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ENVIRONMENTAL DEVELOPMENT

DEVELOPPEMENT ET ENVIRONNEMENT

ЭКОЛОГИЧЕСКИ РАЦИОНАЛЬНОЕ РАЗВИТИЕ

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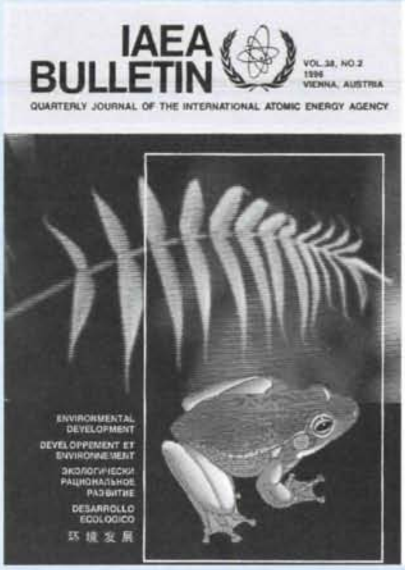

Front Cover: Through a range of activities and projects, nuclear and related techniques are helping scientists to better understand the changing world we live in. They are being fruitfully applied in studies of urbanization and air pollution, climate change and global warming, environmental protection and restoration, and water resources, for example, in many countries and regions. In other ways, nuclear power for electricity production is contributing to sustainable energy and environmental goals, including those related to the sound management of wastes. To assist decision-makers in selecting energy options, the IAEA is supporting efforts to evaluate methods for comparing environmental and related impacts of waste disposal from different sources of electricity generation.
(Cover design: Hannelore Wilczek, IAEA; Stefan Brodek, Vienna.)

Facing Page: Water in many African countries and other arid parts of the world is an especially precious resource, one that IAEA-supported projects are helping countries to more effectively preserve and replenish.
(Credit: Carnemark/World Bank)

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Environmental changes in perspective: The global response to challenges

Through Earthwatch and the Agenda 21 action plan, the IAEA is contributing to global efforts addressing environmental problems

by Pier Roberto Danesi and Hadj Slimane Cherif

As we approach the end of the second millennium, a series of major problems seems to threaten the world's rapidly expanding population: the consequences of global warming, the hole in the ozone layer, pollution of the Earth's oceans, fresh waters, soil and atmosphere, the declining biodiversity, and the degradation of land and soil quality. Concerns appear to be justified, at least as long as the world's main development goals continue to be the economic levels of its wealthiest nations and their high consumption and waste production patterns.

How can we better assess and appreciate the impact that anthropogenic environmental changes have made to our planet and the magnitude of population growth?

It may first be worthwhile to place them into an appropriate time perspective relative to the overall age of the Earth. Our planet was formed about 4.5 billion years ago. It took about one billion years before the first bacterial organisms appeared and about 2.5 billion years before the atmosphere contained enough oxygen to eventually permit the formation of the first modern cells (eucaryotic cells). Nevertheless, their development required another one billion years. The development of life over the following 1.5 billion years progressively brought the environment of our planet to the state it was known to the first *homo sapiens* of about 100,000 years ago. In practice, it took the entire age of the Earth, namely about 4.5 billion years, to develop a natural environment that stayed practically unaffected by anthropogenic effects until about 10,000 years ago.

The "Cosmic Clock". The time of major events which characterized the evolution of the Earth can be represented on what has been called a "cosmic clock". *(See figure, page 4.)* This clock has a dial compressing the entire history of the planet into a 24-hour day. The birth of the planet is set at 00:00 hours and the present is set at 24:00 hours. On this scale the appearance of *homo sapiens* occurs only at about two seconds before present. The rapidity of the induced changes is even more striking when one considers that our ancestors were hunter-gatherers until 10,000 years ago when, with the domestication of plants and animals, agriculture was invented. It is then only at about 0.2 seconds before present in the "cosmic clock", when human communities started to become controllers of the global ecosystem rather than an integral part of it. *(See table, page 4.)*

As agriculture developed and more of the Earth's surface was modified, food surpluses permitted the establishment of permanent settlements. With the introduction of metal-working technology, more efficient tools for environmental manipulation were introduced. Gradually agriculture and metal smelting expanded at the expense of forests. Cleared land was used for cultivation and forest wood for construction and to generate charcoal for larger scale metal smelting. However these processes had moderate or negligible impacts on the global environment until the beginning of the Industrial Revolution (about 250 years ago or just 0.004 seconds before present on the "cosmic clock").

As coal replaced wood for fuel, triggering the rapid rise of fossil fuel consumption and the beginning of industrialization in northwest Europe, the magnitude of environmental changes started to increase dramatically. Intensive agriculture and expanding industrial activities — the creators of food security and wealth which permitted the human race to expand — would also become threats to the Earth's life support system. However, considering that in 1830 the world population was about one billion, it is not surprising that it took more than another

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Rice fields in Indonesia. *(Credit: Curt Carnemark, World Bank)*

century before the world started to become aware of the environmental changes that industrial development and agriculture were causing.

The size of the problem can be fully appreciated when one considers the rapidity of the world population's growth after the Industrial Revolution. *(See graph, next page.)* The population of the world was about 200 million at the time the Greek philosopher Aristotle was born (384 BC). It took about 2000 years (1650) to reach 500 million. Over the next 150 years (by 1830) the population had doubled to one billion and it took only 100 years (1930) to reach two billion.

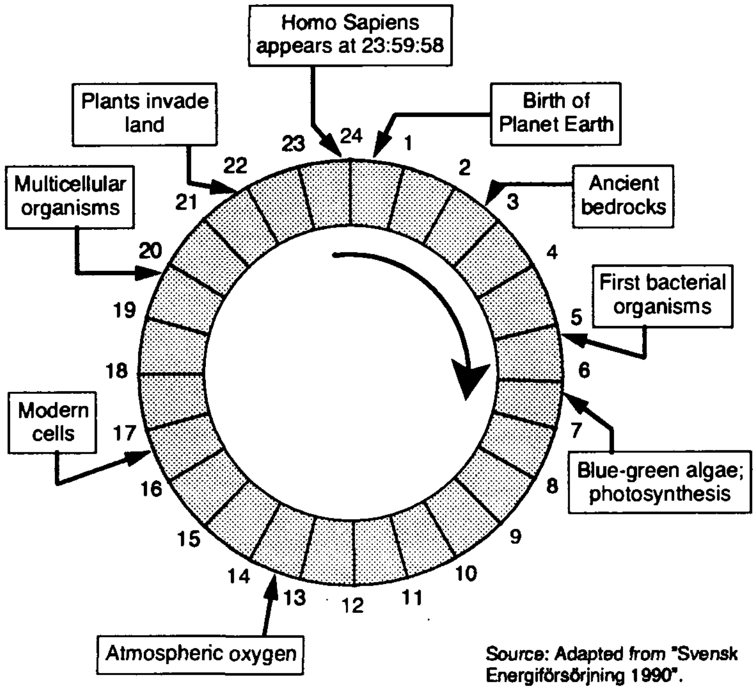
Now, only 65 years later, we are approaching the six billion value. By the year 2100 we will be 12 billion. This population growth is particularly alarming because it will almost entirely occur in the developing countries, which already host 77% of the world population but share only 15% of the world income.

Moreover, actual trends indicate that soon the world population will mainly concentrate (about 50%) in big megacities, having between 15 and 25 million inhabitants. The concentration of people in big cities has strong negative effects on both urban and rural environments. Cities generate huge amounts of solid, liquid, and gaseous wastes, causing water and air pollution problems. Moreover, they can create enormous sanitary problems when human and industrial waste is disposed of without appropriate and costly measures. At the same time, rural areas tend to become environmentally damaged as migration to towns encourages the abandonment of environmentally sound agricultural practices, such as irrigation, terracing, and crop rotation. The push towards the introduction of cash crops creates additional environmental problems.

However, it must be emphasized that the influence of population growth on environmental changes is rather complex. It involves, among others, complex correlations among income levels, production, and consumption patterns. For example, although the industrialized countries contain 23% of the world population, it has been estimated that they are presently producing more than 75% of the world's waste. The main reason is that these countries, with their high living standards, produce and consume large quantities of energy to manufacture goods and deliver the services their population expects. This is inevitably associated with the generation of considerable waste.

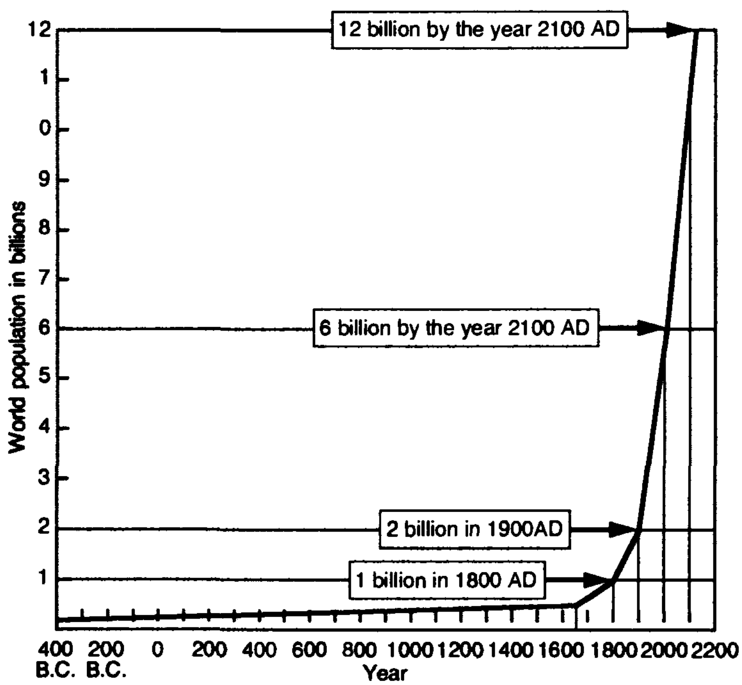
Although the gap in income between the rich and poor countries of the world may not decrease in the future, it is expected that the income levels of the poor countries will slowly rise between now and the year 2025. A minor income in-

The "Cosmic Clock": 4.5 billion years of the planet Earth compressed into one day



Source: Adapted from "Svensk Energiförsörjning 1990".

The population explosion



Source: Adapted from A. Hobson, "Education in Global Change", from "A Planet in Our Hands",G. Marx Ed., Roland Eötvös Physical Society, Budapest, 1995, Page 18.

Some approximate dates important for the evolution of life, humans and culture

	Years before present	Time of the event before present on the 24-hour cosmic clock
Life		
First Vertebrates	500 million	2 hrs and 30 min
First Reptiles	300 million	1 hr and 30 min
First Mammals	200 million	1 hr
First Primates	70 million	20 min
Humans		
Earliest Homides	4 million	80 sec
Stone tools	2 million	40 sec
Homo Sapiens	100 000	2 sec
Culture		
Invention of agriculture	10 000	0.2 sec
First cities and writing	5 000	0.1 sec
Scientific Age (Copernicus)	500	0.01 sec
Industrial Age	250	0.004 sec
Twentieth Century	100	0.002 sec

Adapted from A. Hobson, "Education in Global Change", *A Planet in our Hands*, G. Marx, Editor, Roland Eotvos Physical Society, Budapest (1995).

crease, coupled with a sharp increase of the population, has led to the estimate that by the year 2025 about half of the world's waste (and 85% of the new wastes) will be generated by developing countries. This indicates that it is not simply population growth but population growth combined with living standards that threatens to accelerate environmental degradation.

Signs of environmental changes

At this point, a legitimate question might be asked: To what extent has human development already caused environmental changes during the last two thousandths of a second (0.002 sec), which represents the 20th century, on the "cosmic clock"?

Much has been written on the greenhouse effect caused by the release of carbon dioxide during the burning of fossil fuels and by other gases, and about global warming and whether it already has been detected. Extensive literature also exists on the causes and consequences of the hole in the ozone layer and other signs of local and global environmental changes induced by human activities. Unfortunately, precise environmental indicators are in general still lacking and in most cases only approximate estimates are available. The signs are in any case rather alarming. A few examples will be sufficient to sense the extent of the global and local problems we are and will be facing in the near future.

For example, it has been estimated that each second we lose 1000 tonnes of top soil and 3000 square meters of forest worldwide. Another 2000 square meters of arable land become desert, 1000 tonnes of unwanted gases are released to the atmosphere, and 1000 tonnes of wastes are generated.* The number of living species which become exterminated every day has been estimated to be close to 100.

As far as the production of food is concerned, land degradation is one of the major environmental issues. Population growth, urbanization, and the need to raise the standard of living of developing countries are increasingly modifying land use. Desertification, erosion and urbanization have apparently reduced the arable land per person from about 0.45 hectares (ha) per person in 1960 to about 0.24 ha/person in 1995 and it has been estimated that by the year 2025 this will be further reduced to only 0.13 ha/person. Different regions of the world are affected by land degradation to different extents, with the major problems experienced by the poorest countries of Africa and Asia. *(See table.)* Moreover, chemical problems and lack of water affect more than 50% of the soil, and only 11% of the world soil presents no limitations for agriculture. *(See graph.)*

The mobilization of chemicals in water, soil, and the atmosphere is another issue of serious environmental concern. Today more than 11 million chemical substances are known and 70,000 of them are in general use. The Organization for Economic Co-operation and Development (OECD) has identified only 1500 chemicals produced in excess of 1000 tonnes/year; unfortunately adequate data about the toxicological and environmental effects exist only for a small fraction of them. This means that decisions about their permitted environmental limits have to be taken in most cases in the absence of adequate scientific knowledge. This can lead to negative consequences on people, in the event of uncontrolled release to the environment of toxic substances. It can also create serious impediments to agricultural and industrial development, if regulatory authorities apply rigid precautionary principles to practically harmless compounds.

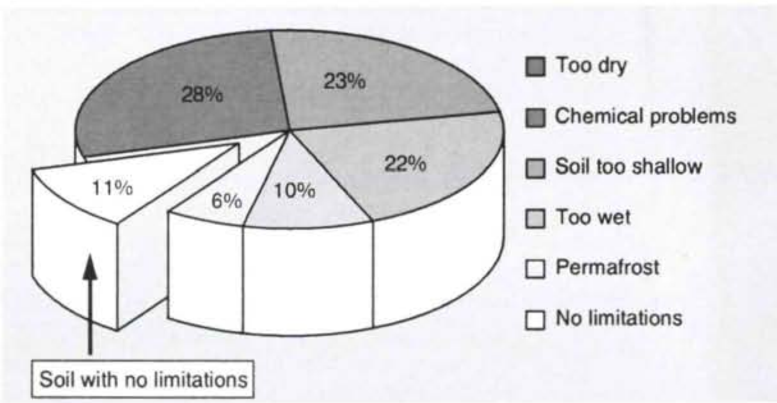
These examples explain why over the years environmental factors have been gradually integrated into most political and economic decision-making mechanisms and have become as fundamental as economics in determining development policies.

Different regions of the world affected by land degradation
(million hectares)

Type	Africa	Asia	South and Central America	Total
Water erosion	170	315	77	562
Wind erosion	98	90	16	204
Nutrient loss	25	10	43	78
Salination	10	26	—	36
			Total	880

Source: H. Oldeman et al., 1990

How world soil conditions limit agriculture



Source: Data from "This is Codex Alimentarius", 2nd edition, FAO/WHO I/T3530E/1/5.94/5000.

The UN response: Agenda 21

The concept of sustainable development stems from the conviction that the basic standard of living of the world's population can be increased without unnecessarily depleting the existing finite resources of the planet and degrading further the environment. At the Earth Summit in Rio de Janeiro in June 1992, a plan of action was formulated and agreed upon by the

* See *Environmental Management Handbook*, S. Ryding, IOS Press, Amsterdam, Oxford, (1992).

world community. This plan, known as Agenda 21 deals, as the name indicates, with the challenges of the 21st century.* The plan addresses many pressing problems of the world and suggests a certain number of interrelated actions. These actions are to be taken by the various key players in different countries according to their capacities, situations and priorities, while taking into account the principles contained in the Rio declaration on Environment and Development.

Agenda 21 covers a large number of topics under the broad concept of sustainable development. It is divided into 40 chapters, covering subjects ranging from combating poverty to protection of the atmosphere, combating deforestation, sustainable agriculture, the management of toxic chemicals and hazardous waste, and science for sustainable development. While the implementation of Agenda 21 is the responsibility of governments, international co-operation should support and supplement national efforts.

In this context the United Nations system has a key role to play and has taken important steps in this respect. In 1993, the General Assembly established a Commission on Sustainable Development (CSD), consisting of 53 elected UN Member States, to ensure effective follow-up to the Rio Conference and monitor progress in the implementation of Agenda 21. The Inter-Agency Committee on Sustainable Development (IACSD), in which the IAEA is an active member, ensures co-ordination among the organizations and specialized agencies of the United Nations system. The IAEA has contributed to the work of the CSD in several sectoral topical clusters, including health, land, desertification, forests and biodiversity, atmosphere, oceans and fresh water, toxic chemicals, and hazardous wastes. The IAEA is also the task manager for the follow-up to the chapter of Agenda 21 (Chapter 22) on radioactive wastes.

The United Nations Environment Programme (UNEP), which has received the mandate to co-ordinate environmental activities in the United Nations system, established in 1995 an Inter-Agency Environmental Co-ordination Group (IAEG). The IAEA is an active member of this consultative body, whose terms of reference and plan of work are prepared in full co-ordination with IACSD.

Within the IAEA's Secretariat, an Inter-Departmental Co-ordination Group on Agenda 21 has been set up for co-ordinated follow-up of the large number of environment and sustainable development projects addressed by several Departments, to make sure that they receive appropriate priority, and to monitor the evaluation and assessment of the relevant results.

Nuclear techniques and technologies for sustainable development. Technology can be the key a more effective and rational utilization of the world's limited resources and to sustainable development as well. The progress in science and technology is a significant factor in setting the pattern and rate of development of the human societies around the world. The common belief is that with the help of science and technology it is possible to find approaches to strike a balance between development needs and environmental conservation.

In particular, the utility and applicability of nuclear science and technology for both developing and developed countries has been amply demonstrated. They have demonstrated their effectiveness in fields such as human health, fresh water resources, climate change, protection of the atmosphere, the oceans and the seas, food security, and sustainable agriculture. Radiation technology and isotope techniques have a broad domain of application in practically all areas covered by Agenda 21 and are indeed relevant to the protection of the environment and to sustainable industrial and agricultural development. Nuclear technology is now a fact of everyday life and the knowledge acquired over 100 years since the discovery of radioactivity still continues to be put to good use for the benefit of humanity, both in material terms and for improving the quality of life.

Earthwatch & environmental monitoring: IAEA contributions

Twenty-five years ago, in 1972, Earthwatch was established as part of the United Nations system-wide mechanism, co-ordinated by UNEP, to monitor major global disturbances in the environment and to give early warning of problems requiring urgent action. In 1994 the mission of Earthwatch was redefined as: *to co-ordinate, harmonize and integrate observations, assessment, and reporting activities across the United Nations system in order to provide environmental and appropriate socioeconomic information for national and international decision-making for sustainable development and for early warning of emerging problems requiring international action.*

The IAEA has participated in Earthwatch activities since its inception. Presently it provides input through its environmental data collection and assessment tasks which constitute a substantial part of its programme. Of primary relevance to the Agency's mandate is the com-

**Agenda 21: Earth's Action Plan*, annotated, D. Nicholas, A. Robinson, Editors, IUCN Environmental Policy and Law Paper No. 27, New York, Oceana Publications (1993).

prehensive technical support for national, regional, and global assessments of radioactive pollutants. The Agency also uses nuclear and nuclear-related techniques for the analysis of non-radioactive pollutants and for the study of the pollution impact on humans and the environment.

With respect to Earthwatch, the Agency is active in various areas: data collection, assessment and reporting; capacity building; harmonization and quality control of data as well as standardization of methodologies to ensure reliable and comparable information on the environment at the national and international level; and establishing early warning, notification and emergency response systems.

Range of IAEA activities. The Agency's activities cover the analysis of radioactive contaminants in the environment and food; environmental radioactivity monitoring for surveillance and for compliance with authorized procedures; the analysis of non-radioactive pollutants (toxic metals, chlorinated organic compounds, pesticides) in air, water, soil, and biota by nuclear and nuclear-related analytical techniques; studies on pollutant transport in air and water; and safety analysis and assessment of nuclear installations and facilities.

Emergency response. Of major relevance to Earthwatch is the Emergency Response System operated in conjunction with the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency. In the Early Notification Convention of 27 October 1986, States Parties have agreed that for an accident having actual or potential transboundary radioactive consequences, they will provide immediate notification to the IAEA and to those countries that could possibly be affected and any supplementary information to take appropriate response actions. Through the Assistance Convention of 26 February 1987, States Parties have additionally agreed to provide available assistance to countries responding to a radiological incident.

In the frame of the two Conventions, the IAEA is required to maintain a list of national points of contact who would receive notifications and co-ordinate implementation activities. To carry out its responsibilities in an effective and timely manner, the Agency has established an Emergency Response Unit. This is a dedicated facility utilizing communication equipment, computers, documents, and databases. Moreover, if an event requires action by IAEA, well-trained experts are readily available.

Environmental data collection. The information collected by the IAEA on radioactive and non-radioactive pollutants is analyzed and made available to the international community through several publications.

Different means are used to collect data, namely through:

- the analysis of samples carried out directly at IAEA Laboratories in Seibersdorf, Vienna, and Monaco by nuclear and nuclear-related analytical techniques. The samples are taken by IAEA experts during missions or are sent to the Agency from throughout the world, including collection stations networks.
- laboratories participating in intercomparison exercises, whereby samples are analyzed by several laboratories to check the reliability of their performance.
- co-ordinated research programmes.
- questionnaires sent to Member States.
- the scientific literature.
- official data from Member States, including responses to formal requests.
- national centres of the International Nuclear Information System (INIS). These centres are designated by the respective governments and maintain close liaison with INIS Headquarters at the IAEA Secretariat in Vienna.

The data relevant to Earthwatch directly generated or collected by the IAEA can be grouped into several categories, namely:

- data on concentrations of radionuclides, trace metals, and organic compounds in soil, air, airborne particulate matter, fresh waters, food and the marine environment (water, sediments and biota). The analytical data refer to (1) man-made and natural radionuclides with determination of strontium-90 (Sr-90), ruthenium-106 (Ru-106), antimony-125 (Sb-125), caesium-134 (Cs-134), Cs-137, plutonium-238 (Pu-238), Pu-239, Pu-240, americium-241 (Am-241), iodine-129 (I-129), potassium-40 (K-40), lead-210 (Pb-210), polonium-210 (Po-210), radium-226 (Ra-226), Ra-228, actinium-228 (Ac-228), thorium (Th), uranium (U); (2) major elements, including calcium (Ca), K, sodium (Na), and magnesium (Mg); trace elements, including aluminum (Al), barium (Ba), chromium (Cr), iron (Fe), manganese (Mn), rubidium (Rb), Sr, and zinc (Zn), as well as ultra-trace elements silver (Ag), arsenic (As), Cs, cadmium (Cd), cobalt (Co), europium (Eu), mercury (Hg), lanthanum (La), Pb, Sb, scandium (Sc), selenium (Se), Th, U, and vanadium (V); and (3) organic pollutants like chlorinated pesticides, herbicides, PCBs, and petroleum compounds. Measurements of accidentally released radionuclides in the environment are part of this effort.
- data on the analytical performance of laboratories in Member States for self-assessment. The efforts are primarily directed towards the production of analytical data acceptable on a global scale. Data on biological and environmental reference materials and laboratory intercomparison exercises using reference materials are also gathered.

- data on disposal of radioactive wastes in the world's oceans, with an inventory of radioactive material entering the marine environment. These data are organized in a database which includes information on the radionuclides entering the oceans as a result of accidents, for example due to the sinking of nuclear submarines and satellite re-entry.
- data on the concentration of tritium, deuterium, and oxygen-18 in composite precipitation samples, along with some selected meteorological data such as monthly mean values of amount of precipitation, type of precipitation, vapour pressure and surface air temperature;
- qualitative and quantitative data on changes in soil organic matter and nutrients, including nitrogen, phosphorus and sulphur, as a result of changes in land management and forest clearing. Measurements of amounts of nitrogen contained in leached water after the application of chemical fertilizers are undertaken. In addition, erosion losses are being measured within catchment basins.
- data on greenhouse gases, flows of energy and materials of the various links of different energy chains, including fossil, nuclear, and renewable energies;
- data on the isotopic composition variations of atmospheric CO_2, CH_4, and CO in time and space, in support of studies on global climatic changes, and on the variation of isotopic composition in lacustrine deposits, speleotherms, tree rings etc., to identify past climatic fluctuations and their causes;
- data and other relevant information on radioactive waste management in Member States, particularly in relation to waste disposal plans and programmes, projected and accumulated waste volumes, waste in storage and national and regulatory policies;
- data on nuclear power reactors in operation, under construction or in the design phase around the world, and data on research reactors;
- data on the safety of nuclear power plants collected from IAEA Member States through missions of expert teams. They include the Assessment of Safety Significant Events Teams, Operational Safety Review Teams, Incident Reporting System for Nuclear Power Plants, International Nuclear Events Scale, Engineering Safety Review Services, International Review of Radiation Safety, and Transport Assessment Reviews.

Likewise information on radiation protection and waste management infrastructures is collected through Radiation Protection Assessment Teams and Waste Management Assessment Programmes.

Finally, the International Nuclear Information System (INIS) collects bibliographical references to published literature and full texts of non-conventional literature on any published item on environmental and economic aspects of nuclear and other sources of energy.

Data analysis and distribution. The IAEA also performs assessments and analyses of data. Examples are the comparative assessment of the health and environmental risk from near-surface disposal of solid hazardous wastes; the assessment of the isotope monitoring of the atmospheric greenhouse gases; the application of integrated approaches to the development, management and use of water resources; the safety analysis and assessment of nuclear installations and facilities using nuclear material and/or radioisotopes and/or ionizing radiation; and the analysis and assessment of radioactive and non-radioactive pollutants in the marine environment.

In consideration that the availability of information is an important factor for the decision-making process as well as for public awareness of environmental issues, a large spectrum of publications is issued by the Agency, ranging from scientific and technical journals to press releases, technical documents, data books, and reports. A number of safety standards, guides, recommendations, procedures, and technical reports are published annually. Reference materials and intercomparison of analytical data are published in Analytical Quality Control Service (AQCS) catalogues and reports. Certain information products and databases, such as INIS or the Global Network Isotopes in Precipitation, now are also available on CD ROM and over the IAEA's Internet-based electronic information services.

An ongoing response

The global dimensions of environmental problems increasingly demand a concerted, committed, and co-ordinated international response. The world's rising population, particularly in developing countries, will place even greater strains on the capacities of cities and countries to meet the social and economic needs of citizens. Greater calls for action are likely, requiring decisions that are factually based, environmentally responsive, and economically sound.

Through various avenues, the IAEA has been working closely with its international partners to support decision-making processes, and to contribute toward global efforts to effectively monitor and assess the extent of environmental changes. The work promises to take on added importance in years ahead, in our ongoing response to understanding and meeting the difficult challenges of an environmentally sound development. ❐

Radioactivity and earth sciences: Understanding the natural environment

The earth's natural radioactivity is helping scientists learn more about geological processes and global climate changes

by Kazimierz Rozanski and Klaus Froehlich

Virtually all natural substances contain radionuclides to a greater or lesser degree. Such natural radioactivity — discovered by French physicist Henri Becquerel a century ago — today is being put to practical uses in many fields of science and industry.

In the geological sciences, the transfer of natural radionuclides according to their physical and chemical properties is being studied to trace the evolution of the crust and mantle of the Earth, to follow processes associated with the hydrological cycle, and to account for some aspects of the composition of the atmosphere. The radioactivity of rocks, minerals, water, and organic matter is widely used in dating geological and archeological materials as well as groundwater.

Energy liberated during radioactive decay is now considered to be one of the main sources of heat within the Earth. The driving force for lithospheric plate movements, mountain orogenesis, and vulcanism may have an origin in the presence of radionuclides. Even on local scale, the presence of radionuclides may give rise to areas of high heat flow in crustal rocks. This in turn causes convective circulation of groundwater which can lead to the formation of hydrothermal systems and associated mineralization.

The discovery and subsequent utilization of fission and fusion reactions have added new elements to the pool of radioactive materials present in the environment. Numerous radionuclides have been added to the earth's ecosystem mainly through atmospheric nuclear bomb tests, and through emissions from the nuclear industry, among others. Tracking their transport through different compartments of the global ecosystem provides new insights into the dynamics of the atmosphere and the hydrological cycle. *(See box.)*

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The earth's natural clock

Perhaps the most characteristic and successful application of radioactivity in earth sciences is its use as a natural "clock" measuring successively various processes occuring on the Earth. The versatility of this clock is remarkable: it can work effectively over more than 15 orders of magnitude quantifying processes ranging from minutes to billions of years. To effectively date any material of geologic or biologic origin, two basic requirements need to be fulfilled: (1) possible sources and sinks of the radionuclide(s) in use need to be carefully assessed; and (2) the past physical status of the system to be dated has to be known or assessed (open or closed system).

A variety of radionuclides is used for geological and archeological dating: radionuclides produced during stellar nucleosynthesis (primordial radionuclides), radionuclides of the natural decay series, radionuclides produced by natural nuclear reactions in the atmosphere (cosmogenic radionuclides) and lithosphere (*in-situ* produced radionuclides), and radionuclides produced in artificial nuclear reactions (anthropogenic radionuclides).

