellenberg repository. Authorities there are looking at the possibility of keeping the facility open and controlled for a period of two or more generations until the time when the decision about the repository's closure can be made.

Disposal costs. As disposal facilities have become technically more advanced, the costs of disposal have risen substantially. In some countries, there is a general noticeable trend to minimize the generation of radioactive wastes as part of cost-reduction efforts. Additionally, less expensive solutions are being sought for disposal of VLLW, as noted earlier.

Recently, a working group was formed with the Nuclear Energy Agency of the Organization for Economic Co-operation and Development on cost issues for LILW disposal. The group will identify cost components, analyze factors affecting disposal costs, and consider the impact of disposal costs on the overall price of generating electricity with nuclear power plants.

Public acceptance issues. As noted previously, the issue of public acceptance has heavily affected the process of radioactive waste management and disposal. In many countries, particularly industrialized ones, greater efforts are being made to overcome public perceptions that are strongly negative. They include enhanced communication programmes to improve dialogue with local communities and the public at large, and clearer demonstrations of a commitment to scientific excellence, environmental protection, and long-term safety in the siting and operation of repositories.

In some countries, financial incentives have been offered to communities accepting waste disposal sites. The compensation should not be considered as a risk premium, however, and safety issues must be discussed and resolved before starting any discussion on the compensation. Examples of financial incentives include monetary payment as well as provision of free electricity and greater employment opportunities.

Regional-multinational repositories. Some countries are expressing interest in establishing a regional-multinational repository whereby a site in a host country would accept radioactive wastes from other countries. The approach holds some economic, technological, and safety advantages, particularly for countries in the same geographical region. A prerequisite for such an approach is the achievement of consensus among the relevant countries and regions, in particular regarding the transboundary movement of radioactive wastes. The IAEA recently has assessed some of the major factors involved in the process of building consensus among interested countries on the various issues entailed in such a regional approach.

In principle, the basic issues involved in a regional-multinational repository are not much different from those related to national projects. But there are some qualitative differences related to the characteristics of the accepted wastes, the liability of partner countries, the division of responsibilities, the application of any required safeguards, and the ownership and transfer of waste materials.

Such regional repositories, which would build upon the best international practices in radioactive waste management, could give some countries the option of not building their own national sites, thereby holding down the total number of repositories worldwide. Additionally, they could provide an alternative for countries with unfavourable conditions for siting their own disposal sites. Disadvantages include the fact that a regional repository may increase transportation activities. It also may be difficult to establish a durable system which can survive changing political or institutional situations and which can assure the long-term collaboration of all partner countries. One of the most challenging tasks associated with such an approach is negotiating agreements which provide partner countries with assurances that all technical, political, and financial obligations will be fulfilled.

International co-operation

The disposal of low- and intermediate-level radioactive waste is based on proven and well-demonstrated technologies. If repositories are properly sited, constructed, and operated — and the radionuclide contents of the waste are controlled and limited — safety can be satisfactorily assured for long periods of time. This can be done by applying multiple protective measures, including engineered and natural barriers, and operational and institutional controls.

Within the IAEA's Member States, greater reliance is being placed upon multiple engineered barriers for safety and environmental protection, and for building public confidence. Additionally, emphasis is being placed on safe and reliable operation systems for remote handling, sheltering, and tracking of waste packages. At the same time, affordable solutions are being sought for the safe disposal of categories of wastes containing very low levels of radioactivity, whose volumes are large. Greater attention also is being given to issues related to the safe disposal of wastes containing naturally occurring radioactive materials, the management and disposal of spent sealed radiation sources, the costs of disposal, public acceptance, the improvement or remediation of existing disposal sites, the long-term safe storage of wastes, and the possible establishment of regional-multinational repositories.

Overall, countries, especially industrialized countries, are experiencing slow progress in developing new repositories with respect to their siting and licensing. These steps typically involve extensive technical reviews by the regulatory body, public hearings, and complex regulatory and legal procedures.

In developing countries, the situation is different. Most of them do not generate large amounts of radioactive wastes yet require technical assistance and guidance to establish sufficient infrastructures and capabilities for safely managing and disposing of wastes. Through its various technical and research programmes, the IAEA is supporting co-operative projects and activities toward these ends. As more radioactive waste disposal facilities are put into operation around the world, the transfer of technology and expertise to developing countries will continue to be of vital importance in helping them to build up their capabilities in this field.

Safe transport of radioactive material: Revised international regulations

A technical overview of the latest main revisions to the IAEA's advisory Regulations for the Safe Transport of Radioactive Material

by Richard R. Rawl

Since 1961 the IAEA at the request of the United Nations Economic and Social Council has issued advisory *Regulations for the Safe Transport of Radioactive Material*, published as IAEA Safety Series No. 6. These regulations have come to be recognized throughout the world as the uniform basis for both national and international transport safety requirements in this area. Requirements based on the IAEA regulations are known to have been adopted in 59 countries, as well as by the International Civil Aviation Organization, the International Maritime Organization, and regional transport organizations.

Recognizing the need to keep the regulations up-to-date with the latest radiation protection principles and evolving transport technologies, the IAEA has regularly issued revisions to the transport regulations. Most recently the revisions have taken place at approximately 10-year intervals and the latest revision began in 1986. The revision process involves a comprehensive series of technical committee and consultants meetings which are mainly comprised of representatives of regulatory agencies in the IAEA's Member States and international safety agencies. The outcomes of these meetings are reflected in drafts of the revised regulations that are circulated for comment and further consideration. In September 1996 the IAEA Board of Governors approved the 1996 draft for publication, and for application to the Agency's operations, and recommended the revised regulations to Member States and international organizations for their adoption.

From a technical perspective, this article briefly reviews the major changes incorporated in the latest revision of the newly issued regulations.

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Technical overview of main revisions

There are numerous minor changes, as well as several major ones, embodied in the 1996 edition. They include those relating to:

Air transport of radioactive material. The new regulations require a more robustly designed package type, called a Type C package, for high-activity packages transported by aircraft. Many of the design and performance requirements for Type C packages recommended in an IAEA technical document (TECDOC-702) were adopted. Type C package requirements apply to all radionuclides. The new performance requirements include:

- those applicable to Type B(U) packages and, if appropriate, packages for fissile materials;
- a puncture/tearing test;
- an enhanced thermal test, with the same technical specifications as the Type B package thermal test but with a duration of 60 minutes;
- a 200 meter water immersion test; and
- an impact speed of 90 meters per second for the "drop" test.

Low dispersible radioactive material. Since the primary hazards being addressed in Type C requirements are dispersion and radiation levels, provisions have been made for materials which exhibit limited dispersibility, solubility, and radiation levels. These provisions are contained in a material category known as "low dispersible radioactive material" (LDM). It was accepted that material (without any packaging) that has limited radiation levels, which when subjected to the Type C impact and thermal tests, would only produce limited gaseous, fine particulate, or dissolved aqueous activity and should be excepted from the Type C packaging requirements. Test specifications for LDM material are included in the regulations and

Type B packages are authorized for their transport by air, with the limit on total activity being that specified in the approval certificate for the Type B package. Multilateral Competent Authority approval of the Type B package design and the design of the LDM is required.

Provisions for the safe transport of uranium hexafluoride. The technical committees which developed the revised regulations dealt with a number of difficult items concerning uranium hexafluoride (UF_6). Uranium hexafluoride is a unique material since its chemical toxicity is generally of more concern than its radiotoxicity and the material is routinely shipped in large volumes. No specific provisions for UF_6 existed in the 1985 edition of the transport safety regulations and a number of issues were considered. Provisions were adopted requiring that UF_6 packages:

- must withstand an internal test pressure of at least 1.4 MPa, but cylinders with a test pressure less than 2.8 MPa require multilateral approval;
- designed to contain 0.1 kg or more but less than 9000 kg of UF_6 must meet the "Type B" thermal test of 800°C for 30 minutes;
- designed to contain 9000 kg or more must either meet the thermal test requirements or have multilateral approval;

Incorporating the exemption values from the *International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources (BSS).* One of the major topics considered in the revision process was the incorporation of the new BSS. The BSS were revised to reflect the consensus surrounding the latest recommendations of the International Commission on Radiological Protection and the transport regulations call upon them as a general provision for radiological protection. Consequently, the transport regulations need to take account of the revised BSS requirements. The most contentious aspect was the adoption of the exemption values given in the BSS.

The transport regulations have always contained an exemption criterion which defined materials subject to their requirements. The current regulations define radioactive material as any material having a specific activity greater than 70 Bq/g. The BSS, however, use a radionuclide-specific approach which leads to derived exemption values spanning seven orders of magnitude, and straddling 70 Bq/g in the case of activity concentration. The BSS also present exemption values for total activity quantities (Bq).

It was recognized that the single exemption level of 70 Bq/g has no dose basis and that it was unlikely that this level satisfied the primary dose criteron of 10 microsievert in a year for exemption for all radionuclides. A set of transport-specific scenarios were developed which reflected various exposure situations (exposure times, distances, source geometries, etc.). Based on these scenarios, both activity concentration and total activity values were calculated which would result in meeting the 10 microsievert per year value. These transport derived values were comparable to the exemption values in the BSS and resulted in recommended activity concentrations ranging from 1 to 10^6 Bq/g.

Given the difficulty in technically justifying the 70 Bq/g value and the similarity in results from the transport scenarios and the BSS scenarios, it was determined to be preferable to simply adopt the BSS derived exemption values. Consequently, the regulations contain both activity concentration and "total activity per consignment" exemption values. For mixtures of radionuclides, the "ratio rule" must be applied so that the sum of the activities (or activity concentrations) present for each radionuclide divided by the applicable exemption value is less than or equal to one.

Other changes. Other changes of interest to shippers and package designers involved in the nuclear fuel cycle include revisions to the requirements applicable to fissile materials. Fissile material exceptions (those conditions under which special packaging is not needed to account for the fissile nature of the contents) were amended and in one case now include consignment as well as package limits. Consideration of accident conditions such as crush and the Type C test conditions were also added.

Implementation of the revised regulations

It will take a number of years for IAEA Member States and international organizations to implement supporting revisions to their regulations based on the 1996 edition of Safety Series No.6.

In the past, it has taken approximately five years for this process to be reasonably complete. The international transport organizations are striving to meet a target date of 1 January 2001, and the Agency's Member States will likewise need to issue revisions in order to remain consistent with the international requirements. ❑

INTERNATIONAL DATAFILE

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
Armenia	1	376		
Belgium	7	5 712		
Brazil	1	626	1	1 245
Bulgaria	6	3 538		
Canada	21	14 902		
China	3	2 167	1	
Czech Republic	4	1 648	2	1 824
Finland	4	2 355		
France	57	59 948	3	4 355
Germany	20	22 282		
Hungary	4	1 729		
India	10	1 695	4	808
Iran			2	2 146
Japan	53	42 335	2	2 111
Kazakstan	1	70		
Korea, Rep. of	11	9 120	5	3 870
Lithuania	2	2 370		
Mexico	2	1 308		
Netherlands	2	504		
Pakistan	1	125	1	300
Romania	1	650	1	650
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	7 207		
Sweden	12	10 040		
Switzerland	5	3 078		
United Kingdom	35	12 928		
Ukraine	16	13 765	5	4 750
United States	110	100 579		
World Total*	442	350 825	36	27 678

*This total includes Taiwan, China where six reactors totalling 4884 MWe are in operation.

Nuclear share of electricity generation in selected countries

Lithuania	83.44%
France*	76.1%
Belgium*	55.5%
Sweden*	46.6%
Slovak Republic	44.53%
Hungary*	42.3%
Bulgaria	42.24%
Switzerland*	39.9%
Slovenia	37.87%
Ukraine*	37.8%
Rep. of Korea	35.77%
Spain*	34.1%
Japan*	33.4%
Germany*	29.1%
Finland	28.13%
United Kingdom*	25%
United States	21.92
Czech Republic*	20.1%
Canada*	17.3%
Russia	13.1%
Argentina	11.43%
South Africa	6.33%
Mexico	6%
India	2.21%
China	1.27%
Netherlands	0.6%

Note: Percentages and data in table are preliminary as of December 1996; they are subject to change. Other countries generating a share of their electricity from nuclear power are Armenia, Brazil, Pakistan, and Kazakstan. Additionally, the share of nuclear generation was 29.07% in Taiwan, China.

