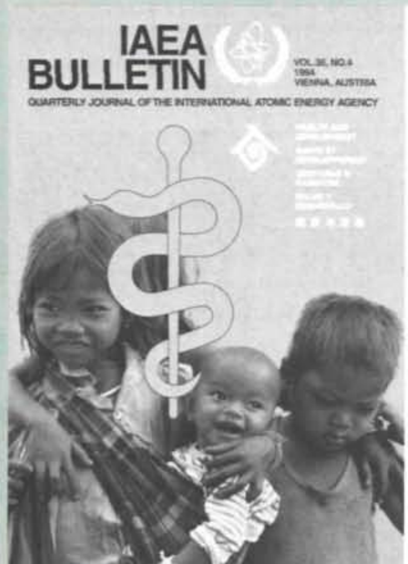


Front cover: Children embracing in the countryside teach us anew about how closely our health is bound to the world around us. Too many people suffer, and often die prematurely, from illnesses linked to industrial pollution, poor nutrition, contaminated food and water, and other unsafe environmental conditions. In important ways, the IAEA is supporting global efforts promoting better health for all. Targeted research and technology-transfer projects are helping physicians and medical researchers use health-related nuclear technologies in their fight against some of the world's most serious diseases and health disorders.

Facing page: A family in Pangasinan, Philippines. This photo — entitled "Shining Through" by Rodolfo M. de Leon in the Philippines — and the front cover photo of children in Viet Nam — entitled "Eyes and Smile" by Tuong Linh in Viet Nam and, in our cover design, set against the international logos for health and the family — were among the award-winners in the World Photo Contest "The Family". The contest was organized by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the Asia/Pacific Cultural Centre for UNESCO (ACCU). More information about the contest and a selection of other prize-winning photos appear on pages 16 and 17.

CONTENTS

Verification of nuclear non-proliferation: Securing the future

International efforts to make the nuclear non-proliferation regime more effective show signs of bearing fruit

by Dr Hans Blix

Momentous changes over the past several years are first beginning to colour the course of international relations. Frequently presented in images and symbols — the fall of the Berlin Wall, nuclear inspection teams at desert sites in Iraq, national flags raised in capitals of a newly formed commonwealth — the events have ushered in unprecedented opportunities, and critical new challenges, for the international community. What implications do they hold for world peace and security, particularly within the context of nuclear developments?

What we have seen so far is generally hopeful. In my view, it augurs well for securing even greater adherence to the nuclear non-proliferation regime that States collectively have built over the past 30 years to stop the spread of nuclear weapons. Underpinned by an intricate web of legal instruments, the regime includes the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), IAEA safeguards agreements, regional nuclear-weapon free zone treaties, nuclear disarmament measures, and nuclear export restrictions. To varying degrees, we have witnessed positive developments in each of these areas in recent years.

The generally optimistic outlook, however, must be tempered because of some major impediments.

Among them are deeply rooted regional tensions in the Middle East and parts of Asia, and ethnic division in regions of Europe. Secondly, there is the case of Iraq, whose extensive clandestine nuclear programme raised serious questions about how close other countries might come to acquiring the materials and technology to develop a nuclear weapon. Thirdly, the breakup of the Soviet Union has added some troubling dimensions to non-proliferation and verification issues.

Dr Blix is Director General of the IAEA.

There are signs that these, and other, difficult challenges are leading to greater vigilance and resolve within the international community. In my view, the post-Cold War's more temperate global climate is favouring the cultivation of some new approaches that alongside traditional ones will serve to make the nuclear non-proliferation regime more effective.

Nuclear non-proliferation

Over the past 30 years, efforts toward preventing the proliferation of nuclear weapons to further countries have been rather successful, a fact frequently overlooked. The number of States having overt nuclear-weapons programmes has stayed at five. A few others are thought to have the capability of assembling nuclear weapons in a short time, if they do not already have them.

Historically less successful have been attempts to halt vertical proliferation — to reduce the number of nuclear weapons among the five declared nuclear-weapon States. Of late, the situation is changing. The United States and Russian Federation are moving to make very substantial cuts to their tremendous nuclear stockpiles, which no longer are menacingly targetted at each other. One can even hope that the prevailing climate will lead all nuclear-weapon States to more deeply question the need for costly nuclear tests they have conducted at the rate of one every nine days since 1945.

Why have most States decided against developing nuclear weapons? The answers vary, and are tied to a number of disincentives and national political considerations.

One practical disincentive is technological. Despite the very special case of Iraq, most developing countries still are not at a technological level where they could develop a nuclear weapon. The lesson of Iraq, however, is that more and more of them could attain that level soon. Moreover, the risk exists, e.g. in the wake of the Soviet Union's dissolution, that a country might succeed in buying a nuclear weapon or weapons-grade material clandestinely.

Another disincentive is grounded in political and security considerations: A good number of States have found that they really would have no use for nuclear weapons, or even that it would be more dangerous to have them than to lack them. When countries like Sweden, Finland, Austria, and Switzerland adhered to the NPT, they may have come to just this conclusion.

In many cases, the lack of incentive for States to acquire nuclear weapons has been linked to the nuclear umbrella held for them by allies, for example in NATO or the Warsaw Pact. These States were able to adhere, as non-nuclear-weapon States, to the NPT. When the NPT was concluded some 25 years ago, such adherence was felt to be particularly important as regards the two World War II enemy powers.

Another disincentive to proliferation is related to the rules of nuclear trade. Again, the case of Iraq has proved instructive, and catalytic. Iraq's success in building a secret foreign procurement network that skirted nuclear trade restrictions prompted States to take a closer look at rules governing the export of sensitive nuclear technology, material, and equipment. Existing restrictions set by supplier countries impeded Iraq's efforts, but did not thwart them.

In light of the revelations, the UN Security Council, in a recent summit statement, has explicitly endorsed the importance of export controls, and major nuclear suppliers have adopted a number of initiatives.

One area that suppliers have examined concerns "dual-use" nuclear-related technologies, which can be items ranging from chemicals to industrial machine tools having both civilian and military applications. At a meeting in Warsaw in early April 1992, the 27 countries adhering to the existing Nuclear Suppliers Guidelines adopted a comprehensive arrangement that they believe will fill a significant gap in controlling the export of these items. They further reached agreement on a common policy of requiring the application of comprehensive IAEA safeguards to all current and future nuclear activities as a necessary condition for all significant new nuclear exports to non-nuclear-weapon States.

The question of export restrictions as such has not been pursued in the IAEA. But it has examined the other side of the coin, namely assurances of supply for peaceful purposes and their linkage to acceptance of effective safeguards. Given the now more apparent relevance of such linkage, it is conceivable that multilateral discussions could bear some fruit in reaching a genuine understanding on this difficult question.

The NPT offers incentives for adherence by promising easier transfer of peaceful nuclear technology to States willing to renounce nuclear weapons. For most developing countries, which have decided they have neither the need for, nor the means of, developing such weapons, the actual "cost" of adherence has been negligible. At the same time, it must be admitted that the "carrots" — in the form of nuclear technology transfer — have been moderately sized. For more technologically advanced countries, on the other hand, access to nuclear technology and fuel-cycle services such as enrichment has been of significant benefit.

Regional approaches and initiatives

The desire to broaden, and in some cases customize, the non-proliferation regime is reflected in the interest countries are showing in regional approaches.

In Southeast Asia and Latin America, the Rarotonga and Tlatelolco Treaties establish nuclear-weapon-free zones incorporating requirements for parties to accept comprehensive IAEA safeguards. In southern Africa, active discussions on such a zone now have started, buoyed by the recent adherence to the NPT of Mozambique, South Africa, Tanzania, Zambia, and Zimbabwe.

A good example of mutual openness and confidence-building has been set by Argentina and Brazil. Their acceptance in late 1991 of comprehensive IAEA safeguards to supplement their own bilateral joint system of nuclear controls is likely to lead soon to their full adherence to the 25-year-old Tlatelolco Treaty. Additionally, Cuba has declared it is actively considering signing the Treaty. This would be another major step towards bringing it into effect.

A few countries, however, still refrain from entering into legally binding non-proliferation commitments, basically for reasons relating to their security considerations. In some of these cases, special tailor-made solutions may be needed. Peace talks now under way on the Middle East offer a forum for the discussion of a security and non-proliferation regime in that region. All the States in the region are on record as supporting a nuclear-weapon-free zone.

In the Middle East, such a zone probably will require verification measures going considerably beyond those now practiced under NPT-type safeguards. Just what kind of safeguards verification would be necessary in the Middle East is one question I am now exploring with governments in the region. Certainly, some form of IAEA safeguards could be part of the verification measures.

During my talks with them in early 1992, political leaders in two of the region's NPT countries, Libya and Syria, expressed assurances of their governments' willingness to co-operate fully with the IAEA in implementing safeguards on nuclear activities in their countries. Libyan officials stated their readiness to invite the IAEA to send inspectors to any site it might wish to visit. Syria, which informed me during the talks of its readiness to sign an NPT-safeguards agreement with the IAEA, did so in February 1992.

In the Far East region, the willingness of the Republic of Korea and the Democratic People's Republic of Korea (DPRK) to negotiate a special arrangement calling for mutual nuclear inspections must be seen as a positive sign. The DPRK's ratification in April 1992 of the comprehensive safeguards agreement it signed with the IAEA is another welcome step.

Verifying nuclear non-proliferation

Measures to verify the commitments of States to nuclear non-proliferation historically have been products of their times, and the influence of recent global developments is no exception.

At the end of the 1960s, the IAEA's verification system was designed to fit the area where it was felt that reassurance was most needed — namely industrially advanced States which were or would be capable of making nuclear weapons. One effect of this, however, is that today the larger part of verification efforts is aimed at Western Europe, Canada, and Japan, where there is a large concentration of fissionable nuclear material. While verification here is certainly desired, the political stability of the countries there gives little ground for concern.

Today, other areas are prompting international interest in thorough verification. Consequently, the IAEA is trying to apply its limited resources accordingly, with the aim of strengthening the overall verification system. Some steps already have been taken, and other measures are being considered by the IAEA Board of Governors.

The Iraq case — the only known instance of a clandestine violation of comprehensive safeguards — naturally and necessarily has led to an extensive and searching debate because of its dimensions. Its most important reminder is that the verification system must be geared to detect *undeclared* nuclear material, and to do so not only in declared installations, but also in *undeclared* facilities. Iraq's multibillion dollar programme, of course, was not declared. In fact, its scope does not appear to have been known even to foreign intelligence organizations.

While it is not certain that inspection systems can be devised to guarantee detection of nuclear programmes developed indigenously and secretly in closed societies such as Iraq's, it is clear that several measures can be taken to considerably reduce the risk that they will escape detection. When the State itself refrains from declaring and identifying its secret activity, the crucial point is to obtain credible information about it and where it is located. Inspectors cannot and will not be allowed to roam the territory of inspected States in a blind search for possible hidden nuclear material and facilities. Information must be obtained through other means.

Measures being taken at the IAEA include additional reporting to the IAEA by States on nuclear-relevant exports and other matters. The Board of Governors already has reaffirmed the IAEA's right to request inspections to identify undeclared nuclear material where there are reasons to believe that such material exists and explanations have not clarified the matter. Should information uncover a nuclear programme in a given State that should have been declared, but was not, the State may well refuse an inspection. Such a case would most likely pass through the IAEA Board of Governors and be transmitted to the United Nations Security Council for appropriate action.

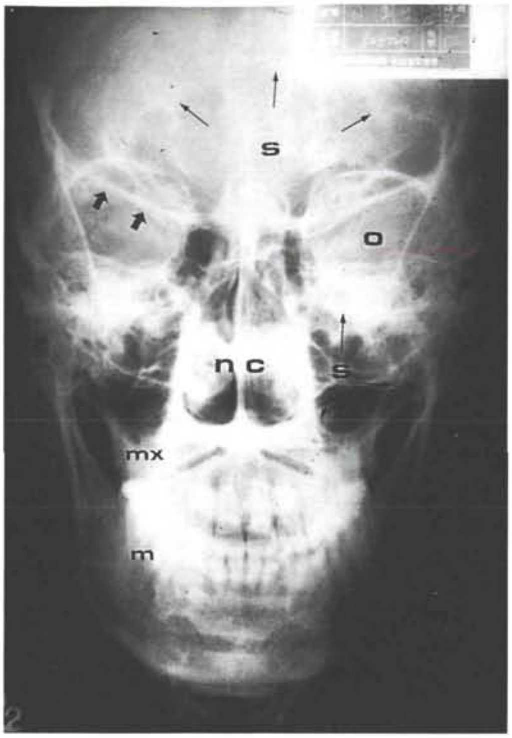
Through their greater capacity for detection, safeguards provided with sharper teeth should have more credibility and a greater deterrent effect. Not only is this needed after the shock of Iraq, it is also needed in a world where we are seeking drastic disarmament and a more universal non-proliferation regime. A world seeking to free itself from nuclear weapons needs to guard itself well against surprises.

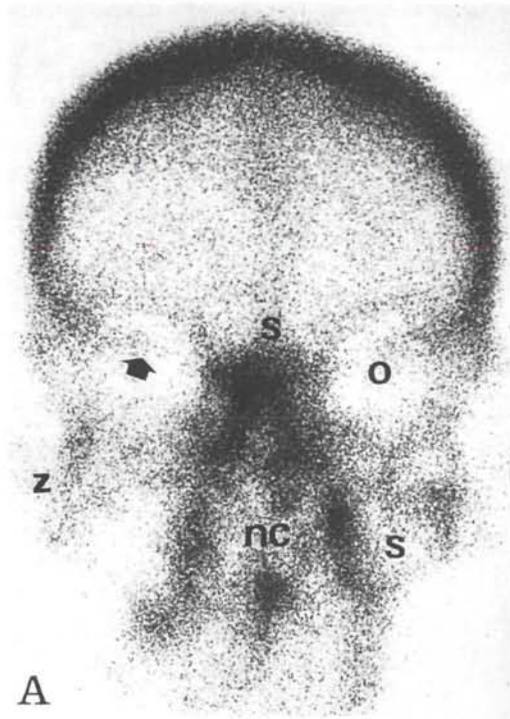
Verification and disarmament

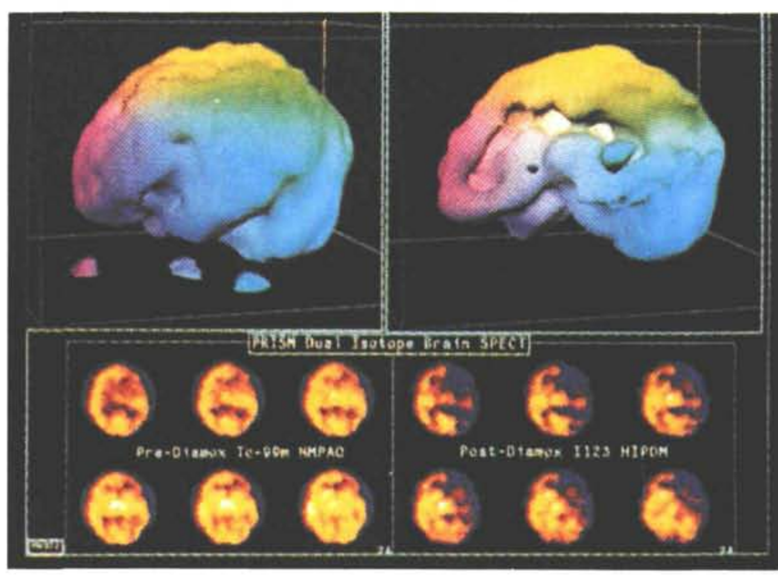
Whereas the IAEA to date has not been entrusted with any role in the disarmament area, it could serve a valuable verification function under certain circumstances.

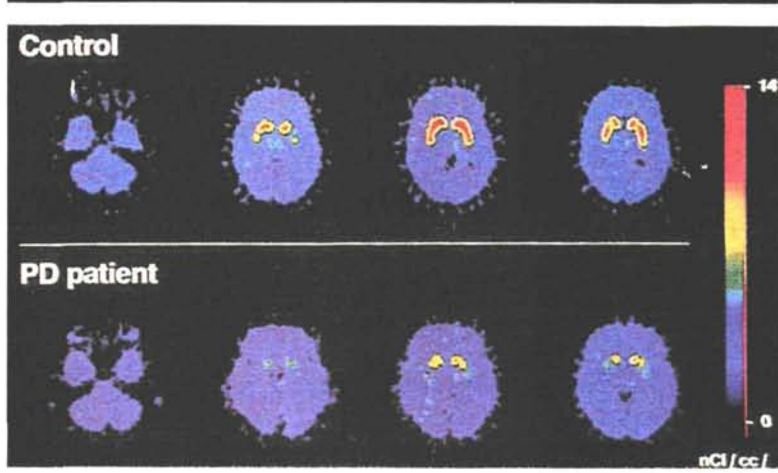
No nuclear weapons have been dismantled yet, and we do not know what plans nuclear-weapon States are contemplating for the verification of the more far-reaching measures to reduce nuclear arsenals as now expected. It may well depend upon the nature of the disarmament measures.

Verification of the actual *dismantling* of nuclear weapons will take place in the military-industrial sector, and can only be entrusted to personnel from nuclear-weapon States. However, if it were to be agreed that at some stage









(Clockwise from top left) VIEWS OF THE HUMAN SKULL: An anterior X-ray view of a normal individual showing in great detail the anatomy of bone structures in the skull. Shown next is the planar, anterior view of the same subject obtained from nuclear medical imaging. It shows physicians that the normal magnitude of phosphonate metabolism is different in each region of the skull, being more active in cranial and facial bones. VIEWS OF THE HUMAN BRAIN: A single photon emission tomography [SPET] of the brain obtained using technetium-99m-HMPAO. The magnitude of concentration of the radiotracer in brain tissue is proportional to regional blood flow. The 12 tomographic slices (lower half) show a severe decrease of blood flow in the left brain regions. In the upper half of the photo, the reconstruction of three-dimensional images from the series of tomographic slices clearly defines the infarcted region. The bottom photo is the result of positron emission tomography [PET] of the brain. The photo's upper half shows images obtained in a normal subject. The lower half shows images of decreased functional neuro-receptors in the basal ganglia in a patient with Parkinson's disease.

Strengthening the international safeguards system

An overview of proposals to further improve the effectiveness and efficiency of the IAEA's safeguards system

by J. Jennekens, R. Parsick and A. von Baeckmann

The safeguards programme of the IAEA continues to be influenced by a wide range of international developments. During the past year, IAEA Member States collectively reaffirmed their commitment to the Agency's objective of seeking to accelerate and to enlarge the contribution of atomic energy to peace, health, and prosperity throughout the world while ensuring that such a contribution is not used in any way to further any military purpose.

This commitment was reinforced through actions by individual Member States. The decision by the Governments of Argentina and Brazil to develop a bilateral safeguards agreement under which the two countries would carry out safeguards inspections jointly and to implement a safeguards arrangement with the IAEA under which all of the peaceful nuclear activities of the two countries would become subject to IAEA safeguards has been widely acclaimed. Similarly the decision by South Africa to ratify the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) and its signature of a comprehensive safeguards agreement with the IAEA in record short time were important steps in the further extension of international safeguards. More recently the adherence of China to the NPT is considered to be a further important international contribution to the non-proliferation regime.

These and other international developments will undoubtedly continue to influence the evolutionary improvements in the IAEA safeguards programme, as they have since its inauguration three decades ago.

The basic principles on which IAEA safeguards have been developed during the past three decades have remained essentially unchanged. However, the recent demands by Member States for improvements in effectiveness and efficiency have emphasized the greater urgency which they now attach to the achievement of further optimization of safeguards criteria and procedures.

It is the Secretariat's view that the impressive increases in safeguards effectiveness and efficiency that have been achieved during the past decade through Member State contributions, technological advances, and lessons learned from experience justify optimism regarding further improvements of the safeguards system. Regardless of the precise direction in which efforts to improve the cost-effectiveness of Agency safeguards proceed, it is clear that the contributions of Member States, and particularly those which have established safeguards support programmes, will be of primary importance.

Superimposed over the continuing interest of Member States in the further optimization of IAEA safeguards is the fact that the technical effectiveness of safeguards has come under close scrutiny. This is a result of the revelations from activities undertaken by the IAEA in Iraq pursuant to United Nations Security Council Resolution 687.

Iraq's non-compliance with the provisions of its safeguards agreement with the IAEA, and the magnitude of its undeclared nuclear-weapon development programme, has forcefully underlined the fact that the safeguards assurances presently provided by the IAEA through nuclear material accountancy verification activities at declared facilities alone are insufficient. They must be complemented and strengthened by activities providing equivalent assurances that undeclared nuclear material and nuclear facilities do not exist in States which have entered into comprehensive safeguards agreements with the IAEA. How these additional assurances can be developed is under careful consideration by the IAEA and its Member States.

Mr Jennekens is Deputy Director General of the IAEA Department of Safeguards, and Mr Parsick is Director of the Department's Division of Concepts and Planning. Mr von Baeckmann is an advisor to the Deputy Director General for Safeguards.

In accordance with its statutory mandate, the IAEA Board of Governors has consistently assigned high priority to the evolutionary development of the IAEA's safeguards system. This is evident from the Board's continuing efforts to monitor and to evaluate the extent to which the Secretariat has achieved the IAEA's safeguards objectives. The Board's extensive consideration of annual reports on safeguards is but one example of the careful scrutiny applied to safeguards activities.

During the past year, the Board devoted appreciable time to the consideration of various proposals put forth by the Secretariat. These proposals and the status of the Board's current consideration of them are outlined in this article.

During its 24-26 February 1992 meetings, the Board deliberated upon proposals regarding:

- the use of special inspections;
- the early submission of information about plans to construct new nuclear facilities;
- the reporting and verification of the production, export and import of nuclear material; and similarly,
- the reporting and verification of the export and import of equipment and materials specially intended for use in nuclear activities.

Special inspections

With respect to the matter of special inspections, the Board reaffirmed the IAEA's right to undertake special inspections in States with comprehensive safeguards agreements, when necessary and appropriate, and to ensure that all nuclear materials in all peaceful nuclear activities are under safeguards. The legal basis for the IAEA's right to conduct special inspections is set out in safeguards agreements concluded pursuant to documents INFCIRC/66 and 153.

Comprehensive safeguards agreements such as those concluded pursuant to INFCIRC/153 include an obligation for the State to accept safeguards on all source and special fissionable materials in all peaceful nuclear activities within its territory, under its jurisdiction or carried out under its control anywhere. Under those agreements, the IAEA has the right and the obligation to ensure effective application of safeguards in conformity with the commitments undertaken by the State in question. The agreements make no distinction between declared and undeclared material. One of the IAEA's obligations is thus to ensure that all materials subject to safeguards are in fact safeguarded.

It is not expected that special inspections will occur very frequently but the fact that they are performed will provide important additional safeguards assurances. These additional assurances may be the result of special inspections undertaken on the IAEA's initiative. States might also wish to take advantage of the special inspection procedure and invite the Agency to conduct such an inspection.

Provision of additional information

The Board further reaffirmed the IAEA's rights to obtain and to have access to additional information and locations in accordance with the IAEA Statute and all comprehensive safeguards agreements.

This action by the Board was taken in recognition of the fact that one important element of any system established to detect the existence of undeclared nuclear activities is information. If a State conceals some of its nuclear activities, the IAEA must have access to information indicating this concealment and thereby establish a basis for pursuing its verification activities. More extensive use and evaluation of available information may make apparent inconsistencies between such information and the State's declared nuclear activities.

There appears to exist a wide consensus that such a process would also contribute to the IAEA's capability to detect the existence of undeclared nuclear activities much earlier than through the present system based on nuclear material accountancy.