How does the radioactive clock function? It relies on the fact that radioactive decay is independent of the physical and chemical conditions and changes in the environment. The rate of decay for a particular radionuclide is governed by the half-life of the decay. This can be defined as the time taken for a given number of atoms of that radionuclide to decay to half that number. To enable dating to be carried out accurately, half-lives that are of the same order as the age of the material to be dated are required. Fortunately, natural radionuclides have half-lives which range from less than one second to more than 10^{10} years. *(See table next page.)* Consequently, a very wide range of dating is possible, including estimates of the age of the Earth and the solar system. Some of the dating methods are based on the relationship between the radionu-

Major applications of natural and anthropogenic radionuclides in earth sciences

Studies of Atmosphere
- dispersion, transport, and mixing processes on local, regional, and global scale (tritium, krypton-85, radon-222, carbon-14)
- transport of water vapour (tritium)
- stratosphere-troposphere exchange (tritium, carbon-14, krypton-85, beryllium-7, beryllium-10)
- sources and sinks of CO_2 and CH_4 (tritium, carbon-14)
- atmospheric deposition (chlorine-36, beryllium-7, beryllium-10, strontium-90, caesium-137)

Studies of Hydrosphere
Continental hydrosphere
- replenishment of groundwater resources (tritium, chlorine-36)
- dispersion studies in surface waters (tritium)
- aeration studies (krypton-85)
- interaction between surface and groundwaters (tritium, radon-222, carbon-14)
- groundwater dating (tritium, carbon-14, krypton-85, argon-39, chlorine-36, krypton-81)
- rock-water interactions (uranium-238, uranium-234, radium-226, radium-228)
- sedimentation rates in lakes and reservoirs (caesium-137, lead-210)
- radioactive waste disposal (chlorine-36, iodine-129)

Ocean
- circulation and mixing processes (tritium, carbon-14, krypton-85)
- age of water masses (tritium, carbon-14, argon-39, krypton-85)
- transfer of anthropogenic CO_2 into the ocean (carbon-14)
- dating of oceanic sediments (carbon-14, potassium-40)
- variations of sea level in the past (carbon-14, uranium-234, thorium-230)

Studies of Lithosphere
- dating of rocks and minerals (potassium-40, argon-39, rubidium-87, lutetium-176, hafnium-174, samarium-147, neodymium-143, rhenium-187, radionuclides of uranium and thorium decay series)
- dating of carbonate deposits (carbon-14, uranium-234, thorium-230)
- dating of lacustrine sediments (caesium-137, lead-210, carbon-14, uranium-234, thorium-230)
- surface exposure dating (beryllium-10, carbon-14, aluminum-26, chlorine-36)
- soil erosion (caesium-137, lead-210, beryllium-10)
- mineral exploration (radionuclides of uranium and thorium decay series)
- earthquake monitoring (radon-222)
- paleoseismicity and volcanic eruptions (chlorine-36, aluminum-26, beryllium-10)

Natural and anthropogenic radionuclides frequently used in earth sciences

Nuclide	Half-life (years)	Origin *
Tritium	12.43	N+A
Beryllium-7	9.7×10^{-2}	N
Beryllium-10	1.6×10^{6}	N
Carbon-14	5730	N+A
Silicon-32	140	N
Chlorine-36	3.01×10^{5}	N+A
Argon-39	269	N
Krypton-85	10.76	A
Krypton-81	2.1×10^{5}	N
Iodine-129	1.57×10^{7}	N+A
Potassium-40	1.31×10^{9}	N
Rubidium-87	4.88×10^{10}	N
Caesium-137	30.17	A
Radionuclides of uranium and thorium decay series		
Uranium-238	4.47×10^{9}	N
Uranium-235	7.13×10^{8}	N
Uranium-234	2.48×10^{5}	N
Protactinium-231	3.43×10^{4}	N
Thorium-230	7.52×10^{4}	N
Radium-226	1602	N
Radium-228	5.75	N
Radon-222	1.05×10^{-2}	N
Radon-220	1.76×10^{-6}	N
Lead-210	22.3	N

* N — Natural (decay of primordial radionuclides produced in stellar nucleosynthesis, interactions of cosmic rays with the atmosphere and/or with the earth's crust); A — anthropogenic (atmospheric and underground nuclear explosions, nuclear industry, watch industry, hospitals, etc.), N+A — significant contributions from both natural and anthropogenic sources.

clide and its decay product, which in such cases is usually a stable daughter nuclide.

Until the early 20th century, the opinions about the age of the Earth differed considerably: the estimates ranged from some tens of millions of years to several tenths of billions of years. The debate was resolved in 1929 when Rutherford used the newly discovered radioactivity for measuring ages of rocks and soon obtained an age of billions of years using the U-He method. The first precise determination of the age of the Earth and meteorites was performed in the early 1950s and was based on lead isotopes, the stable end-products of the respective radioactive decay series. It gave the age of the Earth as 4.55 billion years — a value that remains generally accepted today for the age of the Earth and the solar system.

Detecting natural radioactivity

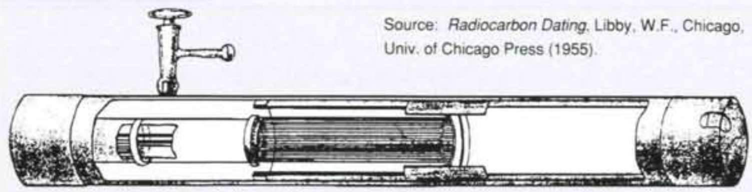
Natural radionuclides were first detected through the ionizing radiation they emit during their decay. This "decay-counting" technique has been progressively developed since the dis-

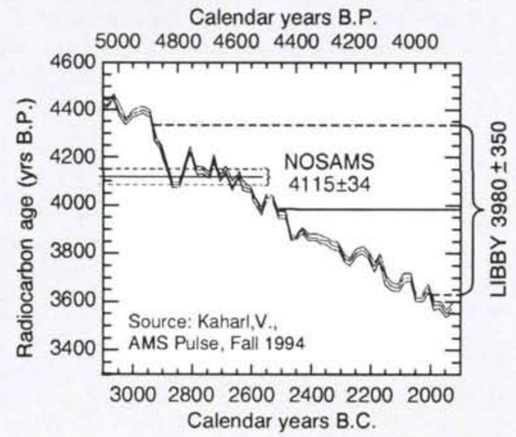
The radiocarbon clock

A multi-wire wall counter used by Willard Libby to measure the carbon-14 content in archeological artefacts *(right)*. Libby won the Nobel Peace Prize in 1960 for his work in developing the method of radiocarbon dating. ***Bottom:*** Example of modern carbon-14 AMS equipment, a commercially available tandetron accelerator dedicated for radiocarbon analysis. The first sample dated by Libby in 1948 was a piece of *acacia* wood from furniture found in Pharoah Zoser's tomb at Saqqara, Egypt. Libby needed about 20 grams of this precious archeological artefact to perform the analysis. Based on astronomical events, hieroglyphics and other historical records, various Egyptologists have consistently dated the reign of King Zoser to about 2600 BC. As shown in the graph, Libby dated the wood to 2030 plus or minus 350 years BC or 3980 plus or minus 350 years BP (Before Present). In 1992, the same piece of *acacia* wood from Pharaoh Zoser's tomb was dated as a first sample in the newly established National Ocean Sciences Accelerator Mass Spectrometry Facility at Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, USA. This time only about *10 milligrams* of wood was sufficient to perform the analysis. The AMS radiocarbon age of the Zoser wood was 4115 plus or minus 34 years BP, i.e. within one sigma error of the first Libby analysis.

To convert radiocarbon years to calendar years, corrections are required which account for fluctuations of radiocarbon content in atmospheric carbon dioxide in the past. Such corrections are based on measurements of radiocarbon concentrations in a series of tree rings dated by dendrochonological techniques. The tree ring calibrated age for the AMS analysis of the Zoser wood yields two solutions with a 95% degree of confidence: 2877 to 2800 BC and 2780 to 2580 BC. This result is consistent with archeological estimates. However, a marked step in the calibration curve during the time of Zoser's reign precludes a high precision calibrated age estimate for this particular material.

(Photo credit: Prof. P.M. Grootes, Christian Albrechts University, Kiel, Germany)



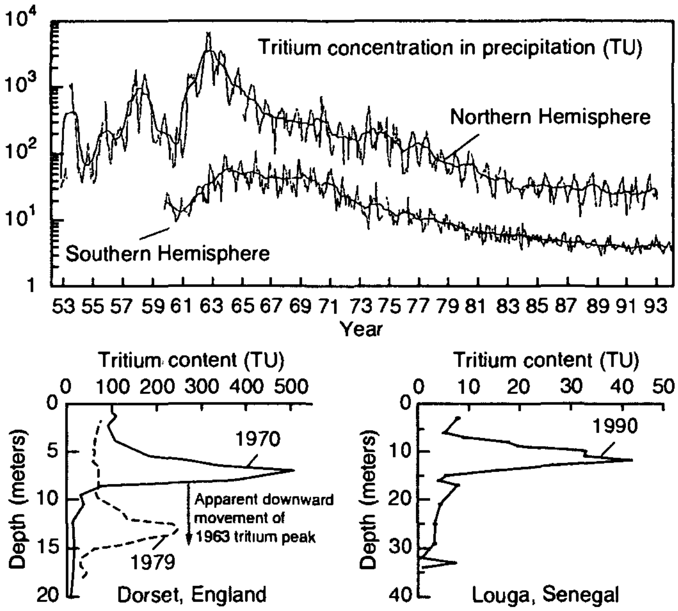


covery of natural radioactivity a century ago. Decay-counting has become a well established field and a wide variety of materials (gases, liquids, semiconductors, etc.) are being used to detect different types of ionizing radiation emitted by various radionuclides. Since the activities of natural radionuclides are usually very low, sophisticated signal processing and background reduction techniques are often employed to increase the sensitivity of such detectors. For the detection of short-lived radioisotopes, with half-lives of less than about one year, the sensitivity of advanced decay-counting techniques is appropriate. Primordial radioisotopes with half-lives greater than about 10^9 years are relatively abundant naturally (since they have not decayed completely over the life of the solar system). The decay-counting is often replaced here by measuring the build-up of stable decay products by conventional mass spectrometry. Radioisotopes with half-lives in the intermediate range of 10^3 to 10^8 years are difficult to measure using the decay-counting techniques since only a small fraction of the atoms decay over a reasonable counting period. For instance, if carbon-14 concentration in organic samples is measured using a gas

Tritium content from atmospheric nuclear bomb tests

Shown in the upper graph below is the increase of tritium content in precipitation as a result of atmospheric nuclear bomb tests. The tritium content of precipitation is being monitored on the global scale by the IAEA/WMO Global Network Isotopes in Precipitation (GNIP). Data of two long-term stations are presented here covering the northern and southern hemispheres.

Lower panel: Penetration of the bomb-tritium peak in the unsaturated zone of the aquifer located in a temperate climatic zone (Dorset, England) and in a semi-arid region (Louga, Senegal). For the Louga profile, obtained in Senegal in the framework of an IAEA regional technical co-operation project, the average replenishment of this aquifer over the past three decades was estimated to be around 22 mm/yr. Such low recharge rates are very difficult to measure using classical hydrological methods.



proportional or liquid scintillation counter, on the average only one atom out of each 10^6 atoms of carbon-14 present in the sample decays and contributes to the measured signal. Therefore, relatively large samples of the analyzed material are required.

Particle accelerators, such as those built for research in nuclear physics, can also be used together with magnetic and electrostatic mass analyzers to measure radioisotopes at very low concentrations. The work in this direction started in the late 1970s. Today, several long-lived radioisotopes which were very difficult to measure by decay-counting (beryllium-10, carbon-14, aluminum-26, chlorine-36, calcium-41, iodine-129) can routinely be measured in small natural samples having isotopic abundances in the range 10^{-12} to 10^{-15} and as few as 10^5 atoms. With this new analytical technique, called Accelerator Mass Spectrometry (AMS), it has been possible to reduce the sample size by several orders of magnitude. For instance, the amount of carbon required for radiocarbon dating could be reduced from a few grams (decay counting) to some tens of micrograms (AMS). Also, the counting period can be reduced substantially. Over the last decade, research applications of AMS have been concentrated in earth sciences (climatology, cosmochemistry, geochronology, geomorphology, hydrology, glaciology, minerals exploration, sedimentology) and in anthropology and archeology (radiocarbon dating). *(See box, previous page.)* Over the past few years, AMS has also become an important analytical tool for the materials and biological sciences.

Dating of groundwater

Radioactive isotopes have found numerous applications in hydrology. Tritium and carbon-14 are extensively used as "dating tools". The atmospheric tests of nuclear fusion bombs carried out during the 1950s and early 1960s released large amounts of artificial tritium into the atmosphere and consequently the hydrosphere. The observation of this transient tritium pulse in the water cycle led to numerous hydrological studies on a global, regional, and local scale. This "bomb-tritium" became a powerful indicator of young water in groundwater systems and a useful tracer in determining the rate of replenishment of aquifers, particularly in semi-arid and arid regions. *(See graphs, this page.)*

In spite of the complexity of the carbon geochemistry in groundwater systems, both natural and anthropogenic carbon-14 became a widely used used tool in assessing groundwater ages in the range between a few thousand and a few tens of thousands of years. For instance, radiocarbon made it possible for the first time to assess the age of large groundwater reserves under the Sahara. *(See graph, next page.)*

The AMS technique also has enabled the applications of some new radioisotopes in hydrology, such as chlorine-36 and iodine-129. With chlorine-36, groundwater ages in large sedimentary basins such as the Great Artesian Basin in Australia were estimated to be in the order of up to one million years. Measurements of iodine-129 in deep formations of water associated with oil deposits help to clarify the origin and age of these waters.

Quantifying erosion and sedimentation

The process of erosion involves different time scales: from relatively fast, often anthropogenically triggered processes of soil erosion, to relatively slow processes of weathering of rock surfaces. Soil erosion represents a serious problem in many parts of the world because of its impact on sustainable agricultural development.

A number of radioisotopes, both natural and anthropogenic, can in principle be used to assess soil erosion rates, depending on the time scale involved. Among them, caesium-137 and lead-210 by far have been the most commonly used.

The IAEA is addressing this problem through the ongoing Co-ordinated Research Programme (CRP) "Soil Erosion and Sedimentation Assessment Studies by Environmental Radionuclides and their Applications to Soil Conservation Measures" with the participation of research institutes from ten Member States. The programme is aimed at further development of isotope-based methodologies for evaluating the soil erosion rates in different climatic settings, for measuring sediment yields from river basins, and for evaluating siltation rates in lakes and reservoirs.

The past decade has seen development of several new methods for quantitative age-determinations of geomorphic surfaces, triggered by the introduction of the AMS technique. These methods are based on the accumulation of cosmogenic radionuclides (beryllium-10, carbon-14, aluminum-26, chlorine-36, and calcium-41) in rocks exposed at the earth's surface. The radionuclides in question are produced in the interactions of cosmic rays with atoms in minerals by high-energy spallation, neutron-capture reactions and muon-induced nuclear disintegrations. The effective dating limits of the radionuclides produced *in situ* are from a few thousands to several millions of years.

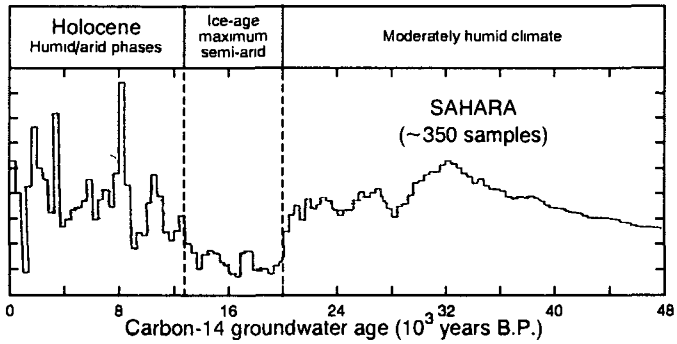
Chronology of past climate variations

Radioisotopes remain the major tool for providing the chronological framework for reconstructions of past climatic and environmental changes. A broad suite of isotopes has been used for this purpose, depending on the time scale of the processes being studied and the nature of samples to be dated. Among them, radiocarbon remains the most often used; hundreds of thousands of radiocarbon analyses have been performed over the last four decades in carbon containing materials from oceanic and lacustrine sediments, tree rings, ocean water, groundwater, atmospheric carbon dioxide.

Additionally, the uranium-thorium dating method is becoming more frequently used. This is particularly the case for its modern version based on the detection of uranium and thorium isotopes in the analysed sample using Thermal Ionization Mass Spectrometry (TIMS) instead of decay counting. This method is capable of dating geological materials (carbonates, sediments) back to about 350,000 years. Of particular importance for high-resolution reconstructions of climatic changes during the last deglaciation are efforts to reconstruct past changes of carbon-14 content in the atmosphere, linked with variations in the production rate of this radioisotope and changes in the circulation of the ocean.

Frequency distribution of radiocarbon ages in groundwater samples collected in the Sahara

The fact that large groundwater reserves are laying beneath the largest desert in the world has been known since the beginning of this century. However, only with the onset of radiocarbon dating has it been possible to estimate the age of these waters. It is evident from the graph (based on data from 350 samples collected in Algeria, Libya, Egypt, and the Southern Sahara) that aquifers in Northern Africa where recharged predominantly during both the pluvial periods of the Holocene and during the interstadials of the last glacial period. The well-marked minimum in the distribution curve ranging from about 12 to 20 thousands of years BP reflects the period of maximum aridity in Northern Africa. The estimation of groundwater age has a direct impact on exploitation of groundwater resouces: the lack of tritium and low concentrations of radiocarbon suggest that the given aquifer is not being replenished at present.



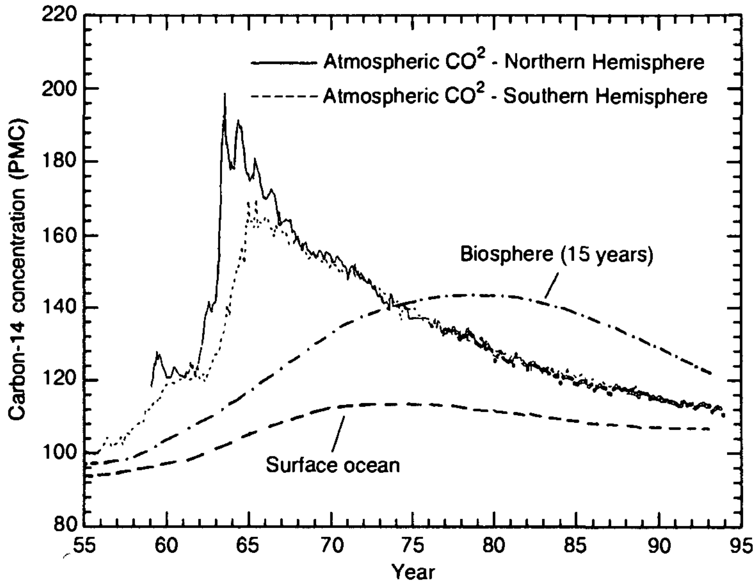
Source. Sonntag et. al, Radiocarbon, 22 (1987), 871-879

Search for the "missing sink"

The nuclear bomb tests in the atmosphere left a distinct "pulse" of carbon-14 concentration in atmospheric carbon dioxide. *(See graph, next page.)* This pulse can serve as a tracer for the global carbon cycle, in an analogous way as bomb-produced tritium is being used in studies of the global water cycle. The atmospheric reservoir of bomb carbon-14 is now being gradually emptied and the excess of carbon-14 activity is going through the biosphere and the ocean carbonate system. By watching the time evolution of carbon-14 in corresponding reservoirs (atmosphere, biosphere, ocean) one can learn more

Changes of carbon-14 concentration in atmospheric CO_2 due to nuclear bomb tests

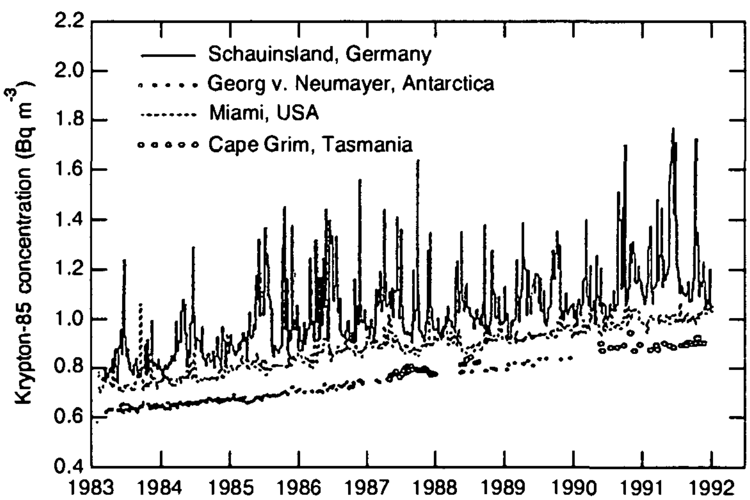
Long-term observations of carbon-14 are performed at several stations of both hemispheres (Schauinsland, Germany; Izaña, Tenerifa, Spain; Cape Grim, Tasmania; Merida, Venezuela; Neumayer Station, Antarctica). Shortly after the atmospheric test ban treaty in 1962, the carbon-14 level in the northern hemisphere was twice as high as the natural level defined here as 100%. The carbon-14 decline after 1963 is caused by strong uptake of bomb carbon-14 by the oceans and the biosphere. The broken line shows the calculated response of the biosphere to the increase of carbon-14 in atmospheric carbon dioxide, assuming that the biosphere is a well-mixed reservoir with turnover time of carbon equal to 15 years. The terrestrial biosphere is probably the most complex reservoir within the global carbon cycle. Atmospheric carbon-14 observations help to assess the nature and dynamics of this reservoir.

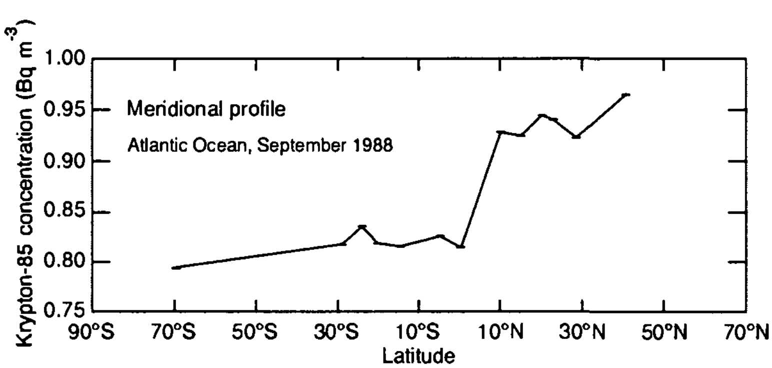


Source Hesshermer et al, Nature, 370 (1994), 201-203, Levin, I Thesis B, University of Heidelberg, (1994)

Krypton-85 concentration in the troposphere

Krypton-85 (half-life 10.76 years) is a fission product and is being released into the atmosphere during reprocessing of spent nuclear fuel. Krypton-85 concentrations in the southern hemisphere are systematically lower due to the fact that major reprocessing plants are located in the northern hemisphere and part of the krypton-85 released at mid-northern latitudes decays before it has a chance to be transported to the southern hemisphere. ***Lower panel:*** Meridional profiles of krypton-85 concentrations in the troposphere are used to calibrate physical parameters of the global models of atmospheric circulation. As inert gas, krypton-85 is also an excellent tracer for young groundwaters.





Source: Weiss et al. STI/PUB/859, IAEA, (1992), W Weiss, Fort. Strahl. Umwelt. Radioec. (1993)

about the rates of carbon transfer among these reservoirs, in particular among the atmosphere and the ocean.

A quantitative understanding of the global carbon cycle is of the utmost importance in view of the fact that carbon dioxide is the main greenhouse gas contributing about 50% to the postulated global warming.

The central problem in balancing the global carbon cycle is the "missing sink" for the CO_2 released every year into the atmosphere by combustion of fossil fuels amounting to about six gigatons. From atmospheric observations of CO_2 it is known that approximately 50% of this amount, i.e. about three gigatons, stays in the atmosphere. On the other hand, the available coupled ocean-atmosphere general circulation models predict that the world ocean is capable of absorbing only about two gigatons per year. The present imbalance amounts therefore to about one gigaton. This "missing sink" is in fact twice as high due to the biospheric sources associated with changes in land use, estimated to be in the order of one gigaton per year.

The results of atmospheric $^{14}CO_2$ observations offer an attractive tool to constrain the global carbon cycle. In fact, in a recently published study, based on the analyses of tropospheric carbon-14 concentrations, it has been suggested that the oceans take up about 25% less anthropogenic CO_2 than had previously been believed. Thus, the search for an additional sink of carbon, not accounted for in the present global carbon budget, needs to be continued.

Improving atmospheric transport models

Krypton-85 is being released into the atmosphere during reprocessing of spent nuclear fuel. The major reprocessing plants operate in the Russian Federation, North America, and Europe and are located in the latitudinal band 30°N to 50°N. Current atmospheric krypton-85 levels (around one Bq/m^3) can be easily measured using the decay-counting technique. Because krypton-85 is chemically inert and the only removal process of importance is radioactive decay, it is considered a very powerful atmospheric tracer.

A quantitative understanding of global atmospheric circulation is indispensable for meaningful estimates of the global balances of atmospheric pollutants and their climatic implications. In particular, two aspects of this circulation have to be described correctly: (1) the large-scale exchange of air between the northern and southern hemispheres, and (2) the intensity of vertical mixing. Because of the complexity of the processes involved, the application of numerical models is indispensable in this field. The most advanced among them, called general circulation models (GCMs), are used also for predictions of climatic consequences of emissions of greenhouse gases. The global distribution of krypton-85 can be used to adjust the model parameters related to the long-range transport and mixing between the northern and southern hemisphere. *(See graph, previous page.)* Other processes of importance, such as convective mixing within the troposphere, particularly in tropical regions and over continental areas of the northern hemisphere, cannot be parameterized by atmospheric krypton-85 distribution because the time scales involved are much shorter. Other tracers such as radon-222 can be used for this purpose.

Perspectives

The impact of the discovery of radioactivity on the earth sciences cannot be overemphasized. Natural radioisotopes have long been used as an important (and often the only) source of information regarding the chronology of geological processes, the history of meteorites and cosmic rays, human evolution, and the dynamics of biological systems. Anthropogenic radioisotopes, although viewed in the public's perception as a threat to the human environment, have turned out to be excellent global tracers. They allow us to better understand the water cycle and to learn more about the biogeochemical cycles of important life-supporting elements such as carbon, nitrogen, or sulfur.

As we approach the coming century, issues related to global environmental change are rising higher on the agendas of many international organizations, including the UN system. Already, the hydro-climatic evolution of the earth over the short-term, and humanity's influence on climate, stands as a major challenge and will necessarily become one of the most important tasks for scientists of the next century.

The quantification of the possible response of the earth's climate to anthropohenic stress is crucial, particularly for the inter-tropical zone. This region, occupied mostly by developing countries, is submitted to extreme hydroclimatic variations, such as droughts and floods. Consequently, predictions of such events over the short-term are a major requirement for the region's sustainable development. Scientific techniques based on the use of both radioactive and stable isotopes have an important role to play in accounting for the mechanisms and processes shaping the continuing hydro-climatic evolution of the globe. ❐

Environmental protection: Nuclear analytical techniques in air pollution monitoring and research

Through IAEA-supported projects in some 30 countries, researchers are tracking and fingerprinting sources of pollution

by
Robert M. Parr, Susan F. Stone, and R. Zeisler

Air pollution has become a matter of global concern, particularly in some of the world's largest cities. It is made up of many different components that affect the environment — and directly or indirectly the health of people. The main components include sulphur dioxide, particulate matter, carbon monoxide, reactive hydrocarbon compounds, nitrogen oxides, ozone, and lead.

Nuclear techniques have important applications in the study of nearly *all* of them. However, it is in the study of *airborne particulate matter* (APM) that nuclear analytical techniques find many of their most important applications. This article focuses on these applications, and on the work of the IAEA in this important field of study.

What is APM?

APM can be described as a mixture of solid and liquid particles suspended in a gaseous state (air). Generally, the size frequency of the particles has a distribution, with two main peaks at about 0.2 micrometers and at about 10 micrometers. *(See figure.)* One can also classify particles sizes according to sources of origin. Particles of a size less than 2 micrometers can be attributed mainly to combustion processes (anthropogenic activity) or gas-to-particle conversion. Particles larger than 2 micrometers are mostly derived from mechanical processes (e.g. soil erosion) or incomplete combustion.

What is the rationale for wanting to study airborne particulate matter? One of the main reasons has to do with its effects on health. *(See box, next page.)* Health problems associated with APM are starting to be regarded with great concern in many countries — and particularly now in *developing* countries — where, in some highly populated cities, the amounts of total suspended air particulates (TSP) are often far in excess of the World Health Organization (WHO) guideline ranges.

WHO advises that the annual average TSP should not exceed 60-90 micrograms/m^3. However, many cities regularly exceed these values. No fewer than 17 of these cities (all of them in developing countries) have moderate to high levels of TSP pollution, mostly derived from coal combustion and industrial sources, and to an extent that is increasing in practically *every* country of the world, from automotive exhausts. In many polluted cities, the most direct consequences are ones that are immediately obvious: reduced visibility of the atmosphere and irritation of eyes and throats. However, much more insidious and important are the longer-term effects on health.

Because health effects are mostly associated with particles in the size range of about 10 micrometers and below (called PM-10 particles) it is these particles that are attracting the greatest attention. Unfortunately, however, there are as yet no internationally recognized air quality standards for PM-10 particles, and most countries do not even monitor them in a regular way (or only started doing so during the last five years). In practice, the air quality standards proposed in the United States are most often used as the basis for comparison, namely that the average annual concentration of PM-10 particles should not exceed 50 micrograms/m^3 and the 24-hour average should not exceed 150 micrograms/m^3 more than once per year. *(See the graph, next page, for a comparison of these averages with the results re-*

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Typical elements determined by nuclear and related techniques in airborne particulate matter

Neutron Activation Analysis (NAA): aluminum (Al), arsenic (As), gold (Au), barium (Ba), bromine (Br), calcium (Ca), cadmium (Cd), chlorine (Cl), cobalt (Co), chromium (Cr), caesium (Cs), europium (Eu), iron (Fe), gallium (Ga), iodine (I), indium (In), potassium (K), lanthanum (La), lutetium (Lu), magnesium (Mg), manganese (Mn), sodium (Na), nickel (Ni), rubidium (Rb), antimony (Sb), scandium (Sc), samarium (Sa), thorium (Th), titanium (Ti), vanadium (V), tungsten (W), zinc (Zn)

Particle-Induced X-ray Emission (PIXE): Al, Br, Ca, Cl, copper (Cu), Fe, Ga, K, Mg, Mn, Mo, Na, niobium (Nb), Ni, phosphorus (P), lead (Pb), Rb, sulfur (S), selenium (Se), silicon (Si), Ti, Zn, zirconium (Zr)

X-ray Fluorescence Analysis (ED-XRF): Br, Ca, Cu, Fe, K, Mn, Ni, Pb, Rb, S, Se, Ti, Zn

ported for São Paulo by a Brazilian participant in an IAEA research programme.)

IAEA-supported air pollution studies

In response to the above evidence and the apparent need of Member States to assess and control air pollution, the IAEA started a Co-ordinated Research Programme (CRP) in 1992 entitled "Applied Research on Air Pollution Using Nuclear-Related Analytical Techniques"; additionally, four technical co-operation projects have been supported. More recently, in 1995, a regional CRP for the Asia and Pacific region began, which is following the same goals and procedures as the first CRP. It is being carried out within the framework of a joint project of the IAEA, the Regional Co-operation Agreement (RCA) for Asia and the Pacific, and the United Nations Development Programme (UNDP) on the use of isotopes and radiation to strengthen technology and support environmentally sustainable development.