* Data as of December 1995 for these countries

IAEA Board of Governors meetings in March 1997

At its meetings in March 1997, the IAEA Board of Governors tooks steps toward the selection of the IAEA's next Director General, who will be appointed at the Agency's General Conference later this year. Specifically, the Board considered the sequence of steps to be followed in the event it does not reach consensus on any single candidate. The present 4-year term of Director General Hans Blix ends in November and he has stated that he is not seeking reappointment. Dr. Blix, from Sweden, has been Director General since November 1981.

The Board's provisional agenda in March also included items related to nuclear, radiation, and waste safety, and the strengthening of IAEA safeguards.

Nuclear, Radiation, and Waste Safety. A report from the Standing Committee on Nuclear Liability noted that the Committee has reached the final stages of its preparatory work on a draft protocol to amend the 1963 Vienna Convention and the draft of a Convention on Supplementary Funding. The full texts of the two instruments, which together revise the international regime for nuclear liability, were prepared at the Committee's session in October 1996 and referred to governments for detailed review. The reviewed texts were further considered at the Committee's meeting in February this year. Once approved, the final texts would be adopted by a Diplomatic Conference which could be convened later this year.

Also before the Board was a report on recent developments relating to nuclear, radiation, and waste safety. The report covers a range of topics, including international conventions on nuclear safety and the safety of spent fuel and radioactive waste management. *(See related item, page 47.)*

Nuclear Safeguards. The Board received a report from its open-ended Committee on Strengthening the Effectiveness and Improving the Efficiency of the Safeguards System, which held its third session 20-31 January 1997 with the participation of representatives from 61 Member States, the European Commission, and the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials. The Committee, being headed by Board Chairman Ambassador Peter Walker of Canada, is completing work on a draft Protocol to expand the legal basis of the IAEA's authority concerning inspection measures that now go beyond present comprehensive safeguards agreements. In January, the Committee made considerable progress during its discussions of the rolling text and related changes and agreed to circulate for further detailed review a consolidated revised text. The Committee's next meeting was being scheduled for early April, when it will consider the consolidated revised text with the intention of reaching agreement on the final draft document for submission to the Board. Toward that end, the Committee has recommended that the Board hold a special session in May to consider and approve the draft model Protocol.

Also on the Board's provisional agenda was a report by the Director General on the implementation of IAEA safeguards in the Democratic People's Republic of Korea (DPRK), where the IAEA maintains a continuous inspector presence. The latest round of technical talks between officials of the IAEA and DPRK took place in January.

IAEA celebrates 40th anniversary this year

Forty years ago, the IAEA officially opened its doors in Vienna, Austria, as the international "Atoms for Peace" agency proposed to the United Nations in the 1950s. To commemorate the anniversary, the Agency and its Member States are planning or considering a range of activities and events over the coming months. They include:

Publication of a history of the IAEA. The book, a joint project with the Monterey Institute of International Relations in the United States, is being written by Mr. David Fischer, an author of several books on nuclear issues. He took part in the negotiations on the Agency's Statute, the work of the Preparatory Commission in the 1950s, and served as Director of the IAEA's Division of External Relations and as Assistant Director General. The project's editorial advisory group includes Mr. Munir Khan of Pakistan, Mr. Lawrence Scheinman of the United States, and Mr. Tadeusz Wojcik of Poland.

Publication of a collection of personal reflections. The essays, written by distinguished scientists and diplomats involved in the Agency's work, will cover various aspects of the IAEA's origins and development, serving to record major trends of activities.

Proposed events organized by Austria, the Agency's host country. A number of special activities have been proposed, including a seminar in May on the topics of sustainable development and nuclear verification; a high-level symposium in October on the IAEA's contribution to international peace, security, and development; a commemorative address in June by IAEA Director General Hans Blix sponsored by the League for the United Nations and the Austrian Society for Foreign Policy and International Relations; visits to the Agency's Laboratories at Seibersdorf; a television programme on IAEA activities; a ceremony at the ANA Grand Hotel in downtown Vienna, where a commemorative plaque is to be placed noting it served as the Agency's headquarters from 1957-79; and participation of Austria's President in the opening session of the IAEA General Conference in September 1997.

Proposed events in other Member States. In Pakistan, proposed events include publication of a brochure on the country's co-operation with the IAEA; organization of a national workshop on nuclear medicine and radiotherapy in March; and commemorative activities in association with the 25th anniversary of Pakistan's Nuclear Institute for Agriculture and a planned international symposium. In Cuba, planned events include hosting the First International Symposium on Nuclear and Related Techniques in Agriculture, Industry, Health, and the Environment, and the third workshop on nuclear physics. *(See item, page 52.)* In the Republic of Korea, the Conference of the Korean Nuclear Society and Atomic Forum in April will include a panel exhibition, while Morocco is considering issuing a commemorative stamp, among other activities. In Slovakia, proposed events include publishing a brochure and historical overview of the country's co-operation with the IAEA. In India, an international symposium on the role of nuclear energy and sustainable development is being considered in September. In Romania, two symposia are being considered by the National Atomic Energy Agency, as well as special television and radio programmes highlighting the Agency's work and a ceremony at the Cernavoda nuclear plant marking the entry into force of the IAEA's Statute. All these events are subject to further confirmation and do not necessarily include the IAEA's direct participation.

General Conference events. Also being proposed — in conjunction with the IAEA General Conference being held in Vienna 29 September to 3 October 1997—is an expanded scientific programme that will focus on key issues for the IAEA's future. Topics being considered include energy and the environment; the future of nuclear science and new applications of nuclear techniques for sustainable development; and the role of verification in a world phasing out nuclear weapons. In addition to the participation of Austria's President on opening day, the General Conference is expected to be attended by senior ministerial and high-level governmental delegates from the IAEA's 124 Member States.

Meeting of parties to Nuclear Safety Convention

Parties to the Convention on Nuclear Safety were scheduled to hold the first preparatory meeting at the IAEA 21-25 April on matters related to the Convention's implementation. The Convention, which entered into force 24 October 1996, has 35 Contracting Parties and has been signed by 65 States. The April meeting will focus, among other subjects, on guidelines regarding the form and structure of reports that States are required to submit for review at periodic meetings, and the process for reviewing such reports. These reports will focus on the measures each State has taken to implement its obligations under the Convention. The first such review meeting is required to be convened no later than 30 months from the Convention's entry into force.

The Convention on Nuclear Safety commits Parties to ensure the safety of land-based civil nuclear power plants. This includes a legislative and regulatory framework; general safety considerations such as quality assurance, assessment, and verification of safety;

human factors; radiation protection; emergency preparedness; and specific obligations on the safety of nuclear installations, siting, design and construction, and operation.

Safety of Spent Fuel Management and Radioactive Waste Management. The sixth and seventh sessions of the open-ended Group of Legal and Technical Experts preparing the draft of a convention on the safety of radioactive waste management were held at the IAEA in early January and March 1997. Progress was made in important areas and the Group arrived at a positive result. The experts drafted a Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management that recognizes that the same safety objectives apply to managing both spent fuel and radioactive waste. The draft text was submitted to the IAEA Director General, with the request for its early submission to the IAEA Board of Governors for consideration and approval. The Group recommended that a Diplomatic Conference be convened later this year with a view to adopting the Joint Convention. Under the chairmanship of Prof. Alec Baer, of Switzerland, the Group was formed in 1995 and has now completed its main work.

Animal health and disease control in Africa

Important steps are being taken by 34 African countries working together to rid the continent of the deadly viral disease called rinderpest that threatens their livestock and agricultural economies. At a technical meeting in Vienna earlier this year organized by the IAEA Department of Technical Co-operation and the Joint Division of the IAEA and Food and Agriculture Organization (FAO), representatives of the main countries involved in the Pan-African Rinderpest Campaign (PARC) further outlined their plans for eradicating the disease from Africa, which they agreed could be achieved over the next three to five years. Also attending were representatives from the campaign's donor organizations, including the European Union (EU) and United States Agency for International Development (USAID).

While PARC involves 34 countries, all but two now have rinderpest under control. This has been achieved through their efforts to vaccinate cattle, in which the IAEA's technical support played a key role. The Agency supported a laboratory network using enzyme-linked immunosorbent assay (ELISA) for monitoring the vaccination process. Now, as mass vaccination comes to an end and efforts concentrate on removing the remaining pockets of infection, the IAEA laboratory network will focus on surveillance using the most modern molecular technologies. These provide rapid identification of the existence of the disease or confirm its elimination.

Popularly known as "cattle plague", rinderpest can affect all cattle in a herd and kill most of them. It killed 90% of all cattle and buffaloes when it first took hold in sub-Saharan Africa at the turn of the century. Though prospects are good that the disease is nearing extinction, its control must be viewed from a global perspective because of its transboundary nature. In many arid areas of Africa, cattle are the staple livelihood of rural people, who rely on long migrations across borders to reach pastures. The animal herds often carry diseases, thus making control a regional problem. This is why the IAEA introduced the laboratory network applying nuclear-based and related diagnostic technologies to help Africa's veterinary services identify infected herds and prevent epidemics from spreading.

During the Vienna meeting, participants defined the problems associated with the surveillance of residual rinderpest and proposed possible solutions. These involved the strengthening of disease surveillance and of the existing network through assistance to regional reference laboratories that will help national laboratories in the diagnosis of rinderpest. They pointed out that the eradication of rinderpest from African countries will not only help to avoid previous disastrous cattle losses, and resulting famines, but will also allow more trade in livestock and livestock products. International livestock trade is regulated through the Organisation Internationale des Epizooties (OIE) by a set of rules and specific declarations relating to various diseases, a process called the "OIE Pathway". For rinderpest, country declarations culminate in the final goal of "Declaration of Freedom from Infection". The majority of African countries are well on the way to achieving this goal and have already made "Provisional Declarations of Freedom from Disease". Meeting participants discussed the requirements for the OIE Pathway and means to strengthen existing rinderpest surveillance systems. Regional workshops in West and East Africa will be organized through the IAEA as part of follow-up actions.

International Symposium. In April 1997, the FAO and IAEA jointly sponsored the International Symposium on Diagnosis and Control of Livestock Diseases using Nuclear and Related Techniques: "Towards Disease Control in the 21st Century". It focused on ways to strengthen the capabilities of countries to apply nuclear and related techniques to problem-oriented research on the nutrition, reproduction, and diseases of livestock.

Isotopes in marine environmental studies

Experts investigating the behaviour of radioactive and stable isotopes in the marine environment recently identified major areas of concern about the protection of the world's oceans and aquatic systems, especially those in coastal/shelf regions. They met at the International Seminar on the Use of Isotope Techniques in Marine Environmental Studies, which was organized in Athens by the Greek Atomic Energy Commission at the National Centre for Scientific Research "Demokritos". The seminar reviewed applications of isotope techniques to environmental studies in marine and aquatic systems; reported on international programmes organized by the IAEA, International Oceans Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization, and the Food and Agriculture Organization (FAO) of the United Nations; and fostered greater collaboration at the regional and global levels.

Through its co-operative programmes, the IAEA has acquired substantial experience in the use of isotopes in the assessment of continental and marine water bodies. Research covers fundamental oceanographic processes and phenomena; the protection and management of the marine environment, including the adequate use of marine resources; and the reconstruction of past and prediction of future aquatic systems. Tracers used include natural radionuclides, radionuclides of anthropogenic origin, and stable isotopes. The seminar identified major environmental problems and questions of current concern over the protection of coastal/shelf regions from land-based sources, eutrophication, and other types of anthropogenic effects on aquatic ecosystems.

Detailed discussions were held on environmental problems of regional seas such as the Mediterranean Sea, the Caspian Sea, the Black Sea, the Baltic Sea, the South Asia Seas, and the Latin American and African coastal regions. Results of the discussions on possible regional collaboration were reported during the final session, and the proposals will now be elaborated within the framework of the IAEA's marine activities in co-operation with the IOC-UNESCO, the FAO, and the United Nations Environment Programme.