In implementing this additional capability, the Secretariat has the very responsible task of carefully evaluating all available information and judging the follow-up actions to be taken. Anomalies and inconsistencies might prompt a number of actions, including the authorization of the conduct of additional safeguards measures such as special inspections. One essential action would involve early consultation with the State concerned and this alone might bring about any necessary explanation or corrective measure. One additional advantage of the improved capability of the IAEA to detect undeclared nuclear activities would be that through its existence any possible intent to enter into a nuclear-weapon development programme might be deterred at an earlier stage.

During its February 1992 meetings, the Board called on parties to comprehensive safeguards agreements to provide preliminary information on programmes for new nuclear facilities and activities, as well as modifications to existing facilities, as soon as the decision to construct, to authorize construction, or to modify a facility has been taken. This information would be updated during project phases of definition, played by some developing countries in the progress of nuclear medicine, which is the most complex of the medical applications of nuclear energy. The first National Institute of Nuclear Medicine was founded in 1948 by the University of Sao Paulo, Brazil; complete validation of the radiotracer principle as a practical tool for medical research was made during the 1950s in the Andean countries (Argentina, Bolivia, Chile, Ecuador, Peru) and in Mexico through pioneering studies on endemic goitre; the first national societies of nuclear medicine to be founded after the one in the United States were in Latin American countries in the early 1960s; the first regional federation of societies of the specialty was in Latin America, founded in 1965 and was catalytic to the foundation of the World Federation, in Mexico City, in 1970. Many of the procedures in use in nuclear medicine were originally developed in these countries during the 1960s and early 1970s.

But this optimistic start was broken by the coincidental appearance of the international financial crisis in the late 1970s and the unprecedented technological advances achieved in industrial countries during the 1980s. These developments closed all doors for the progress of nuclear medicine in developing countries. These countries now urgently need to catch up with progress and to narrow the technological gap. But commercial firms only produce state-of-the-art equipment — very expensive and sophisticated but unsuitable for the conditions in many developing countries. These countries need to be very careful in *adapting* new technologies to their own needs and conditions instead of *adopting* expensive, unsuitable technologies.

Nuclear techniques for human health do not depend upon sophisticated nuclear infrastructure within the country. What is fundamental is a reasonable *medical* infrastructure. Nuclear medicine is relevant but only as a support to other basic diagnostic modalities such as a clinical laboratory, routine radiology, and ultrasound. Similarly, radiotherapy could not be effective in curing cancer if it is not supported by a system for the early diagnosis of cancer or if there are no oncologists and chemotherapists available. In these cases, it could be used mostly to relieve pain and some symptoms, but the patient will eventually die of cancer.

Health professionals in Peru are among those receiving IAEA-supported assistance in applying nuclear medical applications.

Evolving to meet the challenges

Over the past decade, the IAEA's programmes in support of nuclear applications for human health have evolved to address new realities. The move is reflected in the organization structure, as well as in more sharply focused projects. In August 1993, the Division of Life Sciences disappeared from the organizational chart of the IAEA. In its place emerged a new name, the Division of Human Health, whose staff are grouped into four sections — nuclear medicine; applied radiation biology and radiotherapy; dosimetry; and nutritional and health-related environmental studies.

Why the change of title? The old title became inappropriate and misleading because its sub-programmes no longer related to animal and vegetal biology, areas covered under the former Division of Life Sciences. These sub-programmes have fallen fully within the scope of the Joint IAEA/FAO Division. Furthermore, the new title would have the added advantage of helping potential counterparts — mostly from medical institutes — to identify the Division's objectives with their own. This evolutionary change better enables the IAEA to keep pace with progress and to mold the IAEA's medium-term strategies concerning nuclear applications for human health. These strategies include mechanisms for reaching most users of nuclear medical instruments in developing countries.

Will the Division be in competition with WHO? Certainly not. WHO's priorities are in sanitation and prevention of disease. This means more easily said than accomplished. The expectation is that by carefully monitoring and analyzing all information, the risk that clandestine nuclear activities would remain undetected would be considerably reduced. A high degree of transparency in peaceful nuclear energy programmes could be achieved which would provide additional confidence of the non-existence of non-peaceful nuclear activities in such States.

The cost-effectiveness of the early warning system needs to be evaluated. Certainly, the system will not be more reliable or credible than the available sources of information. The potential costs are difficult to predict, changes in national regulation and legislation might become necessary, and the introduction of additional international legal instruments (e.g., protocols) may be necessary. However, the proposed improvements would certainly enhance the effectiveness and credibility of safeguards, which justifies the additional effort.

Reporting and verification of production, export, and import of nuclear material

Safeguards agreements provide only for reporting of the export and import of certain nuclear material. Expansion of the existing requirements for nuclear material reporting to all nuclear material in all peaceful activities would provide assurance that such nuclear material as is not currently subject to reporting is used in accordance with a State's basic undertakings under a safeguards agreement.

Thus, the Secretariat proposed that, regardless of whether or not they fall within current reporting requirements, all imports and exports of nuclear material be reported, with the exception of nuclear material in military activities and some minor quantities in non-nuclear use.

Furthermore, the Secretariat also proposed that the initial inventory of a State with a safeguards agreement should include all nuclear material which is in peaceful nuclear and non-nuclear use, starting with ore concentrate and including material which has not reached a composition and purity suitable for fuel fabrication or isotopic enrichment. Once included in the inventory, the material in non-nuclear use thereafter could be exempted from safeguards, or the safeguards on it could be terminated, in accordance with the provisions of the safeguards agreement.

In its preliminary consideration of these proposals, the IAEA Board of Governors noted that although their acceptance would provide the IAEA with greater assurance regarding the quantities, use, and location of all nuclear material in a State, a number of legal, technical, and economic factors required further study in order to determine the practicability and the value of the additional reporting. As a consequence, the Board decided to continue its consideration of the proposals during its June 1992 meetings.

Reporting and verification of the export and import of certain equipment and non-nuclear material

Reporting by all States on the export and import of certain equipment and non-nuclear material would provide a greater measure of openness about nuclear activities. Hence, it would contribute to confidence in the peaceful use of such equipment and material, as well as associated nuclear material.

The Secreatariat proposed to the IAEA Board that the IAEA establish a list of equipment and non-nuclear material especially designed or prepared for the processing, use, or production of special fissionable material that would be used by all States in reporting the export and import of such equipment and non-nuclear material. The IAEA would consolidate and study these reports with a view to checking that the equipment and material are actually located and used as declared. The record of exports and imports would be treated as "safeguards confidential" information to protect any commercially or industrially sensitive information which it might contain.

The Board of Governors gave only preliminary consideration to the proposals regarding export and import of certain equipment and non-nuclear material. It identified a number of factors which would prevent States from undertaking the full range of reporting requirements included in the Secretariat's proposals and similarly noted that the related verification measures might not be feasible or cost effective. As a consequence, the Board decided that it would continue its consideration of this subject during its June 1992 meetings.

Accelerated development of safeguards

The year 1991 proved to be an exceptional one for the IAEA's safeguards programme. This was largely a result of the actions by the United Nations Security Council requesting the IAEA to undertake a number of responsibilities in Iraq pursuant to the provisions of Security Council Resolutions 687, 707, and 715.

However, months before these additional responsibilities were undertaken, the Board of Governors had requested the Secretariat to pursue a fundamental review of safeguards principles, criteria, and procedures in order to ensure that the IAEA would be able to cope with the increasing demands expected to be placed upon it during the 1990s. A number of safeguards matters were raised during the 1990 NPT Review Conference in Geneva and these matters prompted a great deal of thought by the Secretariat and Member States. A greater awareness of the problem posed by possible clandestine nuclear activities quickly led to proposals regarding additional measures which might be introduced.

The IAEA safeguards system has evolved very significantly since the publication in 1961 of its first Safeguards Document. However, events of 1991 made it clear that the evolutionary development of safeguards approaches needs acceleration. Additional safeguards measures necessary to provide assurance that undeclared nuclear material and nuclear facilities do not exist in States which have entered into comprehensive safeguards agreements must be introduced at an early date. Substantive progress has been made in considering various additional safeguards measures. This progress is the result of a co-ordinated effort involving Member States, international consultants, the Standing Advisory Group on Safeguards Implementation (SAGSI), and the Secretariat.

Needless to say, such a wide-ranging review, extending to the whole spectrum of non-proliferation issues, may sometimes lead to the expression of different views as to the desired extent and rigour of the measures to be applied. However, the desire to reach an effective and workable consensus is undoubtedly present in all discussions.

The reaffirmation by the Board of Governors of the IAEA's right to undertake special inspections in Member States with comprehensive safeguards agreements and to ensure that all nuclear materials in peaceful nuclear activities in the States are safeguarded was an important step towards the desired strengthening of IAEA safeguards. Similarly, the Board's decision to call on parties to comprehensive safeguards agreements to provide preliminary information as early as possible on plans for the construction of new nuclear facilities are an essential improvement of the basis upon which the Secretariat initiates the many and varied activities forming the IAEA's safeguards system. Perhaps more importantly, it is now widely recognized that the early submission of information to the IAEA on nuclear activities in Member States, and to the extent possible its public disclosure by the State, will provide added assurance to all Member States of the peaceful intent of such programmes.

Although the Board of Governors was only able to give preliminary consideration to Secretariat proposals regarding the reporting of the export and import of nuclear material and of certain equipment and non-nuclear materials especially designed for use in nuclear activities, a momentum has been established which will enable the Secretariat to continue to study these proposals and to initiate additional studies on other possible safeguards measures which will contribute to the desired strengthening of IAEA safeguards.

The Secretariat will certainly continue to improve IAEA safeguards effectiveness and efficiency by improving its internal procedures and criteria and by developing new ideas and concepts. We are confident that the ongoing streamlining of IAEA safeguards and its increased role in the non-proliferation regime will provide additional assurances that there are no undeclared nuclear activities that might be used for a nuclear-weapon development programme.

Recent events have confirmed the effectiveness of the present safeguards system for declared materials and activities. It is worth mentioning that, even in the case of Iraq, the system was effective enough to block the easiest route to weaponization, which would have been to divert the highly enriched uranium that was under safeguards at Tuwaitha.

However, these recent events also have confirmed that this effectiveness of the safeguards system must be extended to all nuclear materials and activities in order to detect, in a timely manner, the development of clandestine programmes. This is the aim of the proposals for special inspections, provision of design information, procurement reports, and other procedures which presently are being considered. Ideally, this should proceed from a new spirit of openness and transparency in the exchanges of information between the IAEA and its Member States.

Safeguards are merely the institutionalized and regulated form of transparency. This institution and its associated regulations must be maintained, developed, and continuously rendered more effective and efficient. As a result of more openness and transparency, and additional information and access rights, IAEA safeguards will increase its contribution to world peace and stability and will permit more confidence in the peaceful character of all safeguarded nuclear activities.

Technological developments and safeguards instrumentation: Responding to new challenges

From a variety of directions, advances in technology are influencing safeguards operations and support

by K. Naito
and
D.E. Rundquist

Entering the 1990s, technological tools that were in the research and development stage not so long ago are changing the way inspectors are able to verify nuclear materials at many facilities around the world.

Many new instruments — ranging from advanced video monitoring systems to miniature detectors and analysers — already are in place. In some cases, they have been custom-made for specific safeguards tasks, or for placement in locations, such as underwater storage pools for spent reactor fuel, where inspectors cannot go.

Standing behind the development of many of these new safeguards instruments are a number of factors. They include:

- ***Technological advances in computer-related fields, such as microprocessing and electronics, and specific areas of instrumentation.*** The IAEA's safeguards activities — through an international network of support programmes with more than 10 countries and Euratom — benefit from the expertise of some of the world's top instrumentation laboratories. In some cases, rapid changes in instrument technology have dictated changes, making some equipment obsolete, or making it difficult to ensure availability of spare parts.
- ***Technical developments in the nuclear industry.*** These include more modern fabrication of fuel assemblies for power reactors, and the increasing use of automation and remote handling methods in nuclear fuel cycle facilities, particularly in spent-fuel reprocessing and fuel element fabrication plants. In the process, nuclear material can become less accessible for verification, requiring new safeguards procedures and techniques for verifying inventories.
- ***Efficiency improvements and efforts to reduce the costs of safeguards implementation.*** The IAEA's financial situation has heightened interest in the development of more cost-effective safeguards measures and techniques, particularly with respect to specific types of nuclear facilities.

When considered from a broad perspective, technological developments have substantially improved safeguards instrumentation capabilities. Of course, concomitant with the improvements, new requirements relating to instrument support and training also have risen.

Today, no major gap exists between a specific requirement for an instrument application and the availability of an instrument that, in principle, can accommodate that requirement. In some circumstances, the quality of the instrument is state-of-the-art. Even so, in most situations, the instrument's sophistication or capability has to be compromised to improve its reliability when utilized under industrial conditions.

On the other end of the spectrum, situations remain where the readily available instrument is just barely adequate.

In most cases, safeguards requirements demand stringent specifications that cannot be met by off-the-shelf equipment. Consequently, most Agency safeguards equipment must be custom-designed. This generally insures that technical objectives are met. But it does not insure that the strategy for implementing the new equipment is optimum or that the support infrastructure can readily accommodate it.

In this respect, technological developments have raised an important problem that the IAEA now is addressing: how best to integrate high-technology equipment within the Agency's

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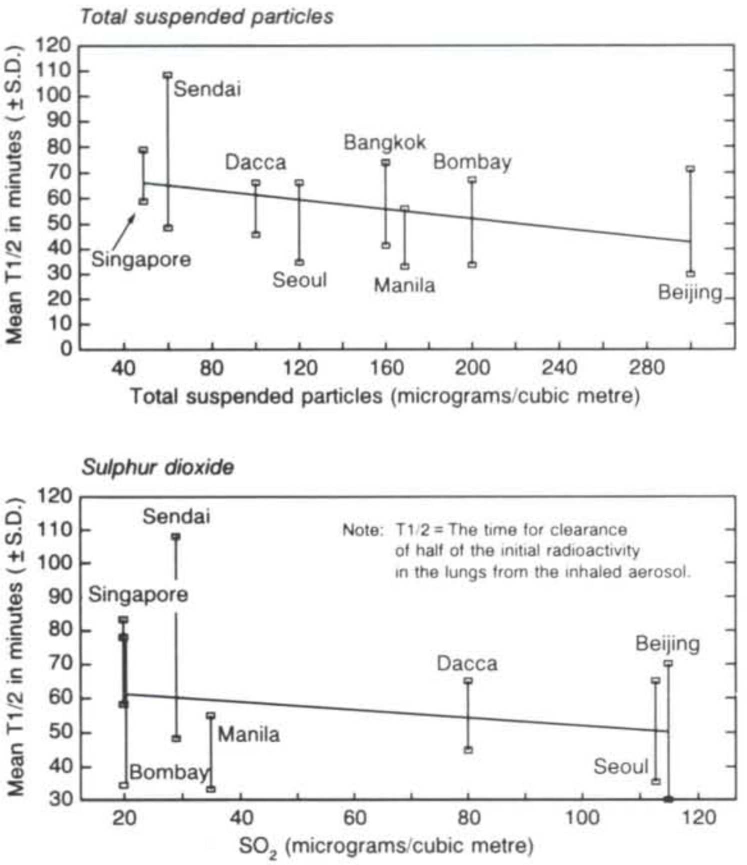
Results of IAEA-supported research in Asia and the Pacific: Effects of air pollution on lung permeability



ing the concentrations of TSP — the pollutant that has the most impact on lungs — and to the concentration of SO_2. Based on the results, it is reasonable to assume that the altered permeability was due to possible lung injury as a result of long exposure to ambient air pollution, as these subjects were otherwise healthy non-smoking adults. The tests, therefore, provide a window to view the effects of urban air pollution on lungs. Before firm conclusions can be drawn, however, the study's findings will require follow-up work.

In a number of respects, this IAEA-supported research has broken new ground in the field, by providing a quantitative method for testing the effects of environmental pollution on the physiology of the human lung. Since lungs are the primary organs exposed directly to the environment, it is now feasible to more closely associate lung damage with the incidence of respiratory disorders. This opens the way for greater understanding of the mechanisms through which air pollution affects human health.

A participant in an IAEA-supported air pollution study inhales a radiolabelled aerosol to measure the permeability of his lungs.

Through its programmes in areas of research and technical co-operation, the IAEA is supporting a range of studies on aspects of air pollution, the environment, and health. In 1995, for example, the expansion is envisaged of an ongoing joint project involving the IAEA, United Nations Development Programme, and countries of the IAEA's regional co-operative arrangement (RCA) in Asia and the Pacific. Its overall focus will be on the use of isotopes and radiation to strengthen technology and support environmentally sustainable development. Currently 15 countries in the Asia and Pacific region are participating in the project, which also includes studies related to sediments and soils, water bodies, and biomonitors.

Toxic heavy metals: Studying human exposures through food and water

For centuries, people have been mining and refining toxic heavy metals, such as lead and mercury. Unfortunately, over time the environment, including foodstuffs and drinking water, has become contaminated with these and other elements. *(See table.)* Some researchers even believe that lead toxicity was one of the factors contributing to the fall of the Roman empire. More certain is the fact that people have been contributing to the long-range contamination of the planet with lead since pre-Christian times, as has been demonstrated recently by an analysis of Greenland ice cores.

Today, the human component remains the most important one in the global bio-geochemical cycling of toxic heavy metals. Moreover, the annual total toxicity of all metals mobilized by human activities presently *exceeds the combined total toxicity of all the radioactive and organic wastes generated each year.**

It is therefore not surprising that many national and international programmes on the assessment of human exposure to environmental pollutants place high priority on the study of toxic heavy metals. At the United Nations level, many of these programmes fall within the framework of "Agenda 21", a group of activities relating to sustainable development which arose out of the 1992 UN Conference on Environment and Development.

IAEA-supported programmes. Arsenic, cadmium, copper, lead, and mercury, among other toxic elements, are all amenable to study by a variety of nuclear and nuclear-based techniques. The main techniques involved include neutron activation analysis, energy-dispersive X-ray fluorescence analysis, particle-induced X-ray emission, inductively-coupled plasma mass spectrometry, and a variety of isotopic tracer studies. Through various avenues, the IAEA is supporting work in specific areas of research. *(See box, next page.)*

One of the most useful applications of nuclear analytical techniques has to do with the use of "biomonitors". Human hair is an example of such a biomonitor, one with historical as well as environmental applications. (Debates, for example, still continue on whether Napoleon died of arsenic poisoning, and whether this can be established by analysis of some hair samples allegedly taken from his corpse.)

A more "living" application of hair analysis is demonstrated in a current IAEA-supported research programme, in which hair is being used to monitor exposure to mercury in pregnant women and their newborn babies. The World Health Organization (WHO) has proposed that levels of mercury in hair should not exceed 4 to 6 micrograms per gram, otherwise there is a risk of neurological damage to the newborn baby. The IAEA's work has shown that this level is exceeded in population groups in several developing countries. Exposure usually arises from consumption of contaminated fish. Particularly high levels (as in some subjects living in the Amazon basin in Brazil) are probably associated with the use of mercury in the extraction and refining of gold. This project also includes studies of the most important organic component of mercury, methyl mercury.

* As measured by the quantity of water needed to dilute radioactive and organic wastes to drinking water quality. See the article by J.O. Nriagu and J.P. Pacyna, *Nature*, Vol. 3, 33 (May 1988).

Typical heavy metals in the environment, and some limits on human exposure to them

	Limit for air[1]	Limit for drinking water[2]	Provisional tolerable weekly intake[3]	Main sources of exposure
Arsenic	0*	10 micrograms per liter	14 micrograms per kg body weight	Contaminated drinking water
Cadmium	10-20 ng/m^3 (urban air)	3 micrograms per liter	approx. 7 micrograms per kg body weight	Occupation; cigarette smoke
Copper	-	1 mg per liter	0.35-3.5 mg/kg body weight	Contaminated drinking water
Lead	0.5-1 micrograms per m^3	10 micrograms per liter	50 micrograms per kg body weight	Occupation; pica[4]; deposition from leaded petroleum products
Mercury	1 microgram per m^3	1 microgram per liter	5 micrograms per kg body weight as total mercury 3.3 micrograms per kg body weight as methyl mercury	Contaminated fish; occupation

* Arsenic at all levels is considered to be a risk factor for cancer.
[1] Guideline value for upper limit of concentration as time-weighted average over 1 year (WHO)
[2] Guideline value for upper limit of concentration in drinking water (WHO)
[3] Maximum acceptable weekly intake for adults (WHO/FAO). The value quoted should be multiplied by the body weight in kilograms to obtain the total maximum acceptable weekly intake for an individual.
[4] Pica is the habit of eating clay, soil, dirt, and other non-food items. It is an important source of lead intake in infants who live in contaminated environments, particularly houses with old lead-based paints.

Communicable diseases and the environment: Adapting to changes

Socio-economic development should lead to better health and quality of life of people. Until recently, however, development has often come to be regarded as synonymous with environmental degradation, pollution, increase in disease incidence, and a worsening of the quality of life of at least a segment of the population that development was meant to benefit. Of late, fortunately, there has been growing acceptance that improved health and quality of life must be in tandem with sustainable development, or else adverse consequences will be unavoidable.

Agricultural development schemes, for example, may lead to changes in the environment that are conducive to disease transmission. The Aswan Dam and its associated irrigation schemes have increased cotton and grain production. However, they have also escalated the incidence of bilharziasis (or schistosomiasis, a severe debilitating disease which WHO es-

Selected IAEA co-ordinated research programmes using nuclear techniques in health-related environmental studies

Years	No.*	Title
1984-89	14	The significance of hair mineral analysis as a means for assessing internal body burdens of environmental pollutants
1984-90	14	Human daily dietary intakes of nutritionally important trace elements as measured by nuclear and other techniques
1985-90	11	Nuclear techniques for toxic elements in foodstuffs (RCA Region)
1987-92	20	Use of nuclear and nuclear-related techniques in the study of environmental pollution associated with solid wastes
1987-92	10	Nuclear analytical techniques for the analysis of trace elements in agroindustrial products and foodstuffs (ARCAL Region)
1990-95	10	Assessment of environmental exposure to mercury in selected human populations as studied by nuclear and other techniques
1992-97	19	Applied research on air pollution using nuclear-related analytical techniques
1996-00		Assessment of environmental pollutants using radioimmunoassay and other related techniques
1995-00		Workplace monitoring and occupational health studies using nuclear and related analytical techniques
1995-00		Secondary (regional) reference materials for environmental studies **
1995-00		Environmental biomonitoring and specimen banking for developing countries **

* Number of participating countries
** Depending on availability of extra-budgetary resources.

Note: A more detailed overview of the IAEA's work in this field can be found in the Proceedings of the IAEA Symposium held in Karlsruhe, Germany, in 1992, *Applications of Isotopes and Radiation in Conservation of the Environment*. See this *IAEA Bulletin's* "Keep Abreast" section for ordering information.

timates affects 200 million people in more than 70 countries) as the snail vectors of the disease multiply in the irrigation channels. Similarly, in Kenya, the Mwea-Tebere irrigation scheme made the country self-sufficient in rice. But it brought malaria (a disease that WHO estimates affects nearly 300 million people in altogether 103 countries) to the area as migrants from the surrounding areas and mosquitoes from the lower basin of the Tana river both moved to Mwea-Tebere. In Brazil, the opening of the Amazon has led to explosive increase in leishmaniasis and malaria. The sandflies which were a component of the sylvatic cycle for leishmaniasis and the mosquito vector of malaria came into contact with immunologically ill-prepared settlers from Brazilian towns who came to the Amazon to exploit new opportunities only to find themselves becoming new targets of the disease pathogens.

In areas such as the forests of Brazil and Colombia, information is often not available on which of the several mosquito species there are vectors of human malaria. In the early 1980s, a technique was developed to help control the disease — an immunoradiometric assay (IRMA) which uses anti-sporozoite monoclonal antibody labelled with iodine-125 to bind antigens of the sporozoite (the infective stage of the malaria pathogen which is carried by mosquitoes).