The objectives of the CRPs are threefold: to support the use of nuclear and nuclear-related techniques for practically oriented research and monitoring studies on air pollution; to identify major sources of air pollution affecting each of the participating countries (with particular reference to toxic heavy metals); and to obtain comparative data on pollution levels in areas of high pollution (e.g. a city centre or a populated area

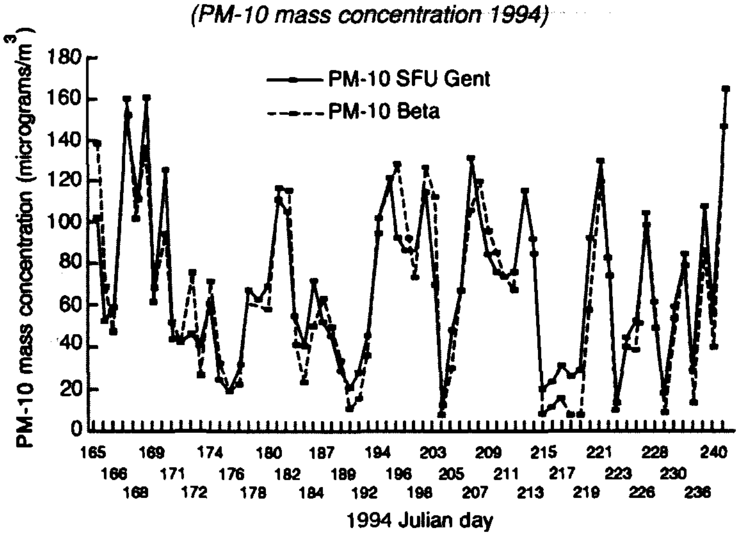
Health effects of air pollution

That air pollution can kill has been known since at least the time of the infamous great London smog in 1952 which, within the space of about a week, is estimated to have been responsible for the premature deaths of around 4000 people. Such smogs have now gone, but recent research is showing that the numbers of deaths currently caused by air pollution are probably higher than was previously even imagined.

To see why, and what is causing these deaths, it is necessary first to understand how air pollution gets into the body, a process that it is largely a matter of particle size. Particles with a size greater than 10 micrometers are generally too large and heavy to travel very far, and those that do reach a human body are mostly filtered out by the nose. It is the *smaller* particles generally referred to as PM-10, having a size of around 10 micrometers or less, that are the most hazardous. The smaller they are, the *deeper* they can penetrate into the lungs. Exactly what they do there is still not fully understood, but some scientists have suggested that the immune system may be reacting to them as if they were invading organisms. This immune response causes inflammation of the tissues in a similar manner to the allergic reaction of a hay-fever sufferer, but with ultra-fine particles the inflammation is deep in the lungs. The worst effects will be felt by those who are already seriously ill with respiratory disease, so many of those who die during periods of high PM-10 would probably have died within a few weeks or months anyway. This is called *cull* by epidemiologists. However, there is evidence from a comparison between cities in the United States with different PM-10 levels that overall life expectancy falls if PM-10 increases, mainly due to increased death rates from cardiopulmonary disease and lung cancer. This is not a *cull* of the infirm, but a real threat to the health of ordinary people.

The numbers of people affected cannot be estimated accurately, and there is even no consensus yet among scientists who are working in this field on how to do this. Nevertheless, some respected government scientists are suggesting that around 60,000 deaths per year may be caused by air pollution in the United States, and around 10,000 deaths per year in the United Kingdom. If correct, these numbers clearly indicate that air pollution is not only an important environmental problem but also an extremely serious public health problem.

Aerosol characterization in São Paulo
(PM-10 mass concentration 1994)



Sampling of airborne particulate matter

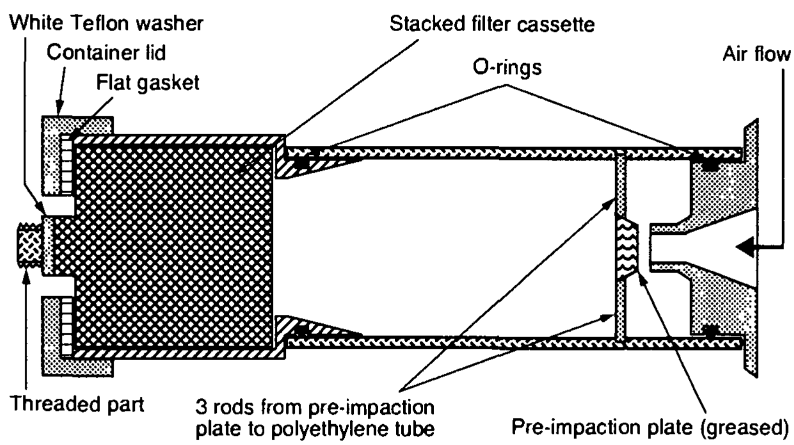
Sampling of APM has much to do with differentiating the size of the particles. Various sampling devices are used for the characterization of APM. The simplest methods involve collection of total suspended matter, without any size selection, and consist of a filter (collection substrate), a pump and a flow meter or controller that draws air through the filter at a known rate. The APM is then collected on the filter. More complicated samplers collect APM in various size fractions.

Collection of APM without size selection. ***Collection of dry deposition samples:*** This type of sampler depends only on gravitational settling of particles. It involves the removal of particles onto a surface or collector in the absence of precipitation. This is to be contrasted with wet deposition (which is the removal of particles by precipitation such as rain or snow), and bulk deposition (which is the combination of wet and dry deposition). ***Collection of total suspended particulate matter (TSP):*** Normally, samplers of this type are "high-volume" air samplers, with large volumes of air being drawn through a low resistance (glass or cellulose) filter. Air flow ranges from 1.1 to 1.7 m^3/min, or about 2000 m^3/day. The inlet duct and collection filter measure 25-30 cm in diameter. This type of sampling is especially useful for monitoring of remote areas, which may have relatively low particulate concentrations, or for monitoring low-level products of anthropogenic nuclear activities.

Collection of APM with size selection. ***Samplers with physical impactor stages:*** The principle of these samplers is to separate particles by size using "obstacles" or impactors. Particles are removed onto solid surfaces using inertial forces; air flows around an obstacle (the impactor), and the particles in the airflow either follow the air stream or, depending on the mass (size) of the particle, impact on the obstacle, and are collected. A cascade impactor consists of a series of stages of particle collectors, each stage collecting different particle size ranges. The largest particles are collected in the upper stages. ***Samplers with virtual impactors:*** Separation in these samplers occurs at a "virtual" surface formed by diverging air streams. Coarse and fine particulates are then carried to separate filters. The size segregation of such devices is not as sharp as for physical impactors, and operation below about one micrometer appears difficult, but problems with collections surfaces are largely avoided. An example of this type of air sampler is a dichotomous sampler. This has a size selective inlet to sample particles larger than 10-15 micrometers, and a virtual impactor which further separates particles into two fractions, coarse and fine. These samplers operate at a "medium" volume flow rate. ***Samplers using centrifugal forces:*** These types of samplers, e.g. cyclones, can also provide particle sizing via flow within a cylindrical or conical chamber. Large particles are removed from a constant air flow on the basis of impaction, where the larger particles impact on the walls of the cyclone. These particles remain on the walls or settle to the bottom of the cyclone, and are generally not analyzed. Cyclones are often used for separating out the fine and coarse fractions of APM. ***Stacked filter units (SFU):*** This type of sampler uses the principle of sequential filtration, where particle fractionation is achieved by partially efficient polycarbonate filters. These filters are utilized due to their specific particle capture behaviour for the desired size fractions. An SFU consists of two filters in series, which are located upstream of a pump. The first filter (coarse stage) collects particles between about 3 micrometers and 15 micrometers. The second filter (fine stage) collects the particles which pass through the first filter, that is particles below about 3 micrometers. These samplers are also operated at "medium" volume flow rate (about 18 L/min or 360 m^3/day).

Personal samplers. These are small, compact air samplers, consisting of a pump and a unit for particulate collection onto a filter. These samplers can either collect total particulate matter, or have some device for particle size differentiation, and are largely low volume samplers (1-5m^3/hr). The sampler is then worn by the person being monitored. These samplers are used to assess individual exposure to air particulate matter.

"Gent" stacked filter unit air sampler. The "Gent" SFU air sampler is specifically designed for the collection of APM in the inhalable (PM-10) size fraction, using the principle of sequential filtration *(see schematic).* This sampler, designed at the University of Gent, Belgium (and currently being provided by Clarkson University, United States), is being used by all participants in the IAEA's Co-ordinated Research Programmes for air pollution research and related projects. The sampler uses an "open face" type stacked filter unit, in which two 47-mm Nuclepore polycarbonate filters (one filter of 8 micrometers pore size and the other of 0.4 micrometers pore size) are employed for the collection of APM. The filter unit is inserted in a cylindrical container, which is provided with a pre-impaction plate for the collection of particles larger than 10 micrometers. The sampler is designed to operate at a flow rate of 18 L/min, where the pre-impaction stage provides a PM-10 cut-off point at standard temperature and pressure. At this flow rate, the coarse (8 micrometers pore size) Nuclepore filter has a d_{50} value of 2 micrometers, so that it actually collects the 2-10 micrometers size fraction, whereas the fine filter collects particles in the size range less than 2 micrometers.



Countries participating in IAEA-supported monitoring and research on air pollution

Participants in global Co-ordinated Research Programme (CRP): Australia, Thailand, Bangladesh, China, Kenya, India, Iran, Turkey, Slovenia, Portugal, Hungary, Belgium, Austria, Czech Republic, Argentina, Chile, Brazil, Jamaica, and United States

Participants in regional CRP: Mongolia, China, Myanmar, Thailand, Republic of Korea, Philippines, Viet Nam, New Zealand, Indonesia, Singapore, Malaysia, Bangladesh, Sri Lanka, and Pakistan

Technical co-operation projects: Costa Rica, Chile, Philippines, Sri Lanka, Portugal

downwind of a large pollution source) and low pollution (e.g. rural areas).

In principle, a wide variety of different kinds of samplers may be used to collect APM. *(See box, page 18.)* For practical reasons, however, all participants in the CRPs are using a relatively simple and inexpensive sampling device. All of them have exactly the same design to ensure comparability of the resulting analytical data. A low volume PM-10 stacked filter unit designed at the University of Gent, Belgium, collects air particulate matter in two size fractions. Samplers of this design have already been supplied by the Agency to about 30 countries. *(See box above.)*

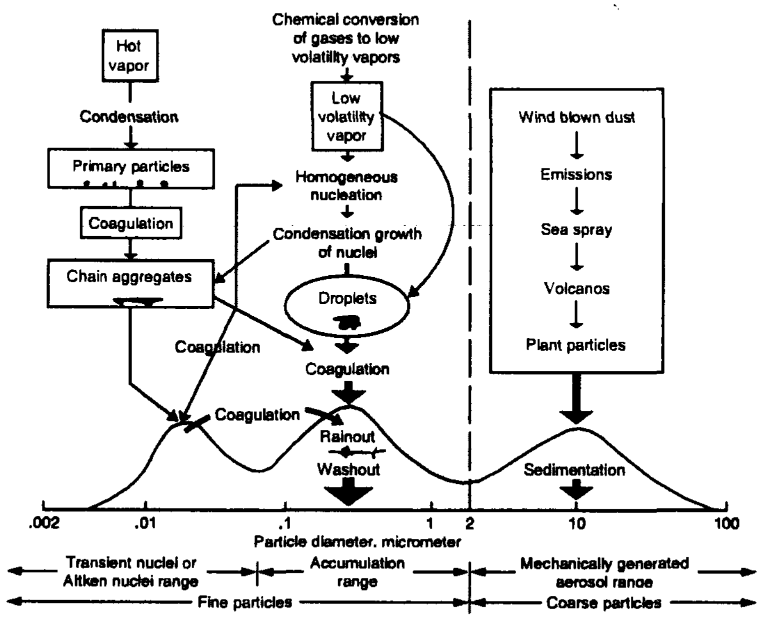
These CRPs are also supported by work at the IAEA's Seibersdorf Laboratories, which have set up one of the Gent samplers for collecting APM in Vienna and at a rural Austrian site. *(See box, right.)* In addition, the Laboratories are actively engaged in developing reference materials for air pollution studies, including reference air filter samples for use by all CRP participants. In this way, it is hoped to be able to ensure that the data collected during the CRP will be of high quality, and that meaningful comparisons can be made between the data reported by different analysts. For the same reason, it has also been decided that most of the data will be evaluated centrally by a single data co-ordinator.

Applicability of nuclear and related analytical techniques. A variety of analytical techniques is being used in these programmes. However, the main emphasis is on nuclear and related techniques, i.e. neutron activation analysis (NAA), energy dispersive X-ray fluorescence analysis (ED-XRF), and particle-induced X-ray emission (PIXE). These techniques have characteristics that make them highly suitable (in fact, *unique*) for conducting non-destructive multi-

Contribution of the IAEA's Laboratories at Seibersdorf

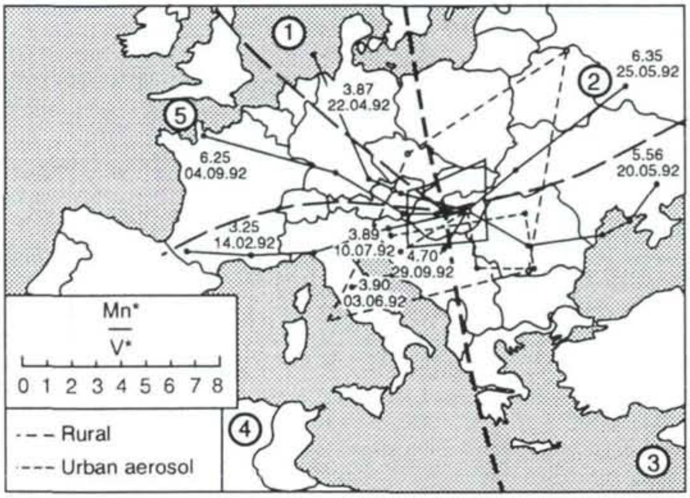
One way the Agency's Laboratories at Seibersdorf are participating in air pollution programmes is through the evaluation of the procedures, including sample collection, preparation, analysis, and data handling. Collection sites for APM using the "Gent" PM-10 sampler were established in an urban residential area in Vienna, and also at the site of the Laboratory in Seibersdorf, as a representative rural area. Possible pitfalls in the sampling and preparation steps, as well as the applicability of different analytical techniques, were investigated, and information on the suitability of the relatively low-volume sampler in developing countries was obtained. Due to the low masses of APM collected by the sampler utilized in the CRPs, highly sensitive analytical methods are required. Nuclear analytical techniques such as NAA and PIXE were shown to be particularly well-suited for analysis of the resulting samples. The multi-technique analytical approach used in Seibersdorf not only provided results for a large number of elements, but, for several elements, provided results from two different techniques, for better confidence in the data obtained. Although the number of samples collected was limited, a small "snapshot" of the trace element composition of APM in the Vienna area, as well as rural Seibersdorf, was obtained. The importance of the characterization of the "blank" (i.e. the trace element composition of the "substrate" or filter), was especially emphasized for samples taken in more remote areas (e.g. a rural site), as many of the trace element concentrations are at, or below, this blank value. Even with the challenges presented in the collection and analysis of APM samples, much information on the trace element composition of inhalable fractions of APM can be obtained by careful analytical work, as well as information on the sources of the APM (both natural and anthropogenic).

Airborne particulate matter



The diagram shows the size ranges, principal modes, main sources of mass of each mode, and the principal mechanisms by which particles are removed from the air.

Wind sector distribution diagrams in Debrecen, Hungary for urban and rural air particulates



Though rather complicated, the graph basically shows that the components of air pollution under investigation had mainly come from two directions: Donets'k, Moscow, and Ural regions of the Commonwealth of Independent States; and northern Italy and the northwestern Balkans. In addition, some particular pollution events could be identified and traced back to specific sources and dates.

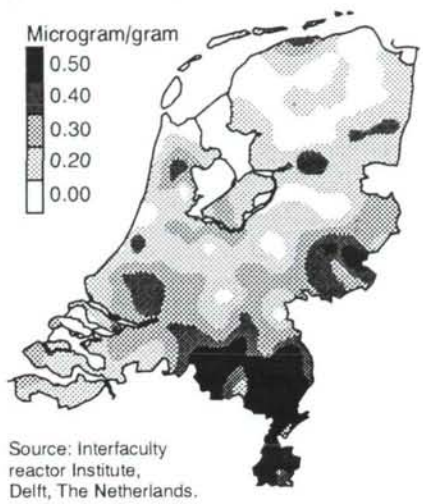
Apportionment of air pollution (PM-2.5 particles) for a city in New South Wales, Australia

Fingerprint	Percentage fingerprint contributions		
	Winter Month July 1994	Summer Month December 1994	Average for 1994
Motor Vehicles	68 ± 7	19 ± 5	54 ± 21
Smoke	18 ± 7	—	8 ± 12
Soil	—	2.7 ± 0.9	5 ± 4
Sea Spray	3.5 ± 0.9	5.4 ± 0.8	4 ± 2
Industry	11 ± 2.6	73 ± 7	35 ± 21
Total Mass	30 ± 2 μg/m^3	9.5 ± 0.6 μg/m^3	14 ± 8 μg/m^3

element analyses of airborne particulate matter on filters. *(See box, page 17.)* All other competing methods require a time-consuming dissolution of the filters, and are generally only applicable to one, or a small group, of elements (an exception is ICP-MS, which is also a nuclear-*related* method). Some of these elements, such as lead (chemical symbol Pb) are of *direct* interest

Calculated contribution from zinc smelters to cadmium air pollution in the Netherlands

(based on analysis of moss samples)



because of their health effects. However, most of them are studied because they can be used to provide a unique kind of *fingerprint* which enables individual sources of pollution to be identified.

Source identification and apportionment. Sources of pollution are characterized by being composed of different mixtures of elements in different proportions. Some examples of elements associated with six fingerprint sources of fine particles appear below, taken from the work of the Australian participant in the IAEA research programme:

- motor vehicles: H, Na, Al, Si, S, Cl, Fe, Zn, Br, Pb, Elt.C (elemental carbon)
- coal combustion: H, Na, Al, Si, P, S, K, Ca, Fe, Elt.C
- smoke: H, Cl, K, Ca, Elt.C
- soil: Al, Si, K, Ca, Ti, Mn, Fe
- sea spray: Na, S, Cl, K, Ca
- industry: H, P, S, V, Cr, Cu, Pb, Elt.C

If several elements that are characteristic of each of these sources are measured in a set of air filter samples, statistical techniques can then be used to estimate the percentage fingerprint contribution from each of them. *(See table.)* This kind of information is extremely useful to environmental authorities because it enables them to see where the pollution is coming from in terms of how it can be apportioned between different kinds of sources.

Another way in which sources of pollution can be identified is by combining information on the trace element content of air filter samples with *meteorological* information, in particular with information on wind direction and recent movements of air masses (so called backward air trajectories). *(See graph on previous page for an example in Hungary.)*

Biomonitoring. The same kinds of analytical and statistical techniques can be applied not only to air filter samples but also to *other* kinds of indicators of air pollution. In recent years there has been a considerable growth of interest in using various kinds of *biomonitors* of air pollution — samples such as moss, lichen, and even tree bark. The "trick" in applying this kind of technique is to choose a biomonitor that obtains most of its nutrients from the air and not from the soil, or other matrix, on which it is growing.

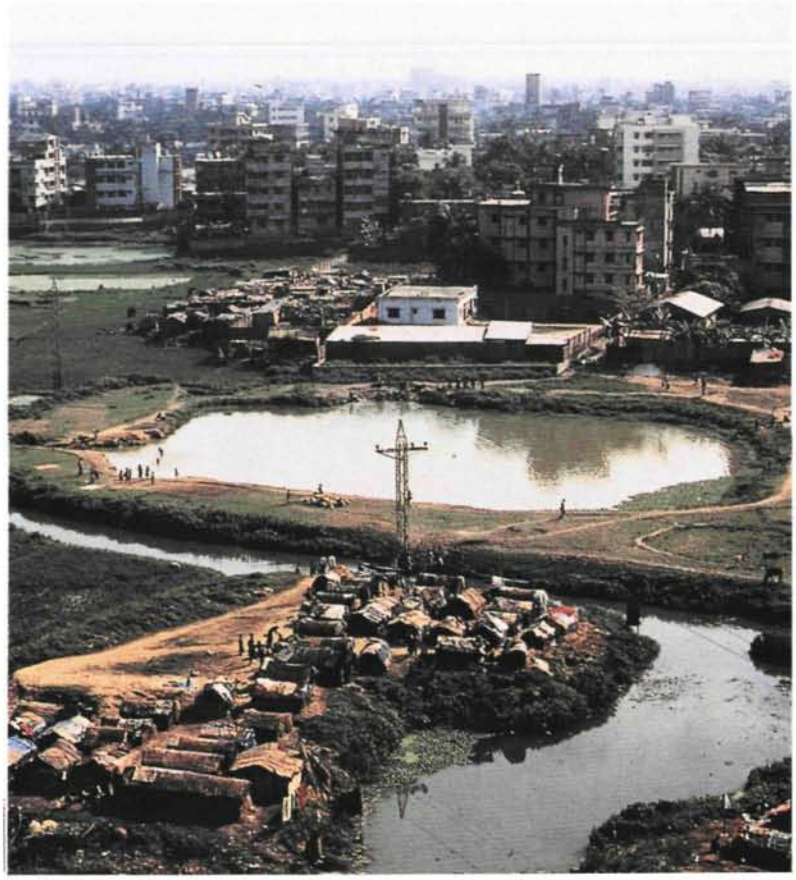
The main advantages of using biomonitors are (1) that the samples can be obtained almost "for free" (it is not necessary to set up expensive air filtering devices, needing electrical power together with frequent supervision and maintenance); and (2) the samples are already "in place" at sampling sites covering large areas (maybe even the whole country).

Surprisingly detailed information on the geographical distribution of air pollutants can be obtained in this way, not only on the *levels* of specific pollutants, but also (by statistical fingerprinting) on the *sources* of this pollution. *(See figure, previous page, for an example in the Netherlands.)* Several participants in the Agency's CRPs are also exploring the use of this kind of technique. The IAEA is well prepared to support further work in this area by having recently certified a suitable analytical reference material, lichen, with the help of 42 research participants from 26 countries.

Future areas of emphasis

The Agency's global CRP on air pollution is due to be completed in 1997, and the regional CRP in Asia and the Pacific in 1999. The information they provide will constitute a unique database on levels and sources of specific kinds of air pollution in major cities in many developing countries.

Since the particles being measured are the ones that are thought to be of direct relevance to human health, the Agency's database can be used to explore possible associations between air pollution and the incidence of cardiopulmonary diseases in the cities and regions being investigated. For most countries, such data has never been reported before. Since the same kinds of air samplers and analytical quality control procedures are being used by all research participants, a high level of confidence in the results is expected from the standpoint of being able to make meaningful comparisons between different cities and countries.



Bangladesh, one of the countries participating in IAEA-supported air pollution research.

New air quality standards are now under discussion in the United States, which are expected to provide guidance not only on PM-10 but also on PM-2.5 particles. The IAEA's programme is already providing information of this kind.

Some of the Agency's work is receiving support in the Asia and the Pacific region within the framework of the joint UNDP/RCA/IAEA project on the use of isotopes and radiation to strengthen technology and support environmentally sustainable development. Discussions are being held with the UNDP with a view to extending this work during the period 1997-99. If approved, air pollution studies will continue to be a major component of this project.

Also in Latin America, within the framework of the ARCAL regional programme, it is hoped to be able to promote the use of nuclear and related techniques for monitoring and research on air pollution, in this case with a major focus on the use of biomonitors.

In all of this work, nuclear and related techniques have been shown to be capable of providing valuable information on levels and sources of air pollution. It is information of a kind that is not only directly useful in itself, but which is practically unobtainable by any other method of nondestructive instrumental analysis. ❐

Uranium mining & milling: Assessing issues of environmental restoration

The IAEA is providing assistance toward solving problems in Central and Eastern Europe and the Newly Independent States

by
Giorgio Gnugnoli, Michele Laraia, and Peter Stegnar

Following political changes in Central and Eastern Europe (CEE) and the emergence of Newly Independent States (NIS) from the former Soviet Union, a great deal has been learned about the environmental situation in these countries. Extensive industrialization and exhaustion of the region's natural resources had been pursued to accomplish quota-based productivity goals. In many areas, the preservation and protection of the environment were often neglected in the process.

The political changes brought forward a fragmentary disclosure of radioactively contaminated sites. They also created conditions in which these countries became receptive to cooperation from a range of countries from which they previously had been isolated.

Although the need for environmental restoration is not limited to the CEE and NIS regions, a few distinctive features may raise additional complications. For example, if the uranium production facilities are found to require some form of remedial action, the size and location of the CEE and NIS production centres pose potential complications in the restoration work. Unlike some countries in which mineral development occurred in remote areas (e.g., the United States) or resulted in relatively small volumes of waste, the CEE countries and NIS face greater logistical complications for two obvious reasons. Firstly, the volumes of the accumulated radioactive waste are far too high to be removed at a reasonable cost. Secondly, safer alternative disposal sites are either not available or else are impractical.

During the 1980s and early 1990s, many older uranium mines were closed because of a decrease in the demand for uranium and an increase in the overall supply. The resulting low prices and the cost of providing the extra measures needed to satisfy society's higher expectations in the area of environmental and radiological protection made production of uranium unprofitable for many low-grade mines. Moreover, this economic consideration has further complicated implementation of site restoration.

Although some of these mines/mills will probably reopen when demand and prices increase, many will be shut down permanently and need to be decommissioned/closed out. As this situation has evolved in a relatively short period of time, limited resources were put into remediating or even securing contaminated areas in CEE countries and the NIS.

The following factors contribute to an increased risk of radioactive contamination:

- long operational periods contribute to greater risk of contamination;
- higher ore grade increases radiation dose rates from the residues;
- natural climatic conditions (e.g., rain, wind) significantly enhance dispersal and contamination; and
- countries with limited resources can only allocate marginal resources to environmental restoration.

Unfortunately, most of the CEE countries and NIS "qualify" under these factors. This article briefly describes some of the typical problems in planning and implementing environmental restoration projects in these countries.

Basic conditions and problems

Although some political, economic, and infrastructural conditions are common to many countries in the CEE and NIS regions, large variations exist. In general, three categories of basic environmental restoration situations can be identified:

- countries with limited development of the uranium industry having small amounts of min-

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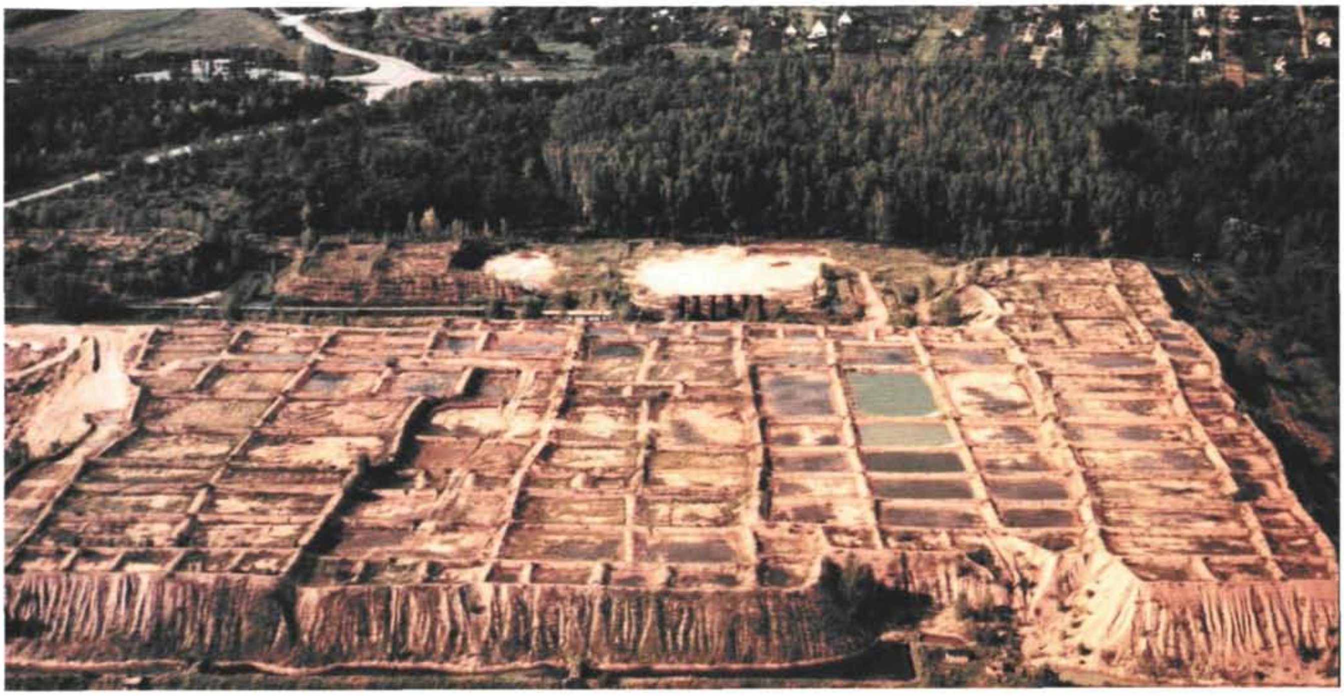


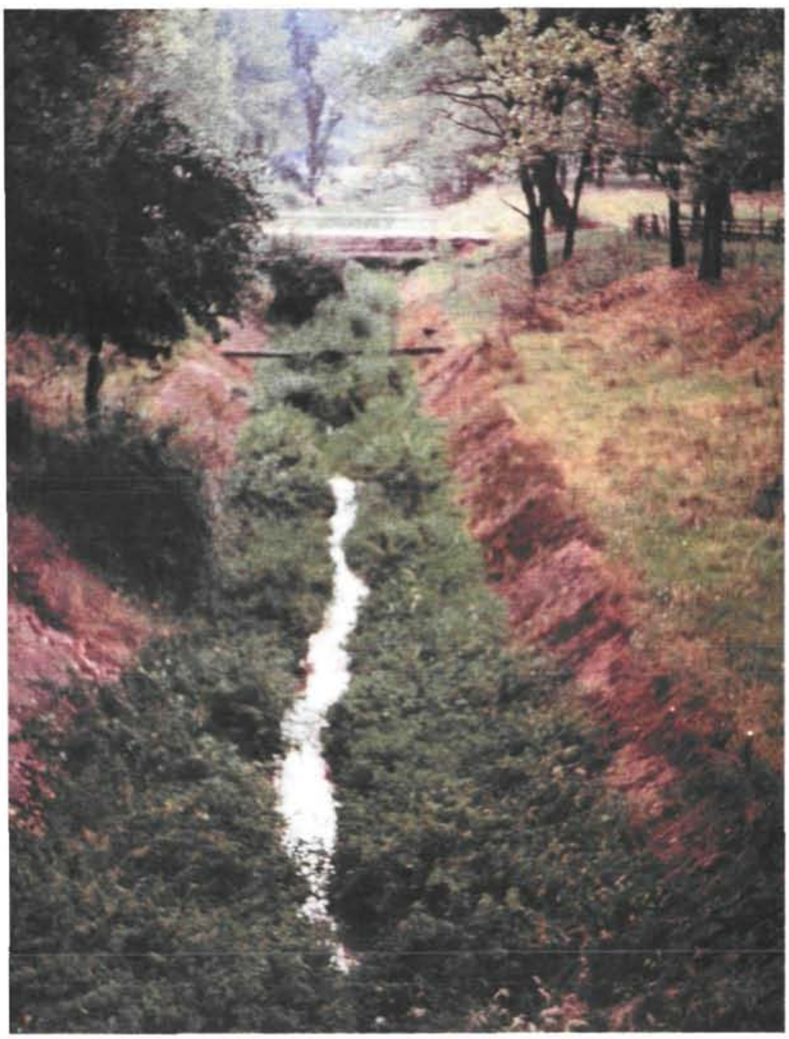
ing/milling waste and few contaminated sites (e.g., Poland);

• countries with a more developed uranium industry having several mines/mills and moderately impacted resources (e.g., Romania); and

• countries with a fully developed uranium industry having many mines/mills and severely impacted resources (e.g., the Czech Republic).