More information may be obtained from the IAEA Marine Environment Laboratory, B.P. 800, MC 98012 Monaco; Fax 00377-9205-7744, and from the Division of Physical and Chemical Sciences at IAEA headquarters.

Safe management of spent fuel from research reactors

More than 60 participants and observers from 41 countries attended an interregional training course earlier this year organized by the IAEA and United States at the Argonne National Laboratory on the technical and administrative preparations required for shipping spent fuel from research reactors back to the country of its origin. Most of the world's research reactors were built 25 to 30 years ago when it was assumed that the spent fuel would eventually be shipped back to foreign suppliers. In many cases, however, countries that have acquired research reactors in the international market have experienced difficulties in returning the spent fuel, often having to store it in facilities that were not designed for long-term storage.

Over recent years, the situation has changed somewhat. In some countries, methods of increasing existing storage capacities and building facilities to modern standards have been developed; however, the relevant information is not always readily accessible outside the country of the fuel's origin. Of the spent fuel assemblies in storage at some 180 research reactors surveyed by the IAEA, about 75% was originally supplied by industrialized countries, and most is of US and Russian origin. In 1996, the United States decided to resume for a number of years its policy for taking back spent fuel of US origin, but the Russian Federation presently does not have a similar programme for taking back spent fuel of Russian origin.

The IAEA organized the course in response to a request from the United States and it was designed to assist countries operating research reactors in safely preparing spent fuel for shipment back to its country of origin. The course featured 26 lecturers and presentations on national experience from more than 35 countries including the United States, Germany, Japan, Russian Federation, Latvia, Portugal, Greece, Republic of Korea, Bangladesh, Mexico, Romania, Chile, Viet Nam, Hungary, Georgia, France, Indonesia, Israel, Philippines, China, Peru, Ukraine, Sweden, Australia, Colombia, Uzbekistan, Kazakstan, Uruguay, Czech Republic, Thailand, Zaire, Argentina, Bulgaria, Belarus, Turkey, and Malaysia. Also featured was an overview of the world situation concerning spent fuel management at research reactors from the perspective of the IAEA, which has prepared a guidebook to assist countries in shipping fuel back to foreign suppliers. During the course, research reactor operators storing Russian-origin fuel urged the Russian Federation to develop a programme for accepting the return of fuel it orginally supplied to research reactors in foreign countries.

Remedial Action at Vinca. In efforts to help prevent potentially serious problems with spent fuel storage at the Vinca research reactor near Belgrade, the IAEA sent a team of experts to the site in February as part of follow-up measures for remedial action initiated over the past year. Spent fuel at the former USSR-designed and built research reactor, which first started operation in 1959 and has been shut down since 1984, is stored in a pool under conditions that have raised safety concerns. The IAEA sent a preliminary fact-finding mission to the reactor site in November 1995 to evaluate the situation. In October 1996, a special follow-up mission of experts from the United States, Russian Federation, France, and the IAEA visited the site for more thorough analysis.

Two major problems have been identified: the first involves a large fraction of the spent fuel sealed in drums that may be over-pressurized by the evolution of corrosion gases, while the second involves the remainder of the fuel, some of it already leaking, in stainless steel tubes. The first requires immediate attention, while the second should be mitigated as soon as possible. Activities in the pool presently are hampered by the murky nature of the water and the presence of copious quantities of sludge and suspended corrosion products. The February mission was sent to assist Vinca operators in devising a plan to vent the storage drums and to clear and purify the pool water. The Agency, however, is not able to bear the cost of conditioning, stabilizing, and packing the fuel, and sources of extrabudgetary funding will be required. Among countries that have offered assistance so far is Italy.

More information may be obtained from the IAEA Division of Nuclear Power and the Fuel Cycle. Information about the training course and IAEA guidelines is available on the ANL's Internet pages on the Worldwide Web: http://www.td.anl.gov/RERTR/FRRSNF.html

In Memoriam: Ambassador Nelson F. Sievering Jr.

The IAEA and international community are paying tribute to the distinguished service and career of United States Ambassador Nelson F. Sievering Jr., who passed away 6 March 1997. Ambassador Sievering, who was the United States Representative to the IAEA and Governor on the IAEA's 35-member policy-making body, the Board of Governors, had served as IAEA Deputy Director General for Administration from October 1980 to December 1987. He is survived by his wife, Dorothy, and two sons.

Born in 1924, Ambassador Sievering graduated from Yale University in 1945 with a Bachelor of Science degree in chemical engineering. He received his Master of Science degree in chemical engineering from Columbia Univeristy in 1948 and attended the New York University Graduate School of Business Administration. After completing his education, he joined the US Atomic Energy Commission in 1948, before being named Deputy Assistant Secretary of Energy for International Affairs in the 1970s. Following his service as IAEA Deputy Director General, and until President Clinton appointed him US Representative to the IAEA in 1993, Ambassador Sievering was a Senior Fellow and Director of the Nuclear Non-Proliferation Program at the Atlantic Council of the United States.

At the IAEA in March, staff and Board members alike reflected upon Ambassador Sievering's dedicated service, many commending his contributions in a book of condolences arranged by the United States mission.

In a message from US Ambassador John B. Ritch III, Resident Representative of the United States to the IAEA and international organizations in Vienna, Ambassador Sievering was fondly remembered: *"As the top administrator of the IAEA and later as United States Governor, Nelson Sievering was a leader in building one of the world's great multilateral institutions. Nelson was a man who deserved the title of Ambassador. Whether engaged in the battles of bureaucracy or diplomacy, Nelson could always be counted on to contribute statesmanship without cant and a generosity to all around him that was unfailing and real. Nelson Sievering represented the United States well. In facing his own tragedies, Nelson displayed a quiet courage that inspired the admiration of those around him. Perhaps his own pain contributed to the personal kindness that was his hallmark. In Vienna and in Washington, Nelson Sievering will be missed and also remembered — as a man who claimed little credit while making a big difference."*

In Memoriam: Mr. Vitomir Markovic

The world's scientific community noted with sorrow the passing of Dr. Vitomir Markovic on 13 March 1997 in Budapest. A senior staff member in the IAEA's Department of Research and Isotopes since 1984, Mr. Markovic was a respected research chemist and project leader whose work will have a lasting impact in many countries around the world.

A frequent contributor to the *IAEA Bulletin* and other magazines and scientific journals, Dr. Markovic was an expert in the field of radiation chemistry and industrial applications of radiation technologies, authoring or contributing to more than 50 papers and articles. Born in 1936 in Yugoslavia, he graduated in 1960 from the University of Belgrade, where he returned to earn his Ph.D in radiation chemistry and radiation dosimetry in 1968. His career included working as a visiting scientist in Denmark, at the Danish Atomic Energy Commission, before taking up the post of Director of the Chemistry Laboratory at the Boris Kidric Institute of Nuclear Sciences in his home country. Before joining the IAEA in 1984, he served as director of several projects in the field of radiation applications for the United Nations Development Programme, as General Chairman of international meetings on radiation processing, and as a visiting professor at the University of Maryland in the United States.

Dr. Markovic will be deeply missed by his friends, colleagues, and the international community which he so richly served with dedication, commitment, and professionalism.

Regulation of radiation sources

Radiation protection specialists will be meeting at the IAEA in May to discuss issues concerning the regulation of radioactive sources and associated implications for the management of radioactive waste. Specifically, they will be examining questions about the exclusion, exemption, and clearance of radioactive sources that cannot or need not be subject to regulatory control for one reason or another.

Some types of radiation sources, such as naturally radioactive potassium-40 present in the human body, are by their nature excluded from regulatory control. Others, such as tracers used in research containing very small amounts of radioactive materials, may be exempted from control because they pose negligible health and safety risks. Some other types of materials require clearance from regulatory control because they no longer present a radiological hazard. Examples are materials for recycling and wastes containing low levels of radioactivity from within the nuclear fuel cycle or from other regulated facilities such as hospitals or research laboratories.

Among the aims of the IAEA's May meeting are to develop strategies for resolving issues through international co-operative action, and to provide advice for the Agency's work in drafting guidance for its safety standards. Working with other organizations, the IAEA has issued international guidance, through the *Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources* (BSS) as well as the revised edition of the Agency's advisory *Regulations for the Transport of Radioactive Materials*, on the concepts of exemption, exclusion, and clearance, and they have been discussed in the context of the draft convention on the safety of radioactive waste management now being prepared. The BSS incorporate international consensus reached in 1988 on the general principles for exemption and clearance from regulatory control that was issued through the IAEA's Safety Series.

Yet more work needs to be done to clarify definitions and extend the application of the concepts to practical problems of radiation protection and waste management. At the national level, regulatory policies for low-level radioactive sources are not always coherent or consistent with respect to excluding, exempting, or clearing them from regulatory control. While the situation has not affected public health and safety, it has raised confusion and given rise to unwarranted fears over exposure to "unregulated" radioactive materials, particularly if such materials cross national borders.

One current issue involves naturally occurring radioactive materials, which can include copper ores or some coals. Concerns have been expressed over the implications of international guidance on exemption for factories that use materials containing naturally occurring radionuclides as part of their process material and the possible need for regulation in situations where it was not previously required. Similar concerns have been voiced about mining wastes that contain naturally occurring radionuclides, which particularly is a potential problem in developing countries. Another issue involves waste management, where the volumes of long-lived low-level radioactive wastes can become too large for disposal in deep repositories.

Earth Summit+5

From 23-27 June in New York, the United Nations is holding a Special Session of the General Assembly to Review and Appraise the Implementation of Agenda 21. Adopted at the UN Conference on Environment and Development — or Earth Summit — in Rio de Janeiro in 1992, Agenda 21 contains strategies for preventing environmental degradation and establishing a basis for a sustainable way of life.

Being called the "Earth Summit + 5", the Special Session will include reviews of global energy issues. The IAEA is contributing to the session by preparing updated publications on sustainable energy options, highlighting the results of the Agency's comparative assessment programme covering electricity generation options, and reviewing the contributions of nuclear applications in medicine, agriculture, hydrology, climate change studies, and other fields that foster sustainable development.

In its contributions, the IAEA will emphasize the important and frequently overlooked role that nuclear power is playing in the electricity generation sector, where it provides about 17% of the world's total electricity without adding to emissions of carbon dioxide.

Cuba: Hosts International Symposium

Cuba has announced it is hosting two international meetings in co-operation with the IAEA this October. One focuses on practical applications of nuclear technologies in fields of agriculture, industry, health, environment, and science, and the other on nuclear physics. Being organized by a committee of representatives from the IAEA, Cuba, and other Latin American countries, the meetings are part of Cuba's commemorative activities marking the IAEA's 40th anniversary year.

International Symposium on Nuclear and Related Techniques in Agriculture, Industry, Health, and Environment. Organized into a number of workshops, this symposium will focus on the wide spectrum of nuclear techniques being applied in the Latin American region. They include those related to pest control; crop production; plant breeding; water resources; non-destructive testing in industry; radiation processing technologies; nuclear medicine, radiotherapy, and radiopharmaceuticals; and nuclear analytical techniques in environmental studies.

Workshop on Nuclear Physics. Topics covered in this workshop include fast neutron physics and activation analysis; software on nuclear applications; development and design of nuclear instrumentation for spectroscopy and experimental physics; and advanced semiconductor detectors and related electronic research and developments.

Call for Papers. The organizing committee is now accepting scientific contributions to the workshops, which will be conducted in Spanish, English, and Portuguese; the deadline for submission of abstracts is 30 April. More information may be obtained from Dr. Luis F. Desdin Garcia at CEADEN in Havana. Facsimile:+537-221518. Electronic mail: root@ceaden.cigb.edu.cu or Mr. Pier Danesi, Director of the IAEA's Laboratories in Seibersdorf, Austria, and a member of the Symposium organizing committee.

Mexico: Tlatelolco Treaty Anniversary

Describing the Treaty of Tlatelolco as a "trailblazer" for nuclear non-proliferation, IAEA Director General Hans Blix addressed the commemorative ceremonies in Mexico, the Treaty's Depositary Government, on 14 February 1997 marking the 30th anniversary of the Treaty's signing.