The method distinguishes the sporozoites of *Plasmodium falciparum* and *P. vivax* — the two most common forms of human malaria — from those which infect primates and other animals. It thus clearly identifies the mosquito species that carries human malaria. The subsequent study of the ecology and ethology of the vector enables the formulation of cost-effective control. Consequently, a species that breeds and rests in and around houses and feeds on humans may be controlled by spraying houses with pesticides such as DDT. If the vector were a forest dwelling mosquito, however, such a strategy would be ineffective.

When used with the malaria antigen NANP, the IRMA technique will measure anti-sporozoite antibody levels in humans. This antibody arises in response to inoculation with sporozoites through mosquito bites . Because of its short half-life, the antibody reflects malaria transmission in the previous 3 to 6 months. The test can be used to compare malaria transmission intensities in different areas, and to detect changes resulting from environmental modification or the application of control measures.

Industrialization and the associated migration from rural areas to cities lead to health concerns beyond those directly related to air pollution from motor vehicles and industries. It often means that migrants are concentrated in shanty towns where overcrowding and poor sanitation can cause the escalation of diarrhoeal, mycobacterial, and other diseases.

Easy access to pharmacies in many urban centres further can lead to the abuse of curative drugs and to the emergence of drug-resistant strains of pathogens. As they move into cities, people bring with them the vectors and diseases which until then had been limited to rural regions. Thus, in some countries in Latin America, for example, Chagas disease has entered cities. The main transmission route is no longer the triatomid bug, but blood banks where the poor sell their blood together with blood-borne diseases.

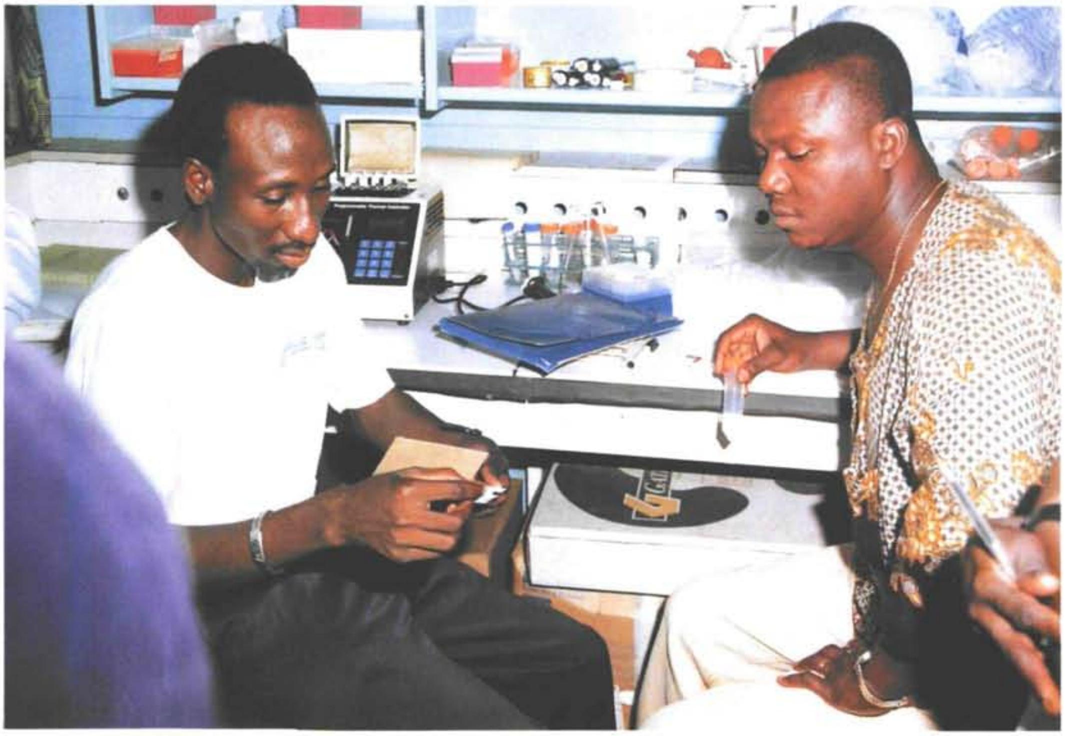
Effective diagnosis can contribute to the control of disease. In laboratories dealing with diagnosis of communicable diseases, the first analysis of clinical material is usually done by microscopy and culture. Both techniques lack sensitivity and specificity. Moreover, culture methods are, in general, slow and laborious and some pathogens may not grow in cultures. The need for rapid diagnosis is partially filled by immunological tests such as radioimmunoassay, in which the indicator reagent is labelled with iodine-125. These immunological tests, though sensitive, sometimes lack specificity. This is particularly the case in developing countries, where tests categorized as "highly specific" in industrialized countries are not as effective against the host of microorganisms prevalent in many developing regions.

Occasionally, technical developments in science enable forward leaps in knowledge and increase the potential for innovation. Biomedical research has experienced such a revolutionary change with the development of DNA technology, which has opened the door to a range of molecular biological opportunities. DNA can be cloned; it can be amplified; and the nucleotide sequence can be determined. Pieces of DNA can be synthesized and these fragments used as molecular probes that bind with high specificity to complementary sequences of DNA. The success of a DNA probe stems from the fact that it can be labelled with radioisotopes of high specific activity. This enables the microbiologist to detect the binding of the probe to the complementary target DNA of a specific organism. DNA probes identify pathogens ranging from viruses to helminths in a variety of clinical specimens.

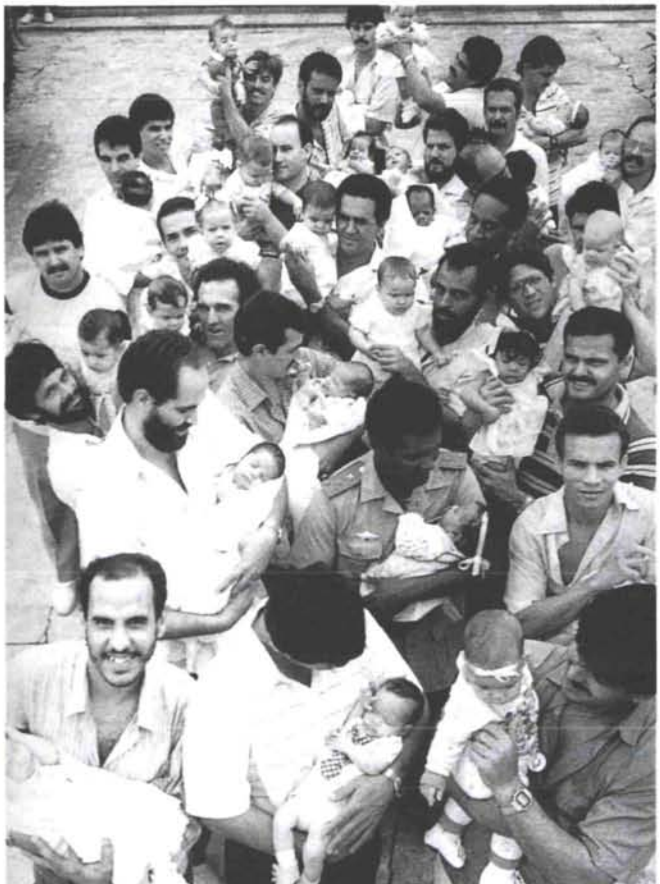
The success of a probe assay partly depends on the number of organisms in the clinical specimen. Some diseases — such as tuberculous meningitis, leprosy, and Chagas disease — are noted for the low numbers of pathogens present in clinical specimens. In such situations, another aspect of DNA technology is harnessed by the microbiologist: the amplification of DNA by the polymerase chain reaction (PCR). PCR is an *in vitro* method for the enzymatic synthesis of specific DNA.

Molecular techniques hold vast potential for solving clinical problems associated with communicable diseases. They are increasingly used in advanced countries where they form the backbone of diagnostic laboratories. Since many of these techniques involve the use of radionuclide tracers, the IAEA is actively involved in the transfer of related technology to developing countries through programmes that support research, training, and the dissemination of information.

In time, these techniques, among others, will play a greater global role in the study, prevention, and control of communicable diseases that find ways to adapt to changing environmental conditions. ❐

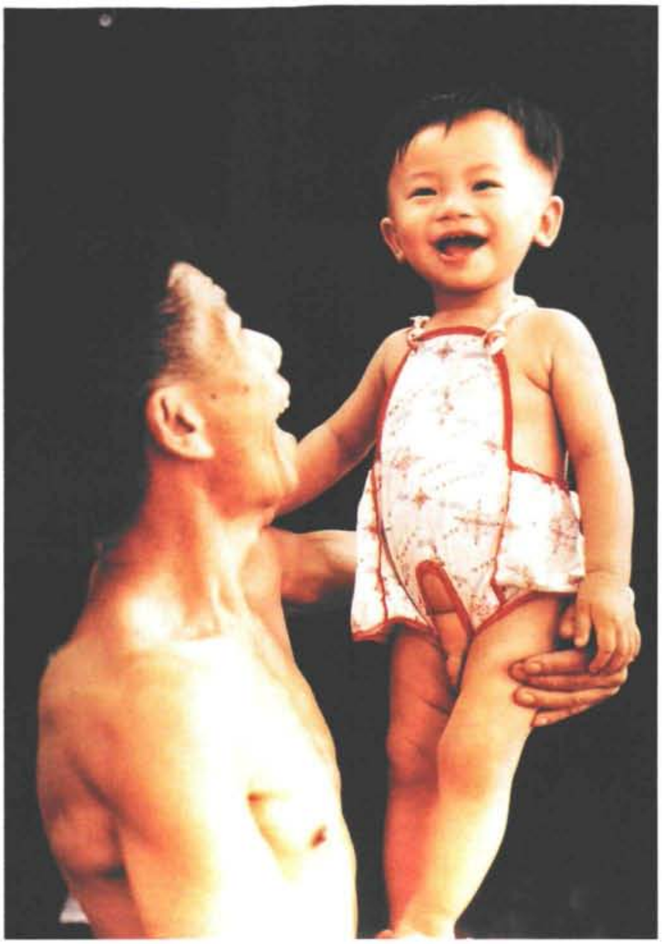


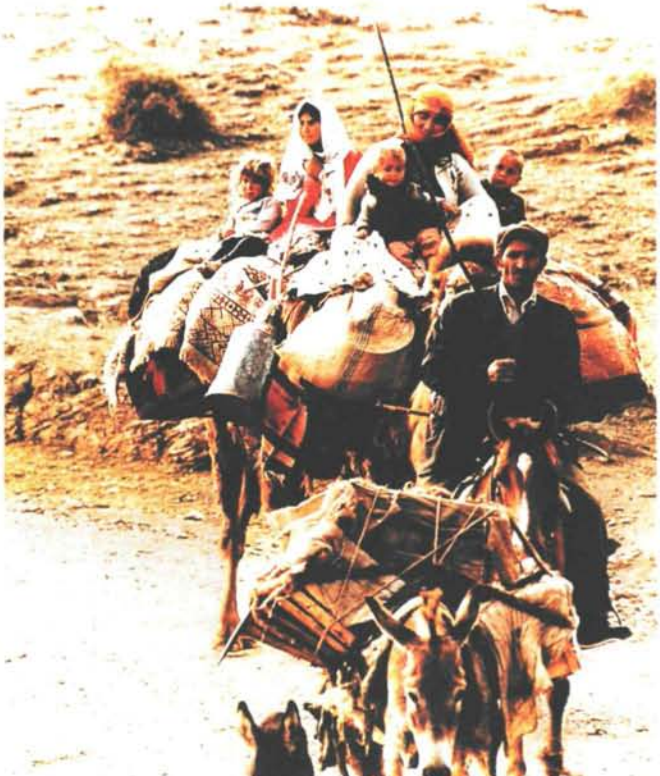
In Bamako, Mali, participants in a project supported by the IAEA and Italy learn the use of molecular techniques in studies of malaria. ***(Credit: Castelino, IAEA)***



Health, Environment, Family

From the joy and pride of nurturing newborns to the special bonds of gathering at family reunions, these illuminating photographs show the richness of the world's people and cultures — yet remind us of the hardships many families face. Among the most acute problems concern health care and proper nutrition, topics that articles in this edition of the *IAEA Bulletin* address from various perspectives. The photographs shown here, and on the cover and inside cover page, are all award winners. They were selected from more than 10 000 entries to the World Photo Contest "The Family" organized by the United Nations Educational, Cultural and Scientific Organization (UNESCO) and the Asia/Pacific Cultural Centre for UNESCO (ACCU) in Tokyo within the framework of the World Decade for Cultural Development and as a special contribution to the United Nations International Year of the Family 1994. *This page:* In "Kazakh Family" by R. Gombojav of Mongolia, the whole family gathers in Bayan Olgui aimak for a commemorative photo, which was awarded a Special Prize in the photo contest. In Habana, Cuba, "Dear Papa" by Humberto G. Mayol captures the special moment for new fathers. *Facing page, clockwise from top, left:* "Pride" by Elaine Abrams of the United States shows the shared emotions of a father and son in China. In Ho Chi Minh City, children brighten the way in "Eyes and Smile" by Tuong Linh of Viet Nam. In Maseru, Lesotho, a young couple and their daughter pose for "First Born at One" by A.C. Ebenebe of Nigeria. In Antalya, Turkey, twins lead the way in an untitled photo by Timurtas Onan of Turkey. In "Families" by Mohammad Reza Baharnaz of Iran, which earned a Special Prize in the photo contest, a family moves to a warmer environment as the cold days of winter approach. *All photos courtesy of ACCU.*





Human health and nutrition: How isotopes are helping to overcome"hidden hunger"

In increasing ways, stable and radioactive isotopes are contributing to research of serious nutritional problems affecting human health

by
Robert M. Parr
and
Carla R. Fjeld

Health authorities in all countries are concerned about the nutrition of their population.

In the industrialized world, major concerns are related to what has been called "over nutrition". With higher affluence and urbanization, diets tend to become higher in energy and fat, especially saturated fat. They also have less fibre and complex carbohydrates, and more alcohol. These and other risk factors are leading to increased incidence of obesity, hypertension, cardiovascular diseases, diabetes mellitus, osteoporosis, anaemia and some cancers, with immense social and health care costs.

For developing countries, the problems chiefly lie on the other end of the spectrum. "Under nutrition", or malnutrition, is the principal enemy, mainly of poor people who experience the most widespread and severe effects of malnutrition.

Some statistics are truly alarming. More than 780 million people — 20% of the developing world — are chronically undernourished. About 190 million children under five years of age, including more than 150 million in Asia and 27 million in Africa, suffer from protein-energy malnutrition. Every day, 40 000 children under the age of five die, and malnutrition is a major contributing factor. Some 2000 million people in more than 100 developing countries suffer from micronutrient deficiencies that can lead to blindness, mental retardation, and even death.

Many problems are not new — indeed, most of them have been recognized for years. Their severity varies widely from one country to another, and also over time. Some countries have observed significant decreases in diet-related mortality in recent years; many others, however, show substantial increases. *(See graphs, page 20.)*

Nutritional problems underlying these trends (particularly in developing countries) are generally not related to an absolute deficiency of food — to overt hunger. In most cases, they are caused by insufficient *quality* of food, or lack of variety, leading to deficiencies of vitamins and essential minerals. Because many effects are not immediately obvious to the naked eye, the World Health Organization (WHO) has coined the term "hidden hunger" to describe these problems.

In a number of ways, the work of the IAEA is contributing to efforts directed at overcoming hidden hunger and other nutrition problems. The rationale for the IAEA's involvement is twofold. First, adequate nutrition is an essential component of any strategy for improving *health*, and the IAEA's Statute specifically identifies "enlarging the contribution of atomic energy to peace, *health* and prosperity" as the major objective of programmes. Second, isotope techniques have a wide variety of applications — some of them unique — for targeted research in human nutrition, for assessing nutritional status, and for monitoring the effectiveness of nutritional intervention programmes. *(See table, page 21.)*

This article provides a brief overview of these techniques and their main applications in areas of human nutrition. It further illustrates how the IAEA's programmes are directed towards helping to solve specific nutrition problems, particularly those affecting women and children in developing countries.

Micronutrient malnutrition: Vitamin and mineral deficiencies

Overview of the problem. Micronutrients — vitamins and minerals — play a wide role in

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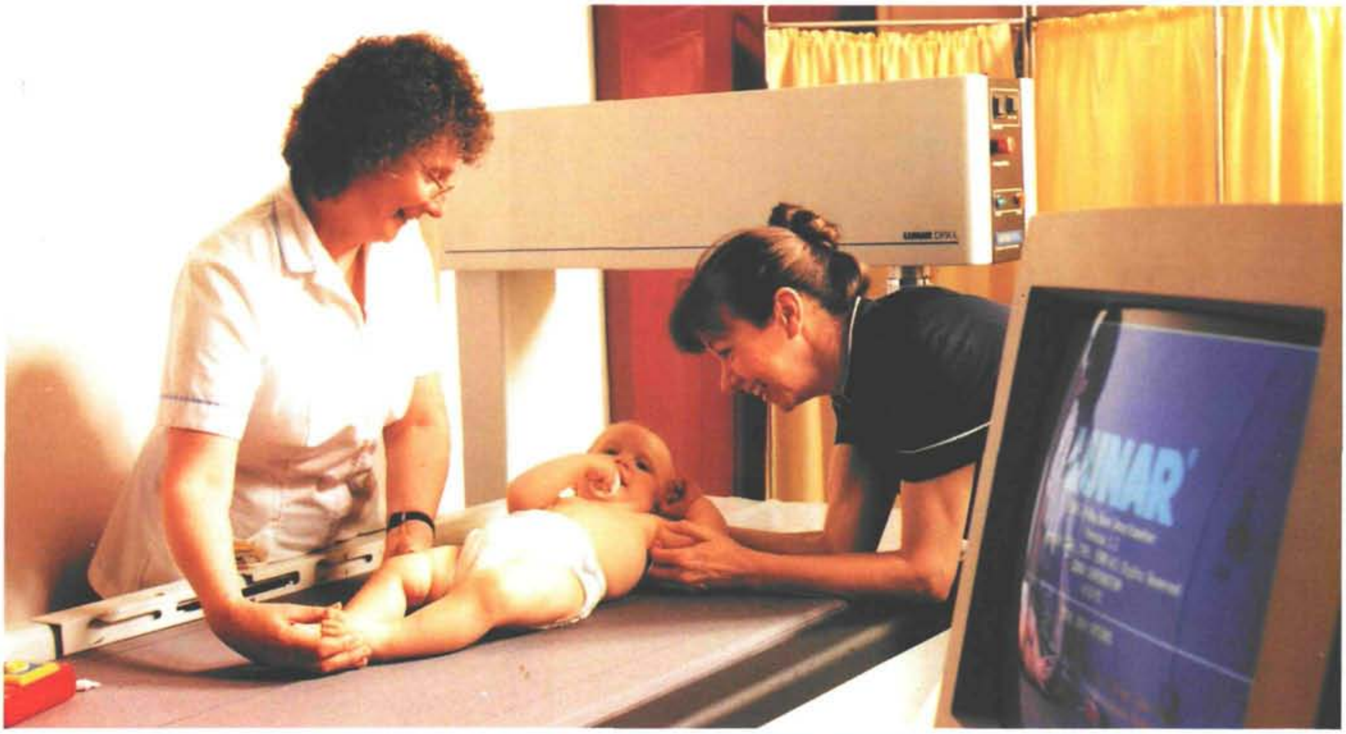


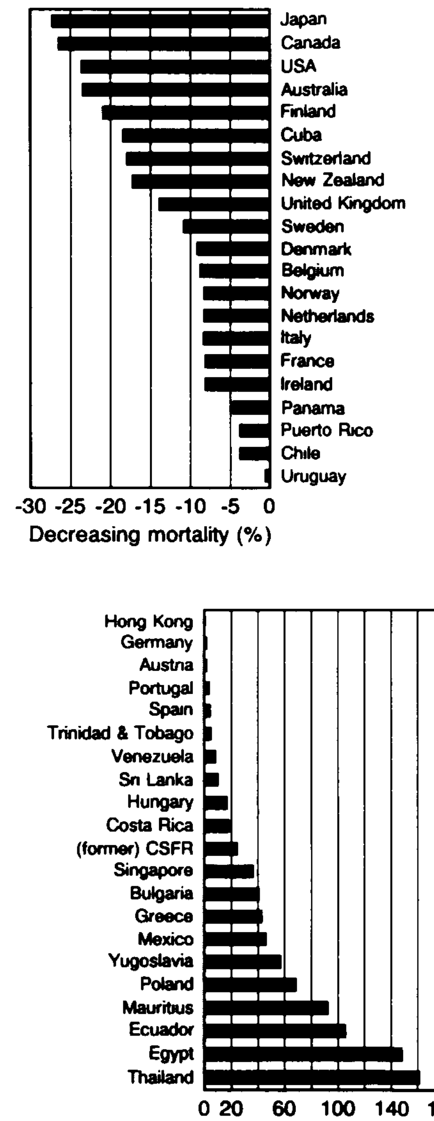
Millions of men, women, and children around the world are undernourished for one reason or another. Through various programmes, the IAEA is supporting work to study nutritional problems and improve the health of people, often placing particular emphasis on maternal and child nutrition. The work includes targeted research projects, technical assistance, and training courses for scientists — such as the one shown at right in Addis Ababa, Ethiopia in November 1993 — on the use of nuclear and related techniques for studying aspects of malnutrition and health. Since 1990, the IAEA has supported nutrition programmes in more than 50 countries. *(Credits: AEA Technology; Schytte/WHO; R. Parr, IAEA)*

World Declaration on Nutrition

One of the most significant recent events in human nutrition was the International Conference on Nutrition (ICN) organized by the World Health Organization (WHO) and Food and Agriculture Organization (FAO) of the United Nations in Rome at the end of 1992. For the first time in history, governments acting in an international forum were asked to think beyond the still-present problems of hunger and survival and to focus squarely on nutrition and health. The outcome was a "World Declaration on Nutrition". It was adopted by government ministers and senior policy makers from more than 150 countries, together with representatives of non-governmental organizations. Selected quotations from this declaration appear below:

- the nutritional well-being of all people is a pre-condition for the development of societies ... it should be a key objective of programmes in human development and at the centre of our socio-economic development plans and strategies
- globally there is enough food for all ... inadequate access is the main problem
- access to nutritionally adequate and safe food is a right of each individual
- there is a high prevalence and increasing numbers of malnourished children under five years of age in parts of Africa, Asia and Latin America and the Caribbean ... particular emphasis should be given to their nutrition problems
- more than 2000 million people, mostly women and children, are deficient in one or more micronutrients
- nutrition goals of the Fourth United Nations Development Decade include .. reducing malnutrition and mortality among children substantially
- nutrition goals of the World Summit for Children (to be reached by the year 2000) include: reduction in severe as well as moderate malnutrition among under-5 children by half of 1990 levels; reduction of iron deficiency anaemia in women by one-third of the 1990 levels; virtual elimination of iodine deficiency disorders; virtual elimination of vitamin-A deficiency and its consequences; and institutionalization of growth promotion and its regular monitoring in all countries by the end of the 1990s
- basic and applied scientific research, as well as food and nutrition surveillance systems, are needed to more clearly identify the factors that contribute to the problems of malnutrition and the ways and means of eliminating these problems, particularly for women, children and aged persons
- the governing bodies of FAO, WHO ... and other concerned international organizations should ... decide on ways and means of giving appropriate priority to their nutrition-related programmes and activities aimed at ensuring, as soon as possible, the vigorous and coordinated implementation of activities recommended in the World Declaration and Plan of Action for Nutrition ... this would include, as appropriate, increased assistance to the member countries.

Change in mortality rates due to diet-related non-communicable diseases



Note: Data applies to subjects 65 years and over, between 1960-64 and 1985-89 in 42 countries.