Typical problems associated with past practices in CEE and NIS include radon release; groundwater contamination; proximity of contamination to populations; lack of resources to conduct restoration; availability of disposal locations/alternatives; absence of regulations or a regulatory infrastructure for restoration; misuse or removal of tailings for use in construction; absence of responsible operators; and large inventories and areal dispersion.

In some cases, groundwater contamination is such a severe issue that major sources of drinking water are threatened by radiological and chemical contamination. Another typical situation in CEE countries is the proximity of uranium production sites to population centres. This proximity has, on occasion, led to the use of some of the waste rock and tailings materials for building purposes. Such structures are constant sources of indoor radon, one of the most significant radioactive hazards.



Above: **The Pécs uranium mining and milling site in Hungary shows "heap leaching" piles and waste rock.** *(Credit: Mecsekore Mining, Hungary)* ***Right:*** **A contaminated channel crossing the village of Yana, near the Buhovo mining and milling site in Bulgaria.**

Special problems of environmental restoration in the region

Site specifications. The siting and characterization of radioactively contaminated sites in CEE countries is probably the most difficult problem in relation to environmental restoration projects. The available data is not only incomplete but also somewhat questionable. A precondition for environmental restoration projects must be the availability of sources of data pertinent to the specific radioactively contaminated sites; otherwise the efforts and resources put into the process are useless.

Organizational problems associated with the political changes. In many CEE countries and the NIS, the old regulatory framework is being changed to reflect newly independent or radically altered political structures. Such frameworks, including the development of new laws and regulations, are planned or are just coming into existence. In some countries, existing laws will necessarily be adapted to changed political situations. There will be a period of transition, as such changes occur and ambiguities in new responsibilities are resolved. This situation is likely to complicate decision-making in environmental restoration.

The funding of environmental restoration work. A number of outside agencies, such as the World Bank and European Bank for Reconstruction and Development, as well as individual countries and groups of countries such as the European Union, are offering support for environmental restoration. However, there can be a lack of co-ordination and, therefore, duplication among these projects that could result in the inefficient use of available funds. Moreover, effective allocation and distribution of financial resources within countries may also prove to be difficult.

Available infrastructures for managing the wastes and residues from remediation programmes. To effectively manage the residues and wastes from the cleanup programmes, countries need waste management infrastructures/facilities to process, store, and safely dispose of any resulting radioactive wastes from restoration. In many CEE countries and the NIS, the stages of the nuclear fuel cycle were regionally co-ordinated. In most countries only parts of this infrastructure remain. Without having practical access to radioactive waste disposal facilities, cleanup efforts may be limited.

Increasing differences among the CEE countries and NIS. Large co-ordinated projects are likely to be more cost efficient and beneficial for these regions than having separate national programmes. Nevertheless, there are tendencies that these countries will go different ways, because of the dissimilarities in the nature of their present economic and political objectives. This is not beneficial in light of the overall goal of efficient use of resources in environmental restoration. Geographical proximity, similar political structure, and the same types of waste dictate co-operation and the use of similar technology and experience.

Public attitudes. Another problem with environmental restoration projects is the governmental, scientific and public view of the problem of radioactive waste. Since radioactively contaminated substances have been commonly used in these regions for nearly 50 years, in conjunction with outdated practices in the handling of the material, the public has had little recourse but to accept the presence of radioactive waste around them. In many instances, the public did not even know that these substances were in such close proximity to their homes. This situation appears to be changing, as people in these countries come to understand the hazards associated with such waste.

Solutions for contaminated sites

In many ways, the strategy used to deal with contamination and releases from operational mining and milling facilities is similar to that used in past practices. For example, erosion-driven, off-site contamination is characterized and, where practical, excavated and returned to the original site. Certain practices and strategies, if put into place during the operational period, can result in significantly reduced restoration efforts at the time of closeout.

Current strategies for mining and milling. Current operations employ certain practices, in conjunction with an overall isolation and burial strategy, which provide a safer and more effective approach to disposal. These waste management practices include spraying ore piles and tailings beaches with water and/or chemical stabilizers; use of baghouses at the crushing and blending areas; combined use of wet scrubbers with baghouses at U_3O_8 drying and packaging areas; grouting mine cavern walls; adding neutralizing agents to tailings liquids, and ventilation of underground mines.

Tailings impoundment and waste rock piles. Current waste management strategies at conventional mines and mills consist of burial, backfilling mines, and deep/shallow lake disposal. These types of disposal strategies can be greatly enhanced by additional features for environmental protection:

- backfilling mines with soil/rock aggregates;
- use of mine bulkheads;

- chemical neutralization;
- liquid waste impoundment liners;
- progressive trench disposal systems;
- pumping of ground water; and
- drainage/seepage collection and treatment systems.

Unconventional mining operations. In many cases, the mineral resource is of a nature which does not easily or economically lend itself to conventional mining and/or milling. Industrial processes are available which permit the resource to be extracted, but without the costs and other burdens associated with conventional ore processing. These processes are generally referred to as unconventional mining or milling. In contrast to conventional mining and milling, these types of operations tend to be smaller scale operations where it is uneconomical or impractical to excavate the ore loads. The main types are *in situ* leaching (solution mining), heap leaching, and byproduct recovery. If these types of smaller scale, relatively economical facilities are properly maintained and operated, CEE countries and the NIS could maintain a production level of U_3O_8 without having the burdens and hazards of large surface waste impoundments.

In some CEE countries, both *in situ* mining and conventional milling have been used (e.g., Czech Republic and Bulgaria). Heap leaching has been used in Hungary. The principle for byproduct recovery is to take advantage of an existing industrial process by diverting the operational — or even waste — stream for an additional extraction process. For example, former uranium mining and milling facilities in Kyrghyzstan (Karabalta) will be converted to processing for gold. Although heap leaching and byproduct recovery are fairly discrete and controllable operational strategies, *in situ* leaching requires a more carefully controlled operational sequence to be successful without contaminating useable aquifers.

Current strategies for restoration

The approach to restoration for contamination resulting from past practices in uranium and thorium mining and milling is very similar to the reclamation efforts usually exerted at the time of operational closeout of current mines and mills. Selecting the scope and extent of restoration is complex, because the impacts from these facilities usually become evident only after a number of years. In effect, the hazard is more of a latent or chronic one. The restoration effort involves one or more of the following:

General earthen construction. Backhoes, bulldozers, and scrapers are the typical kinds of earth-moving equipment involved. However, the radioactive nature of the contaminated soils and rock also requires monitoring of personnel and equipment and decontamination of equipment and work areas.

Cleanup of contaminated materials. In some cases, the residues of past operations have been used for construction purposes off-site. The legacy of this practice is a proliferation of such radioactive wastes in structures and land which would not ordinarily be so contaminated. Unlike the nuclear facilities themselves, there is a limit to the degree of restoration that can be performed at these off-site properties. More regulatory flexibility may be needed in such cases. For example, waste rock utilized in building a rail line may need to be treated *in situ*, because excavation and reconstruction might entail other more disruptive consequences.

Water contamination. Ground and surface water resources present a greater technological problem for restoration. The costs for restoring a deep aquifer forces a higher reliance on natural restoration as part of the overall strategy for cleanup. A number of countries in the CEE and NIS regions are faced with the problem of contaminated water bodies. Others are in the investigation phase to determine the extent of such contamination.

Although exclusive reliance on some of the more expensive technologies may be outside of an individual country's resources, a combined strategy involving natural restoration and active water treatment (e.g. ion exchange) may be worth considering. In many cases, an immediate benefit accrues when the source term is terminated. Uncovered waste rock piles and other radioactive materials should be isolated and stabilized, as soon as possible. Rain can interact with such waste to create additional contamination problems (e.g., acid wash from the waste rock).

An important facet to any restoration strategy is the benefit of partial restoration; natural restoration, or a more simple approach, can be greatly enhanced when the aquifer or water body is restored to an improved condition, which can enable nature to recover (e.g., modifying the pH by addition of neutralization agents as simple as limestone).

Role of monitoring in environmental restoration. In order to adequately characterize the extent of the problem and to measure the progress of any restoration strategy, it is necessary to employ an efficient, reliable, and well-placed monitoring system. Ultimately, such a monitoring system is necessary to demonstrate whether restoration has been successfully achieved.

IAEA programmes in uranium mining and milling

The IAEA has basically three mechanisms in its waste management programme:

• development of documentation to assist countries in implementing their own national programmes.

• providing a forum and clearinghouse for technical exchange of information.

• promoting technical co-operation and assistance to developing countries for peaceful use of nuclear materials.

Two examples of recent IAEA initiatives in this programme are provided below.

An IAEA programme focusing on radioactive waste standards (RADWASS) includes publications of guidance in the area of uranium mining and milling, including a proposed Safety Standard on restoration of facilities and the environment.

The IAEA has also supported a regional technical co-operation project on environmental restoration in CEE. Most of the efforts focus on characterizing the type and extent of waste and in the planning of the implementation strategies for the cleanup. A series of workshops has been held (1993-94) in some of the CEE countries to provide first-hand perspectives of the contamination problem. These workshops addressed characterization of the waste sites, planning restoration, and implementation of and techniques for restoration. The types of sites being considered included uranium mines and mills, but the project was not limited to only mining and milling contamination (e.g., Chernobyl was included). Countries with expertise in rehabilitation and remediation of radioactive waste sites have also taken part in the project. To the extent possible, those entities responsible for the monitoring and cleanup of each site were identified. Without having a responsible or accountable entity, there would remain doubts regarding initiation, execution, and completion of any rehabilitation effort.

This technical co-operation project, now into its 1995-96 phase, consists of establishing work plans for the restoration of mining and milling contaminated sites. Beyond 1996, efforts will shift to the national level, in order to focus on the site-specific aspects of these types of facilities. The results of these workshops have recently been published by the IAEA (as TECDOC-865).

Ongoing challenges

As the CEE countries and NIS move into the global economy, they are faced with significant challenges to compete in the private industrial sector, including uranium processing. Although some of these countries still possess viable quantities of the natural uranium ore, they still need to address the legacy of outdated waste management practices, which have burdened them with large inventories of tailings and waste rock, as well as other industrial waste.

The international community acknowledges this situation and has provided assistance to these countries through a number of means. The IAEA has participated in assistance efforts within the framework of its technical co-operation programme. In doing so, the IAEA is linking this assistance to internationally accepted criteria and standards. This is being done to assure that the future development of resources in the uranium mining and milling industry, as well as the associated environmental restoration of the residues of the past, are performed in a manner which does not repeat the mistakes of the past. ❐

Uranium open pit mining in Uchkouduk, Uzbekistan.
(Credit C Bergman, IAEA)

Sustainable development & electricity generation: Comparing impacts of waste disposal

The IAEA and other organizations are evaluating approaches for comparing wastes and disposal methods from energy chains

by Roger Seitz

Health and environmental impacts that may result from disposal of waste are a growing concern for sustainable development of human society. Waste posing potential hazards to human health and the environment is generated in a number of industry sectors (mining/quarrying, agriculture, manufacturing, electricity generation, medical, etc.). When properly managed, this waste will pose minimal risks to human health and the environment.

However, environmental concerns arise from the fact that the quantity of waste being generated is growing (and expected to keep growing) as a result of increases in the world population, industrialization, and urbanization. Thus, one challenge in developing a strategy for sustainable development is to provide the services necessary to support economic growth and improving quality of life, while limiting the waste generated in terms of potential hazards and quantities and its health and environmental impacts.

As sustainable development brings better living conditions to a growing world population, greater use of energy, especially electricity, will be demanded. Until a suitable alternative capable of meeting the growing demand for electricity is developed, the vast majority of future electricity demand will need to be met by conventional fuels such as coal, natural gas, oil, and uranium/thorium. Thus, sustainable development strategies must include consideration of the waste that is generated throughout energy chains based on these fuels.

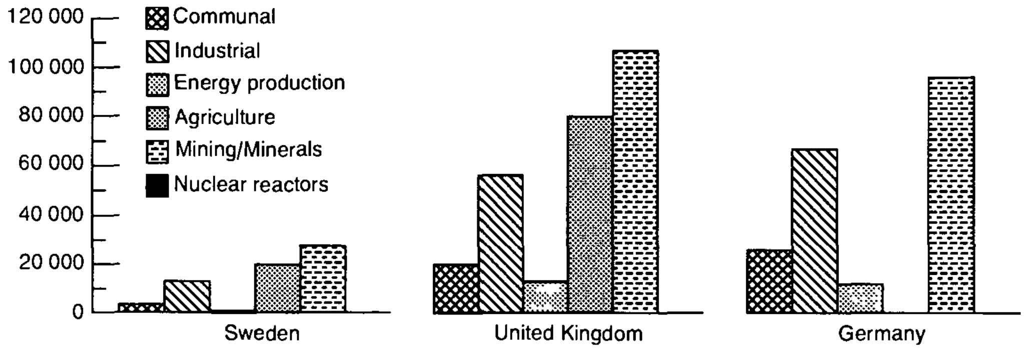
This article provides an overview of the initial stages of an IAEA project to compare wastes and disposal methods from different electricity generation systems and to review approaches used to assess and compare the health and environmental impacts resulting from disposal of such waste. The role of nuclear power in a strategy for sustainable development of human society is emphasized. In this respect, the article highlights the small mass of waste generated as a result of nuclear power when compared to the total mass of waste from all energy chains and other common activities. Selected waste and respective disposal methods from all steps in the energy chains for electricity generation are discussed. (Liquid and gaseous effluents that are discharged directly to air or natural water bodies are not included in this article.) Emphasis is placed on the importance of considering all steps in the energy chains, which yields information on large quantities of waste posing potential long-term impacts from electricity generation systems that are often considered "clean". Radionuclides that are present in many non-nuclear wastes are also discussed.

Mr. Seitz is a staff member in the IAEA Division of Radiation and Waste Safety. Full references to this article are available from the author.

Waste management and sustainable development

The Organization for Economic Co-operation and Development (OECD) estimates that roughly nine billion tonnes of solid wastes were generated by its Member States in 1990. In spite of waste minimization efforts implemented in recent years in nuclear and other industries, this total is continuing to rise. Reviews by the United Nations Environment Programme (UNEP) suggest that the mining/quarrying and agricultural (manure, crop residues, etc.) sectors generate the largest amounts of wastes. Data covering OECD countries and data from the United Nations Statistical Commission and Economic Commission for Europe (UNSC/ECE) support the general UNEP conclusion. They also suggest that in

Estimated waste generation rates for three countries



	Sweden*	United Kingdom*	Germany**
Communal	3 200	20 000	26 383
Industrial	13 000	56 000	67 203
Energy Production	625	13 000	11 917
Agriculture	21 000	80 000	not reported
Mining/Mineral	28 000	107 000	96 667
Nuclear Reactors***	7.7	65	20

* Estimates from Organization for Economic Co-operation and Development, *OECD Environmental Data, Compendium 1993*
** Estimates from United Nations Statistical Commission and Economic Commission for Europe, *The Environment in Europe and North America Annotated Statistics 1992.* Nuclear reactor waste estimates in Energie Wirtschaftliche Tagesfragen, Jan/Feb 1993, *Die Entsorgung von Kernkraftwerken im internationalen Vergleich.* Agricultural waste estimate not provided.
*** Estimates include low- and intermediate-level radioactive waste from *IAEA Waste Management Profiles*, April 1994 (except Germany). Low- and intermediate-level waste data are converted from cubic metres to tonnes assuming an estimate of 2 t/m^3. High-level waste would not change these figures

Notes The data should only be used as rough "order of magnitude" indicators Comparisons between countries may not be relevant because of the different definitions that are employed for waste types and the use of different counting methods. The energy production data do not include mining wastes and the reported data do not include wastes generated in other countries during mining of imported fuel

some countries the industrial, communal, and energy production sectors can account for a large proportion of the solid wastes generated. *(See graph.)* It is interesting to note that the the mass of radioactive waste from nuclear power plants is a small fraction of that resulting from all energy production.

The continuing growth in the quantities of waste being generated and the need for appropriate disposal facilities which protect human health and the environment has led to the increased involvement of a number of United Nations organizations in waste management issues. The United Nations Conference for Environment and Development (UNCED), held in Rio de Janeiro in June 1992, provided an international forum for discussing sustainable development strategies related to waste management in addition to a number of other environmental issues. Agenda 21, the programme of action for sustainable development agreed upon by the governments participating in UNCED, reflects the significance of waste-related concerns. It includes three chapters specifically directed at waste management and references to waste management issues in a number of other chapters.

Through UNCED and Agenda 21, the United Nations and world governments have called global attention to the need for a comprehensive strategy for sustainable development of human society. Agenda 21 includes a number of statements emphasizing that reduction of the amount of wastes being generated is a necessary part of any such strategy. It also includes recognition that regardless of the success of efforts for cleaner production, waste is a consequence of development and will continue to be generated, and thus disposal options capable of protecting health and the environment must continue to be available. The data available support the argument that the minimal amounts of waste generated through nuclear power may help make it a beneficial contributor to a global strategy for cleaner production and sustainable development.

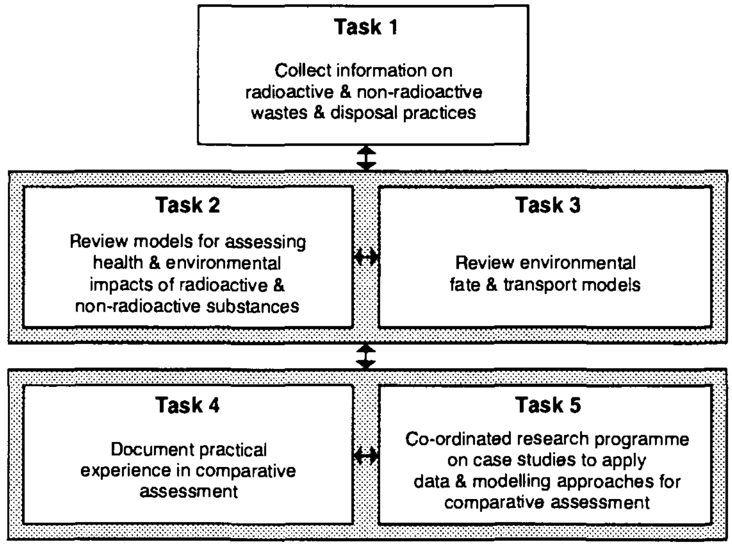
IAEA projects and programmes

The IAEA is undertaking a comparative assessment programme to address the role of nuclear power in a global strategy for cleaner production and sustainable development in the electricity generation sector. This programme is considering health and environmental impacts and costs for many aspects of electricity generation, including normal operations and accidents in all steps of the energy chains for electricity generation. The DECADES project being undertaken by the IAEA in collaboration with a number of other international organizations is a focal point for the programme. Its objective is to enhance capabilities for incorporating health and environmental issues into comparative assessments of different energy chains and strategies in the process of energy planning and decision-making. The project emphasizes the development of computerized tools (data bases, modeling software, etc.) that can be used to facilitate this decision-making.

One part of the IAEA's comprehensive programme, being conducted somewhat independently from the DECADES project, is the subject of this article. In 1995, the IAEA started a project focusing on comparison of approaches for assessing health and environmental impacts from disposal of radioactive and non-radioactive wastes resulting from nuclear and other electricity generation systems. The objectives of the project are (1) to collect, evaluate, and disseminate to Member States data and information on the potential health and environmental impacts associated with disposal of radioactive and non-radioactive waste from nuclear power and other sources; and (2) to evaluate and test approaches for assessing and comparing the potential health and environmental impacts from disposal of waste from nuclear and other energy systems.

A number of organizations — the United Nations Industrial Development Organization (UNIDO), the United Nations Educational, Scientific, and Cultural Organization (UNESCO), UNEP, the UNEP Secretariat for the Basel Convention, the World Health Organization (WHO), the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), and the International Maritime Organization (IMO) — have all contributed, formally or informally, to the project through active participation in meetings, contributions to or reviews of reports, or simply providing information useful for the project.

Tasks in project on comparative health and environmental impacts of wastes from nuclear power and other electricity generation systems



The project is planned to include five tasks which are iterative and parallel in nature. *(See diagram.)* The first task is to identify and compare quantities and general characteristics of wastes and disposal methods from electricity generation systems and other sources. The second and third tasks are respectively planned to include reviews of approaches being used to assess health and environmental impacts from radioactive and non-radioactive substances and models being used to assess the environmental fate and transport of different types of wastes. These two tasks will provide information to enable the health and environmental hazards associated with the waste to be assessed and compared in a quantitative manner. The fourth and fifth tasks are planned to include practical experience through testing of the approaches from the second and third tasks on assessments of the potential health and environmental impacts of wastes from nuclear and other electricity generation systems. In the fifth task, this experience is planned to be obtained through case studies from a Co-ordinated Research Programme involving experts from a number of different countries.

The data on wastes and disposal methods can be used to supplement the databases being developed as part of the DECADES project. However, given the diversity of wastes, disposal methods, and environmental conditions at sites and unique problems associated with modeling long-term release and transport of waste from disposal facilities, assessment approaches for this project are being reviewed somewhat sepa-

Radionuclide contents of selected materials

Material	Radionuclide concentrations (average or maximum as indicated)
Scale and sludges in pipes and equipment for handling produced waters	up to 5000 Bq/g (Ra-226) (average one to hundreds of Bq/g)
Sludges in natural gas supply equipment	up to 100 Bq/g (Ra-226)
Sludges from ponds of produced water	up to ~40Bq/g
Coal/lignite	0.001 - 100 Bq/g (uranium)
Peat	up to 50 Bq/g (uranium)
Geothermal wastes	~ 5 Bq/g (Ra-226)
Uranium mining overburden	~ 1 Bq/g (Ra-226)
Drinking water treatment waste	sludges - ~1 Bq/g (Ra-226) resins - ~1,000 Bq/g (Ra-226)
Phosphate fertilizer	~5 Bq/g (U-238)
Phosphate rock processing waste	slag - ~1 Bq/g (Ra-226) scale - ~40 Bq/g (Ra-226)
Mineral processing waste	~1 Bq/g (Ra-226)

Notes: These values include maximums, averages for specific sets of data, or general ranges of value. In many of the values, the radioactivity associated with only one radionuclide is given, when it is known that a number of other radionuclides will also be present. Thus, the data should be used as rough indicators of the levels of radioactivity that would be found in these materials.

rately from the more traditional atmospheric and operational risk assessment approaches. The emphasis of these tasks is to review and test independent modeling approaches for assessing and comparing the short- and long-term impacts associated with disposal of different energy chain wastes and provide feedback, regarding the effectiveness of different modeling approaches in different situations, that will help Member States to select and use approaches to assess impacts of disposal in their specific conditions.

The results of comparative assessments of the health and environmental impacts of different types of solid wastes may have several potential applications. They may be used (1) as part of an overall comparison of the impact of different energy systems; (2) as an aid to decision-making on waste management policies, by allowing the comparison of impacts of different types of wastes and of alternative management/disposal strategies; and (3) in the evaluation of the potential impacts of the disposal of wastes containing radionuclides, non-radioactive toxic elements/compounds, or both.

Wastes from energy chains for electricity generation

A variety of different sources of energy is used to generate electricity. Generally, these energy sources are classified as "conventional", including fuels such as coal, oil, natural gas, and uranium/thorium, or "renewable", including energy sources such as solar radiation, wind, surface water, biomass, and geothermal. Although some of these energy sources (e.g., solar radiation, wind, water) do not necessarily generate waste as a result of operations other than from maintenance and other general activities, there are wastes posing long-term hazards associated with mining and processing raw materials and manufacturing and decommissioning of solar cells, wind machines, and dams.

In order to identify the different radioactive and non-radioactive wastes associated with a selected electricity generation system, it is convenient to categorize the wastes in respect of the different steps in an energy chain. For the purposes of this article, a generic energy chain is defined as including steps for extraction, fuel preparation, plant operation, and decommissioning. Note that wastes from construction, maintenance, transportation, and treatment processes, as appropriate, should be addressed in each of the steps of the chain.

Often, because of the focus of public attention, there is a perception that the majority of the waste associated with electricity generation using conventional fuels is the result of operation of the facility (e.g., ashes, spent nuclear fuel). However, as discussed earlier, data from the UNEP, OECD and UNSC/ECE suggest that one of the two largest sources of wastes in the world is the mining industry.

This is reflected in the electricity generation sector as well. Relatively large quantities of waste are generated for a number of the electricity generation systems during extraction of the fuel (coal, natural gas, oil, and uranium/thorium). For example, over 80% of the mining/mineral waste reported by the UNSC/ECE for Germany is due to coal mining. Likewise, mining for minerals used in construction materials (metals, concrete, etc.), treatment processes (e.g., limestone for flue gas desulfurization, or FGD), fertilizers for biomass fuels and manufacturing of specialty components such as solar cells result in waste arisings. The quantity and toxicity of waste arisings will vary depending on the extraction method, amount of fuel/mineral needed, and quality of the resource.

Due to the large fuel requirements for production of a given amount of electricity, coal mining generally results in the largest amounts of mining wastes. However, uranium/thorium mining can also result in a large amount of the waste from the nuclear energy chain. Likewise, large volume mining waste is also associated with a number of other energy chains (e.g., photovoltaics used to generate electricity from solar radiation require a number of metal compounds in their construction; phosphate is often used for fertilizers for production of biomass fuels; and numerous raw materials must be mined to produce the materials necessary for construction of dams, power plants, transport vehicles, etc). Another large source of waste for the mining industry is groundwater that is pumped from the mine during excavation or water that flows through the mine after closure. This water can contain a variety of contaminants including naturally-occurring radioactive material, generally abbreviated as NORM (e.g., thorium, uranium, radium), trace metals (e.g., aluminum, mercury, chromium, cadmium, lead, zinc, arsenic, etc.), salts, and sulfur. Coal mine water can also include elevated levels of hydrocarbons.

Although natural gas is often considered a "clean" energy source, exploration and drilling for natural gas and oil are large sources of waste. Waste from these operations include radioactive scale that accumulates on the inside of pipes, drilling muds, and soil contaminated by spills of oil and treatment of produced water. Scale that accumulates on the inside of pipes can contain significant amounts of radionuclides *(see table)* and can require disposal as a radioactive waste. Drilling muds can be contaminated with salts, trace metals (selenium, arsenic, magnesium, curium, zinc, chromium, nickel, aluminum, and iron), and oils and other lubricants. Extraction of oil and gas also includes large quantities of "produced" water from the gas or oil bearing formation (up to 3,000,000 L/day). Such produced water contains a variety of contaminants including NORM (especially radium), trace metals, ammonia, salts, aliphatic and aromatic petroleum hydrocarbons, phenols, and naphthelenes. Sludges resulting from ponds of such water are contaminated with elevated concentrations of the metals, hazardous substances, and radionuclides that were present in the water. Drilling operations also result in a variety of hazardous wastes including asbestos, pesticides, PCBs, and trichloroethylene.

The second step in the generic energy chain is fuel preparation. Fuel preparation can also be a large source of wastes. For conventional fuels, fuel preparation includes cleaning raw coal to remove impurities, refining petroleum products, and milling and fuel fabrication for nuclear power. These wastes from post-mining activities include tailings, water, and solids contaminated with similar materials to the mining wastes (e.g., trace metals, salts, metals and NORM). Refineries generate waste oil and water, a variety of sludges contaminated with NORM, hydrocarbons, trace metals, PCBs, and other contaminants. Fuel fabrication for nuclear power plants results in waste including ashes and sludges contaminated with NORM and trace metals. The manufacture of solar cells (photovoltaics) can be considered an analogue to fuel preparation in the context of solar power. Manufacture of photovoltaics for solar cells results in a variety of toxic or hazardous waste contaminated with arsenic, copper, cadmium, gallium, and zinc compounds.

The third step in the energy chain includes waste generated during operation of the electricity generation plant. These are the most recognized wastes as they tend to receive the most attention. Coal-fired plants generate large quantities of combustion waste including fly ash (airborne combustion products) and bottom ash (heavier combustion products) that result from the burned fuel, as well as gypsum and sludges from different FGD techniques. These wastes are contaminated with NORM and trace metals. It is somewhat ironic that the use of flue gas desulfurization to reduce the greenhouse gases emitted from fossil fuel facilities results in more waste being produced than the ash from the burned fuel. Recycling of fly ash and FGD wastes is being heavily promoted and large quantities are being used for other purposes (e.g., cement additive, backfill, gypsum in construction materials, and many other uses). However, even with recycling, the enormous quantities of ash and FGD waste that are generated far exceed the demand (it is estimated that more than 450 million tonnes of these wastes are unused in the world each year). Oil-fired plants generate lesser quantities of ashes, but can be a large source of FGD waste. Furthermore, some of the boiler cleaning and waste water treatment wastes also contain hazardous materials.