"The Treaty of Tlatelolco has not only helped to keep nuclear weapons out of Latin America," Dr. Blix said. "It has also stimulated the acceptance of non-proliferation on a global basis. Indeed, with the end of the Cold War, the twin goals of universalization of non-proliferation and of drastic or full nuclear disarmament are no longer simply theoretical aims, but targets which an increasing number of seasoned politicians, diplomats, and military leaders are advocating. Non-proliferation is not the end of the road to a saner world, but the beginning."

The Tlatelolco Treaty, which opened for signature in 1967 and establishes a nuclear-weapon-free-zone (NWFZ) in Latin America and the Caribbean, is a forerunner of the global Treaty on the Non-Proliferation of Nuclear Weapons (NPT), which opened for signature a year later, in 1968. Both treaties require Parties to conclude comprehensive safeguards agreements with the IAEA, and include provisions for the peaceful use of nuclear energy.

Tlatelolco's regional approach to non-proliferation has been followed in other parts of the world, including the Pelindaba Treaty in Africa, which opened for signature in Cairo last year, the Rarotonga Treaty in the South Pacific, and the Bangkok Treaty in Southeast Asia. Zonal approaches meeting the particular needs of States in the region could become indispensable in other regions, Dr. Blix said, including the Middle East and Indian subcontinent.

More information about the Tlatelolco Treaty may be obtained from the Organization for the Prohibition of Nuclear Weapons in Latin America and the Caribbean (OPANAL), Temístocles 78, Col. Polanco, Mexico City, Mexico 11560. Facsimile: +525-280-2965.

Malta & Burkina Faso: IAEA Membership

Malta and Burkina Faso have applied to become members of the IAEA. Their applications were favourably considered by the IAEA Board of Governors at its meetings in March, and will now go to the Agency's General Conference in September for approval.

Republic of Korea: Desalting Seawater

More than 150 participants from Asia, Africa, Latin America, and other regions are expected to attend the Symposium on Desalination of Seawater with Nuclear Energy, 26-30 May, in Taejon. The meeting focuses on the application of nuclear energy for the production of potable water at desalination plants.

In recent years, the IAEA in co-operation with other organizations has done a number of feasibility studies in this area, in response to interest from its Member States and their desire to more fully assess the technical and economic potential of nuclear reactors as energy sources for seawater desalination. Additionally, several bilateral and national activities on nuclear desalination are in progress.

The reasons for renewed interest in nuclear desalination, which has been studied as early as the late 1950s, are closely tied to availability of the world's water resources. Although water supply exceeds consumption, water resources are not evenly distributed, with the result that about three-fourths of the world's population does not have enough safe potable water, and many countries face acute water shortages. As part of efforts to solve the problems, more seawater desalination facilities have been installed in some countries over the past decades, and today more countries are interested in applying the technology. The symposium provides a global forum for the exchange of technological experience among countries, both with respect to the design and development of nuclear desalination systems and the prospects for their practical application. It will also update participants on the world's water needs, national desalination programmes and activities, and global co-operative programmes through the IAEA and other organizations.

Myanmar: RCA Silver Jubilee

Nuclear co-operation for peaceful applications of nuclear and radiation technologies was on display in Myanmar in March. The Government hosted the RCA Silver Jubilee Exhibition marking the 25th anniversary of the Regional Co-operative Agreement (RCA) for Research, Development and Training related to Nuclear Science and Technology, which is supported by the IAEA and United Nations Development Programme. The regional arrangement has been instrumental to the transfer of technologies for industrial, agricultural, and other applications. The exhibition was held in conjunction with the 19th Working Group Meeting of RCA participating countries in the Asian and Pacific region. Attending the meeting and anniversary exhibition were delegates from 15 RCA countries, senior Myanmar governmental officials, and representatives from the IAEA.

Israel: Radiation and Health

Participants from over 25 countries attended the International Conference on Radiation and Health in late 1996 sponsored by the Ben Gurion University of Negev and Soroka Medical Center of the Negev in co-operation with the IAEA and WHO. The meeting focused on the problem of radiation exposure to populations, the initial biological effects and how they can be detected, evaluation of delayed effects and how populations respond, risk analysis and the scientific basis of health policies.

The conference brought together scientists from different disciplines to discuss advances in DNA repair, cellular radiobiology, endocrinology, oncology, genetics, nuclear medicine, epidemiology, psycho-sociology, and physics. Particular emphasis was paid to problems of radiation exposure as a result of the Chernobyl and other nuclear accidents. The abstracts will be published in Public Health Reviews. Copies may be obtained from the Secretariat of the Conference, or the co-chairmen Prof. Michael Quastel and Prof John R. Goldsmith, in care of the Institute of Nuclear Medicine, Soroka Medical Center, POB 151, Beer Sheva, Israel 84101.

Canada: 1998 Nuclear Conference

Papers are being invited through May 1997 for the 11th Pacific Basin Nuclear Conference, which is being organized next year by the Canadian Nuclear Society and Canadian Nuclear Association in co-operation with other organizations. Scheduled for 3-7 May 1998 in Banff, Alberta, the conference will focus on the theme of international co-operation in the Pacific Rim for the 21st Century. More information is available from the CNA, 144 Front Street West, Suite 475, Toronto, ON M5J 2L7 Canada, or from the conference Web site on the Internet at http://www.pbnc98.com.

NUCLEAR POWER. Facts about the world's use of nuclear power for electricity generation, and associated environmental and economic benefits, were emphasized by IAEA Director General Hans Blix in Manila recently. Speaking at the Second Philippine Nuclear Congress in December 1996, Dr. Blix said that the world's greater use of nuclear power could "significantly alleviate the dilemma of an increasing need for energy and an increasing need to reduce carbon dioxide emissions". In Manila, he also delivered a separate address on nuclear applications in medical and other fields. Full texts of the statements are available on the IAEA's *WorldAtom* Internet services at http://www.iaea.org/worldatom.

APPOINTMENTS. The IAEA has announced the appointment of Mr. Larry Johnson, of the USA, as the new Director of the Legal Division. Formerly the Principal Legal Officer in the UN's Office of the Legal Counsel in New York, Mr. Johnson succeeds Mr. Willem Sturms of the Netherlands. In other action, Ms. Odette Jankowitsch has succeeded Mr. Karl Keltsch as Head of the Governmental and Inter-Agency Affairs Section, in the IAEA Division of External Relations. Ms. Jankowitsch was formerly a Senior Officer in the Legal Division. In Monaco, at the IAEA Marine Environment Laboratory, Mr. Fernando Carvalho has been named Head of the Marine Environment Studies Laboratory.

SAFEGUARDS WORKSHOP. A three-day technical workshop on safeguards is being planned at the IAEA in May. The workshop is being held pursuant to a 1996 General Conference resolution that requested the Agency to convene a technical workshop on safeguards, verification technologies, and related experience for invited experts from the Middle East and other areas. About 70 experts are expected to participate in the sessions.

INCIDENT REPORTING SYSTEM. The IAEA and Nuclear Energy Agency of the Organization for Economic Co-operation have issued a public information brochure on the Incident Reporting System (IRS), which they jointly operate in the field of nuclear plant safety. The database system draws upon operational experience at nuclear power plants that may be important for accident prevention and assurance of safety. The brochure is available upon request from the IAEA Division of Public Information, or accessible on line through the IAEA's *WorldAtom* Internet Services.

RADIOLOGICAL ASSESSMENTS. The National Radiological Protection Board (NRPB) in the UK has announced it is releasing a new software package for the radiological impact assessment of continuous releases of radioactivity into the environment. Called "PC Cream", the package is a suite of models and data that estimate the transfer of radionuclides through the environment, including the atomosphere and agricultural and marine ecosystems. More information can be obtained from the NRPB, Chilton, Didcot, Oxfordshire, OX11 ORQ, UK. Fax: 01235-833891. E-mail: andy.mayall@nrpb.org.uk.

PEACE DIVIDEND. An article in the March 1997 edition of *Finance & Development* takes a detailed look at the "peace dividend" from reductions in military spending and how it is being used. Recent data on countries' military spending indicate that a sizeable peace dividend has been achieved since 1985, The article, written by Benedict Clements, Sanjeev Gupta, and Jerald Schiff, analyzes how much countries have cut, and how they have allocated the resources. *Finance and Development* is the quarterly magazine of the International Monetary Fund and the World Bank. More information may be obtained from the editor, 700 19th Street NW, Washington, DC 20431 USA, or through the magazine's Web site on the Internet at http://worldbank.org/fandd

IAEA BRIEFING FOR NGOs. In early April, the IAEA convened a briefing in New York with invited representatives of non-governmental organizations. Topics included security in the nuclear field and verification; and the contributions of nuclear energy to the world's sustainable development. The briefing was held in the course of the first meeting of the Preparatory Committee for the Review in the year 2000 of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), under which the IAEA has major responsibilities for verification and technology transfer.

NUCLEAR PLANT DECOMMISSIONING. The Nuclear Energy Agency of the Organization for Economic Co-operation and Development has issued two new reports on international progress in key areas of nuclear plant decommissioning. *The NEA Co-operative Programme on Decommissioning* presents results of a programme involving 12 countries and some 30 decommissioning projects, including 20 reactors and seven reprocessing plants. *Recycling and Reuse of Scrap Metals* presents results from the work of a Task Group in charge of examining the means for maximizing the recovery of valuabe materials from decommissioning activities, as well as for minimizing the quantity of waste from such operations. More information may be obtained from the NEA, Le Seine St. Germain, 12 boulevard des Iles, 92130 Issy-les-Moulineaux, France. Fax: +33-1-45241110.

PUBLIC INFORMATION SEMINAR IN CROATIA. In co-operation with the Croatian Ministry of Economic Affairs, the IAEA organized a public information seminar in Zagreb 25-26 March focusing on nuclear and radiation safety issues. Topics covered included nuclear and radiation applications in various fields; the safety of nuclear power plants and waste management; and Croatia's nuclear-related experience in areas of nuclear medicine and scientific research. The seminar, which also included technical visits to the Ruder Boskovic Institute and theRebro Hospital Clinic, was organized by the IAEA Division of Public Information under an extrabudgetary programme being funded by Japan.

TOWARDS INTERNATIONAL VERIFICATION OF DISARMAMENT. Officials of the IAEA, Russian Federation, and United States are planning to meet for another round of discussions at the Agency's headquarters in May on matters related to the verification of nuclear materials removed from the defense sector. Issues being addressed include legal, financial, and technical aspects of verification activities that the IAEA could undertake. The meetings are in accord with a Trilateral Initiative between the three parties announced in September 1996 at the IAEA General Conference.