Source: WHO

health and development. Besides preventing specific disorders, they protect the lives of mothers and children, stimulate cognitive development, help protect against infections and improve people's capacity for work.

Micronutrient deficiencies can cause harm from the moment of conception because they influence the regulation of growth and other physiological processes. Deficiencies can lead to a vicious cycle that takes more than one generation to correct: malnourished mothers give birth to children who carry the effects into adulthood and, if female, into the next generation.

Iron deficiency is the most common nutritional deficiency in the world today. In infancy and childhood, it can impair learning and the ability to resist disease. The lethargy it induces in adults reduces their capacity to work and to

Examples of IAEA support to human nutrition programmes (1990-1994)

	Research & technical assistance*	Training & seminars**
Argentina	1	
Australia	2	
Bangladesh	4	1
Bolivia	1	
Brazil	2	2
Cameroon	1	4
Canada	2	1
Chile	3	2
China	3	2
Czech Republic	1	
Ethiopia		4
Finland	1	
France	1	
Germany	1	
Ghana		2
Guatemala	2	
Hungary	1	
India	6	20
Indonesia	2	1
Iran	1	
Italy	1	
Jamaica	2	
Kenya		4
Madagascar		1
Malaysia	3	2
Mauritius		1
Mexico	1	
Myanmar	1	2
Netherlands	1	
Nepal		1
Nigeria		2
Pakistan	2	1
Papua New Guinea	1	
Peru	2	1
Philippines	1	2
Poland	1	1
Portugal	1	
Romania	1	1
Senegal		2
Sierra Leone		2
Slovenia	2	
Spain	1	
Sri Lanka	1	1
Sudan	1	2
Tanzania		2
Thailand	1	2
Turkey	1	
Uganda		1
United Kingdom	5	2
United States	11	4
USSR (former)	1	
Venezuela	1	1
Zaire		1

* Number of projects (including research agreements)
** Number of participants/trainees

take care of families and homes. More than 2000 million people worldwide are anaemic or iron deficient, most of them in developing countries. The loss of menstrual blood makes women of child-bearing age particularly vulnerable. Anaemia contributes to high maternal mortality rates, low birth weight, and increased infant mortality.

Iodine deficiency affects production of the thyroid hormones that govern the development and function of the brain and nervous system and regulate body heat and energy. A low level of thyroid hormones can reduce both physical and mental capacity. In pregnant women, iodine deficiency can cause miscarriages and still births. It may lead to irreversible brain damage in the foetus or newborn and cause mental retardation in children. It is estimated that more than 1000 million persons live in areas at risk of iodine deficiency. Two hundred million have goitre — an enlargement of the thyroid gland in the neck — and 26 million are mentally retarded as a result of the deficiency.

Vitamin-A deficiency is the most common cause of preventable childhood blindness, reduces the effectiveness of the immune system, and retards growth and development. At least 40 million preschool children are deficient in vitamin-A, and among them 13 million already have some eye damage. Every year, up to half a million preschool children go blind, partially or totally, from vitamin-A deficiency. Approximately two-thirds of them die within a few months of losing their sight. A lack of vitamin-A and other essential nutrients also makes children

Overview of selected isotope techniques in human nutrition studies

Technique	Application
Radioisotope tracer study (with sample counting)	Body composition (tritium labelled water) *in vivo* study of iron uptake and bioavailability (iron-59/iron-55) *in vitro* study of iron dialyzability (iron-59)
Radioimmunoassay	Iron status (based on serum ferritin) Iodine status (based on T_3, T_4, TSH)
Nuclear analytical techniques (e g NAA)	Trace element content of foods, diets, and human tissues
Whole body counting	Body composition (lean body mass — potassium-40) Uptake, bioavailability of essential micronutrients, e.g iron (iron-59) and zinc (zinc-65)
In vivo neutron activation analysis (NAA)	Body composition (total body nitrogen, calcium, etc.)
Stable isotope tracer study	Body composition (deuterium labelled water) Substrate metabolism (carbon-13 and nitrogen-15 labelled amino acids, fats, etc.) Energy expenditure (deuterium and oxygen-18 labelled water) Uptake and bioavailability of essential micronutrients, e.g iron, zinc and vitamin-A using appropriate stable isotopes

more vulnerable to the severe consequences of diseases such as measles, diarrhoea and respiratory infections. Some studies indicate that even moderate levels of vitamin-A deficiency can lead to stunted growth, increased severity of infection, higher death rates in children, and may increase mother-to-fetus transmission of the HIV virus in HIV-positive women.

Isotope techniques in studies of micronutrient malnutrition

Many micronutrients, both vitamins and trace elements, that are of crucial importance in human nutrition can be studied with the use of isotope techniques.

Iron. Of fundamental importance in any study of iron nutrition is the actual uptake of iron by the body (e.g. from a foodstuff or meal) in a metabolically active form. Much is already known about this. For example, the amount absorbed depends very much on the source of the iron (whether from meat or from vegetables) and on the presence of other substances such as vitamin-C (from fruit and some vegetables), phytate (from some cereal products) and tannin (from tea). However, much still needs to be learned about the interactions between these components, and about ways to optimize iron absorption by appropriate selection of locally available foodstuffs and by the use of food processing methods, such as fermentation and germination.

Isotope techniques provide the only direct way for measuring iron uptake and bioavailability and are correctly regarded as a kind of "gold standard" for iron studies in humans. The most common form of the method is based on incorporation of radioactive iron isotopes (iron-55 and iron-59) into red blood cells following extrinsic labelling of the food or diet to be tested and feeding it to selected test subjects. Blood samples are taken over a period of 2-4 weeks and processed for counting with a liquid scintillation counter. Alternatively, iron-59 can be measured with a whole body counter. More recently, in some countries, the use of stable isotopes (iron-54, -57, and -58) measured by mass spectrometry has come to be regarded as a preferable technique because of the absence of a radiation dose, which therefore permits studies to be made on children and pregnant women.

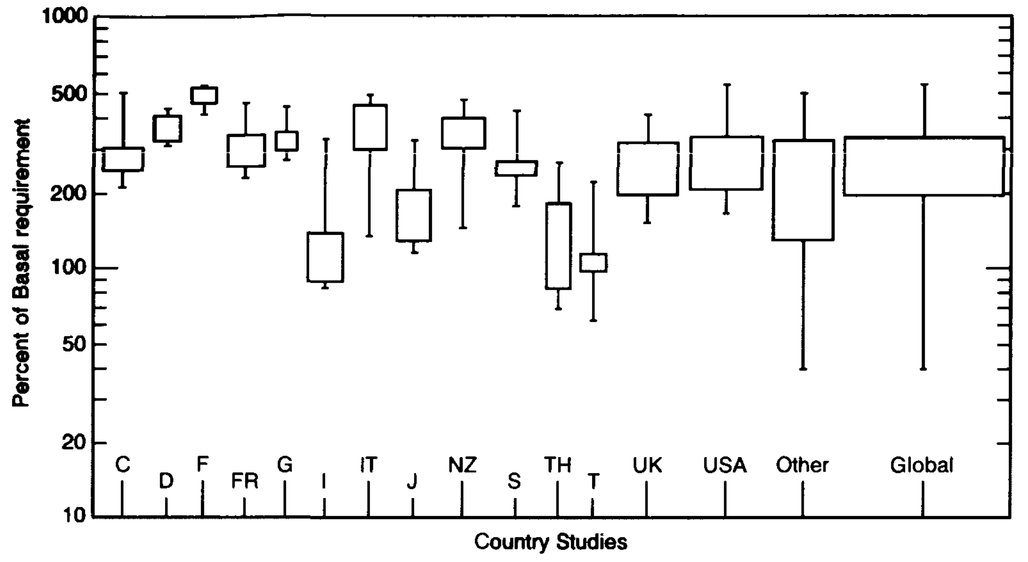
A useful alternative procedure — though less accurate — is one that can be done without the need to resort to using test subjects. The foodstuff to be tested is subjected to an *in vitro* laboratory digestion under conditions that mimic what is happening in the stomach. The release of iron in low molecular weight species is estimated with the help of an iron-59 tracer following dialysis through a synthetic membrane. This is a very useful rapid screening tool.

Isotope methods are also useful for assessing the iron status of individuals and populations based on measurements of serum ferritin. Low serum ferritin reflects depleted body iron stores and is the most specific finding for iron deficiency. Immunoassay — either radioimmunoassay (RIA) or an enzyme-based assay (ELISA) — is the only technique currently available for measuring ferritin.

Iodine. Areas of endemic iodine deficiency are usually identified from measurements of urinary iodine excretion (using non-nuclear techniques). However, useful additional information on the nutritional iodine status of a person or population can sometimes be obtained by looking at the levels of thyroid-related hormones in blood serum. Iodine deficiency of moderate to severe degree results in changes in the pattern of secretion, and therefore serum concentrations, of thyroid hormones. Immunoassay is the technique of choice for such determinations. It relies on the use of antibodies as specific binding agents to detect a diversity of analytes (in this case, thyroid-related hormones such as T_3, T_4 and TSH). A high degree of specificity, sensitivity and robustness is provided. RIA and ELISA are the two applicable forms of immunoassay. For centres that already have access to RIA, this technique is often preferred because it is more robust; also, as shown in several IAEA programmes, it can be made very cost-effective by the use of bulk reagents, some of which may be locally produced.

Vitamin-A. Isotope methods for studying vitamin-A are not yet as well developed as for the other micronutrients just mentioned. However, there is no doubt that they will have uniquely valuable applications in assessing vitamin-A status, e.g. from measurements of plasma clearance of a test dose of isotopically labelled retinol. For human studies, deuterium is usually chosen as the isotopic label.

Large-scale programmes have already been implemented by UNICEF, WHO, and other agencies to prevent vitamin-A deficiency disorders. They include supplementation with vitamin-A, dietary modification to increase intake of vitamin-A (which can be expensive) or of its precursor, beta-carotene (which is from plant sources and can be less expensive), fortification of foods with vitamin-A, and breast-feeding programmes. Isotopic methods are under development which are expected to dramatically improve assessments of vitamin-A status in developing countries.



Dietary intakes of zinc: Overview of studies in various countries

The graph shows the distribution of dietary intakes of zinc in various countries expressed relative to the new WHO/FAO/IAEA basal requirements. The results indicate that only very few data on dietary intakes of trace elements are so far available from developing countries. In the few cases where such data are available, they indicate that dietary intakes of zinc in most developing countries are, at best, only marginally sufficient (and in some cases are actually deficient as judged by comparison with the basal requirements). Partly as a result of this kind of investigation, the possibility that zinc malnutrition may be relatively widespread is now coming to the attention of international bodies responsible for nutrition. It may be anticipated that, during the next few years, there will be a rapid growth in the number of studies of zinc nutrition in developing countries. Nuclear techniques are potentially able to play an important role in this work, and the IAEA is planning to start a new programme on this topic in 1996.

The countries presented are: Canada (C), Denmark (D), Finland (F), France (FR), Germany (G), India (I), Italy (IT), Japan (J), New Zealand (NZ), Sweden (S), Thailand (Th), Turkey (T), United Kingdom (UK) and United States (USA). Countries in the category "other" are Australia, Belgium, Brazil, China, Iran, Malawi, Morocco, Myanmar, Netherlands, Nigeria, Philippines, Poland, Spain, Sudan, Switzerland, the former USSR, and the former Yugoslavia. The "global" category refers to the total data set from all studies.

Other trace elements. Isotope techniques — particularly nuclear analytical methods such as neutron activation analysis (NAA) — are particularly useful for the study of trace elements in foods and diets. Of interest are *essential* trace elements such as copper, manganese, selenium, and zinc (in addition to the iron and iodine already mentioned), and *toxic* elements such as arsenic, cadmium, and mercury. In a recent IAEA-supported research programme in 16 countries, NAA was the technique of choice for 14 of the 24 elements of interest, and served as a quality control procedure for a further group of four elements.

IAEA programmes and plans in areas of micronutrient malnutrition. Since 1990, the IAEA has been supporting a co-ordinated research programme (CRP) in 11 countries on "Isotope-Aided Studies of the Bioavailability of Iron and Zinc from Human Diets". Its main focus has been to obtain critical information needed for planning and implementing national nutrition programmes on dietary diversification and modification, food fortification, and micronutrient supplementation, and in assessing the efficacy of intervention efforts.

Continuing work is foreseen, in collaboration with WHO. It is being done to obtain a better understanding of the quantitative relationships between the absorption of food iron from a meal and the amounts of the main food components that are known to affect iron bioavailability. (One simple example of the importance of these interactions is that drinking tea with a meal blocks iron absorption almost completely.)

It is also expected that the IAEA will support several technical co-operation projects in Africa and Latin America during 1995-96. Among other objectives, they will seek to develop iron-rich weaning foods for babies using local food products. A variety of *in vivo* and *in vitro* isotope techniques are needed for this work, using both radioactive and stable isotope tracers.

With respect to iodine *nutrition*, the IAEA has not yet directly supported work on this subject. However, many programmes have provided indirect support, particularly in relation to the use of RIA for the diagnosis of neonatal hypothyroidism (which is generally caused by nutritional iodine deficiency in the mother).

Several new IAEA programmes on vitamin-A malnutrition are planned. They include a CRP in 1995 to develop new methods for assessing vitamin-A status, to apply existing methods when feasible, and to develop new models for interpreting isotope kinetic data. Secondly, a new area of investigation will be supported which includes the production of foods intrinsically labelled with isotopes of carbon and hydrogen to assess the bioconversion of carotenoids under specific dietary and physiologic conditions. Thirdly, the IAEA will support the use of some techniques in a joint nutrition intervention project with WHO beginning late in 1994 or early 1995 in Latin America.

Concerning trace elements, the data generated through IAEA-supported research covering 25 study groups in 16 countries has already been used in the preparation of working documents for the WHO/FAO/IAEA Expert Consultation on Trace Elements in Human Nutrition. (A soon-to-be published report will propose new values for the dietary intakes of trace elements required to sustain good health.) The data also have served as input to a database on dietary intakes of 35 minor and trace elements in 47 different countries. *(See graph, page 23.)*

Special malnutrition problems of mothers and children

For some population groups — namely mothers and children — protein-related nutritional problems are especially serious. Operating in synergism with diarrhoeal, respiratory, and other infections, poor diets in early childhood lead to growth failure, delayed motor and mental development, impaired immunocompetence, and higher risks of complications and death from infectious disease.

While this form of malnutrition partially results from an insufficient amount of food, a major factor is inadequate dietary quality and diversity. Infection also contributes substantially to protein-energy malnutrition. It causes some anorexia, increases metabolic rates, and diverts protein and other important nutrients from maintenance and growth to processes involved in combatting infection.

In developing countries, poor children under 5 years of age suffer from five to ten episodes of infectious disease per year, as well as subclinical infections. The risk of dying from a given disease is doubled for mildly malnourished children and tripled for the moderately malnourished.

For women, deficiencies of protein and energy during child-bearing years increase maternal risk at childbirth, and lead to low birth-weights and to increased perinatal morbidity and mortality. More than 20 million low birth-weight children are born every year, more than 90% of them in developing countries. Most of these are due to maternal malnutrition.

Sustained access to adequate quantities of nutritious foods would certainly help solve the problems of under nutrition. However, this is not a goal which is immediately achievable. Before that becomes a reality, a key to developing interventions to solve these nutrition problems is the ability to make accurate nutritional assessments and to recommend foods which improve nutrition while making efficient use of scarce resources. Isotope techniques are uniquely and highly suitable for these applications.

Isotope techniques have been used extensively in industrialized countries to provide important information which has contributed substantially to improving understanding of protein nutrition for the past two decades and of energy requirements for the past decade. They are applicable for helping to design practical nutritional intervention programmes, and for monitoring the effectiveness of such programmes. The IAEA's nutrition programmes in the area of protein-energy nutrition aim to transfer established isotope and related technologies, with or without adaptations, to developing countries, as well as promote the development of new techniques and protocols. Work of this kind has expanded considerably since 1992 with the help of additional funding provided by the United States. The two groups of greatest interest in these programmes are mothers and children.

Malnutrition in mothers. Research from around the world has documented that nutrition programmes aimed at malnourished mothers and children lead to improvements in health and well-being. Furthermore, as has been demonstrated in Central America, appropriate nutritional supplements in one generation can have impact on subsequent generations. One of the more important questions in regard to maternal nutrition is nutrition during pregnancy, particularly with regard to weight gain during pregnancy. It is often assumed that mothers who gain relatively more weight during pregnancy will deliver healthier babies and reduce the risk of having low birth-weight infants.

Applications of isotope technologies in studies to improve pregnancy outcome. Maternal body composition during pregnancy — and its relation to dietary intake and pregnancy outcome — is assessed by measuring body composition prior to conception and comparing this with body composition during pregnancy and post partum. This information forms part of the basis of evaluations of nutrient requirements for pregnancy — a critical issue in developing countries.

The other area with broad practical implications concerns the energy requirements for pregnancy. Estimates jointly reported by the FAO, WHO, and United Nations University (UNU) are based on an accepted estimate of total energy needs for pregnancy of 335 MJ. However, this small increment in energy requirement observed for the whole of pregnancy is thought to be due to concomitant reductions in physical activity, particularly in women without access to adequate diets. In general, if the energy requirements of pregnancy *per se* are not met, the results may be either low birth-weight infants, reduced work capacity during pregnancy, reduced fat stores which may be needed as an energy source during lactation, and/or reduced physical activity. The IAEA remains involved in studies in developing countries in which body fat stores are measured using isotope techniques.

IAEA-supported maternal nutrition programmes. The IAEA has contributed in two important ways to improving maternal nutrition during pregnancy. The first was its joint support, with the International Dietary Energy Consultancy Group (IDECG), of a report on the scientific basis and practical application of the doubly labelled water (DLW) method for measuring energy expenditure.* Furthermore, the IAEA has supported several multi-centre and individual studies of energy expenditure during pregnancy. The results of some of these studies provide part of the basis of a reevaluation of dietary energy requirements which is being conducted by FAO, WHO, IDECG, and the UNU.

The DLW method, which was developed by Nathan Lifson and modified by investigators worldwide, is a form of direct calorimetry. It is based on the differential elimination of deuterium and oxygen-18 from body water subsequent to a loading dose of these stable isotopes. Once the two isotopes are administered, their fates are different; they are eliminated at different rates — deuterium only as water, and oxygen-18 as water plus carbon dioxide. The difference between the two elimination rates is therefore a measure of carbon dioxide production during the observation period, typically four to 21 days.

**The Doubly Labelled Water Method for Measuring Energy Expenditure: Technical Recommendations for Use in Humans.* This manual covers major theoretical and practical aspects of the method and has been distributed to researchers in 38 countries. Further information is available from the authors.

Measurement of the body's energy expenditure is important for several reasons. Specifically, it provides very useful information for a wide variety of assessments concerning nutritional interventions. For example, dietary supplements to previously undernourished children may increase the energy available not only for growth but also for activity, which could have great relevance in terms of school or athletic performance. In pregnant or lactating mothers, the drive to sustain pregnancy and lactation may reduce energy available for other functions, including physical activity.

In children with respiratory disorders such as allergies or cystic fibrosis, medications are prescribed which facilitate their breathing. However, as a secondary effect, the treatment may increase energy expenditure and therefore have an indirect and negative effect on weight gain.

Understanding the interactions between the various human functions that are energy-demanding is a key to providing adequate dietary intake. Meeting this need requires measurements of energy expenditure.

Malnutrition in children. For children with protein-energy malnutrition, the nutritional requirements exceed those of well-nourished children. This is because the need to replete weight deficits adds to the nutritional requirements for normal maintenance and growth. Because growth is one of the most universally applied indicators of nutritional status in children, deviations from normal patterns of growth can be analyzed to learn about the severity and remediation of under nutrition. Restoration of normal body weight and body composition through appropriate nutrition in undernourished children requires information about whether or not their body composition has been altered secondary to nutritional deficits.

One way to obtain this information is through anthropometry, a method in which measurements of weight, height, arm circumference, and skinfold thickness are used to estimate body composition. This method is only an estimate, however. Equations which relate the anthropometric measurements to body composition are based on specific population values, regarded as appropriate for the individual, which have been validated against more reliable measurements of body composition using isotopic and other methods.

Applications of isotope technologies in studies to improve child nutrition. Again, one widely used direct method is the measurement of total body water by deuterium and oxygen-18 dilution. Growth analysis is not only concerned with height and weight, but also includes evaluations of body composition.

Deuterium and oxygen-18 can be used without exposing the subjects to radiation and without sacrificing precision of measurements. The use of radioactive tracers (such as tritium) is not uniformly considered to be ethical in research involving children or women of child-bearing age, or in applications utilizing repeated measurements in the same person over a short period of time. Deuterium began to replace tritium as gas chromatography, infrared absorptiometry, and isotope ratio mass spectrometry technologies advanced and precision with these methods became acceptable. More recently, oxygen-18 has been used as a tracer to measure total body water because it avoids the exchange of the label with nonaqueous hydrogen in the body and thus the potential to overestimate the volume of body water. The most significant limitation to its wide use is cost, which is approximately 100 times more than deuterium.

IAEA-supported child nutrition programmes. The IAEA has contributed in some important ways to the improvement of dietary formulations for severely malnourished children through applications involving deuterium, oxygen-18, and carbon-13. Measurements of body composition, protein deposition, and energy expenditure were used in defining a dietary treatment for undernourished children which fosters substantial accelerations in weight gain without compromising the quantity of lean tissue. The result of using the dietary intervention was to reduce hospitalization time by 50%.

Particularly in children of developing countries, under nutrition and infection act synergistically to reduce nutrients available for growth, deplete energy reserves, and significantly increase morbidity and mortality. By better understanding the metabolic effects of infection in undernourished populations, we strengthen our ability to provide the appropriate foods for reducing morbidity and mortality. Stable isotope methods afford us this opportunity. Isotopic methods are being utilized in the new programmes to measure synthetic rates of specific nutrient transport proteins, and synthetic rates of proteins manufactured by the body in response to immunogenic stimuli. Both of these kinds of studies are currently being carried out by teams of scientists from developing and industrialized countries.

One team of investigators, for example, is working to find out how infection may alter children's dietary requirements for protein and amino acids. The work involves quantifying the relative impact of specific infections on protein metabolism and protein anabolism using amino acids labelled with carbon-13 and nitrogen-15. Isotopic enrichments are measured either by gas chromatography-mass spectrometry (GCMS), by combustion GCMS, or by isotope ratio mass spectrometry. The team is also assessing the impact of high altitude living on protein metabolism in undernourished children. They have developed and are validating a basic protocol for assessing rates of protein and amino acid metabolism in the field using non-invasive procedures that can be carried out under field conditions. The team intends to use the data in developing a food supplement that will most efficiently meet requirements for protein and specific amino acids, thereby resulting in the efficient utilization of nutrients for growth.

Nutrition and the elderly

Another population group heavily affected by nutritionally related problems is the elderly. A special concern in many countries is the disease known as osteoporosis. This serious bone disease of the elderly (particularly post-menopausal women) severely limits their quality of life and is placing an increasing burden on the health-care systems in many countries. It is characterized by low bone mass, and microarchitectural deterioration of bone tissue, leading to enhanced fragility and a subsequent increase in the frequency of occurrence of hip and vertebral fractures.

Much still remains to be learned about the aetiology of the disease, about differences in incidence and severity between population groups living in different countries, as well as how to prevent the disease and optimize diagnosis and therapy when it occurs. Although it is generally agreed that osteoporosis is a multifactorial disease, there is little doubt that nutrition is one of the most important of the factors that needs to be taken into account. Included in the many components of the diet that may be important are a variety of minor elements (e.g. calcium, magnesium and sodium) and trace elements (e.g. cadmium, copper, manganese and zinc). Nuclear analytical techniques such as NAA are particularly suitable for the determination of these elements in foods, diets and human tissues, including bone.