Waste from the operation of nuclear power plants is probably the most studied waste in the world, especially spent nuclear fuel. However, data show that the amount of waste generated by a nuclear power plant is very small compared to the waste generated by electricity generation systems as a whole. The main concern for nuclear waste is the high levels of radioactivity in the much smaller quantities of high-level waste. Reprocessing of the spent fuel is conducted in several countries, which reduces the long-term hazards associated with the waste that must be disposed. Low- and intermediate-level waste also results from nuclear power plant operations. This waste includes various trash, piping, and used equipment that are contaminated by radionuclides with relatively short half-lives.

Decommissioning of closed power plants is the last step in the generic energy chain. For coal, oil, and gas-fired plants, decommissioning waste would include building rubble, old equipment from the facility, and contaminated soil resulting from operations. These materials would be contaminated by combustion byproducts and other substances associated with plant operation. Wastes from nuclear power plant decommissioning differs from those from other power plants in the respect that materials that were near the reactor core or primary coolant may require special handling due to elevated levels of primarily short-lived radionuclides. Decommissioning of solar cells, dams, and wind machines would also result in wastes that must be managed. The solar cells, in particular, will contain hazardous compounds posing potential long-term health hazards.

A number of wastes are generated as a result of construction, maintenance, transportation, and waste treatment processes in each of the steps of the energy chain. General construction, maintenance, and transportation wastes would, for the most part, be typical for all of the energy chains, although the quantities and types and levels of contamination will be different depending on the energy chain. For example, waste associated with transportation can be very significant for coal-fired plants due to the enormous volumes of fuel and resulting ash and waste that must be transported on a daily basis. It has been estimated that fifty 40-tonne trucks per day would be required to transport the fly ash and FGD wastes from a typical 1000-MWe coal-fired power plant to a disposal site (rail or other transport can also be used when available). A complete life-cycle analysis would need to include the waste generated while producing the fuel for the trucks or trains and the waste associated with maintaining the vehicles. Disposal of secondary waste resulting from treatment processes that are used for many of the wastes will also need to be considered in a comprehensive comparison.

Naturally occurring radioactive materials

Many of the wastes discussed above, especially those associated with extraction, fuel preparation, and combustion byproducts, contain naturally occurring radioactive materials (NORM). NORM includes isotopes such as carbon-14, potassium-40, uranium-238, radium-226, and thorium-232. *(See table.)* One important aspect of waste containing NORM is that it consists of long-lived radionuclides (e.g., uranium-238 whose half-life is 4.5 billion years), thorium-232 with a half-life of 14 billion years, and their progeny, including radium). The primary radiological health concern associated with NORM is due to radium and its progeny.

Because of the focus on radioactive waste from nuclear power plants, the radionuclides in waste from other energy chains have historically received comparatively little attention. However, more recently, due to the long half-lives and potential hazards associated with the radionuclides in NORM containing wastes, regulators have been forced to consider the radionuclides in the waste from non-nuclear energy chains in the context of the increasingly strict regulations applied to nuclear waste.

Two examples of NORM waste from the oil and gas industry can be used to provide perspective. Firstly, scale that precipitates on the inside of wells and production piping is now often considered a radioactive waste. It is interesting to note that, in some cases, this scale has been shown to contain concentrations of radium-226 that rank at the upper end of international levels for alpha concentrations in low- and intermediate-level wastes that may be disposed of in near surface facilities. Secondly, studies of the large quantities of produced water from wells at oil and natural gas drilling sites have indicated that 50% to 78% of the wells that were surveyed in three states in the United States yielded produced water with average radium concentrations in excess of 1.85 Bq/L (50 pCi/L). Other data suggest that average radium concentrations in water from some wells can be as high as 111 Bq/L (3000 pCi/L). As a comparison, the radium concentration limit for discharges of water from nuclear facilities in the United States is approximately 2.2 Bq/L (60 pCi/L) . Although industry specific requirements may be necessary in some cases, clearly the comparisons to requirements in the nuclear power industry will be made.

Disposal methods for electricity generation wastes

Agenda 21 emphasizes cleaner production, but until new technologies are available, energy fuel chains can be expected to result in a substantial amount of waste. Thus, suitable disposal methods will need to be available. The eventual health and environmental impacts of an energy fuel chain will depend to some extent on the disposal method used. A variety of disposal methods are currently used for waste from energy chains for electricity generation. A brief summary of these methods is provided here.

INSIDE

TECHNICAL CO-OPERATION

International Atomic Energy Agency

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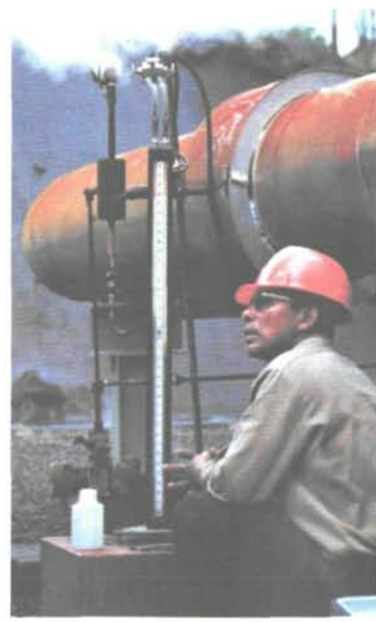
Harnessing the fire below

On opposite shores of the Pacific, in what is called the Circum-Pacific Belt of Fire, El Salvador and the Philippines are steadily developing their geothermal resources to produce electricity. Most countries within this vast girdle of ancient volcanic activity are endowed with geothermal reservoirs — bubbling cauldrons containing fluids several times hotter than boiling water. This dry steam and hot water are potential sources of high pressure to drive turbines and generate power.

Geothermal energy has many advantages, especially for countries that spend scarce hard currency to import fossil fuels for thermal power plants. It cuts the import bills for a start. Being an indigenous source, it also offers greater energy independence. Prefabricated modular systems now make it easier to install and start-up new plants. Another advantage is that geothermal plants can operate year round and are not vulnerable to drought, as hydro is, or fuel supply delays. Properly managed reservoirs can be sustained indefinitely.



A technician from El Salvador's Hydroelectrical Commission (CEL) sampling a geothermal well. (Credit: J. Gerardo/IAEA)

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Tapping the treasure beneath the Sahara

North Africa is a vast arid zone where shortages of water affect all economic activity and the health and well-being of millions of people. In most countries, water is drawn by hand or by versions of the Archimedes screw from shallow wells of groundwater resources. As populations rise and demand increases these sources have become insufficient.

A new source of groundwater is a complex system of water-holding rock expanses located deep underground. Water can be extracted by drilling boreholes several hundred metres down and pumping water to the surface. But experience worldwide shows that this is often a gamble and can even be counter-productive: expensive wells can run dry; the water can bring up unwelcome salts; and intensive extraction can cause surface subsidence. Controlled and sustainable management of the aquifer systems needs a great deal of sophisticated analysis.

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Capital replenishment in Venezuela

Caracas is confronted with a complex water crisis. On the one hand an acute shortage and on the other a glut of unwanted water that has to be carried away and discarded. Water supply is cut off in every district of the city for hours on some days and all day on others. Furthermore, *no* piped water reaches the crowded outskirts. Even the Water Ministry is not exempt. Each day the mass media announce the names of districts, even specific hospitals and schools, that are to receive piped water for that day. "Operation Help is delivering 40 tankerloads of water (about 1 million litres) to the district of Sucre where no water was received in a 20-day period," lamented a recent and typical news story.

Until the early 1960s Caracas, which lies in a shallow valley some 1000 metres above sea level, received domestic water supplies from shallow groundwater. In the 1950s and 1960s rainfed reservoirs were built on nearby higher ground to supply the city's under one million people with treated water. Since then, however, the population has increased rapidly to some five million today, and dwellings sprawl even up the slopes of the basin. The supply network was hard put to cope with increasing water demand even before reservoir levels began to fall after very low rainfall in northern Venezuela for a number of recent years.

Tankers supply water to thirsty districts in Caracas. (Credit: H.F. Meyer/IAEA)

Ironically, there is massive leakage from the concrete pipes laid below ground that bring water from the reservoirs down to the city. Furthermore, the natural drainage of the groundwater was blocked when the nearby Guaire River was "canalized" some years ago. With nowhere to go but upward, the groundwater, swollen by the leakage, has now risen so close to the surface that the underground railway as well as the foundations of other buildings are threatened. This water can no longer be used by the thirsty population because it has reached levels where it is contaminated with sewage and other pollutants. So in many parts of the thirsting city the sound of pumps attest to the ceaseless extraction of groundwater; only to be discarded far away.

Since mid-1994 an IAEA Technical Co-operation project has been helping to resolve that part of the problem which involves the groundwater — using isotope techniques to precisely identify the quantity, flows and quality of water in deeper parts of the aquifer system below the city. The primary aim is to find new water sources to make up for at least part of the current shortfall of 260,000 cubic metres per day. A possible spin-off is that deep-water extraction methods being investigated may lower the water table sufficiently for the costly and wasteful pumping to be halted.

If the aquifer system is to be used, at least during dry spells or for limited local supply, a number of parameters must be established. How much water is held in the system? What is its rate of discharge and recharge? From where does the inflow come? How pure is the water in different parts of the system? What are the processes and pathways of pollution? Conventional hydrogeological techniques cannot provide definitive answers. Isotopes as tracers, coupled with geochemical techniques, can do so with remarkable accuracy and speed.

By the end of 1995 the water authority had 'mapped' the aquifer system — described as a vertical structure in two sub-systems with horizontally distinct areas — and also identified and characterized its sources of recharge. It seems that water from some specific depths could substantially reduce the drinking water shortfall. Other areas of the aquifer system could provide water good enough for irrigation, industrial, and other needs.

The project is transfering technology and knowhow to maintain constant quality control of extracted groundwater. It will

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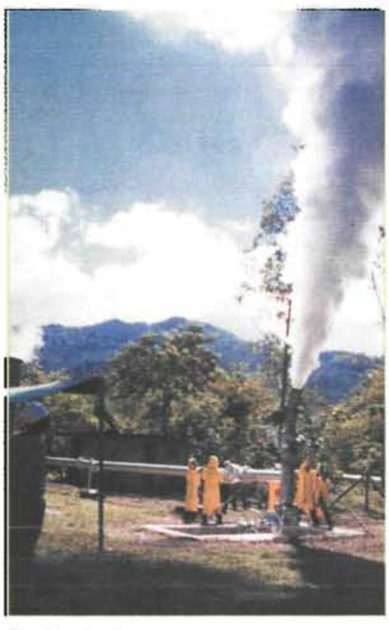
A key benefit in these times of concern about climate change and greenhouse gases is that energy could be exploited in an environmentally friendly regime. Station managers must make sure that the whole watershed in which a plant is sited is protected because that is the source of freshwater that keeps the reservoirs alive. All the extracted water can be re-injected into the reservoir, rather than discharged on the surface. The Philippines opted for geothermal, despite high capital costs, because it would cut projected carbon emissions to 5-10% compared to, for example, coal-fired electricity plants. The choice was endorsed by the Global Environment Facility when it recently provided US $30 million (the maximum possible under its rules) for a new geothermal plant in the Philippines.

The technology to exploit geothermal energy has been applied for nearly 100 years. The first geothermal plant, in Larderello, Italy, has produced electricity since 1904. But it is underused worldwide. Some 18 countries use the energy, but the power generated is only a small fraction of national production. USA, the world's largest electricity producer, generates over 2200 megawatts of electricity (MWe). Other major producers include Mexico (700+ MWe), Italy (500+) and Japan (200+). The real hindrance to developing geothermal has been that key data, for sustainable and environmentally safe management, have been virtually impossible to ascertain. How much steam and hot water is in the geothermal reservoir? At what rate is the reservoir replenished? Where does that water come from? At around US $2 million apiece, drilling wells is an expensive part of developing geothermal energy; so where is it best to drill?

Isotope hydrology techniques can help answer such questions very precisely and quickly. Radioisotopes used as tracers can be tracked deep underground. Stable isotopes can reveal directions, pathways and rates of waterflow in and out of reservoirs. These powerful tools can also show where to drill, and how best to feed extracted water back into the reservoir thus ensuring sustainable use of the resource and that the environment is not harmed by the waste water. Recent IAEA technical co-operation projects have helped Ethiopia, Greece, China, Guatemala, Indonesia, Mexico and Nicaragua to develop capability to exploit geothermal resources by transferring knowhow and equipment for applying isotopic techniques.

El Salvador and the Philippines are already harnessing geothermal heat. The IAEA is supporting activities because of the substantial commitment and high priority given to geothermal energy in the national economic development programmes.

The Philippines is already the world's second largest geothermal electricity producer. Most of its electricity is still generated by burning imported oil, but geothermal's share is now 24% (1,036-MWe) and climbing. A further 680-MWe is expected within three years from ongoing field development, and other potential fields being explored could provide 2500-plus MWe more by about the turn of the century, making it the top geothermal producer in the world.



Credit: J. Gerardo/IAEA

El Salvador also ranks among the world's top 10 geothermal energy producers, though its share is only 14% of national power production, which stands at 900-MWe. The field in Ahuachapan has operated since 1975 and now generates 58-MWe from 32 wells. A new field, in Berlin, began in 1992 and produces 5-MWe from 10 wells. With electricity demand soaring at an average of 9% a year since the economic reconstruction programme began in 1992, thermal power from imported oil and gas provides about 40% of the country's total power. Hydro power provides 46%; its further expansion is limited, however, because the only large river has been almost fully exploited.

The national plan is to double geothermal production in the next five years. At least $180 million of a new $215 million loan from the Inter-American Development Bank will be spent on developing geothermal sources — 15 new wells in Ahuachapan, 18 in Berlin, and exploration elsewhere. The government expects to cut fossil fuel imports by 20% within two years, a savings of some US $32.8 million annually, and progressively reduce them further. Some 225,000 additional households also will receive electricity. Overall, the Model Project is helping to improve national capabilities to interpret isotope and geochemical data critical for long-term geothermal exploration and generation. These stronger capabilities will enable El Salvador to provide analytical services to other countries of the region.

Many hands at work. A common sight at shallow water wells in the Sahara region. (Credit: Carnemark/World Bank)

In 1995, IAEA Technical Co-operation started a four-year Model Project to assemble the basic data and to provide isotope technology to nine North African countries — Algeria, Egypt, Ethiopia, Libya, Mali, Morocco, Niger, Senegal and Sudan — so they could better manage their groundwater resources. Egypt, Ethiopia, Morocco and Senegal — with urgent problems to resolve — are in the first phase (1995/96) of the Model Project. The other five countries will join in the second phase beginning in 1997.

• Egypt now depends on the Nile for almost all its water. The Nile valley is overcrowded already, so the Model Project aims to "reclaim" fringes of the surrounding Sahara. There is already some settlement in Qena and Esna, in the northwest. Can the shallow Nile aquifer sustain some 50,000 hectares and two million people?

• The drought prone Moyale region (some 45,000 km^2) of Ethiopia is home to three million people and has one of the largest cattle concentrations in Africa. Can aquifers below assure a stable supply of water for them?

• South of the Atlas mountains in southwest Morocco, half a million people precariously farm 15,000 hectares in the plains of Tafilalt and Guelmim with supplies from a few ephemeral rivers. Could nearby aquifers provide them with ample and good quality water?

• In the far west of the Continent, 70% of the water supply to Senegal's capital, Dakar (population: 2 million), is drawn from coastal aquifers. Daily demand is 250,000 cubic metres. During dry periods, the estimated shortfall is as high as 100,000 cubic metres a day. How much more can aquifers provide, without causing salt-water intrusion?

These are the principal questions which the first phase of the Model Project is addressing by field studies and analyses of the isotopic composition of local water.

Three isotopes of special interest to hydrology are deuterium (H-2), tritium (H-3) and oxygen-18 (O-18). Because they are heavier than the two other isotopes (H-1 and O-16, respectively), water vapour rising from the ocean to form rainclouds has fewer H-2, H-3, and O-18 isotopes than seawater. When the clouds release their water, more of these isotopes are rained out first; and moisture remaining in the cloud, to be shed later, will have relatively fewer of them. Coastal rain is therefore isotopically different inland and different again in mountains.
Other changes in the ratios of H-2/H-1 and O-18/O-16 (depending mostly on temperature) occur as rainwater moves back to the oceans in various ways, depths and speeds. In the process water acquires telltale isotopic 'fingerprints' in different environments, and analysis of a sample can reveal its 'age', origin and how it got there. Isotope hydrology techniques measure the ratios of a number of other elemental isotopes, i.e., helium, carbon, nitrogen, sulphur and chlorine to aid a variety of investigations.

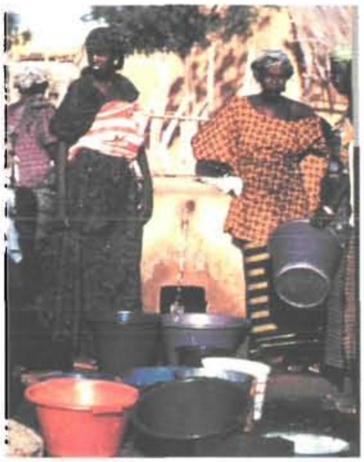
Preliminary results in Egypt appear to be promising. It has been ascertained that the shallow Nile aquifer is being replenished by the gigantic Nubian Sandstone aquifer which lies adjacent to it and at a deeper level. Ongoing studies expect to establish the rate and quantity of replenishment. The fact that the Nubian Sandstone aquifer contains 'palaeowater' which has not been

continued page 6

Isotopes and water management

We call the Earth the blue planet. Photographs from space show a characteristic seen nowhere else in the visible universe. Water is the foundation of all life on Earth. The Earth's surface is two-thirds water and experts calculate that the volume is nearly 1.5 billion cubic kilometers. But only about two per cent is freshwater, and nearly all of that is locked in glaciers, ice caps and deep groundwater reservoirs. Only an estimated 2000 cubic kilometres is readily available to meet human needs. This has been adequate to sustain life on Earth, but global demand for water is doubling every 21 years according to the Food and Agriculture Organization (FAO). As industrial, agricultural and domestic pollution threatens finite supplies, water is becoming an increasingly precious resource.

Recent history has witnessed conflict between nations over rights and access to fossil fuel resources. Such conflicts could also arise in the future over water shortages since many countries in the world lack readily available or abundant water resources to meet their needs. An increasing emphasis in IAEA technical co-operation activities focuses on helping countries (and supporting regional co-operation) to investigate and manage water resources using isotope hydrology. Isotopic techniques provide an important analytical tool for those responsible for managing natural resources. The Agency has established a dedicated isotope hydrology laboratory in Vienna that supports national development activities in natural resources management. Usually, TC projects develop experience and knowhow



Credit: Carnemark/World Bank

through training, expert advice and the provision of equipment to improve local infrastructure and build capacity to study water resources using tracer isotopes.

This issue of INSIDE TC is about using isotope techniques to efficiently and sustainably manage the exploitation and conservation of water. Isotopes are extremely powerful tools for investigating many areas of natural science. Most elements are made up of different isotopes which are virtually identical to one another chemically, but are of different atomic mass. Our indispensable water molecule is made up mostly of two isotopes — hydrogen (H-1) and oxygen (O-16). But along with these 'abundant' ones are 'rare' isotopes, occurring in relatively low and variable concentrations (H-2 and O-18). These rare isotopes permit a broad range of hydrological investigations.

Isotope hydrology has evolved into a multi-disciplinary field: In exploiting geothermal energy resources, isotope techniques help to define the regions of high heat flow and the origins of fluids. Deep wells drilled to depths up to 3 km tap the reservoir to extract steam for transport to a power plant; In investigating sewage pollution in groundwater, boron isotopes can be used to track and measure pollution and contamination pathways. The rapidly increasing concentration of carbon dioxide (CO_2) and methane (CH_4) in the atmosphere may be leading to global warming as a result of the 'greenhouse effect'. Isotope techniques are also proving to be an effective tool in unravelling this complex environmental phenomenon through subatomic analysis of carbon isotopes to determine what happens to greenhouse gases in the atmosphere. The isotopic composition of water can provide information about past climates and enable experts to monitor and compare global warming phenomena and to assess climate change going back tens of thousands of years. Isotopic techniques are also being used to help explain environmental phenomena such as the rise in the sea level of the Caspian Sea. The next issue of INSIDE TC will look into these related applications of isotopic techniques that support environmental management of natural resources.

Over the last ten years the IAEA has supported some 160 technical co-operation projects amounting to $18.8 million in technology transfer and knowhow to help 63 countries develop national infrastructure in isotope hydrology applications. Over 550 students have been trained in isotope hydrology to develop indigenous skills to apply and analyze isotopic investigations for natural resource management. This INSIDE TC describes a few projects that are making a measurable contribution to improving the quality of life for people in communities at various corners of the globe.

actively recharged since the last rainy period some 6000 years ago, is not regarded as a problem. This aquifer covers an area of tens of hundreds of square kilometres, and is the largest known aquifer in the world. It is unlikely to be depleted by extraction for the reclaimed land area. The study is expected to determine how much and at what rate Nile aquifer water can be withdrawn without unwanted consequences.

The news is mixed for Morocco. Isotope data have disproved earlier conventional hydrological indications that the aquifer in the north of the Tafilalt area is being replenished. It is shown to be palaeowater, and imprudent exploitation will mine it dry. But isotopic analyses show that two other systems, in the south of the Tafilalt Plain and in the Guelmim Plain have been replenished by recent rainfall. In May, isotope studies began in the unsaturated zone of the southern Tafilalt basin (through which rainwater percolates down to the aquifer) to quantify recharge and discharge, as well as possible contamination of the groundwater.

In Senegal, authorities hope that project related activities will enable greater withdrawal of groundwater, sufficient to make up 70% of the current shortfall. The focus of the project is to quantify how much could be extracted without threat of seawater intrusion into the aquifers, and to develop tools for prudent management of the resource. Senegal aleady has expertise in the use of isotopes in unsaturated zone investigations. The expertise will support the investigations in Morocco.

Ethiopia's Moyale regional investigations are identifying the replenishment characteristics of the aquifers and very probably the rate of recharge as well. This basic assessment is vital for good water resource management and cannot be derived by other means. Under the project, 14 borehole sites were geophysically surveyed and six new wells have been drilled so far.

Finding new water sources is only valuable if the resources are managed well. The establishment of good management practices is a central objective of the Model Project.

Toward this end, the development of computer models as management tools began early in 1996 with a seminar in Senegal and a workshop in Morocco. Further training and development of software based on project findings will be completed by the end of this year.

This computer software is patterned on that of the United States Geological Survey (USGS) and Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO), respectively. Specialists who were involved in developing the USGS and CSIRO models have been helpful in guiding the project work and providing necessary training.

Project trainees from Algeria, Morocco and Senegal conduct on-site chemical analysis of water beside a rural well in the Dakar peninsula. (Credit K. Froelich/IAEA)

Rainwater that percolates into the ground usually makes its way back to the seas from where it came. Some of it is taken up by plants and eventually transpired into the atmosphere. Some reaches lakes and eventually evaporates. Some strikes a river and quickly returns to the sea. The rest inches along at various depths below the soil surface. Large pockets of this slow moving water saturate multiple layers of rock. These 'saturated zones', also called aquifers, often receive fresh rainfall fast enough to remain saturated. Water can be sustainably extracted from them in various ways from shallow wells to deep boreholes, depending on the rate of replenishment. Some very deep reservoirs received their water during perhaps prehistoric periods of heavy rainfall thousands of years ago. Unreplenished by new rains these 'palaeowaters' are seeping to the seas too, but so slowly that it may be millions of years before they are dry. Meanwhile they are 'ageing' and can be 'dated' by naturally occurring radioisotopes such as carbon–14 to establish whether or not the aquifer is a finite resource.

Progress in seawater desalination

With over 1.4 billion cubic kilometres of seawater available on two-thirds of the world's surface, many water deficient populations could have access to a vast potential for freshwater if an economical means to desalinate seawater can be demonstrated. That is the working hypothesis of a feasibility study begun by the Agency in 1994. It has identified options for utilizing small- and medium-sized nuclear reactors as a possible power source to run desalination plants to produce low-cost potable water in North Africa.

One participant in the feasibility phase is Morocco which is about to undertake a joint pre-project study of a demonstration plant with assistance from the IAEA and China. The plan would utilize a 10 megawatt reactor supplied by China to produce 8,000 cubic meters a day of fresh water. Other participants in the study are Algeria, Egypt (which is also studying project design), Libya, Saudi Arabia and Tunisia. Over US $670,000 in financial support for the study was provided by Argentina, Canada, Jordan, Korea, Libya, USA and the Arab Atomic Energy Agency. The Agency will hold an international symposium on the subject in 1997, in collaboration with UNIDO, WHO, WMO and the EU.

Roundtable starts SIT campaign in Mali

Livestock development in much of Africa is limited by the range of the tsetse fly, which transmits a type of sleeping sickness called nagana (see Cattle killer meets its match, *INSIDE TC*, March 1996). Livestock infection rates of up to 45% in the peri urban zone of

Trypanosomiasis is a growing threat to Mali livestock. (Credit P. Fouchard/IAEA)

Bamako have inspired the Government of Mali to convene a roundtable with its development partners to discuss co-ordinating activities for an integrated approach for tsetse and trypanosomiasis management. The French, German and US aid agencies have sponsored livestock related development projects in the area which were represented at the meeting.

The roundtable on 27-31 May 1996 discussed the possibility of initiating area-wide conventional fly suppression activities (traps, screens and chemical treatments) involving local communities to drastically reduce the tsetse population in an area of approximately 2000 km^2. This is a prerequisite for a potential sterile insect technique (SIT) intervention. The Government undertook to document through a socio-economic study the extent of the tsetse and trypanosomiasis problem. On the basis of these promising discussions, the Agency is moving ahead with technical feasibility planning for boundary mapping and fly range involving release/recapture studies with marked sterile males.

Capital replenishment *(from page 2)*

provide technical training; laboratory equipment especially for quality control of water; and help elaborate a mathematical model to predict changes in flow patterns and water table levels so that the aquifers can be sustainably and safely utilized.

The first substantial result of this work is a decision by the water authority, Hidrocapital, to construct new wells. Their sites and designs are based on data resulting from the IAEA project. Fifteen wells have already been drilled and 50 more will be completed this year. It is estimated that they will be able to provide more than 112,000 cubic metres a day, or some 46% of the current water deficit.

The city intends to continue the wells programme over the long term to ensure that strategic institutions such as hospitals and fire stations will have access to water in case of emergency. Ten hospitals are already being equipped with such wells.

Parched plains wait for mountain manna

The Atacama, lying along the Pacific Ocean coastline in South America, is the driest area in the world with barely a centimetre of rainfall a year. Just north of the Atacama, in Peru, a 7500 km^2 coastal plain gets no more rain, but it has sustained human settlements and agriculture for centuries on the banks of the only two perennial rivers running from the Andean mountains to the Pacific Ocean.

Two early settlements called Moquegua and Tacna have swollen into cities. They lie some 80 km apart, and 15 to 20 km inland. Some 200,000 people now live on this part of the coastal plain, sustained mainly by nearby copper mines and small industries. The port of Ilo, at the very north of the area, has grown into a town since a treaty made it the only access to the sea for neighbouring Bolivia. The busy road from La Paz runs through Moquegua province.

The increasing demand for water in these settlements is already beyond the capacity of the two rivers. The provincial water authorities are now urgently looking for ways to augment the supply, at least for drinking and domestic use. They are looking to the high plateau: the *altiplano* is a vast sub–region (many millions of hectares towering 3400–4000 metres above sea level between the eastern and western chains of Andean peaks in Peru and Bolivia) that gets 300–400 millimetres of rainfall a year. This is not a lot, but some geologists have suggested that there would be large enough aquifers there to supply the plains.

The hydrology of the plateau has never been studied. In 1995 IAEA Technical Co–operation began a two–year project aimed to provide the provinces a complete hydrological evaluation of the *altiplano*, as well as the means of transporting water to the coastal area. Findings from isotope analysis so far are mixed. Most of the aquifers are

Acute water shortages in the Atacama affect everyone. (Credit C. Fjeld/IAEA)

small, in compartments separated by impermeable barriers, and mostly replenished only by nearby rainfall. The hydrology is highly complex.

Evaporation and evapotranspiration (mainly from vegetation) have been found to be very high. The roots of bunchgrass and other native plants do not run deep, so if water close to the surface declines by much, because of extraction, it will seriously affect plant life and cause havoc to the wild vicunas, tamed llamas, alpacas and other animals. It will also jeopardize the lives and traditions of indigenous people who live in scattered settlements and grow crops that have acclimatized to the demanding conditions.

On the other hand some aquifer systems seem promising, and already wells are being drilled based on available study results. The study is using tritium and carbon–14 isotopes to unravel the complexities of the altiplano aquifers and to provide crucial data for development of flow models for accurate water resource management. Water from the high plateau could be transported to the thirsty coastal plain by using dry river beds and canals to feed the perennial rivers.

The Agency has, over many years, helped develop the infrastructure and capability of its counterpart, Peru's Institute for Nuclear Energy (IPEN), which has developed an analytical laboratory in Tacna. An atomic absorption spectrometer and well logging equipment were provided through this project, as well as expert services and training. The provincial water authorities and IPEN must now decide and implement plans to handle several specific problems. For example, the natural transportation route passes high altitude geothermal springs containing boiling water that is very saline and has high levels of boron and arsenic which are poison to plants and people.

Possible solutions include: building some 50 km of canals; constructing a power plant to use the hot water to make electricity and recycle the water into the geothermal reservoir; and building an expensive treatment plant to decontaminate the water. The project, which ends this year, expects to provide data which will help evaluate these options and bring water from the *altiplano*, like manna from the mountains, to the parched coastal plain.

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In the extraction and fuel preparation steps, the large volumes of waste that are produced generally exclude any substantial engineered disposal technology. In some cases, the spoils (waste rock) are placed back in the mined cavities or spread on the ground surface. However, in a number of cases, mining spoils (waste) are now protected using engineered covers to divert infiltration around the potentially harmful waste. Oil and gas drilling waste is typically reinjected into the formation, placed in pits at the drilling site, or spread on the ground surface at the site.

Fuel preparation waste from coal and nuclear energy chains includes large amounts of liquids that are often disposed of in impoundments (man-made ponds or lagoons). Solid waste from fuel preparation (e.g., tailings and evaporation residues) are often covered with an engineered soil cap to minimize infiltration into the waste and to limit the release of gases from the waste. Oil refinery waste is often disposed of using land farming or pit disposal. Hazardous waste from refineries or the manufacture of photovoltaics for solar power is generally sent to a licensed facility. A typical hazardous waste disposal facility includes a lined trench with leachate collection systems and an engineered soil cover to limit water contact with the waste. Other waste associated with fuel preparation will typically be disposed of in landfills or, in the case of some nuclear waste, engineered trenches, or concrete vaults.