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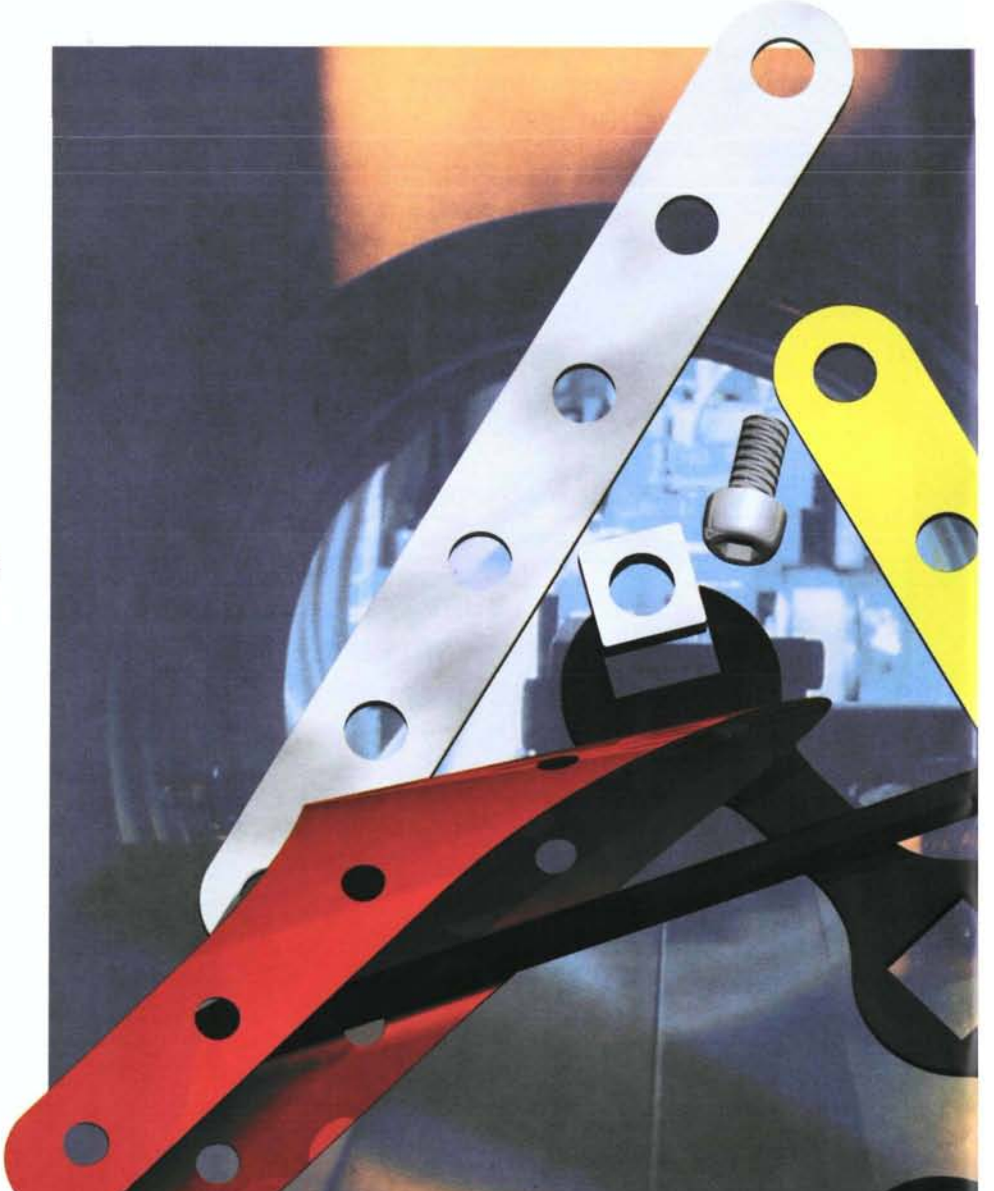

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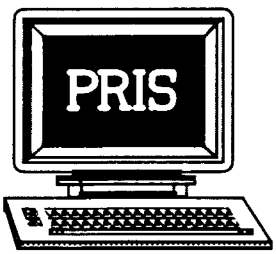


Database name
Power Reactor Information System (PRIS)

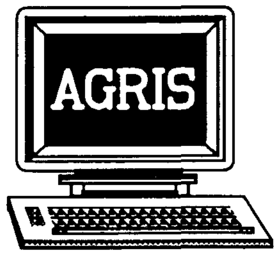
Type of database
Factual

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

IAEA contact
IAEA, Nuclear Power Engineering Section, P.O. Box 100
A-1400 Vienna, Austria
Telephone (43) (1) 2060
Telex (1)-12645
Facsimile +43 1 20607
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 and, 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

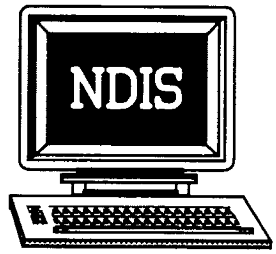
Producer
Food and Agriculture Organization of the United Nations (FAO) in co-operation with 172 national, regional, and international AGRIS centres.

IAEA contact
AGRIS Processing Unit
c/o IAEA, P.O. Box 100
A-1400 Vienna, Austria
Telephone (43) (1) 2060
Telex (1)-12645
Facsimile +43 1 20607
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 agriculture; 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

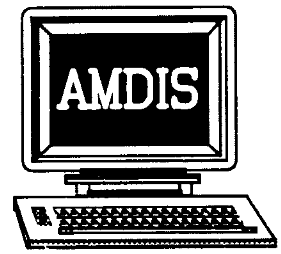
Producer
International Atomic Energy Agency in co-operation with the United States National Nuclear Data Centre at the Brookhaven National Laboratory, the Nuclear Data Bank of the Nuclear Energy Agency, Organisation for Economic Co-operation and Development in Paris, France, and a network of 22 other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

IAEA contact
IAEA Nuclear Data Section,
P.O. Box 100
A-1400 Vienna, Austria
Telephone (43) (1) 2060
Telex (1)-12645
Facsimile +43 1 20607
Electronic mail via INTERNET to ID:
ONLINE@IAEAND.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.

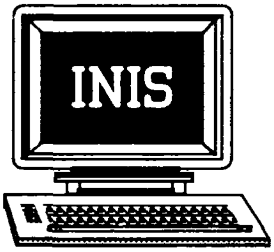
IAEA contact
IAEA Atomic and Molecular Data Unit, Nuclear Data Section
Electronic mail via BITNET to: RNDS@IAEA1;
via INTERNET to ID:
PSM@RIPCRS01.IAEA.OR.AT

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 obtained 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 91 IAEA Member States and 17 other international member organizations.

IAEA contact
IAEA, INIS Section, P.O. Box 100,
A-1400 Vienna, Austria
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Worldwide information on the peaceful uses of nuclear science and technology; economic and environmental aspects of other energy sources.

Coverage
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POSTS ANNOUNCED BY THE IAEA

ASSISTANT TO THE SECRETARY OF POLICY-MAKING ORGANS (97/013), Office of the Director General. This P-3 post assists in the smooth conduct of Policy-making Organs meetings, their Committees and Working Groups. It requires a university degree in a social science, at least six years of relevant experience, particularly in international relations; fluency in one or more of the Policy-making Organs' working languages (Arabic, Chinese, English, French, Russian and Spanish); fluency in written and spoken English is essential.
Closing date: 12 June 1997.

PERSONNEL ANALYST (97/012), Division of Personnel, Human Resource Planning and Control Unit. This P-2 post participates in annual human resource planning processes and provides support for long-range human resource planning and staffing costs control. It requires an advanced university degree in management, public or business administration with specialization in the management of human resources and course work in statistics. Also required is two years' recent experience in human resource planning, job classification or organisational methods and procedures, including experience in the application of quantitative methods; and ability to use computer-based tools in evaluating data.
Closing date: 12 June 1997.

DIRECTOR (97/009), Division of General Services, Department of Administration. This D-1 post is responsible for directing the operations of the Division of General Services and representing the IAEA in negotiations with other international organisations, governmental and municipal authorities, local and international suppliers and contractors. Required is an advanced university degree in business management, finance or civil engineering; fifteen years of experience, with at least five years at a senior management level in some of the following areas: procurement, buildings management and engineering, telecommunications and inventory control; experience in complex financial accounting and computerised systems; fluency in English, French, Russian, or Spanish is essential.
Closing date: 3 June 1997.

UNIT HEAD (97017), Division of Safeguards Information Treatment Department of Safeguards, Section for Data Processing Services. This P-5 post, under the supervision of the Section Head, manages the Unit which is the primary resource on the development and provision of information services required by the Department of Safeguards pertaining to open sources, illicit nuclear trafficking and expanded databases, in order to contribute to the review of information related safeguards. Required is an advanced university degree in information or computer science or nuclear engineering; at least 15 years' relevant experience in information management, processing and analysis in the nuclear industry, or international/governmental services; at least ten years of demonstrated experience in information processing and review, the use of computers in large information systems and the operations of complex databases.
Closing date: July 14 1997

SENIOR SAFEGUARDS INSPECTOR (97/018), Division of Operations, Department of Safeguards, Evaluation Unit. This P-5 post is responsible for co-ordinating the work of country officers and carrying out other responsibilities as assigned by divisional management; participating in Agency safeguards programmes and functioning as a safeguards inspector subject to the approval of Board of Governors. Required is an advanced university degree in a nuclear-related discipline, such as chemistry, physics, engineering, or electronics/instrumentation or equivalent; at least 15 years' experience of combined industrial accounting or destructive/non-destructive analysis; extensive experience in safeguards-related activities such as data analysis and preparation of reports; and supervisory or management experience.
Closing date: 14 July 1997

HEAD, TOKYO REGIONAL OFFICE (97/019), Division of Operations, Department of Safeguards. This P-5 post is responsible for the operation of the Tokyo Regional Office; also participates in implementation of the Agency's safeguards system and functions as a safeguards inspector subject to the approval of the Board of Governors. Required is an advanced university degree in chemistry, physics, engineering, electronics/instrumentation, or equivalent; fifteen years of combined research, industrial and safeguard experience, preferably at Japanese nuclear facilities; knowledge of electronic data processing for the treatment of information.
Closing date: 14 July 1997

SYSTEMS ANALYST (97/020), Division of Scientific and Technical Information, Department of Nuclear Energy. This P-5 post assists in defining priorities and objectives of INIS operations; analysing the System and proposing changes required to effectively meet objectives; and co-ordinating the technical, budgetary and administrative framework of the programme. Required is an advanced university degree in a nuclear-related science or engineering field; fifteen years' experience in information systems and/or computer science as well as in project management; at least five years' experience with computer-based bibliographic information systems. Ability to participate effectively in a multinational team.
Closing date: 14 July 1997

READER'S NOTE:

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

POST ANNOUNCEMENTS ON THE INTERNET. The IAEA's vacancy notices for professional positions, as well as sample application forms, are available through a global computerized network that can be accessed directly. Access is through the Internet. They can be accessed through the IAEA's World Atom services on the World Wide Web at the following address: http://www.iaea.or.at/worldatom/vacancies Also accessible is selected background information about employment at the IAEA and a sample application form. 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, P.O. Box 100, A-1400 Vienna, Austria.

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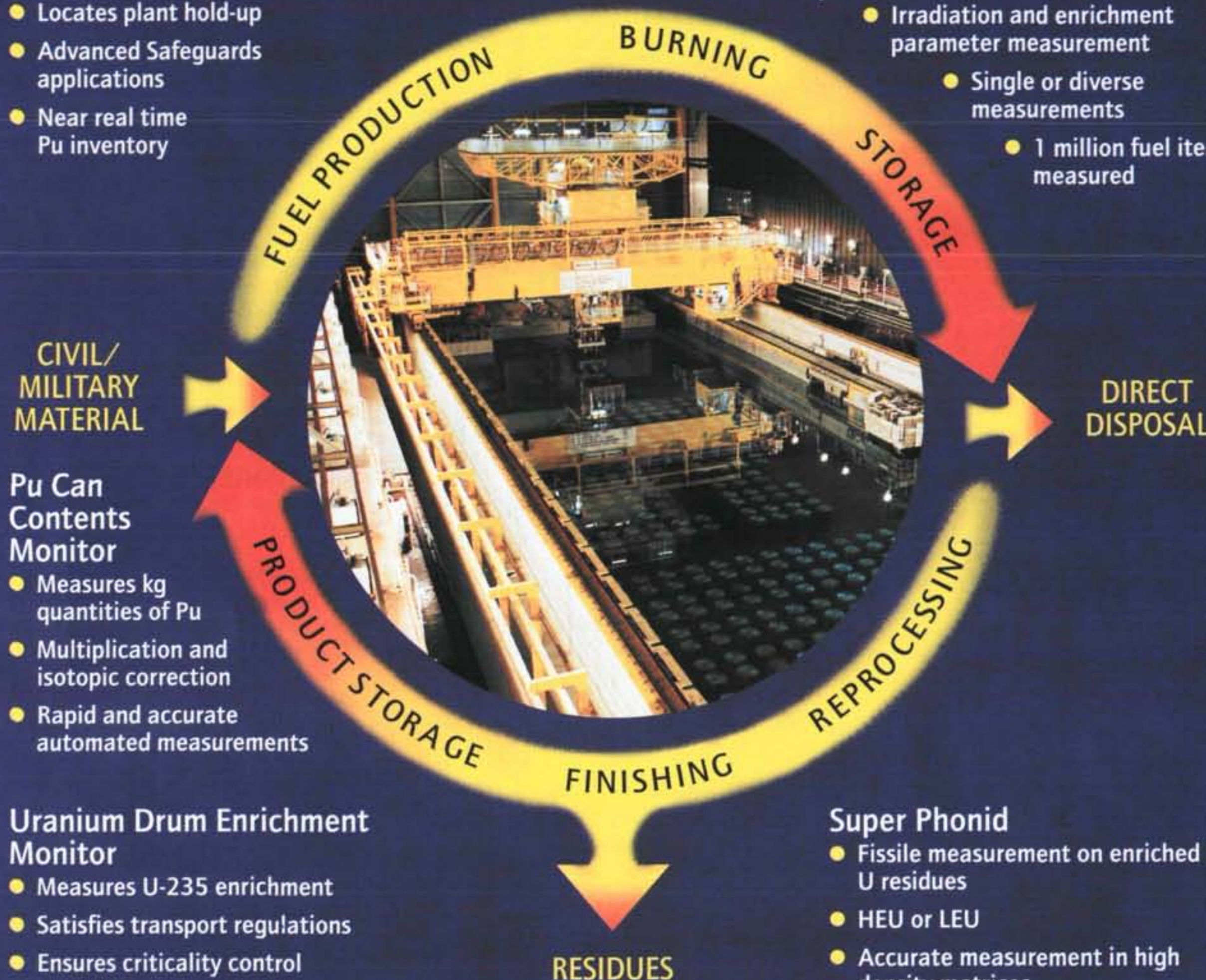

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IAEA UPCOMING CO-ORDINATED RESEARCH PROGRAMMES

Formulation of approaches to compare the potential impacts of wastes from electricity generation technologies (FACTS)

This programme emphasizes co-ordination of the (1) collection, evaluation and development of consistent data sets, where consistent data are currently lacking, for waste quantities and characteristics associated with different electricity generation technologies and (2) formulation of approaches for comparing the health and environmental impacts of radioactive and non-radioactive (chemo-toxic) substances found in waste from the generation of electricity.