The IAEA has just started a new co-ordinated research programme on this topic. It will focus on determining the age of peak bone mass in each study group, and quantifying differences in bone density as functions of the age and sex of persons in the study groups. It will also quantify differences between the study groups in different countries. Supplementary studies will be conducted using NAA relative to the trace-element nutrition of persons in the respective study groups. ❐

Radiation issues, human health, and nutrition research

In recent years there has been a considerable increase in the perception of risk associated with low-level radiation. Concomitantly, there is now a much higher level of concern about the use of radioisotopes in scientific research, particularly if they are administered to normal healthy subjects (and, of course, most of all, if these subjects happen to be children or pregnant women).

Many radioisotope techniques are *in vitro* techniques, which means that the isotope is used in the laboratory as part of an analytical procedure. None of the isotope is administered to the subject, and therefore, for the subject, there is absolutely no radiation hazard. (The only possible hazard is to the scientist who is doing the analysis. Usually he or she has to be classified as a radiation worker, and is required to follow appropriate procedures to minimize the radiation dose to him/herself and co-workers. The possible hazards are extremely small or non-existent and work of this kind is universally accepted to be standard practice for medical and other types of radiation workers.)

For some kinds of nutritional study, however, the most cost-effective procedure is to administer a radioisotope tracer to a test subject (a volunteer). The radiation doses delivered in these kinds of studies are very small. For example, in a typical *in vivo* study of iron uptake using the iron-55/iron-59 dual isotope technique, the dose to the organs receiving the highest exposure is about 0.4 mSv. This is well within the range of variations in normal annual background exposure to radiation (e.g. resulting from living in different geochemical environments or at different altitudes). Expressed another way, it is less than the dose delivered by a modern conventional diagnostic chest X-ray, or about the same as the *additional* radiation dose that an airline passenger would be exposed to on crossing the Atlantic ten times. Although such doses are well within the WHO international ethical guidelines for biomedical research involving human subjects, it is now widely considered to be good practice to exclude children and pregnant women from studies with radioisotopes.

Particularly for children and pregnant women, the currently preferred technique is to use a stable isotope tracer rather than a radioactive one (e.g. iron-58 instead of iron-59). Although the methodologies involved are generally more difficult and more expensive, the use of stable isotopes is without any radiation hazard to the subject and can therefore be justified to ethical committees even for studies in very small children. The IAEA's programmes are also promoting the use of such techniques.

Nutrition, immunity and low-level radiation. Another issue of particular concern is the effect of radiation on the immune system. Radiation is only one of several factors that may influence the general level of immune status in a population; others include nutrition and toxic environmental chemicals. Most investigations of immune status conducted up to now have only focussed on one factor at a time, generally ignoring the others. In populations exposed to higher-than-normal levels of radiation, it is generally difficult, or impossible, to judge to what extent changes in immune status are associated with the radiation and to what extent they may be associated with other factors. A Joint IAEA/WHO Advisory Group Meeting was convened at the IAEA's headquarters in Vienna in May 1994 to throw more light on some of these issues. In particular, the Group was charged with reviewing what is known about these topics and about current research priorities, and to advise the IAEA on the purpose and scope of future actions that could be organized within the framework of a co-ordinated research programme (CRP). The proposed CRP, which is due to start in 1996, will focus mainly on the effects of low-level radiation on immune status in human populations. The main variables of interest are the level of individual radiation exposure, and the nutritional status. Possible study groups include persons living in areas of high radiation background (e.g. in countries where areas of high radiation background are known to occur naturally, or at high altitudes, or in areas affected by the Chernobyl accident). Other possible groups comprise radiation workers and uranium miners.

Nutrition and radiation protection. For the purposes of radiation protection it is convenient to make calculations of radiation doses to individual organs and to the whole body on the basis of a so-called "Reference Man". This is a conceptualized model of a human being whose organ masses, physiological functions, and other characteristics of importance in radiation protection have been defined in a standardized way. Recently, with the financial assistance of Japan, the IAEA's Division of Nuclear Safety has been conducting a programme whose purpose is to refine the concept of Reference Man by collecting data for a so-called Asian Reference Man. Starting in 1995, this programme is due to be extended by new studies which will focus on nutritional and related aspects. The elements of primary interest include caesium, iodine, strontium, thorium, and uranium. The samples of primary interest include nationally representative specimens of total diets and individual staple foodstuffs. The analyses will be done by nuclear and nuclear-related analytical techniques together with other non-nuclear techniques according to the facilities available in the participating countries.

Health care and research: Clinical trials in cancer radiotherapy

Through its health programmes,the IAEA has initiated co-operative clinical studies to improve the outcome in cancer treatment

by Jordanka Mircheva

Countries around the world have seen cancer become the number one health concern. Next to accidents, malignant tumours are the largest cause of human death. About 60% of all cancer deaths occur in people over the age of 55.

On the surface, it appears that age is indeed the most important factor for cancer. This is the case only because the older a person becomes, the longer he or she is exposed to agents that directly or indirectly increase the risk of developing a clinical cancer.

Growing cancer burden. Moreover, the cancer burden is expected to increase worldwide if for no other reasons than that more people exist and they are living longer. Indeed, the statistical estimates show that the number of cancer patients may double in the next 20 years just from the ageing of the population.

Apart from the prospect of death, intractable pain, and psychological trauma, the long duration of the disease and its chronically debilitating effects place a serious economic burden on patients and society at large.

Escalating cost. Cancer cure is expensive and the increasing cancer burden is going to escalate the pressure on national social security programmes, which are already under severe strain in many countries. Therefore, from a strategic point of view, it is imperative that greater steps are taken without delay to reduce both the incidence of cancer and its mortality rates.

Cancer prevention. Outright cancer prevention should be the ultimate goal. Certain cancers can be avoided by limiting exposure to carcinogens and risk factors related to lifestyle, occupation, or the environment. It is clear, however, that any implementation of a tentative scenario for cancer prevention by avoiding contact with carcinogens is far from simple. It would be unrealistic to expect a high rate of success, considering that carcinogenesis (the process of initiation, induction, and promotion of cancer) is unlikely to be linked to a universal cause. At the present time more than 60 carcinogenic factors or exposures have been identified as causes of human cancer. Most of these are widespread and include chemicals, ionizing and non-ionizing radiation, certain parasites, and viruses. However, there is no compelling evidence that we have yet identified all of the most important carcinogens. As a matter of fact, the causes for some common human malignancies remain unknown. Regarding cancer prevention, therefore, apart from tobacco smoking, there does not appear to be any other factor which, if avoided, could make a significant dent in the total cancer burden at present.

Education and cancer screening. Public education and cancer screening are of immense importance for the early detection of malignant growth and therefore instrumental in achievement of better therapeutic results. This approach has been strongly advocated and applied in the vast majority of advanced countries. However, it has not yet produced any significant change in cancer morbidity and mortality rates.

Improved therapeutic methods. Importantly, clinical needs have forcefully stimulated fundamental and applied research. As a result, new concepts and agents have been introduced, which in turn have brought about an improvement in therapeutic methods. Nevertheless, it has been postulated that current research in oncology will not have a substantial clinical impact within the next 10 years.

The weapon of targetted therapy. Given the background of increasing cancer burden, and the limits of cancer prevention, screening, and public education, it becomes apparent that today's most promising weapon in the armamentarium against cancer is therapy targetted either

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at the radical elimination of the tumour or control of its growth. Indeed, early diagnosis and prompt individualized treatment provide cancer patients with the best chance of surviving the disease. With each passing year, more patients with cancer are curable and treatments are associated with less morbidity than in the past. During the last few decades, the cure rate of cancer patients in industrialized countries has slowly but steadily increased from approximately 25% (in 1950) to about 50% (in 1985). It should be recognized that this progress has been due not only to early diagnosis, but also to a gradual improvement of the main modalities of cancer treatment — surgery, radiotherapy, and chemotherapy.

Surgery is the classic method of cancer treatment. It is associated with a high rate of cure in early stages of the disease, when adequate resection of the tumour can take place, even with the price of anatomical deformity and perhaps physiological impairment. Unfortunately, in the majority of cases, diagnosis is made in more advanced stages, when tumour microextensions and regional or systemic metastases present limits to the success of surgical treatment.

Radiotherapy in cancer management

In the treatment strategy against cancer, radiotherapy is the second most important modality after surgery and it has the potential to become an even more important factor. Its main goal is to deliver a precisely measured dose of ionizing radiation to a defined tumour volume so as to destroy cancer cells while inducing minimal damage to surrounding normal tissues. In addition to its curative effects, radiation plays a major role in the palliation of the disease and thus improves the quality of life that remains.

In the future, organ preservation in cancer treatment will assume greater importance, which will significantly augment the role of radiotherapy, particularly for patients with head and neck tumours, carcinoma of the breast, oesophagus, soft tissue sarcomas, carcinoma of the rectum, anus, vulva, and paediatric tumours.

The last two decades have witnessed considerable advances in the radiation treatment of cancer, with cure now being a realistic therapeutic objective. More precise, accurate, and reproducible ionizing radiation delivery systems have been introduced, as have better diagnostic procedures and computerized treatment planning, for example. At the same time, important knowledge about radiation therapy physics and greater understanding of clinical radiobiology phenomena have been acquired. These biological and technical developments in cancer radiotherapy have resulted in substantial improvements of survival rates for patients with Hodgkins' disease, cervical carcinoma, carcinoma of the endometrium, seminomas, and carcinoma of the larynx.

Unfortunately, in a large proportion of malignant neoplasms, local recurrence and distant metastases still are frequent. Radiation therapy's inability to control the disease process is clearly evident in patients with advanced stages of malignant tumours of the head and neck, gastro-intestinal tract, gynaecologic system, skin, bones, soft tissues, etc.

Therefore, specific efforts have been directed towards improving the potential of radiotherapy for local and regional control of cancer through development and investigation of multiple therapy strategies. New techniques for administering conventional radiotherapy have been introduced and supplemented by methods which can be used to modify the response of tumours and normal tissues to radiation. These techniques include changes in the dose rate, combined modality treatment involving cytostatics, sensitization by drugs, or heat, among others. Novel types of radiation having physical and biological advantages — such as fast neutrons, protons, light and heavy ions, and negative pions — are now available.

However, these new concepts and treatment approaches may become effective weapons against cancer and be introduced into routine clinical practice only through fastidious and conscientious clinical studies.

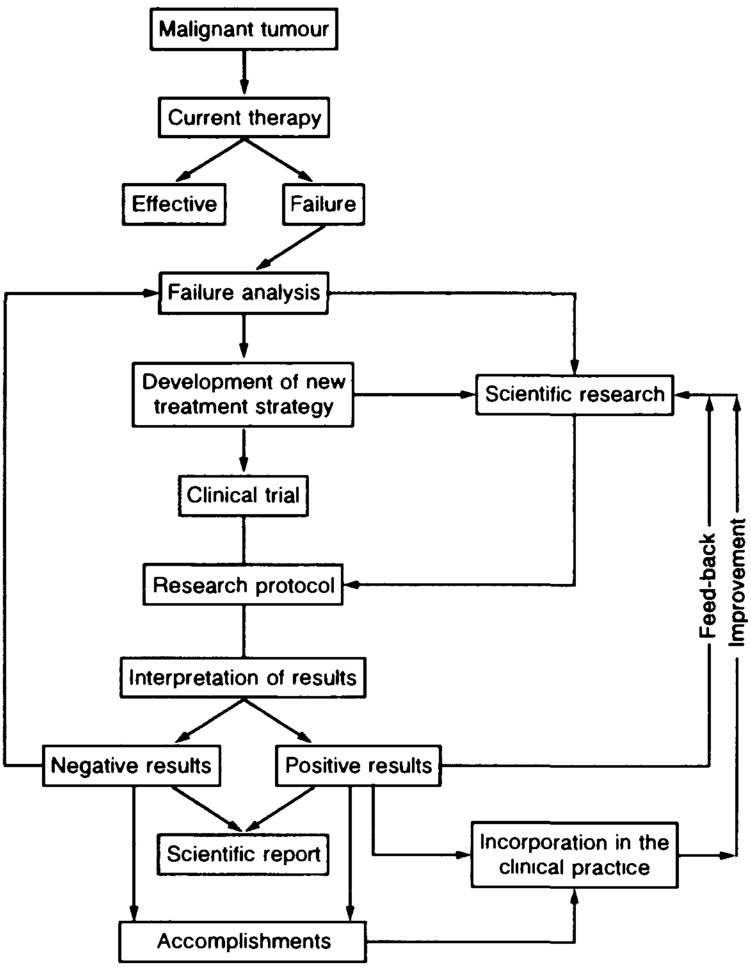
Clinical trials in cancer radiotherapy

With the current state of knowledge, it appears that numerous therapeutic methods can help control malignant growth, yet they still fail to eradicate the tumour. Therefore, as previously noted, only new treatment strategies based on advanced concepts could have an immediate impact on cancer morbidity and mortality rates.

Clinical trials are the most important (if not the only) methodology for validating the efficacy of any new therapeutic intervention. The clinical trial is a relatively recent phenomenon in the history of medical practice. Well-conducted trials have been undertaken only in the past 40 years. Before the era of modern clinical trials, treatment decisions were largely based on faith and tradition, reverence for authority, or simply anecdotal observation. Recently, there has been a large increase in clinical trials due to the development of many new treatment strategies.

The evaluation of a treatment strategy can be accomplished either by retrospective study (if

Key Elements in the Process of Cancer Radiotherapy Clinical Trials



Many elements are involved in properly conducting a clinical trial. Among the most important are the research protocol. It needs to define the trial's objectives; tumour type; stage of disease; treatment programme; quality assurance criteria; procedures in the event of toxicity; criteria for response; review procedures, including ethical review; installment of data centre; recruitment of clinicians and patients; the eligibility of patients; informed consent requirements; data acquisition; and statistical analysis. The clinical trial's accomplishments include improved performance of radiotherapy; better therapeutic rates; the transfer of skills and knowledge; the implementation of quality assurance; improved competence in both clinical and statistical terms; scientific achievements; unbiased results; and savings of time and money.

the treatment concerned has been tried in the past) or with a prospective clinical trial. A major disadvantage of the retrospective studies is the existence of serious biases in the analysis and interpretation of results. This is often due to lack of uniformity in patient selection and treatment procedures, as well as the existence of numerous undocumented facts or factors.

Contrary to the above, the major strength of prospective clinical trials is that the objectives are clearly defined in advance and patients are selected and treated accordingly. The data are also evaluated in a uniform way to ensure that the results are unbiased.

Basic principle of clinical trial. The basic principle behind a cancer clinical trial is to provide specified types of patients with the best known treatment in a preplanned manner and under controlled conditions. The clinical trial thus will allow reliable conclusions to be drawn that can subsequently be applied for the benefit of future patients.

Clinical trials are ethical only if the foreseeable risks are justified in terms of the anticipated benefits to the patient and the community. However, it is unethical to launch a trial if it does not have a chance of attaining the predetermined number of patients to ensure the statistical significance of results; e.g. reliable conclusions. Only a few institutions by themselves can have enough cases over an acceptable time period to establish with certainty and statistical significance the value of a selected treatment regime.

This emphasizes the necessity of conducting multicentre co-operative clinical trials to ensure entrance into the study of the requisite number of patients. The vast majority of multicentre trials are performed by different national institutions. From an international perspective, only the Treatment Branch of the European Organisation for Research and Treatment of Cancer (EORTC) is involved with the conduct of cancer clinical trials in European Union countries and Switzerland. It is of interest to note that of the 282 total EORTC cancer clinical trials active in 1992-93, only 35 deal with the application of radiotherapy in cancer treatment.

In the periodic analysis of cancer clinical trials published by national or international institutions, it is frequently indicated that although the outcome of cancer patients is better if they are treated in a clinical trial, only a fraction (usually less than 10%) of available patients are entered into the study. The insufficient number of cases is the number one obstacle in successful completion of even multicentre co-operative trials.

This lack of patients for trials reflects the existence of a very strict exclusion criteria. On the other hand, it is in accordance with the main eligibility rule for participation in a clinical trial, postulating that each patient should be given individually the best known treatment. In industrialized countries, the majority of cancer patients report to a doctor usually in a relatively early stage of the disease, when the best known treatment is surgery, alone or combined with conventional radiotherapy and/or standard chemotherapy. On the contrary, in developing countries, most patients report at very advanced stages of the disease, when the prognosis is very poor and the chances of improvement by application of the classical methods of treatment is minute. This warrants consideration for designing cancer clinical trials that can jointly include medical teams from radiotherapy departments in developed and developing countries alike.

The IAEA's present and potential role

Seen within this perspective, the IAEA has a unique opportunity to contribute towards improved cancer control, especially in the developing world. Specifically, it can serve as a mechanism through which countries can participate in cancer radiotherapy clinical trials, and it can help ensure the enrollment of the required number of patients. This can be done through creation of an international group of oncological teams from selected centres in developing IAEA Member States and experienced teams from advanced countries, both with an interest and strong scientific and clinical background for participation in a clinical trial.

An existing IAEA avenue for such co-operative work — co-ordinated research programmes (CRP) — can be used to both promote the research and to help ensure the effective transfer of knowledge, skills, and awareness of this methodology in developing countries. The results then become of value to all IAEA Member States.

The successful implementation and completion of a co-operative clinical trial in cancer radiotherapy relies upon the appropriate design of the strategy of treatment, standardization of patient selection, and uniform compliance with a set of carefully defined therapeutic guidelines. In that way, all patients in the study will receive essentially equal treatment regardless of which participating centre enters their case. Therefore, a research protocol must be carefully designed and adopted by all participating parties. Its structure should spell out clearly the objectives of the study, the patients eligibility (including exclusion criteria), the exact type of malignancy and the allowable stages of the disease for the study, the exact details of the therapeutic regimens to be followed, criteria for quality assurance evaluation, criteria for response, procedures in case of toxicity, and statistical methods for evaluation.

Strictly following such a carefully designed treatment protocol, based on the latest scientific and clinical achievements of oncology, will hold many benefits. It should not only help improve the performance of radiotherapy on selected tumours, but it should also serve to enhance the competence of participating parties in the field.

IAEA-supported clinical trials in cancer radiotherapy. A number of IAEA-supported clinical trials are in progress through the mechansim of co-ordinated research programmes.

One is on the clinical application of radiosensitizers in cancer treatment. It is directed towards enhancing the therapeutic gain induced by radiation in advanced cervical carcinoma by the introduction of an hypoxic cell radiosensitizer in the therapeutic management plan.

It is tacitly believed that one reason for failure in cancer radiotherapy is the existence of hypoxic cells that usually compose about 20% of the solid tumours. They are considerably more resistant to radiation-induced cell killing than the well-oxygenated normal cells. It has been found that about three times the radiation dose is required to achieve the same proportion of cell killing for hypoxic cells when compared with well-oxygenated cells.

Although the exact role of hypoxic cells in the failure of radiation to cure tumours is not yet completely known, specific efforts have been directed towards developing drugs that can effectively sensitize hypoxic cancer cells to radiation. In this way, the likelihood of a positive outcome from tumour radiotherapy is improved. The major class of drugs of clinical interest has been the nitroimidazole compounds, with the most examined agent being misonidazole (2-nitromidazole).

Unfortunately, the overall evaluation of results of 33 clinical trials with misonidazole suggested problems. They demonstrated that the possible benefit from the use of this drug in combined cancer treatments involving radiotherapy can be achieved only in a small proportion of cases — mainly head and neck tumours — due to the development of peripheral neuropathy in about 50% of the patients. The problem is that the dose-limiting neurotoxicity of the drug is manifested at a cumulative dose level below which clinically detectable hypoxic cell sensitization cannot be produced. Subsequent developments of hypoxic cell sensitizers included the synthesis of a series of 2-nitromidazole analogs that might be superior to misonidazole in terms of pharmocokinetic, radiosensitizing, and toxicological parameters.

The data presented in scientific literature clearly illustrate that the nitrotriazole derivative known as AK-2123 is an hypoxic radiosensitizer with lower neurotoxicity than misomidazole and with a higher sensitization enhancement ratio under the clinical context.

Paraclinical and clinical results obtained and published by 25 teams from 11 countries indicate a possibility for enhancing the anti-tumour effect of ionizing radiation for certain types of tumours by AK-2123. However, there is an unquestionable need for further systematic studies on toxicological and pharmacological properties of AK-2123, so that a reliable conclusion for the clinical usefulness of the drug in sensitized radiotherapy of tumours can be drawn. This task is an important clinical/scientific area of concern not only for developing countries, but also for industrialized ones. The IAEA-supported CRP, through which a well-designed multi-centre controlled clinical trial can be conducted, offers a good strategy for helping countries achieve beneficial results.

The second CRP is a randomized clinical trial of radiotherapy combined with mitomycin C in the treatment of advanced head and neck tumours.

The squamous cell carcinoma of the head and neck is a common malignancy worldwide with a very poor prognosis for patients with advanced tumours. A large majority of patients die from uncontrolled local disease (tumour persistence/recurrence). The surgical resection followed by post-operative radiation therapy remains one of the most commonly employed management strategies for patients with locally advanced but technically resectable malignancies. However, even with these aggressive treatments, about 50% of patients will experience the local/regional relapse.

The primary control of the tumour, and sequentially the survival of the patients, might be improved if an appropriate cytotoxic drug could be given concurrently with irradiation to enhance the radiation effect. Mitomycin C has been shown to be preferentially toxic to hypoxic cells. Theoretically, the concomitant administration of mitomycin C with its selective toxicity towards hypoxic cells, and the radiation therapy with its maximal effectiveness against well-oxygenated cells, should result in an enhanced therapeutic ratio.

Over the past 12 years, two consecutive randomized clinical trials have been conducted to assess the effectiveness of mitomycin C as an adjunct to radiation therapy (applied alone or in combination with surgery) in patients with squamous cell carcinoma of head and neck. The analysis of results obtained so far suggests that mitomycin C improves the radiation-induced local tumour control without enhancing the normal tissue radiation reactions. However, the number of patients entered into the study until now is not sufficient for statistical validation of the results. Through the organization of a multi-centre clinical trial, the IAEA's CRP can help obtain valuable information regarding the therapeutic benefit in adding mitomycin C to radiotherapy for the treatment of advanced carcinoma of the head and neck tumours. It can also make available the requisite number of cases, so that the results are statistically validated.

The IAEA also has initiated a CRP clinical trial involving the application of radionuclides. Radionuclide therapy with open sources has gained renewed momentum with the availability of new radiopharmaceuticals. The CRP is directed at the use of strontium-89 (Sr-89) and phosphorus-32 (P-32). It seeks to comparatively assess the relative merits of Sr-89 and P-32 in terms of their efficacy and toxicity when used in the palliative treatment of painful malignant bone metastases.

P-32 has been in existence for more than 25 years and it is relatively inexpensive and widely available. Sr-89 is a recent radiopharmaceutical which is very expensive and restricted in availability. Both radionuclides have claimed comparably efficacy, but P-32 is believed to be more toxic to the bone marrow. No comparative evaluation has been made of these agents so far.

The outcome of this randomized controlled clinical trial will have meaningful impact on the use of these agents in developing countries and wherever cost-benefit ratio is an important consideration in health care.

In summary, the IAEA's programmes in cancer radiotherapy are aimed at conducting high-quality clinical trials. This means that the studies address a clinically vital question, are randomized, have a sufficiently large sample size, and conform to high standards of quality control.

Achievements and benefits

The key element of the IAEA's co-ordinated research programmes in cancer radiotherapy is the research protocol. It outlines the study's objectives and clarifies the mechanisms of its implementation in clinical practice.