Operational waste from coal and oil-fired power plants such as fly ash and FGD waste are typically disposed of in ponds, landfills, mine cavities, or surface waste piles. After evaporation and drainage of the water, the sludge remaining at the base of disposal ponds is typically covered with soil. Boiler wash waste for coal, oil, and gas plants may have to be treated as a hazardous waste, which would require disposal in a licensed facility. Low- and intermediate-level waste from nuclear power plants is often disposed of in engineered trenches, concrete vaults, or mined cavities. This waste is also typically packaged prior to disposal. The high-level waste, including spent fuel, is planned to be disposed of in deep geologic formations or stored in a retrievable form.

Future directions

Agenda 21, the programme of action for sustainable development agreed upon by world governments at UNCED, has identified cleaner production (i.e., the need to reduce the amount of waste that is being generated) as a critical element of a strategy for sustainable development of human society. Electricity generation, which is essential for development, is one source of waste where reduction is necessary. In order to assess the potential role of nuclear power in a global strategy for cleaner production and sustainable development, the IAEA initiated a project entitled Comparative Health and Environmental Impacts from Solid Wastes from Energy Systems.

The first task in the project focuses on identifying quantities and types of wastes from energy chains for electricity generation and their associated disposal practices. Subsequent tasks in the project include reviewing and testing of methods that can be used to compare the potential health and environmental impacts associated with waste disposal, for example, from release and subsequent transport in the environment of the radioactive and non-radioactive constituents in those wastes. These reviews will include discussions regarding other comparative assessment studies that have been conducted. Approaches for comparing the health and environmental impacts of radionuclides and non-radioactive toxic elements/compounds and modelling fate and transport of those contaminants in the underground and surface environment will be a crucial part of a waste disposal-related comparative assessment.

This article has summarized some of the information obtained to date for the first task in the project. In this regard, some perspective was provided regarding the nature of the wastes and the masses generated by nuclear power and other energy chains. The mass of wastes from nuclear power was shown to be both a small fraction of the total wastes generated and also a small fraction of electricity generation wastes. This fact supports the potentially desirable role of nuclear power in the context of cleaner production and a strategy for sustainable development of human society.

The importance of considering all steps in the energy chains for electricity generation has also been emphasized in this article. Detailed consideration of each step in the energy chains shows that even energy chains that are thought of as "clean", such as solar power (hazardous metallic compounds) and natural gas (radioactive and hazardous drilling and pipeline waste), result in the generation of waste posing potential long-term health and environmental impacts. Also, the large mass of waste generated in some energy generation chains (e.g., fly ash and flue gas desulfurization waste) creates disposal problems.

Future work on this project will focus on more accurately defining and quantifying wastes and disposal practices typical of current energy fuel chains; reviewing and testing available approaches for modelling the fate and transport of the contaminants in those wastes; and calculating the associated health and environmental impacts. ❒

Nuclear data for science & technology: Centres for development

An update on the IAEA's nuclear data centre, its services, and the contributions to the global network from developing countries

by
Hans Lemmel

A typical example of a modern nuclear physics application is the mineral analysis of geological samples by neutron activation. The sample to be investigated is exposed to a neutron radiation, and the resulting gamma-ray spectrum is analyzed with respect to the intensities and energies of the gamma lines to determine the nuclear composition of the sample and its mineral content. This method, which is used in industrialized countries and increasingly in developing ones as well, requires comprehensive files of nuclear data: the neutron activation cross-sections for the elements occurring in the sample, nuclear half-lives, and the radioactive decay data of the activated nuclides under investigation.

Radiotherapy is another example illustrating the importance of nuclear data applications. Under certain conditions cancer may be treated with nuclear radiations of various types: heavy ions, ionizing charged particles, electrons, photons, or neutrons. To select the most suitable radiation, and to estimate the impact on the tumor and the undesirable effects on the surrounding healthy tissue, computer calculations depend upon a variety of databases, including ionization and scattering cross-sections.

Such data files are available to scientists in all IAEA Member States through the Agency's nuclear data services. Required data files can be obtained on a magnetic tape or on computer diskettes, together with documentation on the format and origin of the data. More recently, the world's major data libraries have also become accessible on-line through NDIS, the Nuclear Data Information System, via the Internet or World Wide Web. Also available are a number of nuclear data handbooks which continue to be convenient to many users, in parallel to the fast development of electronic services.

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The IAEA Nuclear Data Section operates a centre which maintains the world's most comprehensive collection of nuclear and atomic data libraries that are needed for nuclear and radiation technologies in Member States. This article reviews these services, and the particular role of developing countries in this global data network.

Energy and non-energy applications

While nuclear data are now increasingly needed for all types of nuclear technologies, the primary needs for such comprehensive data files came, originally, from nuclear power research and development, which depends upon a large variety of nuclear data. *(See box, next page.)* A large fraction of these data are also needed for non-energy applications. The basic data libraries are, therefore, "general purpose" libraries and not meant for specific applications. *(See box, page 36.)* These data libraries are rather voluminous; each of them has a typical size in the order of 100 megabytes. They are presented in internationally agreed formats for which a variety of data processing computer codes is available.

In addition, a large number of "special purpose" nuclear data libraries have been established for specific applications. They include those specializing in standard reference data for the standardization of nuclear measurements, for detector calibration and neutron dosimetry, and many others. These data libraries use different formats and are smaller in size so that they are most suitable for use on personal computers. There are also nuclear data handbooks, which contain not only tabulations and curves of nuclear data but also detailed instructions on measurement techniques for specific applications. *(See box, page 36.)*

Apart from nuclear power applications, nuclear data files are used for university education;

nuclear physics research; national centres or institutes; research and development; material analysis by neutron activation; industrial processes; dosimetry, detector calibration; production of medical radioisotopes; and applications in radiotherapy.

Nuclear data measurements

Whereas the first nuclear power reactors started with a rather crude knowledge of nuclear data, it soon became evident that their efficiency, economy, and safety require not only detailed and accurate knowledge of all relevant nuclear data but also a careful analysis of the data uncertainties and of their consequences. More accurate nuclear data, permitting predictions of reactor behaviour in unusual operating conditions, increase reactor safety. They also increase the economic operation, providing, for example, more accurate radiation damage cross-sections that enable more reliable prediction of the lifetime of a reactor vessel. Hence, even a small increase in nuclear data accuracy in nuclear metrology can translate into many millions of dollars of savings in power reactor operations worldwide.

Consequently, a comprehensive nuclear data measurement programme was carried out, primarily in the United States, Western Europe, the former Soviet Union, and Japan, starting in the 1950s and culminating in the 1970s and early 1980s. It still continues, though on a lower level. The programme also included various measurements contributed by the more advanced developing countries.

Evaluation of nuclear data

The first nuclear data measurements had rather large uncertainties, and different measurements of the same quantity often showed discrepancies. Considerable efforts were invested to change this picture. They included the development of new methods, measurement facilities, radiation detectors, electronic analyzers, and the preparation of isotopic pure samples until the nuclear data could be determined with the high precision that is required to make accurate nuclear technologies possible.

A new science evolved: the evaluation of nuclear data. Evaluators start from the available experimental data, supplement them with theoretical estimates for energy regions and data types that have not been covered by experiments, and bring the resulting recommended data into file formats required for computer codes in specific applications.

Examples of nuclear data categories

Nuclear Structure and Decay Data

- Isotopic masses; nuclear levels and their properties
- Half-lives of radionuclides and isomers
- Energies and intensities of gamma-rays and emitted particles

Nuclear Reaction Data

- Cross-sections for nuclear reactions induced by neutrons, photons, protons, and other charged particles including heavy ions
- Reactions leading to activation, radiation damage, radioisotope production, fission, spallation, transmutation, etc.
- Yields and energies of gamma-rays and secondary particles
- Nuclear fission: yields of fission-neutrons and fission products, related energy release, etc.

Atomic Data

- Electron interactions
- Fusion plasma interactions
- Atomic processes in medical irradiations

The nuclear data libraries that resulted from these efforts represent an enormous benefit, and the free exchange of nuclear data files among industrialized and developing countries reflects a significant degree of successful technology transfer.

Contributions from developing countries

What role have developing countries played in the development of nuclear data? In the period 1970-90, about 44,000 measurements of neutron reaction data have been performed worldwide, of which 4000 (or 9%) were done in 32 developing countries. To improve the transfer of technology in this field, which can strengthen the capability of developing countries to utilize nuclear techniques in many applications, the IAEA implemented an interregional technical co-operation project on nuclear data techniques and instrumentation in the 1980s. Subsequently, developing countries participated in the Agency's Co-ordinated Research Programme for establishing or improving nuclear databases for specific applications. These included 14-MeV neutron activation cross-sections, nuclear data for medical applications, actinide nuclear data in fission reactors, and nuclear and atomic data for fusion reactor design.

Nuclear data libraries

(acronym, orginator, contents)

Major comprehensive libraries

- EXPOR; International Nuclear Data Centres Network; contains experimental nuclear reaction data
- ENSDF; United States and International Network; contains nuclear structure data and radiation data of radionuclides
- *Libraries containing evaluated nuclear reaction data in uniform "ENDF" format:* ENDF/B-6, United States; JEF-2, Nuclear Energy Agency of the OECD; JENDL-3.2, Japan; BROND-2, Russian Federation; CENDL-2, China
- FENDL; IAEA and International Network; contains nuclear data for fusion reactor design, and for other applications as well

Special purpose libraries

- N.D. Standards; IAEA International Nuclear Data Committee; standards for nuclear measurements
- XG Standards; IAEA Co-ordinated Research Programme; calibration of detectors for gamma rays and X-rays
- IRDF; IAEA in co-operation with other centres; international reactor dosimetry file, neutron dosimetry by foil activation
- IDGAM; Japan-Brazil; identification of radionuclides by their gamma rays
- ALADDIN; IAEA and Data Centres Network; atomic and molecular collision data for nuclear fusion applications
- SGNucDat; IAEA Nuclear Data Section; nuclear data for safeguards
- GANAAS; IAEA Physics Section; neutron activation analysis
- CENPL; China; various evaluated nuclear parameters
- MENDL-2; Russian Federation; nuclear transmutation

Network of nuclear data centres

- National Nuclear Data Center, Brookhaven, United States; services to United States and Canada
- Nuclear Energy Agency (NEA) Data Bank, Organization for Economic Co-operation and Development (OECD), Paris, France; services to European OECD countries and Japan
- IAEA Nuclear Data Section, Vienna, Austria; services primarily to developing countries and co-ordination of the global network
- Russian Nuclear Data Centers, Obninsk and Moscow, Russia; services to States emerging from the former USSR

In addition to these core centres, the Network includes national nuclear data centres in Japan, China, and Hungary. Other countries co-operate without formal participation in the Network.

Nuclear data handbooks

Atomic and Molecular Data for Radiotherapy and Radiation Research (IAEA TECDOC-799, issued 1995)

The Index to the Literature and Computer Files on Microscopic Neutron Data (CINDA, published annually)

International Bulletin on Atomic and Molecular Data for Fusion (IBAMD-49, published twice per year)

Handbook on Nuclear Activation Data (IAEA Technical Reports Series No. 273, issued in 1987 and reprinted in 1995)

Decay Data of the Transactinium Nuclides (IAEA Technical Reports Series No. 261, issued in 1986 and reprinted in 1995)

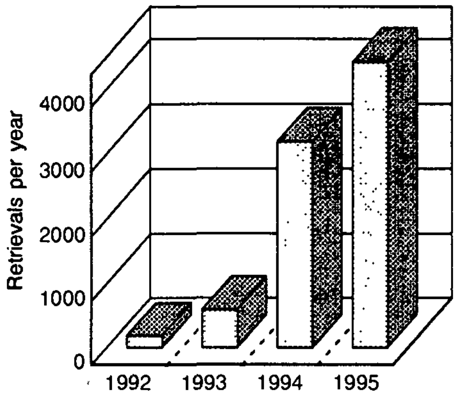
X-ray and Gamma Ray Standards for Detector Calibration (IAEA TECDOC-619, issued in 1991 and reprinted in 1994)

Handbook on Nuclear Data for Borehole Logging and Mineral Analysis (IAEA Technical Reports Series No. 357, issued 1993)

The present situation is not uniform. A number of developing countries — for example, Argentina, Bangladesh, Brazil, Egypt, Israel, Morocco, Pakistan, Thailand, Turkey, Viet Nam, and many Eastern European countries, among others — had and continue to have nuclear data measurement programmes. Some countries — for example, Algeria, Malaysia, Mexico, Myanmar, Saudi Arabia, and various others — reported occasional nuclear data measurements. India, after a very strong nuclear data programme in the 1970s, has reduced these activities noticeably, whereas China started around 1980 with a strong nuclear data programme, and continues to give it strong support.

An interesting example is the Republic of Korea: Although the country has a nuclear power programme, there were, in the past, almost no nuclear data measurements performed there. However, in recent years it was realized that an adequate nuclear physics infrastructure, including data measurements, is a necessity for a country with strong nuclear applications in energy and industry. Consequently, a strong increase in

The Nuclear Data Information System (NDIS)
Development of nuclear data on-line services, presently used by 41 countries



Nuclear data services in 1990-95, by geographical region

	Services by mail		On-line services	
Region	Number of countries	% of request	Number of countries	% of requests
OECD countries	22	24%	17	36%
Former USSR	6	7%	2	17%
Eastern Europe	9	18%	8	40%
Asia, Australia	15	24%	6	1%
Africa and Near East	26	13%	2	3%
Latin America	15	14%	6	3%
	93	**100%**	**41**	**100%**

nuclear data activities there is expected in the near future.

For nuclear power applications, a special effort is needed to process nuclear data libraries into special formats ("multigroup data") required for computer codes. Among the developing countries, it is primarily Algeria, India, Indonesia, the Republic of Korea, and Slovenia which are involved in such activities that are co-ordinated by the IAEA and supported by training courses.

Another co-operative project concerns the maintenance of the international database for nuclear structure and decay data. China, Kuwait, and Russia have joined seven countries of the Organization for Economic Co-operation and Development (OECD) in the project, which is guided by the IAEA and the US National Nuclear Data Centre.

Nuclear data needs in industrialized countries

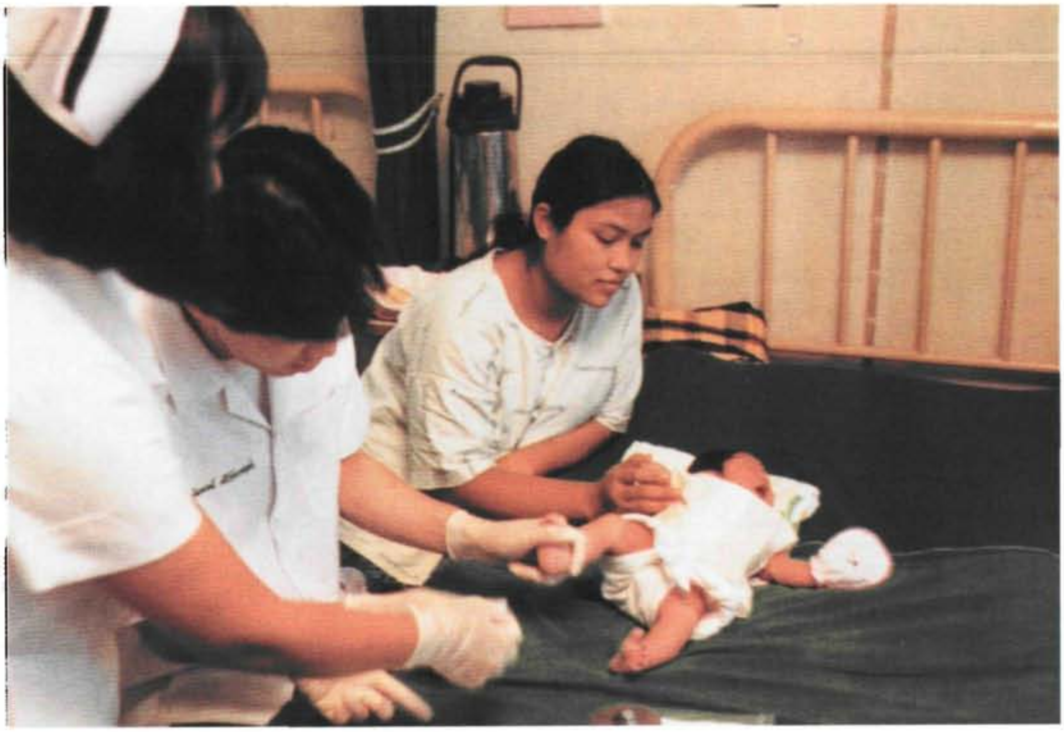
In the field of nuclear data, industrialized countries are presently in a transition phase. Having solved the main nuclear data needs for thermal and fast power reactors, many of the measurement facilities have been closed down. At the same time, many experienced nuclear physicists have retired. Suddenly it was realized that there may be a shortage of young nuclear physicists, and the continuing use of nuclear energy may be endangered unless the know-how of nuclear data measurement techniques is preserved. This concern has been expressed in several expert studies in France, the United States, Japan, Russia, and at the OECD Nuclear Energy Agency (NEA). Furthermore, a group of leading experts convened by the IAEA in 1995 concluded that the Agency's nuclear data programme is of continuing relevance and high priority to all Member States.

At present, the activities of industrialized countries concentrate on nuclear data needs for fusion reactor development and on higher energy nuclear data required to study the transmutation of unwanted actinides produced in power reactors. This research requires expensive facilities that are not available in developing countries.

Besides this advanced nuclear data research, the work to improve nuclear data for fission power reactors continues. Under the auspices of the International Nuclear Data Committee, the data centres compiled a list of nuclear data for which an increased accuracy is required for specific applications in power reactors and nuclear material safeguards. This list includes 290 top priority requests and 430 requests with lower priority. It is intended to serve as a guide to scientists and administrators when planning nuclear research programmes. A similar "high-priority list" for requests about nuclear data measurements was recently established by the NEA. Within the network of Nuclear Data Centres, the NEA plays a leading role in nuclear data evaluation co-operative efforts.

International co-ordination

Already in the 1950s, nuclear data measurements became so numerous that a national Nuclear Data Centre was formed in the United States at the Brookhaven National Laboratory.



Nuclear data are required in a range of fields including health care.
(Credit: H.F. Meyer/IAEA)

In 1964 three more centres were founded at the NEA, the IAEA, and in Obninsk, Russia. These four centres are the core of the Nuclear Data Centres Network co-ordinated by the IAEA. *(See box, page 36.)* They provide the essential link between the producers and the users of nuclear data. The task of collecting the large amounts of data, to compile and evaluate them, and to make them available in formats needed by the users, can be done only by a well co-ordinated international effort. This approach avoids duplication, and maximizes the use of specialized experts in the co-operating centres and countries.

The achievements of this network have been impressive. By a systematic exchange between the centres, a scientist in any Member State has access to all nuclear data information, regardless in which country the data have been generated. Furthermore, the data (at least the main categories of nuclear data) are presented in worldwide uniform formats so that the same set of data processing computer codes can be applied when using evaluated data libraries coming from the United States, Europe, Russia, China, or Japan.

Within the data network, the IAEA Nuclear Data Section concentrates on services to developing countries, whereas the services to industrialized countries are primarily through their national data centres or the NEA Data Bank. In addition to databases received from the co-operating centres for free distribution to all Member States, the products of the IAEA's Nuclear Data Centre result primarily from Co-ordinated Research Programmes and informal co-operative mechanisms. The priorities of the IAEA programme on nuclear and atomic data for applications are determined by the International Nuclear Data Committee, a standing advisory body with members from Brazil, China, Hungary, India, Russia, and eight OECD countries.

Requests for services

Over the past years, the Agency's Nuclear Data Centre has received about 800 requests per year from scientists in 93 Member States. Annually, about 300 data files on magnetic tapes and diskettes, 100 related data processing computer codes, and 2000 copies of printed materials have been shipped. In addition to these conventional request services, more than 4000 electronic retrievals were made in 1995 through the on-line Nuclear Data Information System via the Internet. *(See graph and table, previous page.)*

In the future, it is expected that the demand for on-line services will grow fast, and significant efforts will be made by the IAEA Nuclear Data Section to further widen and improve the services. The number of requests demonstrate that the on-line services are presently used primarily by scientists in European countries. Such electronic access to nuclear data will supplement conventional mail shipments, which for most developing countries remain, for the time being, the main avenue for receiving the information they need in support of their development in nuclear science and technology. ❐

Partners for development: Expert assistance in Malaysia

Expert assignments under IAEA technical co-operation projects have helped Malaysia build up its own levels of expertise

by Ainul Hayati Daud

Since Malaysia became a member of the IAEA in 1969, it has actively participated in the technical co-operation programme (TC). Over the last 15 years, the country has implemented more than 60 projects, valued at nearly US $9 million in the form of equipment, expert services, and fellowship training.

Expert services have proven to be especially valuable over the past years, even though the provision of equipment and training also have played important roles. Since 1989, in terms of TC services received, Malaysia has become less dependent on the provision of equipment. The development of the basic facilities and infrastructure required for implementation of TC-supported projects has been mainly funded by the Government of Malaysia. Consequently, more assistance for training and expert services have been requested and received from the IAEA.

Malaysia considers expert assignments as opportunities in several respects. They enable the country to receive technical advice and guidance on a specific technology; share and adapt new ideas and technologies; and strengthen strategic alliances in the international arena of nuclear science and technology. An expert is always considered a friend, an advisor, and a partner in the peaceful development of nuclear science and technology.

This report reviews the expert assignments received by Malaysia under the TC programme over the 1980-95 time period. It provides data about the type of assignments and expert services, the institutions receiving the experts, and duration of the assignment. Also reviewed is the process of requesting and implementing an expert assignment in Malaysia, as well as the country's related objectives and plans.

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General developments and trends

During 1980-95, a total of 392 expert assignments were received by Malaysia. They were carried out by 273 experts from 48 countries to serve more than 20 institutions in various fields of nuclear science and technology.

Fields of activity. Nuclear science and technology covers a wide range of subjects and involves a variety of expertise. Over the years, Malaysia has focused on three main fields: the applications of nuclear techniques in agriculture; their application in industry and hydrology; and nuclear and radiation safety.

Over the 15-year period, there were 108 assignments involving 75 experts related to the use of nuclear techniques in agriculture; 69 assignments involving 48 experts in the areas of industry and hydrology (including industrial development, with emphasis on non-destructive testing, radiation technology, and hydrological and tracer studies); and 46 assignments involving 33 experts in nuclear safety-related activities in the field of radiation protection.

Home country of expert. The 273 experts assigned to Malaysia over the years were from 48 countries. Almost two-thirds of the experts on assignment to Malaysia were from industrialized countries. Western Europe was the leading region, providing 89 experts who completed 133 assignments (34%), followed by North America with 75 experts completing 101 assignments (26%), and Asia and the Pacific region with 65 experts carrying out 91 assignments (23%).

Among individual countries, the major providers are the United States (21%); United Kingdom (9%); Germany (7%); Canada (5%); Austria (4%); Australia (4%); Japan (4%); and France (3%). Among the developing countries, India (4%), Poland (2%), and Hungry (2%) take the lead in the number of experts they provide. At the same time, scientists from Malaysia have also contributed towards the implementation of projects in Malaysia, by completing 18 assignments (5%). The scientists were recruited as TC programme experts and training course lecturers, or as participants in project formulation and research co-ordination meetings.

Institutions receiving experts. Since 1980, more than 20 institutions and hundreds of individuals in both government and private organizations have directly or indirectly benefitted from the IAEA's expert services. They include research institutes, the regulatory board, the utility company, universities, and research committees (a group of scientists from relevant institutions formed to carry out a multi-disciplinary and integrated project).

During the past 15 years, 20 institutions in Malaysia have received 392 expert assignments. Slightly more than half of these assignments (202) were received by research institutes. They are followed by research committees and universities, with 80 (20%) and 37 assignments (9%) respectively. The Malaysian Institute for Nuclear Technology Research (MINT) — which is responsible for the implementation and promotion of applications of nuclear science and technology in Malaysia — received the highest number of assignments, namely 161 (41%), involving 112 experts.

Length of tenure. The length of the assignments have varied considerably, depending on the activity and the nature of assignment, the type of expertise required, and the status of the expertise available in Malaysia. The majority of assignments (almost 61%) have had a term in the range of two to five weeks; about one-fifth were around one week long; and 6% were less than one week long. Longer term assignments (from several months to just over one year) were received mainly for project activities involving lengthy experiments and field work such as product formulation, exploration and mining of nuclear raw materials, monitoring of fertilizer uptake, and insect rearing. Assignments of less than one week were normally for pre-project fact-finding missions, project formulation meetings, lectures at training courses, and participation in a co-ordinated research meeting.

Over the years, the average duration of assignments has fallen from about five weeks to three weeks. At the same time, the number of assignments has doubled. This reflects the increasing self-reliance of the country's expertise, as external experts are being required only for more specialized assignments of shorter duration.

Also interesting to note is that the length of assignments from countries such as Australia (47 days) and Poland (56 days) have been high, even though the number of experts completing the assignment has been small. This indicates that experts from these countries were available for long-term assignments. On the other hand, the length of assignments for major providers of expert services, such as the United States, United Kingdom, Germany, and Canada have been mainly within the range of two to four weeks, even though the number of assignments completed were mostly higher than those from other countries. This implies that the experts from these countries were mainly available for short-term assignments in specialized activities.

When comparing the number and length of assignments for each institution, notable trends are observed. In the case of the Geological Survey Malaysia, Perak (GSMP), it received only 12 expert assignments but the duration per assignment was 73 days; the case is similar for the Geological Survey Malaysia, Sarawak (GSMS). This is because projects in the field of prospecting and mining of raw materials mainly involve activities such as field trips, data collection, and analysis, which require more extensive expert services.

The role of the Malaysian Institute for Nuclear Technology Research

The TC programme in Malaysia is administered by the Division of Policy, Planning and External Relations MINT through the Office of External Relations. Expert requests are received and reviewed before submission to the IAEA Technical Co-operation Department for recruitment through Malaysia's Science Attache in Vienna. The review looks at the relevance and the suitability of the request in relation to the implementation the project, including the proposed dates and duration of the assignment, the duties of the expert, and the background (justification) of the request. The actual recruitment is carried out by the Experts Section of the IAEA.

Once a curriculum vitae of a suitable expert is received from the IAEA, the project's contact officer in Malaysia is informed, approval is sought, and the date of the mission is proposed to the IAEA. Necessary arrangements such as a government clearance, visa (if required), reservation of accommodation, transportation and programme of assignment are then processed. At this stage, the project contact officer is encouraged to communicate directly with the expert to discuss technical details and the work plan for the mission. The IAEA is kept informed of the status of the arrangements.

Once the Office of External Relations receives confirmation and the expert's travel itinerary, the project contact officer is informed and all arrangements are finalized. Assistance such as transportation and provision of information about

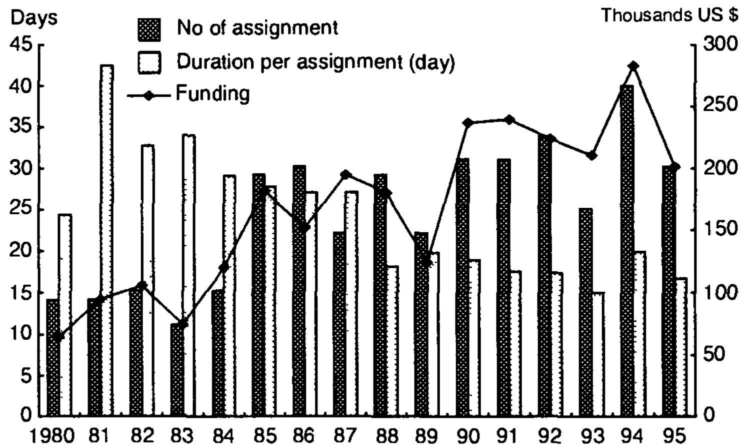
Malaysian institutes, universities and organizations receiving IAEA expert assignments, 1980-95

- Atomic Energy Licensing Board (AELB)
- General Hospital Kuala Lumpur (GHKL)
- Geological Survey Malaysia, Perak (GSMP)
- Geological Survey Malaysia, Sarawak (GSMS)
- Institute for Medical Research (IMR)
- Lembaga Letrik Negara (Utility-Tenaga National Berhad)
- Malaysian Agricultural Research and Development Institute (MARDI)
- Malaysian Institute for Nuclear Technology Research (MINT)
- Rubber Research Institute Malaysia (RRIM)
- Standard for Industrial Research Institute Malaysia (SIRIM)
- *Research Committees,* including Research Committee for Marine (RCM); Research Committee for Mutation Breeding (RCMB); Research Committee for Sterile Insect Technique (RCSIT); Research Committee for Soil Science (RCSS); Research Committee for Tissue Graft (RCTG)
- University Kebangsaan Malaysia (UKM)
- University Malaya (UM)
- University Pertanian Malaysia (UPM)
- University Sains Malaysia (USM)

Malaysia is extended to the expert upon arrival to facilitate his or her assignment in Malaysia.

At the end of a mission, the Office of External Relations receives a detailed report including recommendations that need to be evaluated by the institute and the hosting project officer. The report is discussed and comments are made where necessary and a copy of the revised report is then transmitted to the IAEA. The project officer takes note of the recommendations and actions are taken accordingly. The Office of External Relation continues monitoring the implementation of the recommendations. It further maintains dossiers, records, and reports on the conduct and implementation of the mission.

Expert assignments received by Malaysia, 1980-95

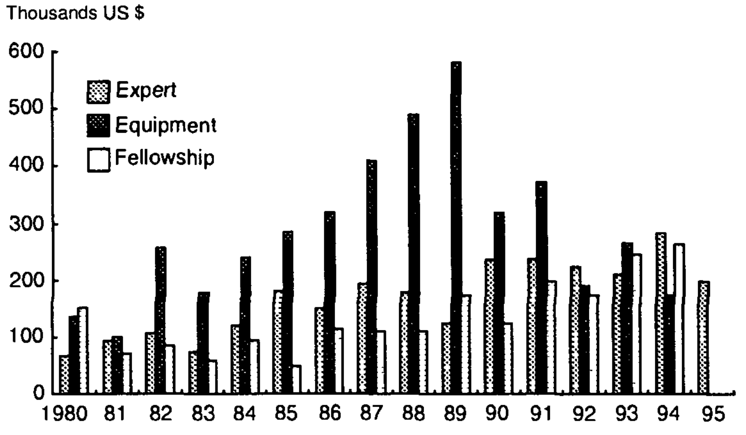


Future challenges and directions

As applications of nuclear and related technologies in Malaysia become more developed, certain levels of expertise are being reached. The expertise extends to areas such as project management, non-destructive testing, radiation protection, energy studies, radioimmunoassay, agriculture, tissue grafting and banking, and radiation processing technology, hydrology, tracer and sealed source technology.