Optimization of synthesis and quality control procedures for the preparation of fluorine-188 and iodine-123 labelled peptides

Cyclotron-produced radionuclides such as the positron-emitter F-18 and the single photon emitter I-123, when used in combination with peptides specifically reactive with molecular determinants present on diseased cell populations, have excellent potential for permitting molecular nuclear medicine to make a significant impact on important health care problems. Using vasoactive intestinal peptide (VIP) as a model, the labelling methods and validation strategies acquired will hopefully allow the participants to pursue other peptide/ligand systems of particular interest to national health care priorities.

Spent fuel performance assessment and research (SPAR)

The goal of the programme will be to continue building a comprehensive international database on the behaviour of spent fuel under long-term storage conditions. Such information is necessary and useful in addressing licensing or other safety issues related to long-term spent fuel storage in Member States.

Long-term behaviour of low- & intermediate-level waste packages under repository conditions

To promote research, co-operation and exchange of information among Member States on the state-of-the-art, experimental methods and understanding of processes involved in the long-term behaviour, including durability, containment of radionuclides and gas generation of short-lived low- and intermediate-level waste packages, in near-surface repository conditions.

Molecular techniques in animal disease diagnosis in developing countries

To deal with development of systems for the detection and identification of disease agents involving radioisotope-based polymerase chain reaction (PCR) technologies. Emphasis will be placed on techniques to detect rinderpest and related viruses and contagious bovine pleuropneumonia (CBPP).

Health-effects of airborne particulate matter in mining, metal refining and metal working industries.

To undertake workplace and personal monitoring of airborne particulate matter in the mining, refining and metal working industries, including tissue analyses of the workers so exposed, and to study the health effects of such exposure. The expected outcome is to obtain relevant and reliable data on sources and levels of workplace pollution in various countries and to better understand the effects of toxic compounds on the health of exposed workers.

These are selected listings, subject to change. More complete information about IAEA meetings can be obtained from the IAEA Conference Services 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

APRIL 1997

Symposium on Diagnosis and Control of Livestock Diseases using Nuclear and Related Techniques: "Towards Disease Control in the 21st Century", ***Vienna, Austria*** (7-11 April)

International Symposium on Isotope Techniques in the Study of Past and Current Environmental Changes in the Hydrosphere and the Atmosphere, ***Vienna, Austria*** (14-18 April)

Seminar on Current Status of Radiotherapy in the World, ***New York, USA*** (17-19 April)

MAY 1997

Workshop on Safeguards: Its Verification Technologies and Related Experience ***Vienna, Austria*** (13-15 May)

Symposium on Desalination of Seawater with Nuclear Energy, ***Taejon, Republic of Korea*** (26-30 May)

JUNE 1997

Symposium on Nuclear Fuel Cycle and Reactor Strategies: Adjusting to New Realities ***Vienna, Austria*** (3-6 June)

SEPTEMBER 1997

Symposium on Radiation Technology in Conservation of the Environment, ***Zakopane, Poland*** (8-12 September)

IAEA General Conference, ***Vienna, Austria*** *(29 September-2 October)*

OCTOBER 1997

Symposium on International Safeguards ***Vienna, Austria*** (13-17 October)

FAO/IAEA Regional Seminar on Nuclear Techniques for Optimizing the Use of Nutrients and Water for Maximizing Plant Productivity and Environmental Preservation ***Piracicaba, Brazil*** (27-31 October)

NOVEMBER 1997

International Conference on Physical Protection of Nuclear Materials: Experience in Regulation, Implementation and Operation ***Vienna, Austria*** (10-14 November)

Symposium on Upgrading the Fire Safety of Operating Nuclear Power Plants ***Vienna, Austria*** (17-21 November)

International Conference on Low Doses of Ionizing Radiation: Biological Effects and Regulatory Control ***Seville, Spain*** (17-21 November)

IAEA BULLETIN

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1959
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1960
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Colombia
Ghana
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1961
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Zaire

1962
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1963
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Bolivia
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Libyan Arab Jamahiriya
Syrian Arab Republic
Uruguay

1964
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Jordan
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Uganda

1968
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1969
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Ireland

1972
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1994
Former Yugoslav Republic of Macedonia
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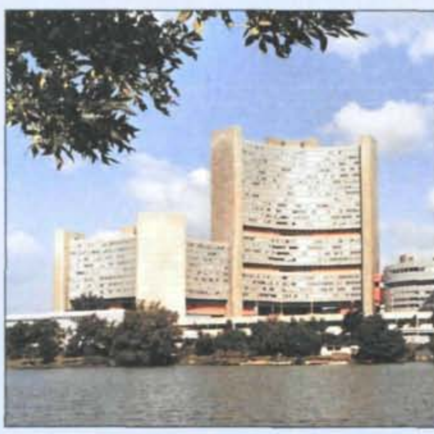
1995
Bosnia and Herzegovina

1996
Georgia
Moldova

Eighteen ratifications were required to bring the IAEA's Statute into force. By 29 July 1957, the States in bold face (including the former Czechoslovakia) 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.

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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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INSIDE

TECHNICAL CO-OPERATION

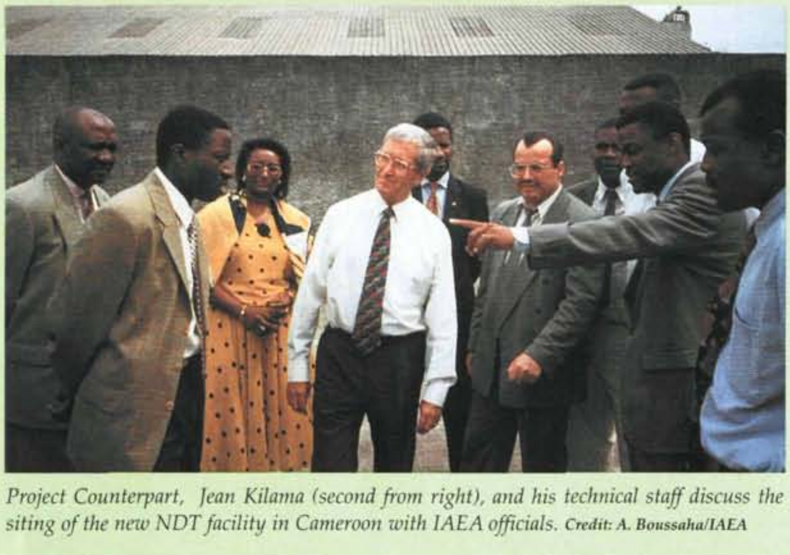
International Atomic Energy Agency

March 1997 Vol. 3, No. 1

CONTENTS:

NDT: An indispensable tool for industry

Cameroon's National Hydrocarbon Corporation (NHC) is involved with a consortium of international oil companies in a US$2 billion project to build 1,060 kilometres of pipeline to carry oil from Chad to northern Cameroon. An essential part of the project is quality control of pipe segments and welds, as well as fittings, pumps, valves, and other components during construction. Their integrity has to be maintained throughout the pipeline's operational life, for safety, efficiency and environmental protection.



Project Counterpart, Jean Kilama (second from right), and his technical staff discuss the siting of the new NDT facility in Cameroon with IAEA officials. Credit: A. Boussaha/IAEA

Non-destructive testing (NDT) techniques are vital to providing the high level of quality assurance required for such industrial activities. Until recently, Cameroon's participation in the operation — and therefore its benefit in employment and income — has been limited because it lacks NDT capability and operators of its own. An IAEA technical co-operation Model Project launched this year aims to help Cameroon develop its NDT capabilities for quality control in industry and, specifically, to establish NDT centres that could participate in the implementation of certain services needed for the pipeline.

continued on page 4

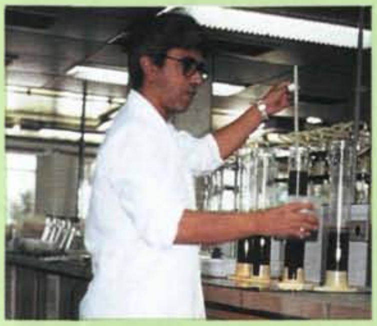
Brazil turns beam on chemical effluents...

Hoechst do Brazil is one of the largest chemical and pharmaceutical manufacturers in the region, and its operations create complex streams of waste. Even after in-plant processing to make them acceptable for conventional sewage treatment, some residues need to be impounded for long periods or interred in engineered tombs. So the charges for treatment and disposal are invariably high. Hoechst do Brasil currently pays over US$10 million bi-annually to the sanitation company of Sao Paulo State (SABESP) to discharge liquid effluent from just one production site.

Hoechst's waste is in many ways representative of waste from large industrial activities generally. Faced

continued on page 2

Brazil turns beam on chemical effluents...*(from page 1)*



SABESP technician conducting tests on chemical effluents. Credit: S. Ratnasabapathy

with increasing treatment problems from rapid industrialization, Brazil is looking for new solutions. Its Institute for Nuclear Energy and Research (IPEN) recently did preliminary treatment tests on Hoechst effluents using an electron beam on the scale of a small pilot plant. The stream contained low molecular weight aromatic and chlorinated hydrocarbons, phenols, as well as dyes and other complex organic compounds partly unaffected by the conventional biological treatment methods used by SABESP. The results for various stream components ranged from modest but promising to encouraging, even at the relatively low doses delivered (5-20 kGray).

The IAEA is supporting this effort through a technical co-operation Model Project launched in 1997 to raise the level of research and evaluate the potential of electron-beam treatment of complex industrial wastes on a commercial scale. Under it Hoechst do Brasil, and IPEN are jointly involved in funding and implementing three principal activities: upgrading the pilot plant; introducing procedures to better characterize the irradiated waste; and optimizing operating conditions to produce effluents that meet both national and international standards. In this project SABESP and IPEN are also working on the disinfection of urban sludges and domestic effluents. The IAEA will help upgrade the effluent characterization lab and, because post-irradiation toxicological studies are a crucial element of the project, help with both radiation and chemical hazard monitoring and protection.

The experimental results will help to assess the economic feasibility of treating the waste on an industrial scale. The project is designed to produce reliable data on engineering, performance, and costs so that the cost-benefit ratio of electron-beam treatment can be properly assessed. If the figures show it is conducive to commercialization, the process could spread beyond Hoechst and also beyond Brazil.