In actual terms, the research protocol is a reflection of the latest scientific achievements in oncology. Strictly following the protocol should guarantee the successful implementation and completion of the IAEA's proposed programmes. This, in turn, will improve the performance of radiotherapy, e.g. cure rates and survival of cancer patients, and increase the competence of participating parties in the field and encourage a wider use of this multimodal approach in oncological practice, particularly in developing countries. ❐

Radiation dosimetry in health care: Expanding the reach of global networks

The IAEA and WHO are jointly taking steps to improve quality assurance services for hospitals and radiotherapy centres

by Peter Nette and Hans Svensson

Back in 1968, a panel of international experts meeting in Caracas were given some disconcerting news: While more than 50 cobalt-60 radiotherapy units were in routine use throughout Latin America, there were only five qualified hospital physicists and no laboratory for performing instrument calibration. In other words, there was no system in place to ensure the accuracy of doses that patients under radiotherapeutic care were receiving.

The news from the Caracas meeting — jointly convened by the IAEA and World Health Organization (WHO) — triggered an action plan for improving the situation, not only in Latin America but in all regions of the world.

The plan featured three components: (1) establishment of an IAEA/WHO dose intercomparison service for hospitals in developing countries, to help them monitor and correct treatment doses; (2) establishment of an IAEA/WHO network of dosimetry laboratories to help standardize radiation measurements in radiotherapy centres; and (3) provision of training in radiation dosimetry through the IAEA.

Today, these three components are in worldwide service, playing important roles in supporting efforts to improve patient care and treatment involving radiotherapy.

In this article, the strides that have been taken, and problems that still remain, are reviewed in a global context. Also discussed are steps being taken toward a formidable goal, namely setting up a worldwide quality assurance programme covering dosimetry checks for millions of patients that undergo radiotherapy each year.

Mr. Nette is Head of the Dosimetry Unit of the IAEA's Laboratories at Seibersdorf, and Mr. Svensson is the former Head of the Dosimetry Section of the IAEA's Division of Human Health.

Services and networks in dosimetry

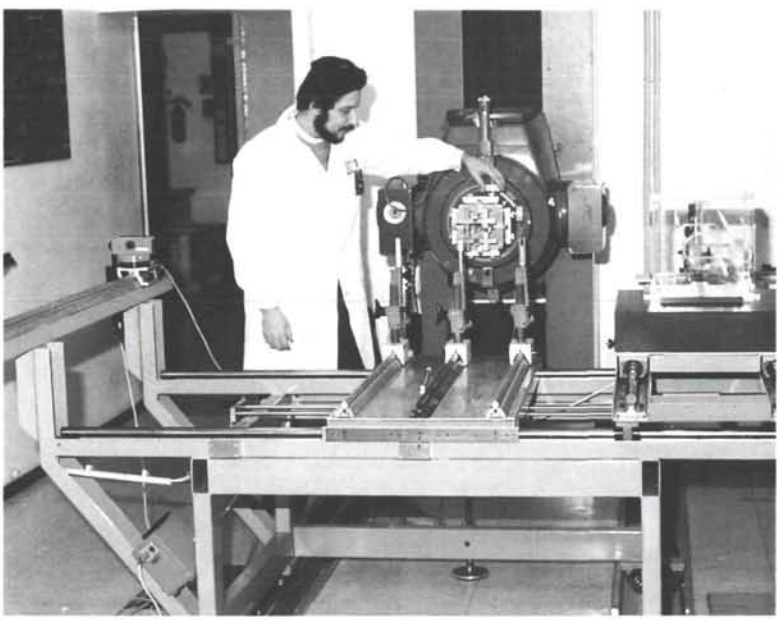
Malignant tumours — cancer — will affect many of us. In the industrialized world, generally 20% and 30% of the population gets cancer. The overall percentage right now is lower for developing countries, mainly because people there have such short expected lifetimes. That situation is likely to change as the causes of early death are reduced.

Cancer treatment includes surgery, chemotherapy, and radiotherapy, or any combination of the three. In many countries, radiotherapy plays a role in the management of 50% to 60% of all cancer patients, either as a curative treatment or as an agent to relieve pain.

For treatments with a curative aim, it is of great importance to concentrate the radiation to the solid tumour and surrounding tissue, including what is called the microscopic spread of cancer cells. The radiation effect is dependent on the amount of radiation energy that is transferred to the tumour or the healthy tissues — i.e the absorbed dose to the tumour and tissue. Since water absorbs radiation in a similar way as tissue, the physical quantity that has been agreed upon to specify the irradiation is therefore the absorbed dose to water. This quantity has to be determined with the highest achievable accuracy, taking into account the delicate balance of radiation damage (destruction of healthy tissue) and radiation benefit (tumour eradication or tumour growth control). The dose determination for each patient involves highly specialized work generally carried out by a medical physicist in close co-operation with a radiation oncologist. It is based on qualified measurements and computations.

Through various avenues, a number of services are available to assist countries in the field of radiation dosimetry.

The IAEA/WHO postal TLD dose intercomparison service. For participating hospitals,



At the IAEA's Dosimetry Laboratory: Evaluation of irradiated TLDs *(above)*, and the calibration of an ionization chamber.

the IAEA and WHO jointly offer an intercomparison service using small radiation dosimeters, technically called thermoluminescence dosimeters (TLDs). They consist of encapsuled lithium fluoride powder and are prepared and calibrated at the IAEA's Dosimetry Laboratory in Seibersdorf, Austria.

Through the service, the TLDs are mailed, together with a mountable irradiation stand, to WHO offices for distribution to participating radiotherapy hospitals in developing countries. There, under defined patient treatment conditions, they are exposed in the cobalt-60 beam of the treatment unit to what the resident physicist determines to be the specified dose. The TLD capsules are then returned to the IAEA's Laboratory for evaluation of the actual dose. The deviation between the hospital's quoted dose and the IAEA evaluated dose is reported through WHO to the hospital. A deviation of more than 5% is considered to be unacceptable and should result in a recalibration of the hospital's radiation beam used for patient treatment.

The IAEA/WHO network for secondary dosimetry laboratories (SSDLs). One of the recommendations of the Caracas panel was to establish conformity of radiation measurements in radiotherapy departments throughout the world. In industrialized countries, hospitals achieve conformity through calibration of their dosimeters to national primary standards. The heavy workload of the world's existing 13 Primary Standard Dosimetry Laboratories (PSDLs) unfortunately does not allow the calibration of reference dosimeters from thousands of other hospitals worldwide. Competent national authorities, therefore, have designated SSDLs to provide certified calibrations.

One requirement in the science of radiation measurements (radiation metrology) is that standardizing laboratories should compare their standards against each other at regular intervals. For primary standards, the organization of such intercomparisons is the responsibility of the International Bureau of Weight and Measures (BIPM) in Paris, France.

For SSDLs, the same need applies, and an international SSDL network was set up in 1976 by the IAEA and WHO. It includes a technical assistance arm, whereby most of the participating developing countries can receive financial support and expert guidance and advice. Today, the network extends to nearly 60 laboratories, most of them in developing countries. The administrative and co-ordinating work is shared by the IAEA and the WHO, with the IAEA being responsible for the technical development of member laboratories.

The IAEA's Dosimetry Laboratory in Seibersdorf functions as the network's central laboratory. Many national PSDLs and some international bodies — among them the BIPM, the International Office of Legal Metrology, and the International Commission on Radiation Units and Measurements (ICRUM) — support the work of the SSDL network. Additionally, a standing SSDL Scientific Committee is available for advice when needed. Consultants and advisory groups further can provide assistance in the implementation of specific projects, such as the drafting of technical reports, guidelines, and manuals.

The existing global distribution of SSDLs and PSDLs shows that most countries have established an infrastructure for standardization of radiation

A test programme for SSDLs: Results of an IAEA pilot study

Three SSDLs, those in Argentina, India, and Thailand, are participating in an IAEA pilot study designed to strengthen quality assurance services in radiotherapy. The study has involved quality control tests that the three SSDLs have successfully passed:

Test 1: The SSDLs were asked to calibrate a set of ionization chamber dosimeters. Their calibration factors were then compared with previously established ones from the IAEA. (This test still is to be completed by Thailand.)

Test 2: The SSDLs evaluated TLDs from hospitals during an intercomparison run, using their own calibration curves as well as one supplied by the IAEA. Results were then compared.

Test 3: The IAEA participated as a "hospital" in a national intercomparison run organized by each SSDL.

Test 4: TLDs were sent for irradiation to their respective national hospitals by the SSDLs and the IAEA, with the IAEA's TLDs going to 10% of the hospitals. The SSDLs evaluated their returned TLDs, while the IAEA evaluated its own, and the results were then compared.

measurements. However, additional efforts are necessary for expanding the network's reach, especially for the African continent.

The IAEA's dosimetry laboratory. As previously noted, the IAEA's Dosimetry Laboratory at Seibersdorf, about 30 kilometers from Vienna, Austria, is the Central Laboratory of the IAEA/WHO network of SSDLs. The laboratory's work covers the:

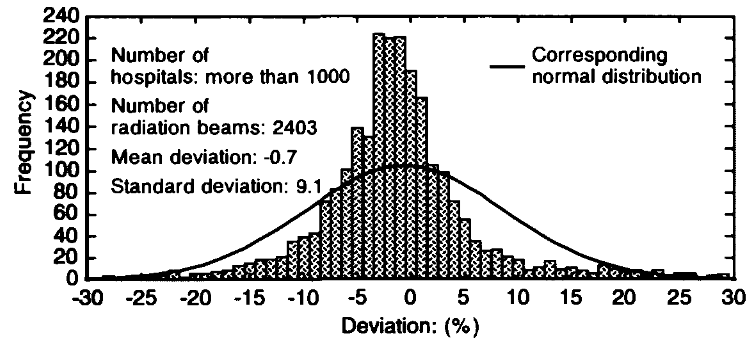
- organization of dose intercomparison measurements for SSDLs;
- performance of dose intercomparisons for some 100 radiation therapy centres each year;
- provision of calibration certificates for reference dosimeters from SSDLs and hospitals;
- acceptance of SSDL staff for on-site training;
- design and development of special methods and devices for use in hospitals and SSDLs;
- operation of the International Dose Assurance Service for radiation processing facilities in IAEA Member States.

The laboratory, for example, has prepared more than 80 batches of TLDs, sent them out and evaluated them through the postal dose intercomparison service. The service has reached about 1000 hospitals in developing countries.

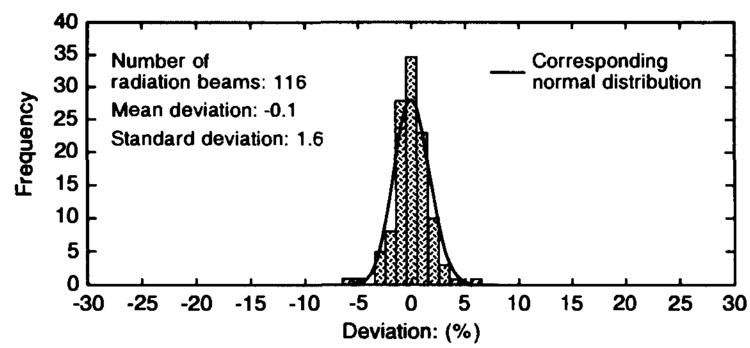
Until 1991 all results were from cobalt-60 irradiations. Since then, the service has been

Results of intercomparisons conducted by the IAEA's Dosimetry Laboratory: Frequency distributions

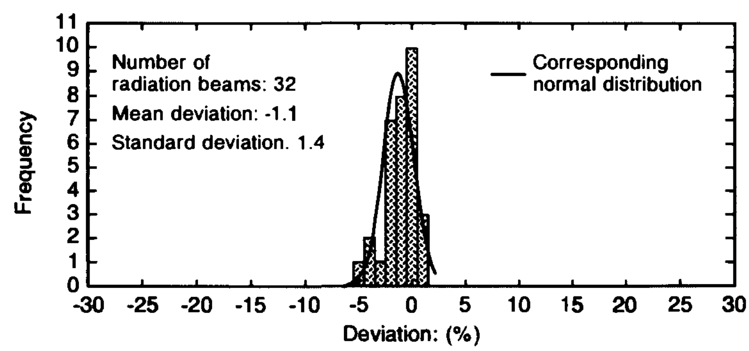
Hospitals worldwide up to 1994:



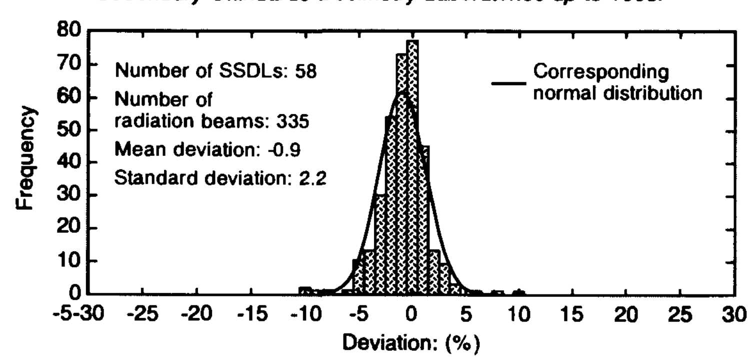
Hospitals in Europe and United States:



Radiotherapy departments in Australia:



Secondary Standards Dosimetry Laboratories up to 1993:



expanded to include X-ray beams from medical accelerators that increasingly are being installed in developing countries. This expanded service involved the support of medical physics departments in 12 renowned radiotherapy centres in Europe and the United States. These departments provided reference irradiations to the IAEA for evaluation. Two TLD intercomparison runs, one with 48 hospitals in Europe and the United States, and the other with all radiotherapy departments in Australia, were done. *(See graphs.)* They can be considered as representative samples of the situation regarding radiation beam calibration in industrialized countries.

Since 1991, the IAEA laboratory has sent a follow-up TLD set to those SSDLs and hospitals that have had poor results; they thus are asked to repeat the intercomparison measurements. Up to now, all follow-up measurements with SSDLs have shown improvement, providing results within the established acceptance limit. Follow-up measurements with hospitals in developing countries, however, have not been satisfactory in many cases, even after a second follow-up.

In all intercomparison runs, the quality of the IAEA's own performance is monitored. In that monitoring process, some TLDs are irradiated with a reference dose in the International Primary Dosimetry Laboratory of BIPM and/or at National Primary Laboratories and evaluated by the IAEA. The results indicate that the accuracy of dose determination with the IAEA's TLD system is about 1% — well below the acceptance limits for SSDLs (3.5%) and hospitals (5%).

A quality audit network

Today about 2000 cobalt-60 units and medical accelerators are in routine use in developing countries, based on responses to a survey being done by the IAEA. In addition, more and more accelerators are being installed that also produce electron beams for patient treatment. The TLD service, therefore, needs to expand accordingly by providing calibration checks for electron beams. The coverage of all machines, however, is beyond the capacity of the IAEA Dosimetry Laboratory's small staff.

As noted earlier, results clearly show that the calibration of radiation beams in developing countries has to improve considerably to reach the conformity prevailing in hospitals of industrialized countries and in SSDLs. Follow-up measurements of poor results only solved the problem in some of the hospitals. Consequently, more attention is required, as well as on-site measurements and discussion with hospital physicists. This, however, cannot be done with a quality control service centralized in the IAEA.

In addition, an effective quality control system for dosimetry involving patient treatment must look at more than just the calibration of the radiation beam. It also has to examine all dosimetric steps from dose prescription to dose delivery to the patient. Only then can the dose to the tumour in each individual patient be known with the required high accuracy, and only then can the different centres share their experiences to find the best treatment procedure.

A pilot study for a quality control programme is now being carried out by European centres with the IAEA's co-operation. Such a programme necessitates the use of dosimeters in human shaped phantoms that undergo radiotherapy as if they were patients. To include all European hospitals, the participation of several reference centres is required to operate a TLD service and to follow-up detected discrepancies.

The European scheme has been modified by the IAEA/WHO for implementation in developing countries. For several years, three SSDLs — those of Argentina, India, and Thailand — have been operating their own national TLD radiotherapy service based on the IAEA's methods. They have, therefore, been asked to participate in the pilot study using their TLD systems. *(See box.)* At these centres, the IAEA will continuously monitor the quality of TLD work, as a step toward achieving conformity worldwide in the determination of absorbed dose and the accuracy of the absorbed dose measurements.

In years ahead, radiotherapy is expected to increase in importance for cancer treatment, especially in the developing world. An improvement in the accuracy in dosimetry is needed to introduce modem treatment techniques. In principle, a quality assurance programme should ensure that all patients treated with a curative aim receive the prescribed dose within a margin of about 5%. Setting up a such a programme by the year 2000 is a formidable task, since it would have to include dosimetry checks for several million patients irradiated each year.

While the major work for such a programme must be decentralized, the IAEA and WHO through the organization of SSDLs are in the best position to co-ordinate the global effort. The pilot studies of the European quality assurance network and of the three SSDLs in IAEA Member States move into closer view the introduction of similar networks for SSDLs and hospitals in other regions. This could lead to a global programme having the potential to significantly improve patient care for millions inflicted with cancer. ❐

Biological effects of low doses of ionizing radiation: A fuller picture

The two latest reports of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) provide a comprehensive overview of current knowledge

by Abel J. González

When the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) submitted its 1994 report to the United Nations General Assembly this year, the international community received a fuller picture of the biological effects of low doses of ionizing radiation. The 272-page 1994 report specifically addresses epidemiological studies of radiation carcinogenesis and adaptive responses to radiation in cells and organisms.

The report is designed to supplement the more extensive 928-page report that UNSCEAR presented to the UN in 1993.* That report addressed global levels of radiation as well as major issues of radiation effects, including the mechanisms of radiation oncogenesis; the influence of level of dose and dose rate on stochastic effects of radiation; hereditary effects of radiation; radiation effects on the developing human brain; and late deterministic effects in children.

Taken together, these two reports provide an impressive account of current knowledge on the biological effects of ionizing radiation. This article — though by no means an account of all essential information — summarizes the highlights of UNSCEAR's assessment of the effects of low doses of ionizing radiation, hereinafter called "low radiation doses" *(see box, page 39)* in the context of available radiobiological evidence.

Radiobiological effects: The current understanding

Since the beginning of the 20th century, it has been known that high doses of ionizing radiation produce clinically detectable harm in an exposed individual that can be serious enough to be fatal. Some decades ago, it became clear that low radiation doses also could induce serious health effects, although of low incidence and only detectable through sophisticated epidemiological studies of large populations. Because of the work of UNSCEAR, these effects are now better and more widely understood and better quantified.

Effects at the cellular level: DNA damage and repair mechanisms. The biological effects of radiation derive from the damage it causes to the chemical structure of the cell. For low radiation doses, damage to the *deoxyribonucleic acid (DNA)* in the cell's nucleus is of concern. The damage is expressed as *DNA mutation* occurring in genes in chromosomes of *stem cells*, which can alter the information that passes from a cell to its progeny.

While DNA mutation is subject to efficient repair mechanisms, the repair is not error free. Most damage is repaired, but some damage remains or is badly repaired, and this has consequences for the cell and its progeny. *(See box, page 38.)*

Evidence of cell adaptation. There is experimental evidence that DNA mutations can be reduced by a small prior conditioning dose of radiation, probably because of stimulation of the repair mechanisms in cells. *(See box, page 42.)* Such a process of *adaptive response* has been demonstrated in human lymphocytes and in certain mouse cells. The cellular response is transient and there appear to be individual variations. As it is recognized that the effectiveness of DNA repair is not absolute, adaptation is likely to occur together with the processes of DNA mutation and its subsequent effects. The balance between

* See the 1994 UNSCEAR Report, *Sources and Effects of Ionizing Radiation*; UN Pub. Sales No. E.94.IX.11; United Nations, New York, (1994), and the 1993 UNSCEAR Report: *Sources and Effects of Ionizing Radiations*; UN Pub. Sales No.E.94.IX.2.; United Nations, New York (1993). Also see the *IAEA Bulletin*, Vol. 35, No. 4, page 49 (1993), for highlights of the 1993 report.

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Radiation Exposure and Living Matter

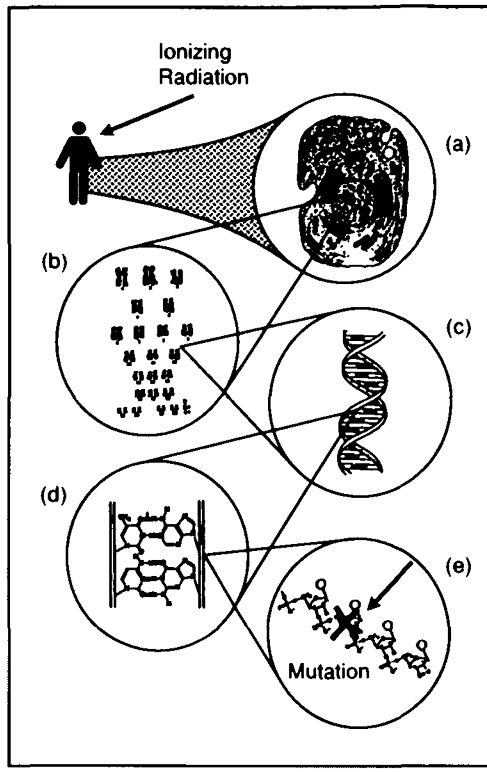
Interaction of radiation with biological material affects the smallest unit of living matter capable of independent existence: the ***cell***, **(a)**. A typical cell is a sack of fluid, or ***cytoplasm***, enclosed by a membrane, which embeds a ***nucleus*** containing the ***chromosomes*** — threads of complex biological substances, including the more essential compound of life, ***deoxyribonucleic acid or DNA*** — that carry life-sustaining information. The chromosomes hold the ***genes***, a segment of DNA that codes the information, and allows its transmission from a cell to its descendants. The cytoplasm also embeds ***organelles*** governing important metabolic functions of the cells and the generation of vital energy.

The human body contains a total of around one hundred trillion (or 10^{14}) cells. They are variable in shape and size, the average diameter being lower than 10 micrometres. The large majority of cells are ***somatic cells***, i.e. those which make up the bulk of the organism. A relatively minor number of cells pass on hereditary information from the organism to its descendants during reproduction: they are called ***germ cells***[1]. From the large number of human cells, only a fraction has stem-like properties, i.e. are able to reproduce a progeny of cells. The human body contains a total of around 10^{10} to 10^{11} of these ***stem cells***; their fraction varies among tissues and organs, and also with age.

Radiation can ionize any atom in the cell components. An important outcome is the production of active ***chemical radicals***, extremely reactive compounds, able to promote chemical changes in the cell. These changes may either damage essential cellular functions, and potentially kill the cell or prevent it from reproducing, or alter the genetic information. The ***target cells*** for the radiation effects that are expressed as a modification of the cell's genetic information are the stem cells. Interactions of radiation with cell material may occur at random at any moment during the dynamic process of reproduction of stem cells. At low radiation doses, there may be a great deal of incident radiation per cell but the frequency of interactions is extremely low. UNSCEAR estimates that a low radiation dose (e.g. 1 mSv per annum) will produce, on average, circa one interaction per cell in a year.

The human cell contains 46 chromosomes **(b)** and a large number of genes that determine the characteristics of an individual. Genes exist in alternative forms called ***alleles*** — one from each parent — which occupy the same relative position in chromosomes having the same structural feature. One allele may be ***dominant*** over the other, determining which aspect of a particular characteristic the organism will display; the only "dominated" allele is known as ***recessive***.

The gene component, DNA **(c)**, is a pair of linear long chain-like molecules called ***polynucleotides*** wrapped around one another, as a spiral ladder-shaped double-helix complex molecule composed of



two chains — or strands — wound around each other. This complex molecule comprises numerous individual units or ***nucleotides*** **(d)**. Nucleotides are made of four types of complementary bases called ***adenine*** and ***guanine*** and ***thymine*** and ***cytosine***. The sequences of the bases express the genetic code.