At this point in time, Malaysia is ready to participate in the IAEA's expert services programme to assist other countries in developing nuclear and related technologies. At the same time, Malaysia expects that its own requirements *for expert assistance from the TC programme* will increase, in line with the country's advancing use of nuclear technologies. However, as past trends have shown, the expert assignments should be of short duration and for sharply focused and specialized needs. ❐

Assistance received by Malaysia under the IAEA Technical Co-operation Programme, 1980-95



IAEA Board of Governors meetings

At its meetings in June 1996, the IAEA Board of Governors was scheduled to consider items ranging from the Agency's programme and budget to technical co-operation activities to measures for strengthening the effectiveness and efficiency of the safeguards system, namely through the development programme known as "93+2".

In his introductory statement to the Board on 10 June, IAEA Director General Hans Blix addressed matters related to these and other subject areas.

Programme and budget for 1997. Noting that the Board's Administrative and Budgetary Committee had expressed its view in May 1996 that a "firm basis appeared to exist" for agreement in the Board on the 1997 budget, Dr. Blix outlined measures that the Secretariat had taken in response to comments that had been raised by the Committee. The Committee had requested the Secretariat to revise some of its proposals in the 1997 budget, which had proposed an increase of US $1.9 million, equivalent to a real increase of 0.9%, and to look for further savings in administrative and support costs.

Technical assistance and co-operation. Citing examples in Tanzania, Costa Rica, and other countries, the Director General said that the concept of model projects that now guides technical co-operation activities "is successfully demonstrating that nuclear techniques can make an important contribution to social and economic development". At the same time, he said, the management of technical co-operation continues to be reviewed to achieve even greater efficiency and effectiveness. He further noted that, although the level of contributions to the Technical Co-operation Fund still is below levels achieved in the 1980s, the situation has improved and he urged continuation of the present trend.

Regarding other projects related to the transfer of technology, Dr. Blix mentioned activities related to the preparation of feasibility studies for the technology of nuclear desalination and to applications in isotope hydrology, including two regional technical co-operation projects in Africa and the Middle East involving 13 countries having an acute shortage of water.

Safeguards. In reviewing progress to date on proposals for strengthening the IAEA's safeguards system, Dr. Blix stated that the time has come for point-by-point discussions directly between government representatives, including safeguards experts, lawyers, and diplomats, on the proposed measures requiring complementary legal authority. In this connection, he said that it had been recommended that arrangements be made, perhaps through establishment of a Board committee, to examine, adjust, and finalize the draft protocol which had been prepared. "Over the past several years, the Board has maintained a steady momentum leading to the proposals," Dr. Blix said. "This momentum should not be lost....The final aim and gain of better verification and greater transparency is a higher degree of confidence between States — locally, regionally, and globally — and a facilitation of the transfer of peaceful nuclear technology, equipment, and material."

Among other matters, Dr. Blix also reported on the implementation of safeguards in the Democratic People's Republic of Korea (DPRK), where the IAEA is maintaining a continuous inspector presence. He said that the next round of technical talks between the IAEA and DPRK was now foreseen later in June, and that for its part, the Agency has proposed that these talks should focus on the need for urgent implementation of measures adequately to preserve relevant information without which the Agency will lose the possibility of being able, in the future, to verify the correctness and completeness of the DPRK's initial declaration. The discussions also would cover issues related to safeguards implementation in the country, including the installation of Agency monitoring equipment at nuclear waste tanks in the reprocessing plant and the monitoring of the freeze under the US-DPRK Agreed Framework.

Nuclear safety. The Convention on Nuclear Safety is nearing entry into force, Dr. Blix reported, and the Agency has taken important preparatory steps for its implementation, including developing procedures and guidelines with representatives from Member States concerning the Convention's peer review process. The draft Convention on the Safety of Radioactive Waste Management has made good progress, he said, and could be ready by the end of this year or early next.

A report on the outcome of the June Board meetings will appear in the next edition of the *IAEA Bulletin*.

International Chernobyl conference concludes in Vienna

An International Conference in Vienna this April has summed up the scientific understanding of the major social, health, and environmental consequences attributed to the Chernobyl accident that occurred in Ukraine a decade ago. More than 800 scientists and government officials in fields of nuclear energy, radiation safety, and health care attended the meeting, which was jointly sponsored by the IAEA, European Commission (EC), and World Health Organization (WHO). Participants included high-level governmental representatives from the accident's three most heavily affected countries — Belarus, Russian Federation, and Ukraine — and delegates from more than 70 other States and intergovernmental organizations. The Conference carefully reviewed the many scientific, medical, environmental, social, and political issues involved in assessing Chernobyl's impact, in the context of major changes over the past decade in countries of the former Soviet Union.

"The Chernobyl reactor accident covers a dimension which goes far beyond the boundaries of nuclear safety and radiation protection," said Dr. Angela Merkel, Germany's Environment Minister and President of the Conference. "The actual effects of this disaster have social and economic aspects which are possibly far more significant than radiation exposure itself."

While the Conference (April 8-12) did not expect to reach scientific consensus on all issues involved, its results are intended to place the Chernobyl consequences into perspective and can serve as the factual basis for decision about future work and collaboration.

The summary of the Conference results covers major issues, including those related to:

Initial fatalities and injuries. The explosion on 26 April 1986 and early release of radionuclides resulted in 28 deaths attributed to acute radiation sickness, and three deaths attributed to other causes. These fatalities occurred among the plant staff, firefighters, and emergency workers (liquidators) who initially responded to the accident, including 134 patients diagnosed with acute radiation syndrome. Since then, over the past decade, 14 additional patients have died; only some of these deaths might be attributable to radiation exposure.

Incidence of thyroid cancer. There has been a substantial increase in reported cases of thyroid cancer in Belarus, Ukraine, and some parts of Russia, especially in young children, generally attributed to exposure to radioiodine during the early phases of the accident in 1986. Up to the end of 1995, a total of about 800 cases (including 400 in Belarus alone) have been reported in children who were under age 15 at the time of diagnosis. As of April 1996, three children have died from thyroid cancer. Over the next decades, there will most probably be an increase in the incidence of thyroid cancer among those who were children in 1986; the number of cases is difficult to predict because of the considerable uncertainties in dose estimates. The group at risk should be closely monitored throughout their lives, since treatment should be successful in most cases that are diagnosed early.

Long-Term radiation health effects. Apart from increase in thyroid cancer, there have been some reports of increases in the incidence of specific malignancies in some populations living in contaminated territories and among the liquidators. These reports are not consistent, however, and may require further investigation. Using predictive models, the number of fatal cancers due to the accident among the 7.1 million residents of contaminated territories and strict control zones is calculated to be of the order of 6600 over the next 85 years against a spontaneous number of 870,000 deaths due to cancer. Few fatalities due to radiation-induced leukaemia would theoretically be expected. The total expected excess fatalities due to leukaemia would be of the order of 470 among the 7.1 million residents of contaminated territories and strict control zones; these cases would be impossible to distinguish from the spontaneous incidence of about 25,000 fatalities. Among the 200,000 liquidators who worked in 1986-87, the total expected figure would be of the order of 200 fatalities against a spontaneous number of 800 deaths due to leukaemia.

Other health-related factors. Many changes in health have been seen in the exposed population that are not the result of radiation exposure. There are significant health disorders and symptoms, such as anxiety, depression, and various psychosomatic disorders attributable to mental stress among the population of the region. These are widespread and may well be the most important legacy of the accident. The psychological impact cannot be completely dissociated from that of the breakup of the Soviet Union, and any forecast should therefore take into account the economic, social, and political circumstances of the three countries.

Environmental consequences. No dramatically obvious long-term impacts on populations or ecosystems have been observed. Effective countermeasures can be taken at specific sites to achieve significant reduction in the uptake of radiocaesium into food. In general, no food produced by the collective farm system exceeds established international radiation levels, although some foods produced by private farmers do, as well as mushrooms, game and other wild foods.

Nuclear safety remedial measures. The technical causes of the Chernobyl accident are well known and the safety levels of the 15 similar types of RBMK plants operating in Lithuania, Russia and Ukraine have been raised to practically prevent the same type of accident from occurring again. More RBMK safety improvements are required however, and further steps are needed to stabilize the sarcophagus built to confine the destroyed Chernobyl Unit 4. RBMK safety issues were examined at an international forum in early April in Vienna and were reported to the subsequent Chernobyl Conference.

The Conference featured a range of sessions at which experts reviewed the findings of work carried out to date, including the outcome of two major international conferences, one hosted in November 1995 by WHO and the other in March 1996 under EC auspices in Minsk. Opening addresses were made by IAEA Director General Hans Blix; WHO Director General Hiroshi Nakajima; H. Tent, Director General for Science, Research and Development of the EC; and M. Griffiths, Director of the United Nations Department for Humanitarian Affairs (UNDHA). The Conference further featured national statements by Alyaksandr Lukashenko, President of Belarus; A. Shoigu, Minister for Emergencies, Russia and Yevgeni Marchuk, Prime Minister of Ukraine; and seven keynote presentations by representatives of the United Nations Educational, Scientific and Cultural Organization (UNESCO); United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR); Food and Agriculture Organization (FAO) of the United Nations; Nuclear Energy Agency (NEA) of the Organization for Economic Co-operation and Development; and of organizations in Germany, Japan and the United States on the results of major bilateral post-Chernobyl assistance projects with Russia, Ukraine and Belarus.

The technical symposium featured eight separate topical sessions on the range of social, health, and environmental subjects. Topics included clinically observed health effects; thyroid effects; longer term health effects; other health-related effects, including psychological effects, stress and anxiety; consequences for the environment; the social, economic, institutional and political impact; nuclear safety remedial measures; and the consequences in perspective, a prognosis for the future. A panel discussion further explored the public's perception of the Chernobyl accident.

Conference Proceedings are being published by the IAEA, and the next edition of the *IAEA Bulletin* will feature extensive coverage of the results. Highlights also are available through the IAEA's World Atom Internet Services (address http://www.iaea.or.at/worldatom/thisweek/preview/chernobyl).

Agriculture scientists at Seibersdorf develop new techniques

Agency scientists are playing important roles in the development of new methodologies being used by developing countries to improve agricultural production.

Leguminous plants, such as soybean or common bean, are important food and forage crops in developing countries due to their high protein content. Certain beneficial nitrogen fixing *bacteria (Rhizobium or Bradyrhizobium)* found in the root nodules of these plants "fix" atmospheric nitrogen and make this important nutrient available to the plant. These nitrogen fixing systems play a key role in promoting sustainable agricultural production by greatly reducing the need for, and lessening the pollution from, the application of nitrogenous fertilizers. They are also used in intercropping and mixed cropping systems because nitrogen is passed on to succeeding or companion crops so maintaining the fertility of the soil.

The Soil Science Unit at the FAO/IAEA Agriculture and Biotechnology Laboratory in Seibersdorf developed methodologies that utilized the stable isotope, nitrogen-15, to quantify the amount of nitrogen fixed and thereby provide a means of selecting highly effective bacterial strains for inoculating soils. Since many soils contain aggressive native strains which only fix small amounts of nitrogen, in addition to effectiveness, competitive ability is an important parameter. Recently, the Soil Science Unit developed new molecular biology techniques, known as the *gusA* and *celb* marker gene techniques, for simple identification of bacterial strains. Strains marked with either *gusA* or *celB* can be visualized by the development of a blue or red colour. Microbial identification is essential in order to select competitive and stress tolerant strains for inoculation into soil. Only simple equipment and basic microbiological procedures are needed to perform the technique.

To enable developing countries to utilize this technology, a GUS Gene Marking Kit was developed in Seibersdorf by the same Unit. The kit is suitable for microbiologists and agronomists in countries who wish to use the system but who are not familiar with the methodology and do not have the resources to establish it in their laboratories. At present, 24 scientific groups participating in ongoing FAO/IAEA Co-ordinated Research Programmes or Technical Co-operation Projects have received the kit.

The development of new molecular biology methodologies and their transfer to the Third World will promote the use of "organic" systems in an effort to achieve sustainable agricultural practices. In addition, they will allow scientists to gain a better understanding of the immense diversity of soil bacteria in these countries which has not been utilized to date.

Nuclear power: Status and outlook

Worldwide a total of 437 nuclear power reactors with a total capacity of 344,442 megawatts-electric (MWe) are operating for the production of electricity, and another 39 units with a total capacity of 32,594 MWe are being built *(see the International Data File page in this edition)*. In 1995, four new nuclear power plants were connected to electricity grids in India, the Republic of Korea, the Ukraine and the United Kingdom, based on information reported in the IAEA s Power Reactor Information System. Two units were shut down in 1995, Wuergassen in Germany and Bruce-2 in Canada.

According to IAEA statistics, by the year 2000 installed nuclear capacity worldwide will grow to between 361,000 and 368,000 MWe. Since all the units to be commissioned by the turn of the century are already under construction, the range in the estimates reflects uncertainty associated with possible delays in construction and licensing.

After the turn of the century, the range of uncertainty in the estimates of nuclear power capacity is wider owing to a number of technical, economic, environmental and policy factors. The low and high projections reflect contrasting but not extreme underlying assumptions on the different driving factors that have an impact on nuclear power deployment.

In the low case, the present barriers to nuclear power deployment are assumed to prevail in most countries during the coming two decades. Economic and electricity demand growth rates remain low in industrialized countries. Public opposition to nuclear power continues, and environmental concerns such as the risk of global climate change do not become strong driving factors in energy policies aiming towards switching from fossil to nuclear energy. Institutional and financing issues prevent or slow the implementation of previously planned nuclear programmes in particular in countries in transition and in developing countries. Under these rather pessimistic assumptions, most of the nuclear units under construction would be completed, but new nuclear units would be ordered mainly in the countries where nuclear power is a major component of the electricity generation mix, such as France, Japan, and the Republic of Korea. Owing to the large number of units that would be shut down at the end of their scheduled operating lifetime, the total nuclear capacity in the world would start to decrease after 2010 and in 2015 would be only slightly higher than in 2000, i.e., some 375 gigawatts-electric (GWe). The share of nuclear power in the world electricity supply would decrease from about 17% at present to some 12% in 2015.

The high case reflects a moderate revival of nuclear power development, that could result in particular from a more comprehensive comparative assessment of the different options for electricity generation, integrating economic, social, health, and environmental aspects. This case assumes that some policy measures would be taken to facilitate the implementation of nuclear power programmes, such as strengthening of international co-operation, enhanced technology adaptation and transfer, and establishment of innovative funding mechanisms. With these assumptions, the total installed nuclear capacity worldwide would reach some 535 GWe in 2015 and the share of nuclear power in total electricity generation would be about 14%.

Joint NEA/IAEA international peer review of WIPP safety

Agreement has been reached in Paris between the United States Department of Energy (DOE), the OECD Nuclear Energy Agency (NEA), and the IAEA to organize an international peer review of the long-term safety analysis of the Waste Isolation Pilot Plant (WIPP), a US disposal facility expected to receive long-lived radioactive waste in the near future.

This peer review, requested by the US DOE's Carlsbad Area Office, will be organized jointly by the NEA and IAEA as part of the services offered by the two agencies in the field of radioactive waste management to their Member States. The WIPP is designed to permanently dispose of transuranic radioactive waste generated by defense-related activities. Transuranic waste consists primarily of clothing, tools, rags, and other disposal items contaminated with radioactive elements, mostly plutonium. Located in the State of New Mexico, 42 km (26 miles) east of Carlsbad, WIPP facilities include disposal rooms excavated in an ancient, stable rock salt formation, 654 meters (2150 feet) underground.

As in most countries with nuclear programmes, the preferred method for the disposal of long-lived radioactive waste, such as transuranic waste, is its long-term isolation in a system of multiple barriers located in deep and stable geological formations. The WIPP site was selected and constructed to meet the criteria established by the responsible US regulatory authority, the Environmental Protection Agency (EPA), for the safe long-term disposal of transuranic waste. A formal license application for the disposal of transuranic waste at this site is to be submitted by the DOE to the EPA. This application, called the Compliance Certification Application, will include an assessment of the long-term safety of the repository after its closure.

The objective of the joint NEA/IAEA peer review will be to examine whether the post-closure assessment of the WIPP is appropriate, technically sound, and in conformity with international standards and practices. For the purpose of the review, the NEA and IAEA will constitute a joint secretariat and appoint a group of independent international experts in the various disciplines involved in long-term safety assessments, such as geology, geochemistry, material sciences, radiation and environmental protection, and nuclear safety. The expert group will include representatives from nuclear regulatory bodies, radioactive waste management agencies, universities, and research institutions.

The review will start in October 1996 and be conducted over a 6-month period, on the basis of detailed documentation provided by the US Department of Energy and discussions with the specialists involved in this project during a visit to the WIPP. A report containing the international expert group's findings will be transmitted to the Department of Energy. Through such peer reviews, it is possible to benefit from the experience of the world's leading experts in nuclear waste disposal and radiological safety assessments and to take into account the approaches followed by other advanced countries towards the safe disposal of long-lived radioactive waste. These reviews are in line with the NEA and IAEA common objective of promoting the adoption of safe policies and practices for the disposal of radioactive waste in their respective member countries.

Recent IAEA symposia

International Symposium on Experience in the Planning and Operation of Low-Level Waste Disposal Facilities, 17 - 21 June 1996. Most countries are involved in the management of low-level radioactive wastes (LLW) that arise from nuclear fuel cycle activities and from the use of radionuclides in medicine, research, and industry. In some countries, LLW disposal facilities have been in operation for many years and a considerable base of experience in operation exists. A few repositories have even reached the end of their operational lives and have been closed, so a limited amount of experience now exists on closure and post-closure phases of waste disposal. On the other hand, efforts in other countries are still being made to site and license the first repositories.

This symposium brought together experts from countries well experienced in the field and those where LLW management and disposal is at earlier stages of development. Participants addressed topics related to organizational issues (including the regulatory framework, planning, licensing, and identification of inventories); siting (criteria and approaches, including socio-economic considerations; site investigation and evaluation); design (criteria and approaches; performance of engineered barrier; design of repository); construction; operation (commissioning; waste acceptance; waste emplacement; control of operation; monitoring); closure (closure criteria; closure approach; capping system and performance); post-closure approaches (institutional control issues; monitoring and corrective action; long-term record keeping); safety assessment (methodology; use of case studies); quality assurance; research and development; and international and regional co-operation. Symposium proceedings are being published by the IAEA.

FAO/IAEA International Symposium on the Use of Nuclear and Related Techniques for Studying Environmental Behaviour of Crop Protection Chemicals, 1-5 July 1996. Pesticides are an integral component of agricultural systems throughout the world. It is generally accepted that this will continue for the foreseeable future in many circumstances if the production of food of acceptable quality is to increase.

However, pesticide use has costs as well as benefits. As far as the environment is concerned, information must be provided before a product is registered to provide assurance that it can be used without unacceptable hazard to non-target organisms. In addition, post-registration surveillance and monitoring studies are necessary to check that the fate and environmental effects of pesticides under field conditions are consistent with predictions.

Much of the data is generated with the use of radioisotopes and other nuclear or related methods which can be applied in studies related to the fate and effects of pesticides in the various environmental compartments (soil, water, and air) and in terrestrial (agricultural and non-agricultural) and marine ecosystems.

For a variety of reasons, developing countries often have to rely on data generated elsewhere in order to assess the acceptability of a compound, particularly if it is off-patent. This symposium examined the circumstances under which extrapolation from one environment to another is valid on the basis of data generated under comparable conditions. It also considered ways in which relatively simple methods can be used to verify the field applicability of data obtained in sophisticated experimental conditions. Symposium proceedings are being published by the IAEA.

Summit meeting on nuclear safety and security

Leaders of the Group of Seven countries and the Russian Federation singled out efforts of the IAEA in key areas of nuclear development at the Moscow Summit hosted by President Yeltsin in Moscow 19-20 April 1996.

Specifically, official documents issued after the Summit expressed strong support for the Agency's safeguards inspection regime, which plays a critical role in providing assurance against diversion of nuclear materials. They also called for efforts to stimulate work already in hand for the strengthening of the safeguards regime and at the same time called upon States to provide adequate funding for this purpose.

The IAEA further noted the reported intention of the Russian Federation to place sensitive nuclear material surplus to weapon requirements under Agency inspection in the future would reinforce a trend already initiated by the United States. However, such inspection would obviously entail a significant increase in the Agency's inspection responsibilities over time.

With respect to the subject of the "safe and effective management of weapons fissile material designated as no longer required for defense purposes", the G-7 stated their intention to convene an international meeting of experts, preferably by the end of this year, to examine available options and possible development of international co-operation in the implementation of national strategies. In the IAEA's view, this meeting could usefully complement the Agency Symposium on fuel cycle and reactor strategies planned in 1997.

The Summit further addressed the issue of the liability regime, which seeks to ensure adequate compensation for damages arising from nuclear accidents. Summit participants expressed desire to see progress in this area, which could lend new impetus to work currently under way in the framework of the IAEA.

Physical protection of nuclear materials was another area of increasing importance discussed at the Summit. The G-7 encouraged ratification of the relevant Convention by all States and application of recommendations developed within the IAEA in this regard. The Agency's Secretariat is doing everything it can, within existing overall resource constraints, to provide assistance in this domain to Member States wishing it.

The Summit also called upon States to fully support international safety conventions under IAEA auspices. Specifically, leaders urged countries to sign the Convention on Nuclear Safety so that it can be brought into force, and they called for the effective finalization and prompt adoption of the Convention on the Safety of Radioactive Waste Management, which is being drafted under aegis of the IAEA. The full text of the Moscow Nuclear Safety and Security Summit Declaration has been issued by the IAEA as an Information Circular (INFCIRC/509).

Uranium 1995: "The Red Book"

The IAEA and Nuclear Energy Agency (NEA) of the Organization for Economic Co-operation and Development have jointly issued the latest edition of the "Red Book", *Uranium 1995 - Resources, Production and Demand.* It presents the results of the 1995 review of uranium supply and demand in the world, and is the foremost reference in this field. The report provides a statistical profile of the world uranium industry as of 1 January 1995. It contains data on uranium exploration activities, resources, and production for 54 countries, updating the 1993 edition. Significant new information is provided for a number of countries for which data was previously not easily accessible, and this edition contains reports for 23 of the 25 uranium-producing countries, which accounted for about 92% of world uranium production in 1994.

The world uranium market has changed dramatically in the 1990s due to political and economic developments in uranium-producing and -consuming regions. The over-production of the 1980s has changed during this decade to a more ambiguous situation where production is meeting less than 60% of demand.

Meanwhile prices have remained low because a continued abundant supply of uranium is expected from new sources. While world nuclear electricity generating capacity and its nuclear fuel cycle requirements continue to expand modestly, uranium stockpiles are decreasing and uranium production has been contracting in most regions of the world. However, a steady increase in uranium spot prices since late 1994 suggests that the situation may be changing.

The "Red Book" shows that seven nations hold almost 90% of the world's recoverable uranium resources. For each country, the book gives the total number of tonnes of uranium oxide (U^3O^8)which are "reasonably assured", plus estimated additional resources. Australia holds 29% followed by Kazakhstan with 19%, Canada with 11%, South Africa and Namibia each with 9%, Brazil with 8%, and the United States with 4%.

More information may be obtained from the IAEA Division of Nuclear Fuel Cycle and Waste Management. The book may be purchased from the OECD, 2 rue André-Pascal, 75775 Paris Cedex 16 France.

Chile: Medfly-free benefits

Chile's successful eradication of the Mediterranean Fruit Fly with the help of the radiation-based technology called the Sterile Insect Technique (SIT) is expected to give the country's fruit industry access to new export markets. The economic impact to Chile's international trade is estimated by Chilean authorities to represent an increase of up to US $500 million annually over the next 5 years.

The Medfly is a pest that destroys millions of dollars in fruit per year in infested areas. Because of quarantine reasons, it had been interfering with Chile's multibillion dollar fresh fruit export industry. Although the southern and central regions of Chile were already free of this pest, its produce was still being restricted from certain international export markets because of fear of outbreaks originating from the Medfly's presence in northern Chile.

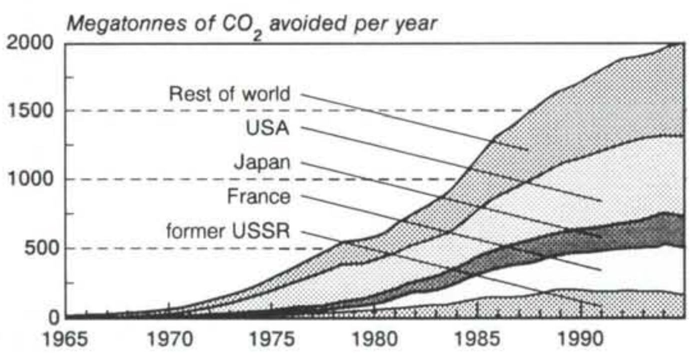
The fly was eradicated using the SIT, which was applied following a decade of Chile's unsuccessful attempts to rid its northern region of the fly using insecticides. The technique relies on rearing vast numbers of male insects in special facilities that are sterilized by low doses of radiation and then released into the wild where they mate without producing offspring.

The SIT project was supported by the Joint Division of the IAEA and Food and Agriculture Organization (FAO) and the IAEA's Department of Technical Co-operation working with the Chilean Agricultural Service. The Agency provided support in areas of project planning, the design of the construction of a Medfly mass-

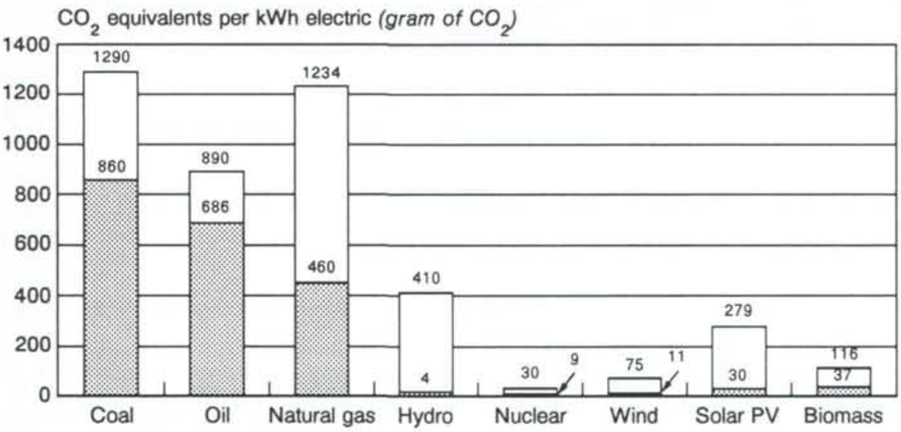
Correction

In the *IAEA Bulletin,* Vol. 37, No. 4, graphs accompanying the article "Nuclear Energy and the environmental debate: The context of choices" reflected editorial errors. The graphs, with corrections shown in italic, appear here. We regret any inconvenience our oversight may have caused readers.

Avoidance of Global CO_2 by Nuclear and Hydropower



CO_2 Equivalent Emission Factors of Different Energy Sources (full energy chain; maximum and minimum values)



rearing and sterilization facility in Chile's Arica-Lluta Valley, the training of professional project staff, the provision of expert services and specialized equipment, and the administration of Chilean project funds held in trust. As a result, a Medfly mass-rearing facility with a production capacity of about 60 million sterile flies per week was completed in 1993, when sterile releases were initiated. No wild Medflies have been detected in Chile since early 1995, thereby successfully concluding the country's 32-year unceasing campaign against this pest, which was first introduced into Chile in 1963.

The Chilean Government's official announcement of the Medfly eradication was made at a ceremony in December 1995 presided over by the former President of Chile, the Minister of Agriculture, and foreign dignitaries.

Mali: SIT campaign kicks off

The Government of Mali convened a roundtable discussion in late May 1996 with its development partners to discuss co-ordinating activities for an integrated approach for the management of tsetse flies and trypanosomiasis. The French, German, and United States aid agencies have sponsored livestock-related development projects in the area which were represented at the meeting.

Livestock development in much of Africa is limited by the range of the tsetse fly, which transmits a type of sleeping sickness called nagana. Livestock infection rates of up to 45% have been recorded in the peri urban zone of Bamako in Mali.

As reported in the June 1996 edition of *INSIDE TC (see the green pages insert),* the roundtable 27-31 May 1996 discussed the possibility of initiating area-wide conventional fly suppression activities (traps, screens, and chemical treatments) involving local communities to drastically reduce the tsetse population in an area of approximately 2000 square kilometers. This is a prerequisite for the potential use of the sterile insect technique (SIT), a radiation-based technology applied against insect pests to reduce their populations in the wild. The Government undertook to document through a socio-economic study the extent of the tsetse and trypanosomiasis problem. On the basis of these promising discussions, the IAEA now is moving ahead with technical feasibility studies on aspects of a SIT campaign.

Lebanon: Ratifies safety convention

Lebanon has become the 21st country to ratify, accept, or approve the Convention on Nuclear Safety, depositing its instrument of ratification 5 June 1996. The action brings the Convention closer to its entry into force, which will occur three months after the date of deposit of the 22nd instrument of ratification, acceptance, or approval, including the instruments of 17 States, each having at least one nuclear installation which has achieved criticality in a reactor core.

The Convention, which is under IAEA auspices, was adopted in Vienna on 17 June 1994. It aims to legally commit participating States operating land-based nuclear power plants to maintain a high level of safety by setting international benchmarks to which States would subscribe. An innovative element is the responsibility of Parties to submit reports on the implementation of their obligations under the Convention for peer review at periodic meetings.

Dominica and St. Kitts & Nevis: Safeguards agreements

Safeguards agreements have entered into force between the IAEA and the Commonwealth of Dominica, and between the IAEA and St. Kitts and Nevis. The agreements came into force on 3 May and 7 May 1996, respectively.

Both agreements were concluded in connection with the States obligations under the Treaty on the Non-Proliferation of Nuclear Weapons.

Egypt: African NWFZ Treaty

Addressing the Conference for the Signing of the African Nuclear-Weapon-Free Zone Treaty in Cairo 11 April 1996, IAEA Director General Hans Blix commended the "untiring efforts of the countries of this continent in nuclear arms control and disarmament".

He noted that the Treaty (also called the Pelindaba Treaty) goes further than the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), to which 51 countries of the Organization for African Unity (OAU) are already party.