...Argentina irradiates urban sludge

Sewage sludge irradiation plant in Tucuman, Argentina
Credit: CNEA

A major waste problem afflicting large cities worldwide is disposal of sewage sludge; the lumpy semi-solid stuff left after liquid waste carried by urban sewers is treated. One widely adopted "solution" is to dump it in the sea. But this not an option everywhere. Tucuman, for instance, Argentina's sixth biggest city (population: 400,000), lies far inland in a high valley in the northeast. The Andes are on its east side, while the Atlantic ocean on its west is more than 1,000 kilometres away.

What can be done with the nearly 90,000 tonnes of sludge the city sewage treatment plant's anaerobic digestors produce each year? The city budget cannot afford incineration. Burial is a health hazard because the valley is sheltered by mountains and has a warm climate, conditions conducive to the spread of diseases. There is already a high incidence of cholera, diarrhoea and hepatitis. The current solution is clearly unsatisfacory: dumping it in the Sali River, which goes dry in the winter when it freezes in the mountains.

Utilising the expertise of a mature nuclear industry, Argentina opted to address the problem by irradiating Tucuman's sludge. The Atomic Energy Commission (CNEA) adapted a German-design gamma irradiator to local requirements, and will also make available the cobalt-60 sources required to produce the radioactive charge required to treat up to 180 cubic metres of sludge per day. So the world's first irradiation plant dedicated to decontaminating urban sludge on a commercial scale now stands next to the city sewage depuration plant. It will come into operation later this year.

Irradiation technology for sludge has been well tested. Pilot scale plants were operational in Germany, Japan and the United States for many years and clearly demonstrated the feasibility. But less costly technologies were available. As long as these worked adequately and economically, sewage firms and municipalities were unlikely to invest in irradiation. But when new plants and extensions to old sludge disposal systems are needed, irradiation can be an option, particularly if a profitable use can be found for irradiated sludge.

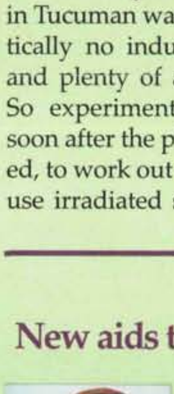
Many rapidly developing countries are studying the option, mostly still on a laboratory scale. India has been studying various possibilities in a demonstration-size plant for the past seven years. In most countries, growth of industries around urban centres has complicated the economics. Irradiation has no effect on industrial wastes such as heavy metals, which makes post-irradiation sludge unsuitable for uses such as agriculture.

Conversely, one principal reason for selecting the irradiation route in Tucuman was that there is practically no industry near the city and plenty of agricultural needs. So experiments began in 1996, soon after the plant was constructed, to work out the best regimes to use irradiated sludge as fertilizer and soil-amendment material. Both are in demand in this predominantly agricultural zone, where many areas have soils that are nutrient depleted and suffer from erosion and compactment.

Argentine scientist, Cecilia Magnavacca, measures sugarcane yield in a field fertilized with irradiated sludge.
Credit: CNEA

Argentine scientists have taken part in FAO/IAEA Co-ordinated Research Programmes (CRPs) on radiation treatment and safe re-utilization of sludges. Moreover, a new three-year TC project was initiated in 1997 to assist the Tucuman experiments by providing experts, equipment and training in nutrient evaluation of the particular post-irradiation sludges and their agricultural value. In the short term, the project will benefit farmers by allowing them to replace chemical fertilizers with irradiated sludge. Over the longer term, degraded lands could be recovered and sanitary conditions in the zone should improve.

New aids to cure old ills



Prof. Janusz M. Rosiak

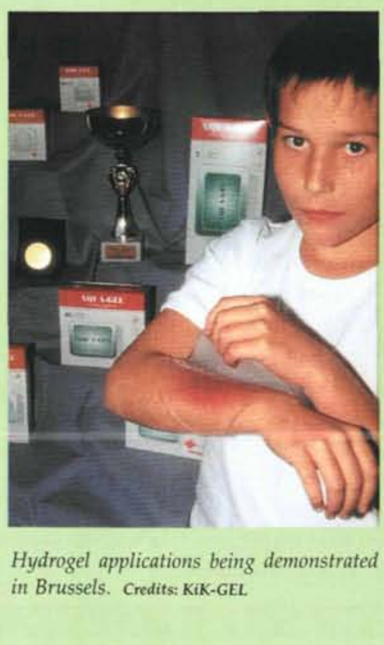
Research and development to use radiation to synthesize and bond together various materials for biomedical applications has been going on since the 1970s. Some of these so called "biomaterials" are now widely used medically, mostly to treat burns and other wounds, and already on the hospital doorstep are derivative devices that can be implanted in patients' bodies to treat a variety of ailments and conditions. Radiation has opened the way to producing such materials. It is able to synthesize, mold, fabricate and sterilize them in a single operation, at any temperature and pressure, in viscous, solid and heterogeneous forms, and in complex phases at various doses.

The Institute of Applied Radiation Chemistry at Poland's Technical University in Lodz is one of several centres particularly active in recent years in developing a variety of new biomaterials, generally called hydrogels. Many products are in advanced stages of development and trials. A few have passed all the clinical tests and been approved by a number of national authorities, including the U.S. Food and Drug Administration (FDA).

Further information on hydrogel dressings can be obtained at http://www.gwc.net.pl./kikgel.
Prof. Rosiak can be contacted via e-mail at rosiakjm@mitr.p.lodz.pl.

The 'Rosiak-method' for hydrogel dressings was developed by the Lodz group led by Prof. Janusz Rosiak. It won the gold medal in 1993 at the Brussels Eureka World Exhibition of Invention, Research and Industrial Innovation. Two Lodz hydrogels, one for dressing bedsores, burns and other wounds and skin grafts; the other for internal controlled release of prostaglandins to treat ulcers — are on the market in the Czech Republic, Germany, Hungary, and Slovakia.

"Though we patented technology only in developed countries like Germany, the UK and the USA, it has been transferred within the framework of IAEA expert missions and projects to developing countries like Brazil, China, Indonesia and Malaysia", says Rosiak who collaborates closely with the Agency. Hydrogel dressings prevent bacterial invasion from outside, while being permeable to drugs such as antimicrobials and allowing gases and water vapour to escape from the wound site. The material adheres well to the wounds and normal skin but, unlike stitches, can be removed painlessly. Lodz has other products at an advanced stage, including an artificial pancreas (the gland which produces insulin), grafts for blood and other vascular vessels, eye inserts to slowly release the alkaloid pilocarpine against glaucoma, and materials for dental surgery.



Hydrogel applications being demonstrated in Brussels. Credits: KiK-GEL

NDT: An indispensable tool for industry *(from page 1)*

No major advanced industrial activity is conceivable without NDT techniques today. And it is an indispensable item in maintaining industrial safety. Reconstruction of the pipeline system in war-shattered Sarajevo, for example, which is funded by a \$20 million World Bank credit and \$60 million via bilateral arrangements, would be impossible using the old destructive testing methods. IAEA technical co-operation has just started a Model Project here too, to increase and upgrade national NDT capability.

Modern NDT techniques began with radiographic testing shortly after the discovery of X-rays in 1895. It developed rapidly, for quality control of arms and other military products, during the Second World War. Research and development in the 1950s was largely sponsored by the nuclear and aerospace industries in their search for new inspection technologies to ensure safety via the quality and reliability of critical components.

The five most widely applied techniques are dye penetrant, eddy current, magnetic particle, radiographic (still the most popular), and ultrasonic testing. No country aspiring to enter the global industrial market can do without these.

Most everyday industrial products are immensely complex, made up of numerous components welded and assembled. The average automobile includes some 2.5 kilometers of wiring and 100 critical welds. To be safe and reliable, products and factories alike depend on each and every part functioning properly for at least its minimum design life, and quality control of components begins with detecting and correcting defects and imperfections in the materials of which they are made.

To be competitive, manufacturers must turn out products that are safe and reliable. They must also keep production costs down and cannot afford factory shutdowns or overuse expensive materials. Only NDT techniques can do the precision checks and measurements plant operators require, on both plant and products, while the manufacturing process is underway.

Levels of NDT certification

The reliability of any NDT test depends on the abilities of those responsible for performing it. The IAEA qualification and certification system, based on national procedures in highly industrialized countries, is based on the new ISO standard, which details three levels of competence.

Level 1 - may be authorized to set up equipment, do tests under written instructions and supervised by level 2 or 3, classify (with written approval of a level 3) and report the results.

Level 2 - may be authorized to perform and direct testing according to established or recognized procedures.

Level 3 - may be authorized to direct any operation in the (NDT) methods for which certification has been received.

Certification is done by a National NDT Society which is affiliated with the ICNDT. Eligibility for examination is based on duration of training in each NDT method. Trainees must progress from one level to the next and minimum experience is specified for each level and method. Access to level 3 by a certified level 2 operator could take 1-4 years, depending on educational qualifications in science or engineering prior to NDT training.

Nearly 30 years ago, Argentina asked the UN Development Program (UNDP) for help to set up a national center for non-destructive testing. The simple request sparked a very successful IAEA/TC regional program involving 18 countries in Latin America and the Caribbean (LAC). A second programme based on the same lines, involving 13 countries in Asia and the Pacific was completed in 1996, and a third, for the African region, started in 1991 and has just entered its second five-year phase.

Regional and national training under technical co-operation projects is focused on the five main techniques (noted earlier), with the primary objective of developing national NDT capacities to meet a country's immediate and foreseeable needs. This means hands-on experience with NDT equipment, procedures, standards and techniques; interpreting the results of inspections; diagnosing the causes of detected defects of fabrication or deterioration of material in service and, where need be, taking remedial actions. To be sustainable, national capability must be established to train, examine, license and certify professionals and staff; absorb and introduce NDT equipment, procedures, standards and techniques from technological advances made worldwide; and to develop new techniques.

The strategy for the IAEA programmes in LAC was to establish a common regional system that met international standards. The strategy also aims to train large numbers at lower levels initially, and then to help those more capable to progress to the top level — capable of training, qualifying and certifying others. In this way the hierarchy needed to provide professional services throughout the region would gradually be put into place. Competence required for certification at all the three recognized levels (see box at left) must always meet the highest international standards.

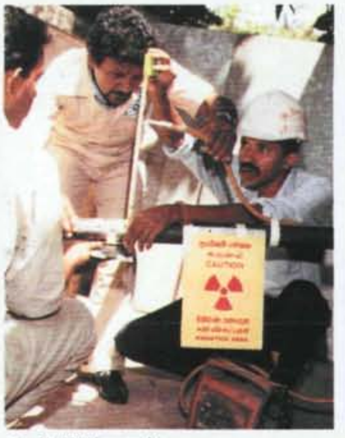
All 18 LAC countries have now set up national NDT societies to oversee and ensure adherence to such standards and meet their needs. Most have their own level-3 personnel able to train and certify others as demand for services increases with continued industrialization. Between 1984 and 1994 some 22,000 people were trained in the region, without any project input but keeping to IAEA guidelines and methods set by the project.

Membership in the International Committee for Non Destructive Testing (ICNDT) signifies recognition that a country's technical competence has reached the top level. At the start of the regional programme only Argentina and Brazil were members. In 1989, ICNDT accepted 11 additional memebers. The LAC regional programme also influenced the drafting of a standard by the International Organization of Standardization (ISO) for qualification and certification of NDT personnel. The training programmes for the main NDT techniques, elaborated and published by the IAEA as technical documents (TECDOC-407/628), are a recommended guideline in the new ISO standard.

NDT entrepreneurs

Sri Lankan mechanical engineer Upul Ekanayake (shown below at right) was trained in the United Kingdom in 1982 under an IAEA fellowship and later certified (level-2) in NDT. He gained experience as an NDT inspector in the State Engineering Corporation of Sri Lanka for six years and then worked with the Bahrain Inspection Establishment for 30 months as an inspection engineer. Back home he started his own company, Electro Ref Engineers (ERE), to service air conditioning and refrigeration systems. Employing NDT personnel trained and certified by The Sri Lanka Atomic Energy Authority (SLAEA), ERE was the first private company in Sri Lanka to introduce NDT techniques to its client industries. In 1995 the company had a turnover of some 3,000,000 SL rupees from NDT activities alone. Ekanayake says his company is expanding to meet increasing demand, and with the help of the SLAEA, plans to train more staff, including himself to improve and extend ERE's services to the public and private sectors.