Directly, or indirectly by the action of chemical radicals, radiation can induce changes in the sequence of bases and therefore alter the genetic code. This process is referred to as ***mutation***, or a sudden random change in the nucleotide sequence of a DNA molecule **(e)**, resulting in alterations in the genetic code that, as a consequence, may cause the cells and all cells derived from it to differ in appearance or behaviour — referred to as a change in ***phenotype***. Possible alterations are ***point mutation***, or replacement of one nucleotide by another, and ***clastogenic mutation*** including ***insertion*** or ***deletion***, which is the addition or removal of any piece of DNA, from one base pair to quite extensive parts, and ***inversion***, which is the excision of a portion of the double helix followed by its reinsertion in the same position but in reverse orientation. Mutation is passed on from an individual to his or her progeny during reproduction via the ***germ cells***.

A cell or organism whose phenotype has been altered by mutation is referred to as a ***mutant***. The more common generator of mutants is random errors in DNA replication during cell reproduction. The mutation rate is increased if the cell is exposed to physical or chemical ***mutagens*** or agents able to cause mutation. Heat is probably the most important environmental mutagen. Radiation is a rather mild mutagen.

Mutation is effectively repaired by the cell through mechanisms which are not yet well understood. It is likely that, if a point mutation occurs in just one base of one DNA strand, repair would be easy as the complementary base in the other strand apparently can act as a template for the repair; but for mutations occurring in the same location of both strands, or if clastogenic damage occurs, error-free repair would be less likely.Radiation seems to be a stimulant of the repair process. *(See box on Adaptive Response, page 42.)* It seems, however, that there is always a chance of misrepair, even in single strand point mutations.

Unrepaired mutation is responsible for the detrimental fate of a mutated cell. If a mutation is not properly repaired, the outcome for the cell can be twofold: either the cell dies — for instance through *apoptosis*[2] — or it survives as a viable but transformed cell that may give rise to a new family of mutant cells. The two outcomes will have very different consequences for the organism. At low radiation doses, the killing of cells is sparse and does not usually have serious health consequences. But a mutant cell can evolve to cause serious health effects: if it is a somatic cell, it can be the initiator of a malignancy, and if it is a germ cell, of hereditary diseases.

Radiation Doses

The term ***radiation*** means energy propagating in the form of electromagnetic waves or photons, or in the form of subatomic particles. Ionizing radiation is radiation of sufficiently high energy to cause — in the medium through which it passes — the production of pairs of ions, i.e. of atoms or groups of atoms that have either lost or gained one or more electrons to become positively or negatively charged, and the corresponding complementary electrons. For biological effects, the medium in which ion pairs are produced is biological material, more specifically cellular material.

The term ***radiation (absorbed) dose*** generally means the amount of energy which is absorbed from ionizing radiation by a unit mass of material. This quantity is expressed in unit energy per unit mass, that is in joules per kilogram, which takes the special name gray (Gy); [1 Gy = 1000 milligray (mGy)]. For radiation protection purposes, the absorbed dose is weighted to take account of the effectiveness of different radiation types and the radiosensitivity of various organs and tissues. The resulting quantity is termed effective dose, and its unit sievert (Sv) [1Sv = 1000 millisievert (mSv)]; for photons in the intermediate energy range, 1 mGy is approximately equal to 1 mSv.

The term ***low radiation dose*** is used to mean a radiation dose lower than designated levels; sometimes it is also informally used to mean a low dose rate, i.e. low dose per unit time. In specialized radiobiological forums, low radiation dose (and dose rate) refers to exposures for which it is very unlikely that more than one event of energy absorption from radiation will occur in the critical parts of a cell (and damage it) within the time during which repair mechanisms in the cell can operate. Thus, UNSCEAR concluded that low radiation dose refers to a total dose of less than 200 mSv and dose rates below 0.1 mSv per minute (which in fact is a very high dose rate of around 5000 mSv per annum).

For the non-specialized public, low radiation doses are deemed to correspond to levels similar to those from, for instance, natural background exposure or some very common radiation exposures such as those arising during air travel. Natural background exposure varies widely around the world. Some "normal" [and "elevated"] values of annual dose rates are as follows: for cosmic rays, 0.38 mSv [2.0 mSv]; for terrestrial radiation 0.43 mSv [4.3 mSv]; and for exposure to radon, 1.2 mSv [10 mSv]; leading to an average total of around 2.4 mSv per annum. The average annual dose for very frequent flyers (such as aircrew) is around 2.5 mSv. These dose rate levels of a few mSv per annum are expected to deliver, during a lifetime, doses of above around 100 mSv, which are of the order of magnitude of the low radiation doses designated by UNSCEAR.

stimulated cellular repair and residual damage is not yet clear.

Dose-response relationship. If DNA mutation depends on radiation's interaction with a single cell, then the frequency of DNA mutation — in cases of no interaction between cells — should follow a linear-quadratic relationship with dose. *(See box, page 42.)* Furthermore, if it is assumed that, for low radiation doses, mainly single interactions of radiation rather than multitrack effects are dominant, the frequency of cells with one or more interactions, and consequently the frequency of DNA mutations, will simply be proportional to dose. Thus, if a fraction of mutations remain unrepaired, the expected number of mutated cells will be proportional to the dose.

[1] ***Germ cells*** are: the ***testis seminiferous tubule cells*** which divide by mitosis into ***spermato gonia*** and then into ***spermatocytes,*** followed by a meiosis into ***spermatids*** which eventually develop into ***spermatozoa;*** as well as the special ***oogonia*** cells within the ovary which divide by mitosis into ***oocytes*** which after two meiotic divisions become an ***ovum.*** The fusion of a spermatozoon and an ovum forms a ***zygote,*** the origin of a new being.

[2] ***Apoptosis*** is an orderly, systematic and programmed process of self-destructive death of the cell. Probably as a result of genetic altrations, the cell enters into a period of cytoplasmic basophilia and nuclear condensation, followed by eosinophilia and cytoplasmic condensation, cell fragmentation, and dissolution and, typically, phagocytosis by neighbouring cells. Contrary to ***cell terminal differentiation,*** which is a cessation of cell replication, to cellular ***senescence,*** which becomes manifest only at the end of the life span of the cell, and to the disorganized cellular death by ***necrosis,*** apoptosis is an orderly cellular process of self-destruction which can be initiated at any moment in the cell life. It is speculated that radiation can be an important initiator of apoptosis which might have a potentially beneficial influence in tumour promotion and malignant progression.

Cell killing: deterministic effects. A number of radiation interactions in the cell and some of the unrepaired DNA mutations may lead to the death of the mutated cell, or prevent it from producing progeny. This may occur as a result of the cell's *necrosis* (i.e. its pathological death as a result of irreversible radiation damage) or *apoptosis* (i.e. a programmed self-destruction of the cell) or because the normal cellular reproduction is hindered. For low radiation doses, cell killing is sparse and therefore of no negative consequence to health owing to redundancy of cellular functions and cellular replacement. For high radiation doses which could kill large numbers of cells in an organ or tissue, the cell-killing effect could be lethal for the tissue and, if vital tissues are involved, for the individual concerned. Although killing of individual cells occurs at random, the health effects resulting from the extensive cell killing at high doses are called *"deterministic effects"* because they are predetermined to occur above a threshold level of dose. Deterministic effects, therefore, are not clinically expressed at low radiation doses. Exceptionally, the killing of a few essential cells during organ development *in utero* may result in severe harmful effects clinically expressed in the newly born; these effects are generally referred to as *"effects in embryo"*.

Cell transformation: stochastic effects. Other unrepaired DNA mutations may produce modified but viable stem cells. If the modified cell is a *somatic cell*, it can be the initiator of a long and complex process that may result in severe "somatic health effects", such as cancer. Alternatively, if the cell is a *germ cell*, the mutation could be expressed as *hereditary health effects* in the progeny of the exposed person. These health effects, both somatic and hereditary, deriving from a cell modification are called *"stochastic effects"* because their expression is of an aleatory, random nature.

Carcinogenesis

A most important stochastic effect of irradiation is *carcinogenesis*. It is believed to be a multistage process and is usually divided, albeit imprecisely, into three phases: cancer *initiation*, tumour *promotion*, and malignant *progression*. *(See box, page 41.)* It is presumed that radiation is important as an *initiator* rather than as a *promoter* or *progressor*. For low radiation doses, therefore, as the likelihood of initiating mutations is proportional to dose, the likelihood of carcinogenesis should also be proportional to dose.

Immune response and cell surveillance mechanisms. It is argued that immune response may not play a major role in moderating human radiation carcinogenesis. However, specialized immune functions in certain organs and the existence of non-immunogenic cell surveillance mechanisms suggest that a proportion of early pre-neoplastic cells may be eliminated before they become established. Other mechanisms defending against tumour induction and development include the already mentioned DNA repair, apoptosis, terminal differentiation and phenotypic suppression. Altogether, these mechanisms will reduce the probability that a specifically damaged target cell will progress to frank malignancy; to estimate this probability, however, is extremely difficult.

Adaptive response in organisms. Evidence of organic adaptive response to radiation exposure in laboratory mammals has been reported in the literature. However, because of the lack of conclusive evidence, UNSCEAR remains doubtful whether adaptation also occurs at the cellular system level and whether the immune system plays any role in the process.

Epidemiological evidence of carcinogenesis. Although it is not yet possible to determine clinically whether a specific malignancy was caused by radiation, radiation-induced tumours and leukaemia have been detected and statistically quantified by epidemiological studies of populations exposed to relatively high radiation doses. From initiation until the clinical expression of the cancer, a period of time — termed the latency period — elapses. The duration of the latency period varies with the type of cancer from a few years in the case of leukaemia to decades in the case of solid tumours. The action of radiation is only one of many processes influencing the development of malignancies and, therefore, the age at which a radiation-induced malignancy is expressed has been found to be no different from the age for malignancies arising spontaneously.

Epidemiological studies of a number of populations exposed to generally high-dose and high-dose-rate radiation — including the survivors of the atomic bombing of Hiroshima and Nagasaki in Japan and patients exposed in therapeutic medical procedures — have provided unequivocal association between radiation dose and carcinogenesis.

The most comprehensive source of primary epidemiological information is the Japanese survivors' "life span study". This has demonstrated a positive correlation between the radiation dose incurred and a subsequent increase in the incidence of, and mortality due to, tumours of the lung, stomach, colon, liver, breast, ovary, and bladder, and also of several forms of leukaemia but not for lymphoma or multiple myeloma. Of the 86 300 or so individuals in the "life span study" cohort, there were 6900 deaths due to

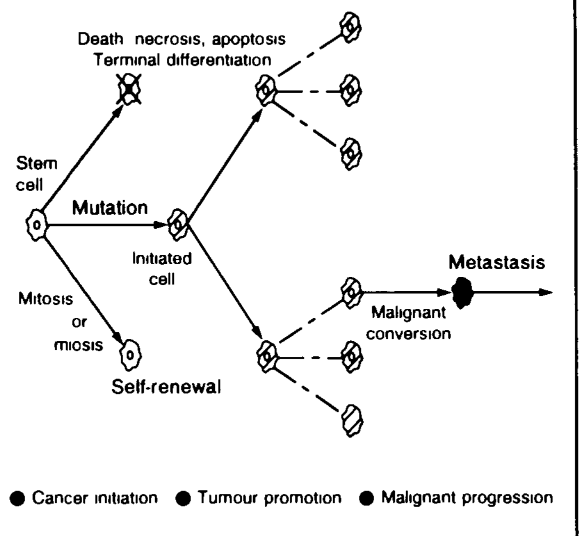
Carcinogenesis: A Multistage Process

Carcinogenesis is believed to be a multistage process usually divided into three phases: cancer initiation, tumour promotion, and malignant progression.

Cancer initiation. Most, if not all, cancers seem to "initiate" from DNA mutation in a single stem cell which thus becomes a modified, carcinogenic cell. This process involves loss of control over the cellular reproduction cycle and differentiation. It is presumed to start as a result of deactivation of ***tumour suppressor genes*** that seem to play a crucial role in regulating cellular proliferation. The loss in activity of these genes, through for instance a deletion or a mutation, can lead to uncontrolled cell growth. The process of initiation of carcinogenesis might also be the result of conversion of ***proto-oncogenes***, which seem to be involved in regulating the proliferation and differentiation of cells and can potentially become oncogenes and transform the cell into a malignant cell. Relative target sizes for the induction of these events would tend to indicate tumour suppressor genes as the most radiosensitive targets. It is presumed that the initiating event centres on single gene deactivation in a number of possible genes and that initiation is an irreversible process.

Tumour promotion. The promotion stage involves the clonal expansion of an initiated stem cell into a focus of non-terminally differentiated cells. The initiated cell can be stimulated or "promoted" to reproduce by agents that, alone, may have low carcinogenic potential but that are able to enhance greatly the yield of neoplasms induced by prior exposure to an initiator. Radiation, like many other agents, can act independently as initiator and promoter. After initiation, the transformed cell may have some proliferative or selective advantage over normal cells, such as a shorter reproduction time. However, the transformed cells and their immediate progeny are surrounded by normal cells, which constrains their pre-neoplastic properties as they are prone to be eliminated in the competitive reproductive process. Elimination becomes more unlikely as the number of transformed cells increases. Thus, the promotion stage seems to be potentially interruptible and reversible.

Malignant progression. After initiation and promotion, a futher stage of "progression" is needed to complete the multistage carcinogenesis. It is characterized by a progressive tendency towards increasing malignancy. Progression might be facilitated by additional alterations in initiated and promoted cells to become promoter - independent and invasive. The principal phenotypic characteristic of the malignant progression is the ability to spread, or metastasize, from the primary tumour mass and to establish secondary growth foci, or metastases, at other sites. This is a complex, multifaceted process that appears to involve a series of subsequent genetic changes within the evolving pre-neoplastic clone of cells, including changes in growth rate, growth factor response, invasiveness, and metastatic potential. The progression stage includes angiogenesis, detachment, invasion, release, survival (host interaction), arrest, extravasation and invasion, new growth, angiogenesis. Thus the process is repeated until clinically important metastases are produced. Whether and how radiation exposure influences the changes leading to progression and the different stages of the progression process is not yet known. The progression stage also appears to be irreversible.



solid tumours during 1950-1987, but only approximately 300 of these cancer deaths can be attributed to radiation exposure. The epidemiological data for leukaemia incidence in this same period indicate statistically that 75 cases out of a total of 230 leukaemia deaths can be attributed to radiation exposure. The incidence data also provide evidence of excess for thyroid and non-melanoma skin cancers. The study provides little or no evidence of radiation induction for cancers of the rectum, cervix, gall bladder, larynx, prostate, uterine cervix, uterine corpus, pancreas, kidney, renal pelvis, or testes, or for chronic lymphocytic leukaemia and Hodgkin's disease.

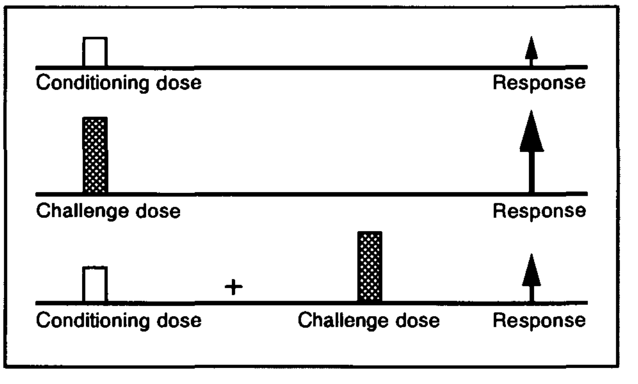
Epidemiological studies on the effects of low-dose-rate exposure undertaken for occupational exposures have shown conflicting evidence. While a number of occupational studies have reported a significant excess risk of leukaemia in workers exposed to radiation — which is broadly in agreement with the estimates derived from high-dose-rate studies — other studies have failed to demonstrate any positive correlation. *(See author's note, page 45.)* Studies of lung cancer in miners occupationally exposed to radon, however, have been able to provide a consistently positive correlation between excess cancer incidence and radiation dose.

Many environmental exposure studies have been carried out, notably on the incidence of

Adaptive Response

The possibility has been known for many years that low doses of radiation may cause changes in cells and organisms, reflecting an ability to compensate for the effects of radiation. It has been suggested that estimates of the risk of stochastic effects from low-level radiation may have been overstated because no allowance has been made for this process, which is referred to as adaptation or ***adaptive response***. The term adaptive response is used to refer to the possibility that a small dose of radiation — which is variously referred to as the *adapting, inducing, priming, or* ***conditioning dose*** — may condition cells by inducing processes that reduce either the natural incidence of malignancies or the likelihood of excess malignancies being caused by a further radiation dose — usually referred to as the ***challenge dose***. *In vitro* adaptive response of lymphocytes takes place between about four and six hours after exposure to a conditioning dose within a range of dose of about 5 mGy to 200 mGy, and remains effective for around three cell cycles. Following a challenge dose, repair is manifested as a reduction — below the expected levels — in chromosomal aberrations, sister chromosomatic exchanges, induced micronuclei, and specific locus mutations, sometimes by a factor of about two. Moreover, bone marrow cells and spermatocytes from mice exposed to a challenge dose that followed a conditioning dose also showed reduction in the number of chromosomatic breaks compared with cells exposed to the challenge dose alone.

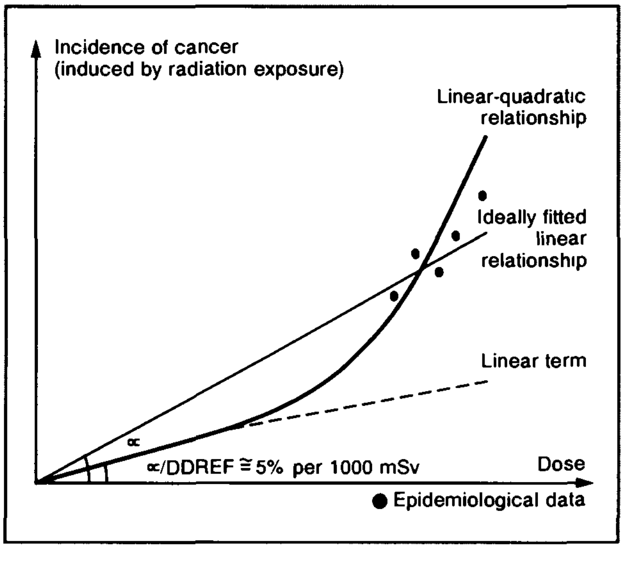
It seems that many agents can be activated sometime after exposure to the conditioning dose and can reduce DNA mutations due to the subsequent exposures to the challenging dose. These include gene coding for transcription factors — i.e. factors affecting the process of transfer of genetic information of DNA — and synthesis of enzymes involved in the control of the cell cycle and therefore in the proliferation of cells as well as in the repair of damage. Observations support the hypothesis that conditioning doses activate certain genes and that this is quickly followed by the synthesis of enzymes responsible for DNA repair. If these enzymes become available in adequate concentration at the time the cells receive the challenge dose, the extent of DNA repair seems to be improved. The adaptive response mechanisms are thought to be similar to those operating after exposure to other toxic agents, including trace amounts of oxidizing radicals. The adaptive response to radiation, therefore, may be the result of a general mechanism of cellular response to damage.



Dose-Response Relationship

It is presumed that radiation acts through single track interactions occurring randomly according to a Poisson distribution in a homogeneous population of cells. It can be mathematically shown that a linear-quadratic expression describes the theoretical ***dose-response relationship*** — i.e. the mathematical relation between the dose incurred and the probability of expression of an attributable radiation effect. This relationship fits most of the available epidemiological data. For low radiation doses, there are so few radiation tracks that a single cell (or nucleus) is very unlikely to be traversed by more than one track. Thus, under these assumptions the dose-response relationship is almost bound to be linear, independent of dose rate and without dose threshold.

Since most available radioepidemiological data are for high doses only, the approach commonly used for assessing the risk at low doses is to fit an ideal linear dose-response relationship to the data in order to project it for low doses for which data are lacking. As the real dose-response curve is assumed to follow a linear-quadratic relationship, with the linear term prevailing at low doses, a reduction factor — which is called "dose and dose rate effectiveness factor" or DDREF — has to be applied . Based on experimental data, it seems that the DDREF should be small. For cell tranformation and mutagenesis in somatic and germ cells, DDREFs of around two or three have been observed, although at low dose rates no reduction in effects was observed (i.e. the DDREF was unity), over a large range of doses. Taken together, the available epidemiological data suggest that for tumour induction the DDREF adopted should have a low value, probably of around two and no more than three. In the case of hereditary disease, a DDREF of three is supported by most experimental data for animals.



leukaemia in populations living near nuclear installations. Although a few such studies were initially reported to have provided positive correlations between clusters of leukaemia cases and the proximity of nuclear installations, further evidence indicates that it is unlikely that such clusters can be attributed to radiation exposure. A particular exception is a study on people exposed to high level discharges of radioactive materials into the Techa River in the former USSR, among whom leukaemia was found to be in excess. Comparisons of cancer incidence in areas of high and low levels of exposure to natural background radiation have not produced any statistically significant associations.

Inconclusive epidemiological evidence of adaptive response. The human epidemiological studies on adaptation have been of lower statistical power. Therefore, they do not provide evidence of an adaptive response expressed as a decrease in the prevalence of spontaneously occurring human cancers. Moreover, the extensive animal experiments and limited human data provide no conclusive evidence to support the view that the adaptive response in cells either decreases or increases risks of cancer in humans owing to the effects of radiation at low doses.

Models for carcinogenesis. Risk assessments of carcinogenesis are carried out by extrapolation from the limited epidemiological data available, taking account of theoretical assumptions from plausible radiobiological models. For instance, in order to obtain the full lifetime risk in an exposed population, it is necessary to project the frequency of induction of excess cancers noted during the period of observation over the entire lifetime of the population. This is now done through a *"multiplicative" model* (rather than through a simple *"additive" model*), which assumes that the rate of induced cancers will increase with age, in proportion to the spontaneous cancer rate (which also increases with age).

Three multiplicative projections are used by UNSCEAR: one assumes that the excess relative rate remains constant throughout life, the others that it will decrease some time after the exposure (the risk of exposure induced death is higher with the constant model while the years lost per induced case can be higher with the other models).

On the other hand, the lack of epidemiological data on the induction of cancer and leukaemia at low doses means that incidence data at high doses must be used for risk estimates. A reduction factor should be applied to the risk deduced from a theoretical linear (non-threshold) fit to the high-dose and high-dose-rate epidemiological data. A reduction factor of about two, which is estimated with considerable uncertainty on the basis of theoretical assumptions and some epidemiological data, is used by UNSCEAR in its risk assessments. *(See box, page 42.)*

Hereditary effects

Any unrepaired DNA mutations in germinal cells that are non-lethal for the cell could in principle be transmitted to subsequent generations and become manifest as *hereditary disorders* in the descendants of the exposed individual. Epidemiological studies have not, with a statistically significant degree of confidence, detected hereditary effects of radiation in humans. However, on the basis of genetic experimentation with a wide range of organisms and cellular studies, and taking account of the statistical limitations of the negative human findings, it is conservatively assumed that there can indeed be induction of hereditary effects in humans following radiation exposure. The potential hereditary effects may be the result of:

- dominant mutation (i.e. a mutation in the *dominant allele* of a *gene*, which can be inherited from only one parent and which leads to disorders in the first generation and can be passed unexpressed through several generations);
- recessive mutation (i.e. a mutation in the *recessive allele*, which can only be inherited from both parents — otherwise, the dominant allele would prevail — and which produces little effect in the first few generations but may accumulate in the population's gene pool, i.e. in the whole of the genes that are present in a population; and
- potentially, *multifactorial disorders* due to mutations resulting from the interaction of several genetic and environmental factors.

The process of generation of hereditary disorders from radiation is less well understood than that of carcinogenesis but the assumptions made are similar: stochastic single cell origin of the disorder with any radiation interaction is fully capable of being an initiator. Therefore, the response at low radiation doses is also presumed to be linear with dose, with no dose threshold.