Unlike the NPT, he said, the Pelindaba Treaty prohibits the stationing and testing of any nuclear explosive device in the territories of the Parties; it also commits its Parties to apply the highest standards of security and physical protection of nuclear material, facilities, and equipment to prevent theft and unauthorized use; it prohibits armed attack against nuclear installations in the zone; and it prohibits the dumping of any radioactive waste.

Under the Pelindaba Treaty, the IAEA is entrusted with the obligation of verifying, through its safeguards system and in accordance with the complaint procedure provided for in the Treaty, compliance by the Parties with their commitment to use nuclear energy exclusively for peaceful purposes. Dr. Blix pointed out that the Agency currently applies safeguards to 26 nuclear facilities in five African States party to the NPT (Egypt, Ghana, Libya, South Africa, and Zaire) and in one State (Algeria) pursuant to facility-specific agreements. A safeguards agreement with Algeria linked to the country's adherence to the NPT has recently been signed and may be expected soon to come into force, he said.

At the signing ceremony, representatives from 43 African States signed the Pelindaba Treaty. (The full text of the Director General's address is accessible through the IAEA's *World Atom* Internet services at http://www.iaea.or.at/worldatom.)

Tanzania: Tsetse control

A new insectary has been inaugurated at the mass-rearing facility of the Tsetse and Trypanosomiasis Research Institute (TTRI) in Tanga. Along with other refurbished insectaries and new equipment provided by the IAEA with the support of major donors, the insectary will be used in a campaign to combat the tsetse fly on the island of Zanzibar using the Sterile Insect Technique (SIT), a radiation-based technology for suppressing and eventually eradicating populations of insect pests.

In remarks at the inauguration ceremony, IAEA Director General Hans Blix commended what he described as outstanding progress in the tsetse eradication project. "The progress made at Tanga and on Unguja has received considerable attention by other African countries," he said, noting that other countries in the region have inquired about the eradication project. For the future implementation of these projects in the region, TTRI may very well be one of the production facilities to supply the necessary sterile flies, as well as serve as the major training site for technicians and scientists, he said.

Sweden: Nuclear perspectives

Speaking at a nuclear conference in Kalmar in June 1996, IAEA Director General Hans Blix reviewed the actual and potential role of nuclear power as an energy source in the context of issues related to safety, non-proliferation, waste management, public opinion, and environmental concerns. He addressed the Conference on Accelerator-Driven Transmutation Technologies and Applications, which the Agency co-sponsored.

"Nuclear power is a demanding technology," he said, "but it is the technology that for the foreseeable time has the greatest potential to give significant amounts of energy with minimal contribution of greenhouse gases. As it is economically viable, it does provide a 'no regret' option. Even a drastic expansion of nuclear power might not, alone, give the response we need to the greenhouse threat, but it could go a rather long way."

In noting that nuclear power development has stagnated in many countries, while growing modestly in others, Dr. Blix pointed out that all sources of electricity generation will be needed in years ahead to meet the world's rising demands. He cautioned, however, against an over-reliance on coal, oil, and gas which now dominant the energy picture, or on the potential role of renewable energy sources, which can be expected to contribute marginally to production. Regarding nuclear development, he urged that all efforts should continue to further reduce the risk of accidents, to develop further the solutions which already exist for the disposal of nuclear wastes, to prevent the proliferation of nuclear weapons and illicit trafficking in nuclear material, to develop new types of nuclear reactors that are safer, simpler, and even more economic than present ones, and to find broader use of nuclear power than just electricity generation.

Jamaica: Safeguards seminar

The IAEA and the Agency for the Prohibition of Nuclear Weapons in Latin America (OPANAL) co-sponsored a seminar in Kingston 25 April 1996 on IAEA safeguards that focused on the process of verifying compliance with non-proliferation commitments. Participants attended from countries in Latin America and the Caribbean region.

In addressing the seminar, IAEA Director General Hans Blix presented a comprehensive overview of the peaceful and safe uses of nuclear energy, reviewing developments in areas of technical assistance and co-operation, nuclear power for electricity generation, and safeguards and non-proliferation.

"The IAEA spans a full spectrum of nuclear-related activities," he said. "Those that usually come to public attention are those relating to nuclear safety and to our role in attempting to curb the spread of nuclear weapons. These areas are of central importance....however, there is an important balance to be preserved between these functions and the services the Agency provides to its developing Member States who look to the IAEA to provide assistance in raising their level of technical sophistication and thereby improving the quality of life for their populations."

(The full text is accessible through the IAEA's World Atom Internet services at http://www.iaea.or.at /worldatom.)

Russian Federation: Signs Vienna Convention

The Russian Federation has signed the Vienna Convention on Civil Liability for Nuclear Damage, for which the IAEA is the Depositary. To date, 26 States have become parties to the Convention, which entered into force in 1977 and is one of the instruments establishing the global legal framework for nuclear liability.

To strengthen the liability regime, international legal experts meeting under IAEA auspices presently are amending the Vienna Convention and drafting a new convention on supplementary funding.

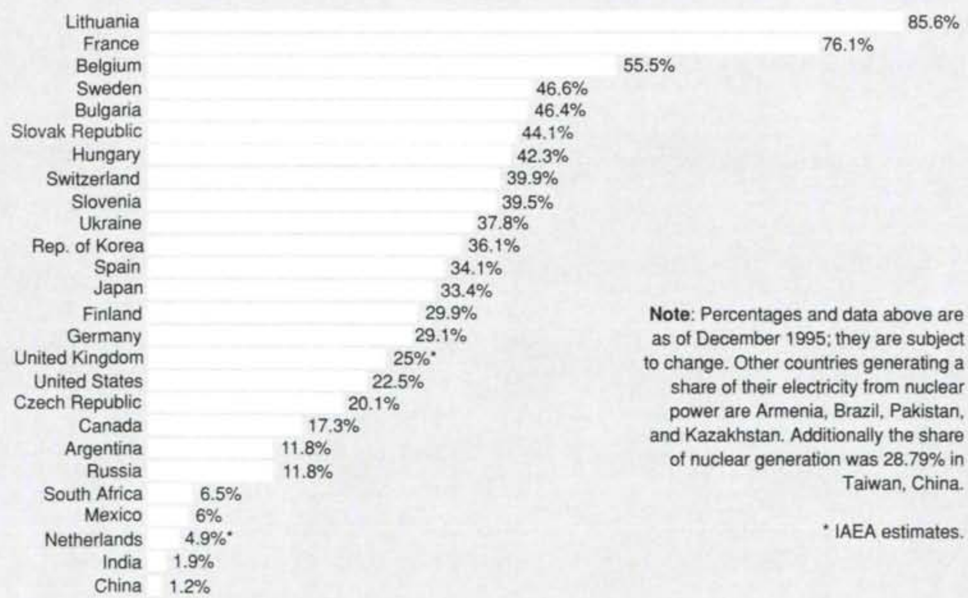
Nuclear power status around the world

	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	5 631		
Brazil	1	626	1	1245
Bulgaria	6	3 538		
Canada	21	14 907		
China	3	2 167		
Czech Republic	4	1 648	2	1 824
Finland	4	2 310		
France	56	58 493	4	5 810
Germany	20	22 017		
Hungary	4	1 729		
India	10	1 695	4	808
Iran			2	2 146
Japan	51	39 893	3	3 757
Kazakhstan	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			2	1 300
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	7 124		
Sweden	12	10 002		
Switzerland	5	3 050		
United Kingdom	35	12 908		
Ukraine	16	13 629	5	4 750
United States	109	98 784	1	1 165
World total*	437	344 422	39	32 594

* The total includesTaiwan, China where six reactors totalling 4884 MWe are in operation.

Notes to table: During 1995, two reactors were shutdown (including Bruce-2 in Canada which could restart in the future).

Nuclear share of electricity generation in selected countries



Note: Percentages and data above are as of December 1995; they are subject to change. Other countries generating a share of their electricity from nuclear power are Armenia, Brazil, Pakistan, and Kazakhstan. Additionally the share of nuclear generation was 28.79% in Taiwan, China.

* IAEA estimates.

Republic of Korea: The scientific trail of X-ray tubes

The old and the new in the scientific and medical worlds of radiology came together in Seoul recently with a special technical exhibition on the development of X-ray tubes. The exhibition displayed an impressive collection of X-ray tubes, scientific papers, and historical books and photographs. It was conceived and organized by Mr. J.W. Nam, a former IAEA staff member, expert in radiation physics, and life-long student of Wilhelm Conrad Roentgen and his century-old discovery.

Mr. Nam, who has written a book in Korean about Roentgen and his life, has been collecting X-ray tubes since 1955. The exhibit featured 43 typical tubes that have been manufactured over the past four decades. They ranged from the oldest gas-ion tubes to "Coolidge" tubes to modern tubes entirely made of metal or half-glass and half-metal. The exhibit also included selected papers and references from Mr. Nam's collection of 120 papers, 20 historical books, and sundry photographs, and illustrations from the scientific literature tracing the development of the tubes.

Based on the collected trail of references, Mr. Nam has been able to date the technical development of X-ray tubes since the time of Roentgen's discovery in 1895. *(See box.)*

The Seoul exhibit of X-ray tubes and the supporting technical literature was organized to mark a century of scientific progress in the application of X-rays.

Readers interested in learning more about the exhibit and scientific collection are invited to contact Mr. Nam at Hyodong Villa A-101, 4-2 Shinyong-dong, Chongno-ku, Seoul, Republic of Korea.

Chronology of the Development of X-ray Tubes

1895 Discovery of X-ray by Roentgen

1896 Introduction of concave (focusing) cathode; anti-cathode; and ion tube with adjustable vacuum

1899 Water-cooled ion tube (platinum anti-cathode)

1903 Tungsten and tantal as anti-cathode material (since 1909, ion tube with tungsten anti-cathode)

1910 Rotating anode ion tube (principle idea proposed in 1897, practical design appeared in 1929)

1913 Hot cathod (Coolidge) tube; valve rectifier (kenotron)

1914 Hard glass tube envelope

1915 Hooded-anode tube

1918 Line focus (Goetze) tube

1920 Oil-cooled tube

1925 Grez-ray tube

1926 Beryllium-window tube

1928 Hollow-anode tube

1929 Heavy tungsten/copper anode (rotating anode tube)

1932 Grid-controlled tube (stationary anode)

1937 Grid-controlled tube (rotating anode)

1941 Betatron

1943 Thoriated-tungsten filament rectifier

1945 Hard glass tube with oil insulation

1959 High speed tube

1962 Rhenium-alloyed tungsten composite anode

1971 Glass-metal tube with molybdenum (Mo) anode

1972 Crack-proof anode with mechanical stress relief

1973 Three-layer anode (W-Re)+Mo+graphite or (W-Re)+W+(W-Zr-Mo)

1979 Metal-ceramic tube

1981 Three-focus tube

1989 Direct anode cooling with noiseless rotor

The exhibition in Seoul attracted scientists, students, and members of the media in the Republic of Korea. In the top left photo, Mr. Nam *(right)* briefs visitors and guests on the types of X-ray tubes featured in his collection, which has been compiled over the past four decades. *(Credit: J.W. Nam)*

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Closing date: 30 September 1996.

ANALYTICAL CHEMIST (96-046), Department of Research and Isotopes. This P-1 post participates in ongoing research, training and analytical service activities of the agrochemicals unit. It requires a university degree in analytical organic chemistry or a closely related discipline with experience in the analysis of trace quantities of organic compounds, especially pesticides, by using gas chromatography and HPLC.
Closing date: 30 September 1996.

SECTION HEAD (96-045), Department of Safeguards. This P-5 post has the prime responsibility for instrumental measurements, analyses and surveillance applications in the Department of Safeguards. It requires an advanced university degree (or equivalent) in physical science or engineering (nuclear or electrical) and a minimum of 15 years of experience in nuclear research and/or industry with substantial experience in conducting instrumentation programmes.
Closing date: 30 September 1996.

UNIT HEAD (two posts) (96-044), Department of Safeguards. This P-5 post participates in the execution of the Agency's safeguards system and functions as a safeguards inspector subject to the approval of the Board of Governors. It requires an advanced university degree in chemistry, physics, engineering or electronics/instrumentation or equivalent, and at least 15 years of combined research, industrial, and safeguards experience in the nuclear fuel cycle, processing of nuclear materials, nuclear material accounting and/or destructive/non destructive analysis.
Closing date: 30 September 1996.

SENIOR TRAINING OFFICER (96-043), Department of Safeguards. This P-4 post designs and implements the technical training activities offered by the Safeguards Training Section. It requires a university degree or equivalent with emphasis in a nuclear science, and at least 10 years of combined experience in the nuclear industry including experience in a training position.
Closing date: 20 September 1996.

UNIT HEAD (96-042), Department of Research and Isotopes. This P-4 post leads the Soil Science Unit in its implementation of agreed laboratory activities in support of the FAO/IAEA subprogramme in soil fertility, irrigation and crop production. It requires a Ph.D. or equivalent in soil science with particular experience in soil biology, soil fertility and crop production, followed by at least 10 years of relevant experience.
Closing date: 20 September 1996.

LIAISON/PUBLIC INFORMATION OFFICER (96-041), Division of External Relations, Department of Administration. This P-4 post at the IAEA Liaison Office at the United Nations in New York follows developments in areas of interest to the Agency, represents the IAEA at relevant meetings, and carries out liaison and public information activities. It requires an advanced university degree or equivalent in political science, international relations, law or social studies, and at least 10 years of relevant experience.
Closing date: 20 September 1996.

UNIT HEAD (96-040), Department of Research & Isotopes. This P-4 post supervises the Chemical Analysis Unit in the Agency's Safeguards Analytical Laboratory (SAL) in Seibersdorf and is responsible for the performance of the elemental assays of nuclear samples, and for the coordination of the analyses of safeguarded nuclear materials at SAL. It requires a Ph.D. in analytical chemistry or equivalent professional experience, and at least 10 years of relevant professional experience.
Closing date: 20 September 1996.

SENIOR ENGINEERING SAFETY OFFICER (96-039), Department of Nuclear Safety. This P-5 post advises and assists with matters regarding the engineering and operational safety of nuclear power plants. It requires a Ph.D. or equivalent higher degree in engineering or physical science, and a minimum of 15 years of relevant national and international experience in the safety of nuclear power plants.
Closing date: 20 September 1996.

RADIATION ONCOLOGIST (96-037), Department of Research and Isotopes. This P-4 post assists and advises Member States on matters related to promotion, identification, and co-ordination of programmes in the fields of rdiation oncology and applied radiation biology and their applications in human health. It requires a Ph.D. (preferably) or equivalent degree in radiation biology, and at least 10 years of experience in clinical radiation oncology and applied radiation biology.
Closing date: 26 August 1996.

NUCLEAR MEDICINE PHYSICIAN (96-036), Department of Research and Isotopes. This P-4 post assists in formulating, guiding, monitoring and evaluating the Agency's programme for assisting Member States to apply *in vivo* open sources of radionuclides for diagnosis and treatment of diseases and for research on human health. It requires a university degree in medicine with at least 10 years of comprehensive and specialized clinical experience in all aspects of *in vivo* nuclear medicine as applied to patient care, teaching and training and research at university level or equivalent.
Closing date: 26 August 1996.

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 suitable qualified women as well as men. More specific information about employment opportunities at the IAEA may be obtained by writing the Division of Personnel, P.O. Box 100, A-1400 Vienna, Austria.

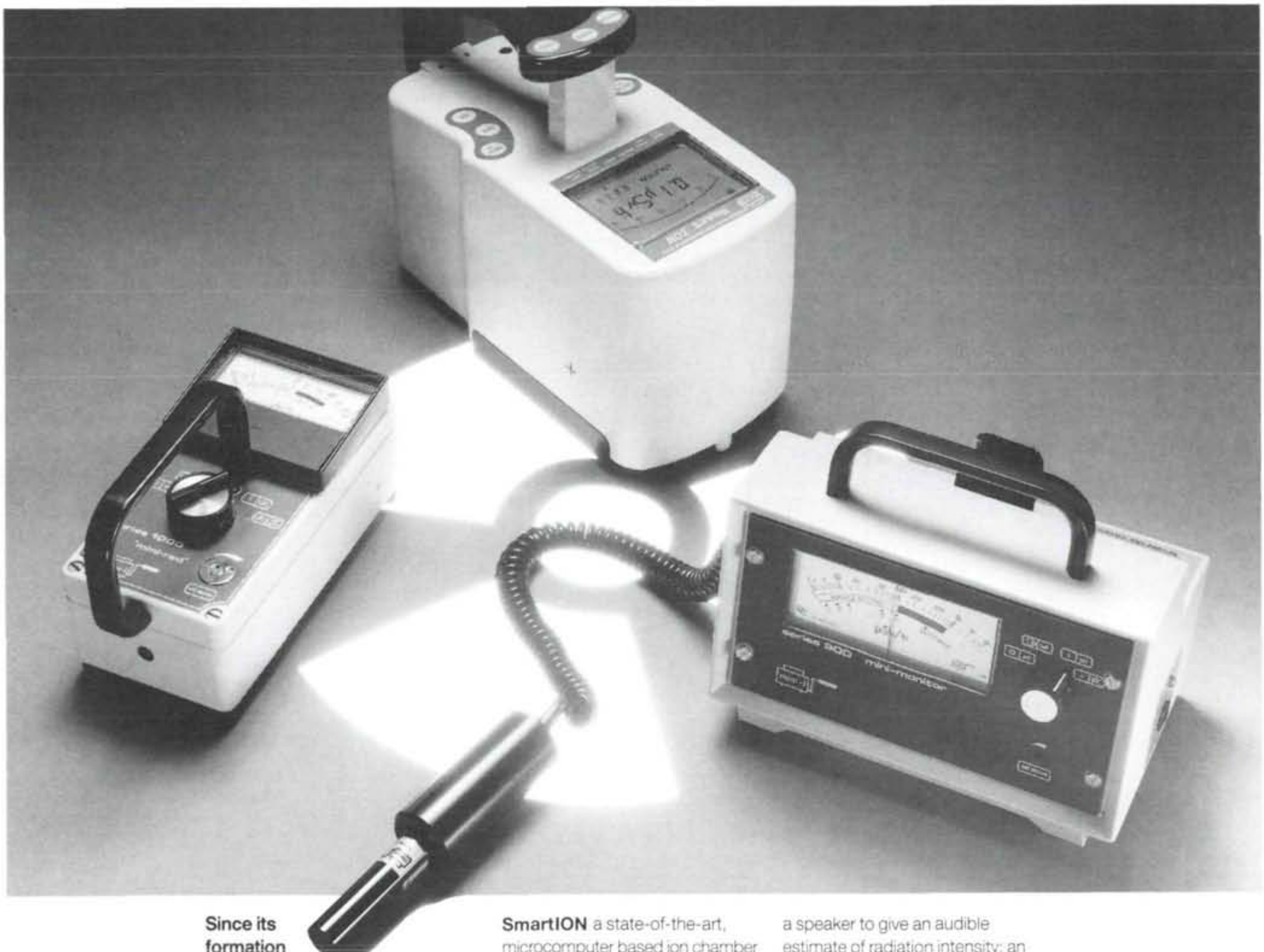
ON-LINE COMPUTER SERVICES. IAEA vacancy notices for professional positions, as well as sample application forms, now are available through a global computerized network that can be accessed directly. Access is through the Internet. The vacancy notices can be accessed through the IAEA's *World Atom* services 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.

IAEA BULLETIN 1995

Authors and Contributors
Vol. 37, Nos. 1-4

Morgan

Radiation Measurement and Control-rely on Mini's range and know-how.



Since its formation in 1963, Mini Instruments has produced a wide range of units for the accurate monitoring and measurement of radiation and contamination. Illustrated is a selection of up-to-the-minute Mini units of which there are nearly 40,000 currently in use throughout the world.

SmartION a state-of-the-art, microcomputer based ion chamber survey meter for the measurement of Gamma, Beta and X-ray radiation, and which sets new standards in versatility, accuracy, operational simplicity and reliability.

The 1000 Series Mini-Rad gamma survey monitor for use by research, hospital and industrial organisations as an inexpensive, convenient and reliable gamma doserate meter.

The 900 Series of monitors for radiation control. All units have a large logarithmically scaled meter: a speaker to give an audible estimate of radiation intensity: an alarm which can be set to trip at any level on the scale: battery or mains operation.

Full technical information and prices are available on request.

Mini Instruments Limited,
15 Burnham Business Park,
Springfield Road,
Burnham-on-Crouch, Essex,
CM0 8TE. England.
Telephone: 01621 783282.
Fax: 01621 783132.

mini-I

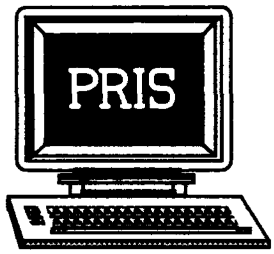
MINI-INSTRUMENTS LTD

RAD/CON

RADIATION AND CONTAMINATION INSTRUMENTATION

ON LINE DATABASES

OF THE INTERNATIONAL ATOMIC ENERGY AGENCY



Database name

Power Reactor Information System (PRIS)

Type of database

Factual

Producer

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

IAEA contact

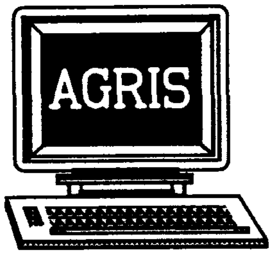
IAEA, Nuclear Power Engineering Section, P.O. Box 100
A-1400 Vienna, Austria
Telephone (43) (1) 2060
Telex (1)-12645
Facsimile +43 1 20607
Electronic mail via BITNET/INTERNET to ID:
NES@IAEA1.IAEA.OR.AT

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 grid, date of commercial operation, date of shutdown, and data on reactor core characteristics and plant systems; energy produced; planned and unplanned energy losses; energy availability and unavailability factors; operating factor, and load factor.



Database name

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

Type of database

Bibliographic

Producer

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

IAEA contact

AGRIS Processing Unit
c/o IAEA, P.O. Box 100
A-1400 Vienna, Austria
Telephone (43) (1) 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

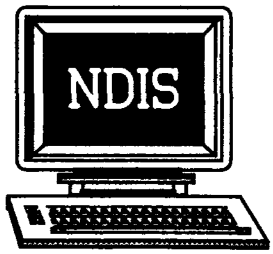
more than 130 000

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 aquaculture; agricultural machinery and engineering; natural resources; processing of agricultural products; human nutrition; pollution; methodology.



Database name

Nuclear Data Information System (NDIS)

Type of database

Numerical and bibliographic

Producer

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

IAEA contact

IAEA Nuclear Data Section,
P.O. Box 100
A-1400 Vienna, Austria
Telephone (43) (1) 2060
Telex (1)-12645
Facsimile +43 1 20607
Electronic mail via BITNET/INTERNET to ID:
RNDS@IAEA1.IAEA.OR.AT

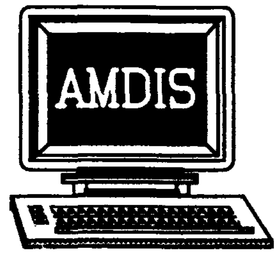
Scope

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

Data types

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

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



Database name

Atomic and Molecular Data Information System (AMDIS)

Type of database

Numerical and bibliographic

Producer

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

IAEA contact

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

Scope

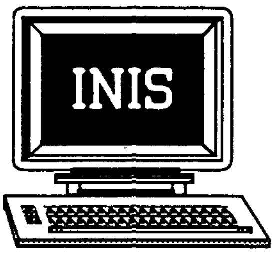
Data on atomic, molecular, plasma-surface interaction, and material properties of interest to fusion research and technology

Coverage

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

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

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



Database name
International Nuclear Information System (INIS)

Type of database
Bibliographic

Producer
International Atomic Energy Agency in co-operation with 91 IAEA Member States and 17 other international member organizations

IAEA contact
IAEA, INIS Section, P.O. Box 100, A-1400 Vienna, Austria
Telephone (+431) 2060 22842
Facsimile (+431) 20607 22842
Electronic mail via BITNET/INTERNET to ID: ATIEH@NEPO1.IAEA.OR.AT

Number of records on line from January 1976 to date
more than 1.6 million

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

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

IAEA UPCOMING CO-ORDINATED RESEARCH PROGRAMMES

Dose determination with plane-parallel ionization chambers in therapeutic electron and photon beams
To investigate the accuracy of the data and procedures included in the new code of practice. In addition, differences with existing recommendations will be quantified to analyze the possible impact in patient dosimetry.

Compilation and evaluation of photonuclear data for applications
To develop a data file of evaluated photonuclear reaction cross sections. The list of nuclei should include natural elements and isotopes of importance in biological, structural and shielding materials, as well as actinides, fission products and a few others.

Assuring structural integrity of reactor pressure vessel
To facilitate the international exchange of information, provide practical guidance in the field of monitoring reactor pressure vessels and to develop and assess a uniform procedure of testing specimens for the assessment of RPV structural integrity.

Development of radiological basis for the transport safety requirements for low specific activity materials and surface contaminated objects
To assist the Agency in developing transport safety requirements. This CRP will provide a basis for classifying low level radioactive materials (such as low level waste) and for modelling potential releases in the event of transport accidents.

Development of methodologies for optimization of surveillance testing and maintenance of safety related equipment at nuclear power plants
To provide an exchange of experience in investigating and analyzing different strategies to improve and optimize maintenance and surveillance testing focusing on nuclear power plant safety, and to stimulate the exchange of methodologies and techniques to carry out such optimization processes.

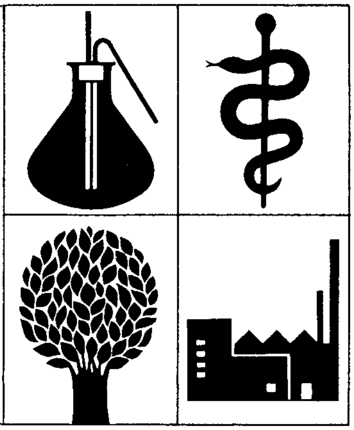
Biosphere Modelling and Assessment methods (BIOMASS)
To analyze and quantify the behaviour of radionuclides in the biosphere in support of assessments of the radiological impact of practices and interventions related to nuclear fuel cycle activities, including waste management,

Modelling transport of radioactive substances in primary circuit of water cooled reactors
To compare and improve computer codes for modelling the transport of radioactive substances in the reactor primary systems.

Reference Asian Man Project (Phase 2): Ingestion and organ content of trace elements of importance in radiological protection
To obtain high quality analytical data on dietary intakes (ingestion) and body composition of representative Asian populations, with special reference to trace elements that are of importance in radiological protection.

Use of radiation processing to prepare biomaterials for applications in medicine
To promote research and development of materials for use in medicine and industry, applying methods of radiation synthesis and technology.

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

AUGUST 1996

Seminar on Nuclear Techniques for the Detection and Management of Cancer
Colombo, Sri Lanka (12 -16 August)

SEPTEMBER 1996

IAEA General Conference, 40th session
Vienna, Austria
(16 - 20 September)

OCTOBER 1996

16th IAEA Fusion Energy Conference
Montreal, Canada (7 - 11 October)

Symposium on Reviewing the Safety of Existing Nuclear Power Plants
Vienna, Austria (8 - 11 October)

NOVEMBER 1996

Symposium on Harmonization of Health-Related Environmental Measurements Using Nuclear Analytical Techniques
Hyderabad, India (4 -7 November)

Seminar on the Use of Isotope Techniques in Marine Environmental Studies
Athens, Greece (11-22 November)

APRIL 1997

Symposium on Diagnosis and Control of Livestock Diseases Using Nuclear and Related Techniques
Vienna, Austria (7 - 11 April)

International Symposium on Applications of Isotope Techniques in Studying 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

Seminar on Nuclear Techniques for Optimizing the Use of Nutrients and Water for Plant Productivity and Environmental Preservation
Piracicaba, Brazil (12 - 16 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 (2 - 6 June)

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IAEA BULLETIN

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IAEA MEMBER STATES

1957
Afghanistan
Albania
Argentina
Australia
Austria
Belarus
Brazil
Bulgaria
Canada
Cuba
Denmark
Dominican Republic
Egypt
El Salvador
Ethiopia
France
Germany
Greece
Guatemala
Haiti
Holy See
Hungary
Iceland
India
Indonesia
Israel
Italy
Japan
Korea, Republic of
Monaco
Morocco
Myanmar
Netherlands
New Zealand
Norway
Pakistan
Paraguay
Peru
Poland
Portugal
Romania
Russian Federation
South Africa
Spain
Sri Lanka
Sweden
Switzerland
Thailand
Tunisia
Turkey
Ukraine
United Kingdom of Great Britain and Northern Ireland
United States of America
Venezuela
Viet Nam
Yugoslavia

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

1959
Iraq

1960
Chile
Colombia
Ghana
Senegal

1961
Lebanon
Mali
Zaire

1962
Liberia
Saudi Arabia

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

1964
Cameroon
Gabon
Kuwait
Nigeria

1965
Costa Rica
Cyprus
Jamaica
Kenya
Madagascar

1966
Jordan
Panama

1967
Sierra Leone
Singapore
Uganda

1968
Liechtenstein

1969
Malaysia
Niger
Zambia

1970
Ireland

1972
Bangladesh

1973
Mongolia

1974
Mauritius

1976
Qatar
United Arab Emirates
United Republic of Tanzania

1977
Nicaragua

1983
Namibia

1984
China

1986
Zimbabwe

1991
Latvia
Lithuania

1992
Croatia
Estonia
Slovenia

1993
Armenia
Czech Republic
Slovakia

1994
Former Yugoslav Republic of Macedonia
Kazakhstan
Marshall Islands
Uzbekistan
Yemen

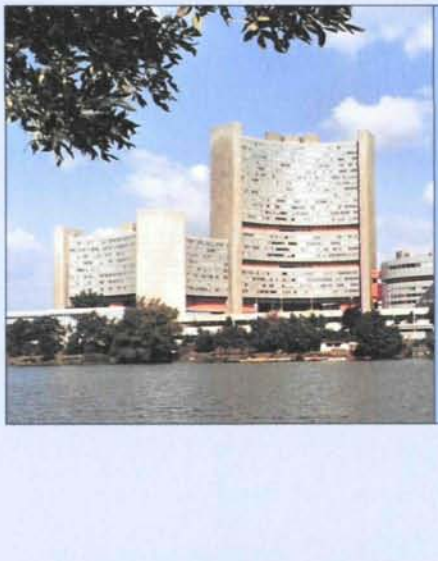
1995
Bosnia and Herzegovina

1996
Georgia

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

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

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



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

IAEA headquarters, at the Vienna International Centre.

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

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

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

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

SCIENCE AND HUMANITY

ALOKA

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