A common trend in Asia and Latin America is that both the public and private sectors now tend to hire NDT services rather than retain permanent staff and equipment of their own. Operators have responded by forming companies, such as Ekanayake's ERE, with NDT and other support staff and equipment, to provide the services. Such use of high-paid expertise and support staff is a boost for national employment, industrial safety-efficiency and the economy as a whole. But the key role remains with national NDT laboratories, such as of SLAEA, that have absorbed the most advanced techniques. These can train and help to certify trainees and also act as independent arbiter in disputes between service-providers and their clients. Many national labs are increasingly undertaking industry-orientated research in NDT.



Credit: U. Ekanayake

The "Industrious" Atom

NDT techniques are critical to quality and safety in advanced industries.
Credit: CGA

The most common uses for radiation processing are in industry. Major industrial activities from heavy industries, such as automotive, aerospace and rail transportation to electronics and microchips, employ nondestructive testing (NDT) techniques to assure quality control and safety. NDT services range from design studies, sensors and control systems; to X-ray and gamma ray inspection and measurements using tracers such as helium and other gases. The photo illustrates a process called microfocus X-ray tube inspection of an aircraft engine. NDT inspectors are specialists certified to exacting standards by national/international NDT boards. Other radiation processes are used to develop new materials with improved performance, reduce spoilage of foods and to mitigate environmental pollution.

The role of IAEA Technical Co-operation is to advise its Member States on developments and new techniques, and to help develop national capabilities to support safe and effective applications of radiation processing. This **INSIDE TC** describes some industrial uses of radiation and the people that are making quality management a reality in developing countries.

Radiation adds stretch to latex

Malaysia's latest development plan (1996-2000) reflects the vision of virtually all the rapidly developing countries of the Asia/Pacific region: industrialize, with emphasis on high technology, while protecting the natural environment. However, the country's rapid industrialization has already resulted in serious air pollution. Now, with support from IAEA technical co-operation programmes, radiation technologies are increasingly being applied across a range of industries in Malaysia and other Asia/Pacific countries to help lessen such pollution.

The conventional process is called vulcanization, or cross-linking, and entails heating and adding sulphur or other chemicals to form cross-links between the characteristic long chains of elastomer molecules — as has been done for more than a century to make rubber tyres. The more sulphur used, the harder the product. The vulcanized product withstands higher temperatures, pressures, and mechanical challenges to its integrity.

But sulphur vulcanization has significant human health, environmental and even economic drawbacks. It needs high temperatures to start the chemical reactions; it emits smelly and toxic gases; and it produces numerous unwanted chemical residues that have to be removed from the final products.

One promising radiation application improves the properties of elastomeric (stretchable) materials such as natural and artificial rubber and rubber-like plastics, which are used in numerous products, from insulated wiring in automobiles to condoms. Radiation cross-linking is a well-proven method that bypasses all these negative effects. Rubber, plastics and other polymers are cross-linked simply by exposing the material to high energy gamma rays from a cobalt-60 source or high energy electron beams. Radiation cross-linking is a room temperature treatment, itself an important cost advantage; it is easily controlled; and the desired properties are obtained simply by changing the dose (irradiation time). The transformed materials are in no way inferior to those produced by sulphur vulcanization.

Indonesian trainees get hands on experience with radiation vulcanization. Credit: IAEA

IAEA/TC has sponsored a number of national projects to help transfer such radiation technologies to developing countries. In addition, a Regional Co-operative Agreement (RCA) supported by the UN Development Programme (UNDP), provided international expert visits, workshops, seminars, scholarships, training and hands-on experience. The principal objective of these activities has been to promote transfer of the techniques and know-how from counterpart national nuclear research institutes (NNRI) to the commercial industrial sectors.

For the rubber-growing countries of the RCA group, the radiation cross-linking of natural rubber latex to make a variety of products, such as surgical gloves and condoms, is most important. The Radiation Vulcanization of Natural Rubber Latex (RVNRL) products are free of nitrosoamine compounds and RVNRL gloves have low ash content and low emission of sulphur dioxide when incinerated.

Many Asia Pacific countries have already advanced toward commercialization of RVNRL, with trial or pilot scale production of rubber-dipped products underway in India, Indonesia, Malaysia, Philippines, Sri Lanka, Thailand and Viet Nam. India and Indonesia set up semi-commercial plants in 1993. Malaysia began operating the third plant in 1996, which is the largest in the region with maximum capacity of 6,000 cubic metres of radiation vulcanized latex a year. Thailand will have the fourth in operation late this year.

Later in the year the Agency will organize a co-ordinated research programme (CRP) on RVNRL, which will link a network of developing and developed countries in the field according to a strict research protocol over a 5-year period. Japan, where radiation cross-linking is used in almost every industry, will play a lead role.

R&D on RVNRL has been done in nine latex producing countries with technical assistance from Japan's Takasaki Radiation Chemistry Research Establishment. Trials of dipping products done in the early 1990s in Indonesia and Viet Nam suggest the need to improve physical properties like tensile strength and tear resistance. This research may be conducted at the four new plants. Another new effort led by Japan has begun to develop low-cost irradiators for small-scale RVNRL and dipping-product manufacturing. As a substantial amount of latex produced in the region is from small scattered plantations, easier access to small plants will accelerate the commercialization process.

In brief: Updates of stories and news events

Advanced degrees in Medical Physics

One of the original 12 Model Projects approved in 1994 "National programme of training in Medical Physics" successfully completed its objectives in Mexico at the end of last year. Medical Radiation Physics is concerned with the accurate and safe medical exposure to ionizing radiation for the treatment of cancer and the diagnosis of human disease. It is also allied with health physics in regard to radiation protection and safety.

During 2 years of operation 15 hospital employees (physicists and engineers) upgraded their skills by participating in an advanced educational training programme consisting of 4 modules of 10 weeks duration each: module I on fundamentals of medical physics, II on radiological safety and quality assurance, III on radiotherapy treatment planning and IV on diagnostic radiology and nuclear medicine. Ten of the participants have successfully completed their training and have received an accredited diploma in Medical Physics. Parallel to this training, an agreement was reached between the National Institute of Nuclear Investigations (ININ) and the Autonomous University of the State of Mexico (UAEM) culminating in the establishment at the University of a modern syllabus leading to MSc and PhD degrees in Medical Physics covering the areas of radiotherapy, diagnostic radiology and nuclear medicine. This programme now continues without assistance from the Agency and is open to students from the region; 20 students are currently enrolled.

Andean barley is spreading

A new Model Project in Peru "Introduction of barley and other native crop mutant cultivars" is expanding the results achieved under previous efforts (see "Barley climbs the Andes" — **Inside TC**, March 1996). The objective is to increase food supply and farm income in the Andean Highlands by introducing a radiation-induced mutant barley line called "UNA La Molina 95". Earlier field testing successfully demonstrated that the new variety is drought and frost resistant, has a high nutritional value, matures early and provides yield increases up to a factor of two even under the harsh growing conditions in the highlands.

One of the immediate objectives is the development of sufficient seed capacity (up to 400t per year) to support widespread cultivation. Near the coastal town of Canete, on one of many seed production plots supervised by the project counterpart Mr. Romero Loli, harvest is already underway and soon the Government will start distributing the seed to farmers living or resettling in the highlands. Further field research is expected to yield new varieties of barley and kiwicha in 5-6 years time, whereas an advanced M2 generation of quinoa may produce a promising new variety within 3 years.

Targeting rinderpest eradication in Africa

Representatives of the main countries involved in the Pan-African Rinderpest Campaign (PARC) outlined their plans for eradicating the disease from Africa, and agreed it could be achieved over the next three to five years at a meeting in January 1997, organized by the Department of Technical Co-operation and the Joint FAO/IAEA Division. PARC involves 34 countries with all but two having rinderpest under control. Also attending were representatives of the campaign's donor organizations, including the European Union (EU) and the United States Agency for International Development (USAID).

During the Vienna meeting, participants defined the problems associated with the surveillance of residual rinderpest and discussed possible solutions. These involved the strengthening of disease surveillance and of the existing network through regional reference laboratories that will help national laboratories in the diagnosis of rinderpest. Participants agreed that the eradication of rinderpest from African countries will not only help to avoid disastrous cattle losses and resulting famines, but will also allow more trade in livestock and livestock products.

International livestock trade is regulated through the Organisation Internationale des Epizooties (OIE) by a set of rules and specific declarations relating to various diseases, a process called the "OIE Pathway". For rinderpest, country declarations culminate in the final objective "Declaration of Freedom from Infection". The majority of African countries are well on the way to achieving this goal and have already made "Provisional Declarations of Freedom from Disease".

In Memoriam

Vitomir Markovic
August 1936 — March 1997

In recognition of his long and distinguished service to developing countries in the field of industrial applications.

Private sector adopting nuclear techniques

Extending the shelf life of agricultural produce is a key element of food security
Credit: IAEA

Over the past 15 years, some 40 cobalt-60 irradiators have been supplied to developing countries through IAEA technical co-operation projects, along with the required regulations, infrastructure, and trained personnel to operate them safely. These facilities have been used for many purposes including sterilizing medical supplies, extending the life of fresh foods and dried foodstuffs, synthesizing industrial materials, modifying the physical properties of plastics and eradicating insect pests.

But such techniques become truly sustainable only when they move beyond the laboratory and the national counterparts to the industrial sector, where people with business know-how and financial resources can apply them commercially.

Attracting private industry is seldom easy, but occurs when projects can contribute sustainably to the recipient national economies. One noteworthy example is Gamma-Pak Holdings, a Turkish private company recently established in Istanbul. Turkey's first gamma irradiator, a medium size Cobalt-60 plant built under an IAEA/UNDP/Turkish Government project, began operating in 1993 at a nuclear research centre in Sarayköy, Ankara. A group of entrepreneurs led by Kubilay Göktalay were impressed by its performance and conducted a market survey of the Istanbul region. In 1994, they launched Gamma-Pak, purchased their own, much bigger, gamma irradiator and got it up and running in Istanbul's large industrial zone.

Gamma-Pak's irradiator is already making profits. Targeting the industrial needs of companies in the Istanbul region, Gamma-Pak contractually irradiates single-use medical products such as surgical gloves, syringes and catheters and decontaminates spices and dried fruits for trading companies. One area of growing promise uses idle capacity to crosslink polymers to make floor heating pipes.

Though completely private, Gamma-Pak is operated under the rules and supervision of the Turkish Atomic Energy Authority. "The links between government and private company are permanent", IAEA officials say. "The safety of equipment, product, personnel, public and the environment are issues for national nuclear authorities. So as long as the plant exists the links exist."

Peru provides another example of nuclear technology extending to the private sector. An IAEA project to support the installation of a multi-purpose irradiation facility, launched in 1984, made little headway over almost 10 years because the Atomic Energy Commission (IPEN) had difficulties raising its share of funding. But IPEN project counterpart Carlos del Valle and IAEA staff resisted repeated calls to abort the project. Their perseverance paid off in the early 1990s, when two entrepreneurs - Jesus Aymar Alejos and Manuel Mendoza - became convinced that the irradiator had commercial potential for their two separate companies.

Together with IPEN they formed a new company, Inmune Sociedad Anonima, and completed the essential ground structures dedicated to accommodate the irradiator, which was provided by the Agency with project funds. The plant was formally inaugurated in April 1996, but has yet to break even because its throughput is limited to medical products and a few others items. The irradiation facility was built next door to Santa Anita, a planned commercial centre for agricultural produce from all over the country. It is expected that a large portion of the throughput would be from excess agricultural produce from the centre.

Aymar, the General Manager, and partner Mendoza have begun to build-up production from a number of sources. They say they want it to be a gradual but steady progression. They have plans to put in new operations and modernize the plant. The new owners believe that their services will be both economical and make a major contribution to greater food security in Peru.

INSIDE Technical Co-operation is researched and written for the IAEA by an independent journalist assigned by Maximedia. The stories may be freely reproduced. For more information contact: IAEA TC Programme Co-ordination Section, P.O. Box 100, A-1400 Vienna, Austria. Tel: +43 1 2060 26005; Fax: +43 1 2060 29633; e-mail: foucharp@tcpo1.iaea.or.at