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.

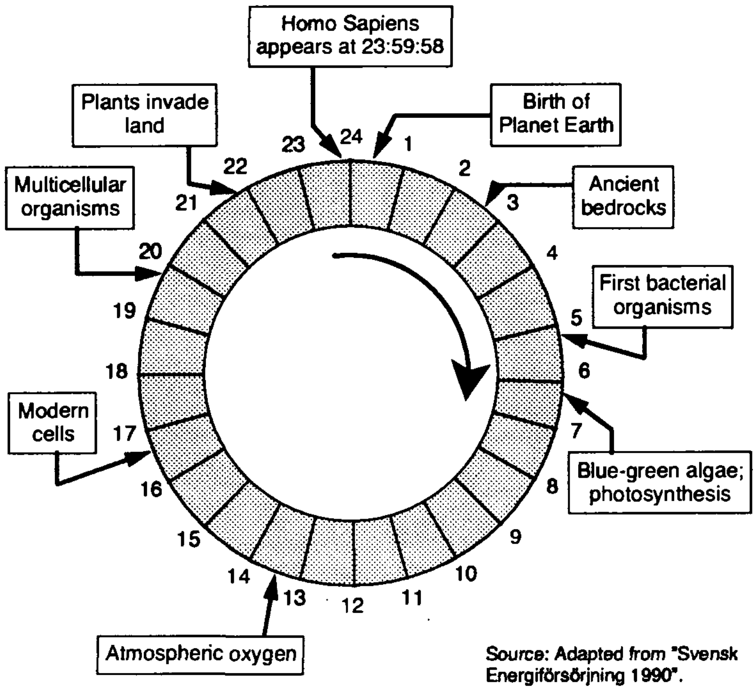
Now, only 65 years later, we are approaching the six billion value. By the year 2100 we will be 12 billion. This population growth is particularly alarming because it will almost entirely occur in the developing countries, which already host 77% of the world population but share only 15% of the world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



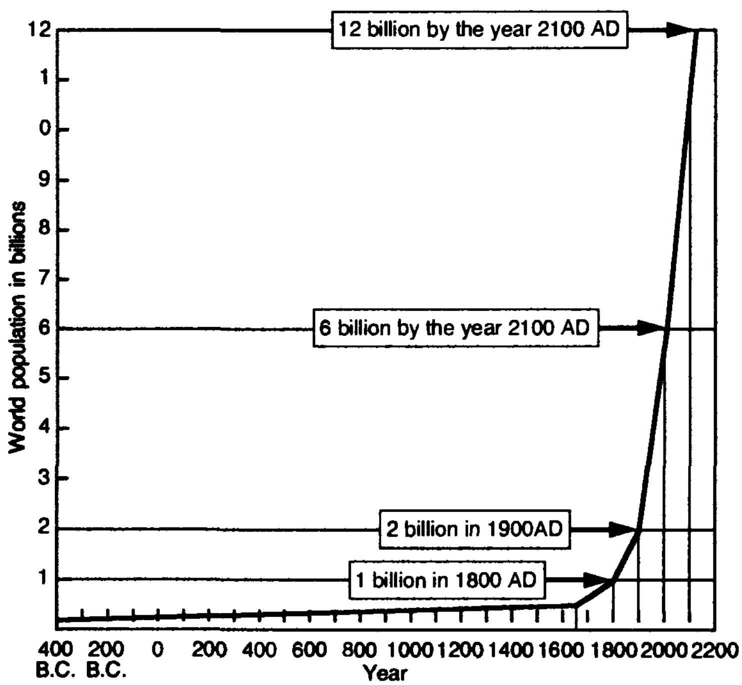
Source: Adapted from "Svensk Energiförsörjning 1990".

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).

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.

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.

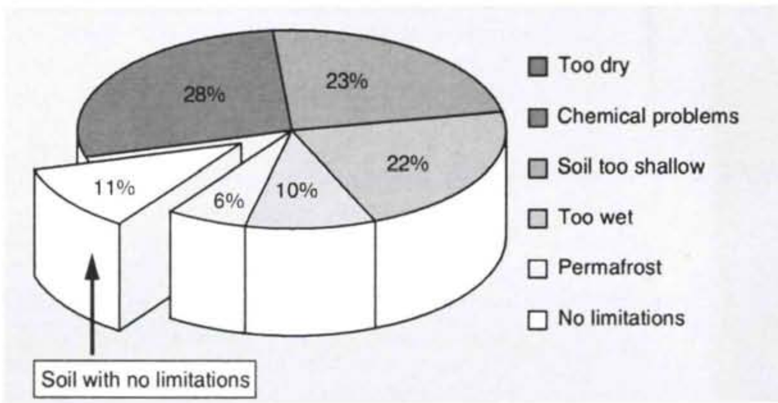
These examples explain why over the years environmental factors have been gradually integrated into most political and economic decision-making mechanisms and have become as fundamental as economics in determining development policies.

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. ❐