Models for hereditary disorders. In view of the lack of direct epidemiological evidence, incidences of radiation induced hereditary effects in humans are estimated through two indirect methods which use data from animal experiments. The *doubling dose (or relative mutation) method* provides the estimate in terms of the additional number of cases of hereditary disease attributed to radiation, using the natural prevalence (of such a disease) as a reference frame. It aims at expressing the likelihood of a hereditary disease being induced by radiation in relation to its natural general occurrence in the population. (Thus, the *doubling dose* is the dose expected to produce as many mutations as those that occur spontaneously in a generation and it is obtained by dividing the spontaneous mutation rate in a locus — or position — of a relevant gene in a chromosome by the expected rate of induction of mutations per unit dose.) The *direct (or absolute mutation) method* directly assesses the expected incidence of hereditary diseases by combining the number of genes at which mutations can occur with the expected number of mutations per unit dose and the dose itself. It is therefore aimed at expressing the likelihood of hereditary diseases absolutely, in terms of the expected increase in the prevalence of the disease. The estimates of risk do not usually include the many hereditary diseases and disorders of complex, multifactorial aetiology, in view of the fact that any effect of radiation upon the incidence of multifactorial disorders should be only slight and is highly speculative.

Effects on the embryo

Effects of radiation *in utero* are generally referred to as effects on the embryo. They can occur at all stages of embryonic development, from zygote to foetus and may include lethal effects, malformations, mental retardation and cancer induction. The first three may be the possible outcome of deterministic effects during embryonic development, particularly at the period of formation of organs.

Evidence of effects on brain growth and development has emerged after observations of severe mental retardation in some children exposed *in utero* at Hiroshima and Nagasaki. The effects from high-dose, high-dose-rate exposure *in utero*, particularly linked to the period between 8 and 15 weeks after conception, seem to indicate a downward shift in the intelligence quotient (IQ) distribution. For low radiation doses, this potential effect on the embryo is undetectable in the newborn.

Studies of *in utero* exposures have given conflicting evidence of carcinogenesis in the child, from relatively high risk to essentially small undetectable risk, including (possibly) none at all. There is no biological reason to assume that the embryo is resistant to carcinogenesis but on the basis of current data such effects cannot be quantified with any certainty.

Highlights of UNSCEAR's conclusions

Taking account of the available radiobiological and radioepidemiological information, UNSCEAR has made a number of quantitative estimates in relation to health effects of low radiation doses. As a result, the scientific body continues to consider that radiation is a weak carcinogen and an even weaker potential cause of hereditary diseases. A summary of UNSCEAR's quantitative estimates follows:

- **Epidemiological Estimates:**

Lifetime mortality:

- □ 1.1% after exposure of 1000 mSv for leukaemia and 10.9% for solid tumours (12% in total). For reference, in UNSCEAR's 1988 report, the corresponding data was 1.0% for leukaemia and 9.7% for solid tumours.
- □ linear between 4000 mSv and 200 mSv (little evidence at lower dose).

- **Radiobiological Estimates:**

For low (chronic) radiation doses of around 1 mSv per year:

- □ *probability of an excess malignancy:* 10^{-4} per year
- □ *lifetime probability*: 0.5%
- □ *proportion of fatal cancerns in the population that may be attributed to radiation*: approximately 1 in 40.

The above estimates are based on the following assumptions and inferences:

Assumptions:

- □ *cells in the human body:* 10^{14} cells per individual
- □ *target stem cells:* 10^{10} to 10^{11} cells per individual
- □ *initiating event*: single gene mutations in one of around ten possible genes
- □ *induced mutation rate (per cell):* 10^{-5} per 1000 mSv
- □ *excess probability of malignancy:* approximately 10%; and
- □ *interactions per cell*: 1000 per 1000 mSv.

Inferences:

- □ *excess malignancy*: 1 per 10^{11} to 10^{12} target cells receiving 1000 mSv;
- □ *rate of target gene deactivation*: 10^{-4} per cell per mSv; and
- □ *probability that a single track will give rise to an excess malignancy:* 10^{-14} to 10^{-15}.

- **Risk Estimates**:

Risk of malignancies:

- □ *lifetime probability of radiation induced fatal cancers*:
  5% per 1000 mSv in a nominal population of all ages; and
  4% per 1000 mSv in a working population.

Risk of hereditary effects:

(via doubling dose method)

- □ *probability of hereditary radiation effects for all generations:*

1.2% per 1000 mSv (or 1.2% per generation for a continued exposure of 1000 mSv per generation)
- □ *probability of hereditary effects in the first two generations:* 0.3% per 1000 mSv

(via the direct method)
- □ *probability of hereditary effects (clinically important disorders) in the first generation:* 0.2% and 4% per 1000 mSv.

Risk of effects on embryo:
(for those exposed *in utero* in the period between 8 and 15 weeks after conception)
- □ *downward shift of IQ distribution:* 30 IQ points for 1000 mSv
- □ *dose required to shift from normal IQ to severely mentally retarded:* 1000 mSv or more
- □ *dose required to shift from low IQ to severely mentally retarded:* a few hundred mSv.

Taking UNSCEAR's estimates together and adding to them an estimated detriment from non-fatal cancers, the International Commission on Radiological Protection (ICRP) has recommended the use — for radiation protection purposes — of total nominal risks from stochastic effects of radiation of:
- 0.0073% per mSv for the whole population; and
- 0.0056% per mSv for all adult workers.

These have been the nominal risk factors used in developing the new International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources.*

Outlook

Thanks to the work of a unique body in the UN system, UNSCEAR, the biological effects of ionizing radiation are better known than those of many other chemical and physical agents affecting human beings and the environment. However, there are still many unanswered questions in radiobiology, in particular in relation to the effects of low radiation doses. One problem is the lack of empirical evidence. It should be emphasized that at low dose levels, epidemiological studies presently have only a restricted capability to detect and quantify statistically significant stochastic radiation effects — both somatic and hereditary. As a result, unequivocal direct observational evidence of the effects of low level radiation does not exist and will probably not be obtainable for a long time. Obtaining unequivocal evidence would require sound epidemiological studies, able to associate an increased incidence of specific health effects with radiation exposure. Such studies would have to overcome inherent statistical and demographical limitations and moreover should include correct case ascertainment, appropriate comparison groups, sufficient follow-up, control of confounding factors and well-characterized dosimetry. It is not now feasible to obtain such evidence for the effects of low radiation doses and therefore a continuing lack of direct evidence on such health effects is to be expected.**

Because of these limitations, radiation risk estimates have to rely on an idealized radiobiological model, intended to provide the basis for interpreting the available epidemiological results for high radiation doses. Although the model reflects sound understanding so far, it is rather simple, perhaps even simplistic, and it is still evolving. Scientific developments are taking place that will extend knowledge of the biological effects of radiation and may necessitate changing the model. Research in molecular biology, for instance, may provide new information on the mechanisms of cancer induction. The mechanisms of adaptive response and the role of radiation exposure in the initiation, promotion, and progression of cancer will be better understood. The coming years might change our view of the health effects of low radiation doses.

Notwithstanding the rapid progress in relevant scientific branches, UNSCEAR has not yet found it necessary to make any major revision to its perception of the biological effects of radiation and the consequent risk estimates. Nearly a quarter of the human population incurs fatal malignancies but, as UNSCEAR indicates, only "about 4% of deaths due to cancer can be attributed to ionizing radiation, most of which comes from natural sources that are not susceptible to control by man". □

* The standards were developed under the auspices of the IAEA and five other organizations: the Food and Agriculture Organization, International Labour Organization, Nuclear Energy Agency of the Organization for Economic Co-operation and Development, Pan-American Health Organization, and World Health Organization. For a report on the new standards, see the author's article in the *IAEA Bulletin*, Vol. 36, No. 2 (1994).

** Author's note: At the time this article is being issued, the International Agency for Research on Cancer is releasing the results of an epidemiological study on cancer risk among 95 673 nuclear industry workers. The study gives the most precise direct estimates of mortality due to protracted low radiation doses. As reported in *Lancet* (344: 1039-43), the estimates "provide little evidence that the [UNSCEAR] estimates...are appreciably in error".

Technology transfer for safe management of radioactive waste: Tailoring the approaches

In response to wide-ranging needs, the IAEA has developed standardized packages and tools to assist countries in specific areas

by Donald Saire, Curt Bergman, Candace Chan, and Vladimir Tsyplenkov

Most countries around the world do not have nuclear power plants. Of the IAEA's 121 Member States, for example, about 75% fit into this category. They apply nuclear technologies chiefly for research, medical, industrial, and other purposes. From the standpoint of radioactive waste mangement, this broad range of nuclear applications, as well as each country's own level of infrastructure and stage of development, creates a diverse set of challenges.

Through its programme on radioactive waste management, the IAEA provides assistance to countries that includes direct and indirect transfers of various types of technologies and services. The aim is to help countries effectively protect human health and the environment, now and in the future, from the radiological hazard of radioactive waste. The diversity of national needs and interests is reflected in the IAEA's programme, which incorporates technology-transfer projects that have been specially tailored to address specific types of requirements. This article reviews key elements and strategies of that programme.

Identifying the needs and strategies

To better understand the overall profile of countries, the IAEA has developed an internal classification that groups countries by the type and quantity of generated radioactive waste. *(See table and boxes, page 48.)* Countries are faced with a range of needs to solve specific waste management problems, a fact that has been clearly identified by the IAEA's Waste Management Advisory Programme (WAMAP) and other expert missions.

Currently, only a few developing countries are able to comply fully with the requirements for proper and safe waste management. For most developing countries, the situation varies from non-compliance to quasi-compliance. The requirements to be met by these countries include the establishment of a comprehensive waste management infrastructure. The infrastructure covers such elements as legal framework, regulatory body, operating organizations, resources, and trained personnel. Through the IAEA's Radioactive Waste Safety Standards (RADWASS) Programme, international consensus in these and other areas is being documented.

Through its entire range of programmes in the field of radioactive waste management, the IAEA aims to bring all countries to a minimum level of compliance and to develop necessary components to sustain a system. This is a long and time consuming process but one that will ensure an adequate level of safety to workers and the public.

In the past, the most obvious means of assistance was transferring waste management technology that already had been proven in industrialized countries. Although adequate technological proficiency is very important, experience has shown that this is not enough, since technology is only one of the necessary components of the required infrastructure. It cannot be sustained or implemented without the other supporting infrastructural elements. Even if the IAEA does not have the authority or legal responsibility to ensure that a country has the adequate infrastructure, a moral responsibility remains — especially in cases where the IAEA provides nuclear technology and equipment, or radioactive material itself.

Mr. Saire is Head, and Mr. Bergman, Ms. Chan, and Mr.Tsyplenkov are staff members, of the Waste Management Section in the IAEA Division of Nuclear Fuel Cycle and Waste Management.

IAEA strategy for technology transfer

Many requests received from developing countries for technical assistance in radioactive waste management are similar in scope and objectives. The volumes, characteristics, and activity levels of the wastes generated, or expected to be generated, are also often quite similar.

Taking this into account, the IAEA embarked upon a strategy for providing technical assistance in the form of standardized packages for centralized waste management facilities, and supporting tools, techniques, and practices that can be easily modified to meet the needs of an individual country. These standardized packages and tools include the following:

- the Sealed Radiation Sources (SRS) Registry;
- a design for a Spent Sealed Sources Facility (SSSF);
- a design for a centralized Waste Processing and Storage Facility (WPSF);
- a series of Technical Manuals for processing and storage of radioactive waste arising from nuclear applications.

The SRS Registry. This computerized database is being developed within an IAEA programme covering spent sealed sources. The registry project's main intent is to create a basic management tool that would be useful to countries in their efforts to control and record information on sealed radiation sources on a national, regional, or local level.

Several practical requirements were established for the registry system. It should track lifetime information about a source — from cradle to grave (or its return to supplier); be useable by a wide range of organizations e.g. regulators, operators, laboratories, etc.; be easy to use and maintain; and it should not require special software or sophisticated equipment.

The registry has two basic functions. First, it maintains information on essential characteristics of a sealed radiation source, such as the name of the radionuclide, activity, source serial or other identification numbers, physical location, the user organization, the source owner, its supplier, its intended or dedicated use, and any associated housing or equipment type. Second, the registry enables the recording of pertinent information on the source when its useful life is over (i.e., becomes spent) so that proper processes or decisions can be determined. It must also provide complete archiving capabilities.

A version of the registry was released to several IAEA Member States for field testing which concluded in June 1994. Comments received thus far during the testing phase have been extremely positive. A number of Member States have already requested the database for immediate use, despite its developmental stage.Their rationale is that a nearly complete registry is better than none at all. A final version of the registry is expected to be available by January 1995.

The SSSF design package. In 1993, in response to the growing need to safely handle, condition, and store spent radiation sources before their disposal, the IAEA began developing a standard design package for a facility where all predisposal operations could be carried out in one unit. Such facilities are needed but do not exist in many developing countries, especially where radionuclides are used only in a few hospitals or research institutes. The SSSF design incorporates specific requirements, such as simplicity of technology, convenient maintenance, flexibility, economy, and safety. The standard facility is a single story building divided into a number of rooms and areas where spent sources can be received, monitored, stored for decay or until conditioning, immobilized if required, and prepared for transfer to interim storage.

The design package recommends a range of equipment and consumables required for performing the handling and immobilization of spent sealed sources. The interim storage facility may be adjacent to or on the same site as the SSSF, or it may be on a distant site requiring vehicular transport. Three types of construction design are available to suit warm arid, warm humid or cold climates.

The WPSF design package. This reference design package was specifically developed to facilitate the processing of different radioactive

Scene from an IAEA training course on radioactive waste management. *(Credit: C. Chan, IAEA)*

Radioactive waste arisings

Apart from the operation of nuclear fuel cycle facilities, radioactive wastes arise from a range of activities. They include:

Nuclear research centres. Radioisotopes are produced in research reactors for different purposes by irradiation of special targets or in a particle accelerator from which the desired isotopes are subsequently extracted or processed in nearby hot cells or laboratories. Some installations are located in a nuclear research centre where radioisotopes also are used and handled. The volume of liquid and solid radioactive wastes produced by the individual users of radioactive materials in the centre is not likely to be large. Most of the radioactive wastes, solid and liquid, are contaminated with short-lived radioisotopes and are candidates for decay storage and subsequent discharge, or for disposal as non-radioactive wastes. Wastes containing long-lived fission products, including transuranic nuclides, are produced only by a few laboratories of developing countries. Only a very small part of the radioactive waste is contaminated with long-lived radioisotopes.

Hospitals. The application of radioactive materials in medical diagnosis and therapy is extremely important and continuously expanding. In many cases alternative methods are not available. The main areas of application are radioimmunoassay, *in vivo* and *in vitro* diagnostic techniques, radiotherapy, and medical research. These represent the use of not only unsealed sources, but also highly concentrated sealed sources housed in shielded assemblies.

Industry. Certain industries use radioactive material mainly in the form of sealed sources for non-destructive analysis or testing, quality control, evaluation of plant performance and development of products.The quantities of radioactive materials used depend largely on the development and level of the national technology.

Universities and other research institutes. Research establishments and universities are most commonly involved in monitoring the metabolic or environmental pathways associated with materials as diverse as drugs, pesticides, fertilizers, and minerals. The range of useful radionuclides is normally restricted and the activity content of the labelled compounds is usually low. However, some research establishments may use some rather exotic radionuclides. The radionuclides most commonly employed in toxicology studies of many chemical compounds, and their associated metabolic pathways, are carbon-14 and tritium, as they can be incorporated into complex molecules with considerable uniformity. Iodine-125 has proved to be very valuable in the labelling of proteins. A wide spectrum of radionuclides is available for research and investigation.

IAEA technical guidance and assistance

In a new series of IAEA technical documents in areas of radioactive waste management, nine documents have been issued:

- *Minimization and Segregation of Radioactive Wastes*
- *Storage of Radioactive Wastes*
- *Handling, Conditioning and Disposal of Spent Sealed Sources*
- *Handling and Treatment of Radioactive Aqueous Wastes*
- *Handling, Treatment, Conditioning and Storage of Biological Radioactive Waste*
- *Treatment and Conditioning of Radioactive Solid Wastes*
- *Treatment and Conditioning of Radioactive Organic Liquids*
- *Treatment and Conditioning of Spent Ion Exchange Resins from Research Reactors, Precipitation Sludges and Other Radioactive Concentrates*
- *Design of a Centralized Waste Processing and Storage Facility*

Classification of IAEA Member States by types and quantities of radioactive waste

To better understand the overall profile of countries, and to determine the best type of assistance package, the IAEA has grouped countries by the types and amounts of radioactive wastes generated. The first three groups are the focal point of this article.

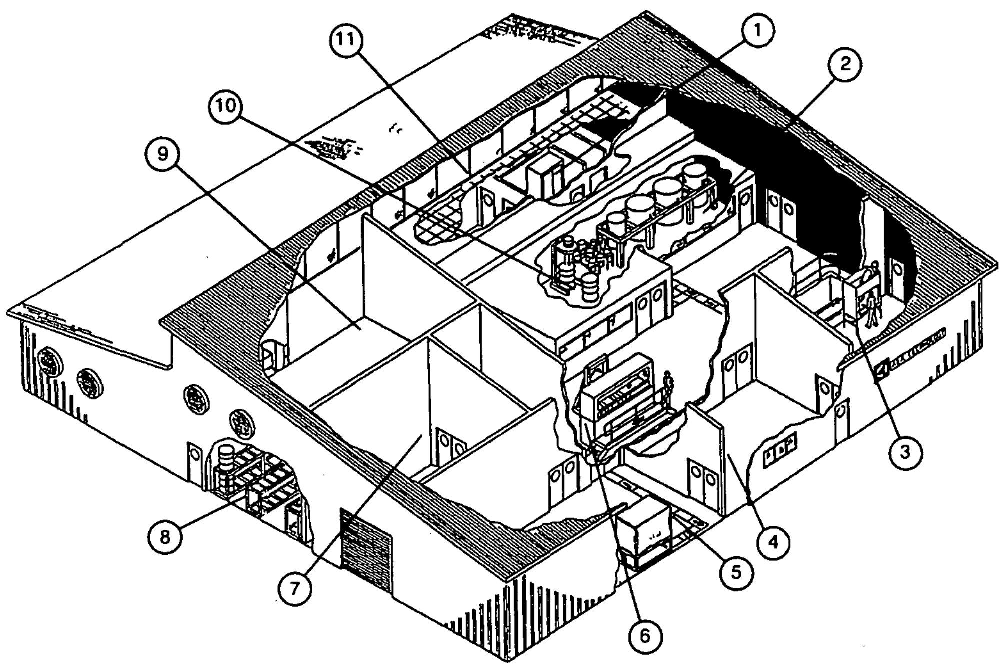
Group A: Countries with single use of radionuclides in hospitals and other institutions.

Group B: Countries with multi-use of radionuclides in hospitals and other institutions.

Group C: Countries with extensive use of radionuclides and with one (or more) nuclear research centre capable of indigenous production of several radioisotopes (in research reactors or particle accelerators).

Group D: Countries with extensive use of radionuclides and nuclear power plants planned or in operation.

Group E: Countries with nuclear power plants and fuel cycle operations.



1. Offices 2. Liquid effluent treatment plant 3. Laboratory with fume cupboard 4. Monitoring and counting room 5. Workshop and decontamination 6. Solid waste sorting and compaction 7. Receipt and dispatch bay 8. Interim storage 9. Ventilation services 10. Cementation area 11. Changing rooms

Schematic of the WPSF waste processing building

waste streams that have various activities, physical properties, and chemical composition, and that arise from multiple uses of radioisotopes and their production.

In preparing the reference design and to define its requirements, the IAEA carefully reviewed radioactive waste management techniques employed throughout the world. First, the processes selected for inclusion in the reference design had to be well proven and established, and be tolerant to changes in waste feeds. The equipment selected had to be robust, simple in design, and simple to operate and maintain. The design also had to incorporate appropriate radiological protection means to ensure safe operation. *(See schematic, which shows the type of facility that would result from the reference design package.)*

The design's recommended waste processes include liquid waste precipitation, solid waste compaction, and cementation of sludges. The design includes all supporting equipment and services necessary to safely operate the processing plant. The separate waste store is a large, simple building with no extra features other than lighting.

Benefits of reference design packages. By offering the above design packages, the IAEA and its Member States benefit in two important ways. First, the service promotes the availability of plant designs that can be modified according to national needs. Second, since the resources for providing technical assistance to developing countries are limited, there is considerable merit in developing an application or concept which meets the needs of several countries and can be used repeatedly.

The packages provide further support to the IAEA's technical assistance programmes in areas of handling, processing, and storage of low- and intermediate-level waste. Experts visiting developing countries can use the packages as the basis for providing an effective technical and economic approach to solve problems.

Technical support and training

Technical manuals. The IAEA has published technical reports and safety documents on radioactive waste management for more than three decades. These documents have provided Member States with basic reference material and comprehensive surveys of the state-of-the-art technologies.

A new series of technical documents recently was initiated to help countries that require straightforward and low-cost solutions to waste management problems. This series — entitled *Technical Manuals for the Management of Low-*

and Intermediate-Level Wastes Generated at Small Nuclear Research Centres and by Radioisotope Users in Medicine, Research and Industry — is intended to provide (1) guidance on maximizing practicable use of indigenous resources; (2) step-by-step procedures for effective application of technology; and (3) recommendations on technological procedures which can be integrated into an overall national waste management programme.

Currently, nine manuals in this series have been prepared and published as IAEA technical documents (TECDOCs). *(See box, page 48.)* Additional subject areas may be identified and covered in the future.

Technical assistance projects. Another avenue of support is a technical assistance project, which offers the opportunity for providing expertise, technology, individual training, and equipment for specific waste management needs. The objective of such projects is to offer the necessary support to develop the expertise for self-sufficiency in the safe management of radioactive waste. Since 1976, the IAEA has supported 60 technical co-operation projects on radioactive waste management in 42 countries. Currently, 36 countries receive different types of such technical assistance through more than 40 projects. In addition, there are currently five regional projects under way.

The assistance includes the provision of equipment and facilities. Among them are a solid waste compactor, equipment for chemical precipitation and waste cementation units, and various monitoring and measurement devices.

Model projects. Also being implemented is a model project to upgrade the waste management infrastructure in selected developing countries. The project recently started and includes the use of standard packages for upgrading the different parts of the waste management infrastructure.

Training. Many scientists and technicians have been trained through IAEA technical assistance projects in countries having established waste management programmes. Additionally during the last 4 years, nine regional and three interregional training courses have been held, with a total of 300 participants from 60 countries. Practical exercises and technical demonstrations included sessions covering chemical precipitation of liquid waste; compaction of solid waste; conditioning of spent sealed sources; and surface decontamination.

International meetings. Scientific meetings are an additional tool for the exchange of technical knowledge. In October 1994 in Beijing, China, the IAEA organized a seminar entitled Radioactive Waste Management Practices and Issues in Developing Countries. It was specifically designed for developing countries and focused on management practices and technologies for waste from operations not related to the nuclear fuel cycle. The IAEA also provides financial support to selected experts from developing countries for attendance at international conferences and symposia sponsored by professional and trade organizations.

Research support. While the IAEA itself does not conduct any research in the field of radioactive waste management, its co-ordinated research programmes (CRPs) encourage and foster it on topics of wide interest. Participation usually involves both developed and developing Member States, thus serving as an excellent forum for technology transfer.

Presently, CRPs on the use of inorganic sorbents for treatment and conditioning of liquid waste, and on treatment technologies for low- and intermediate-level wastes generated from institutional sources are of particular importance to developing countries. The studies include the adaptation of well-established processing technologies for the management of specific wastes in countries and for other local conditions.

Awareness of responsibilities

The use of the atom must be linked with the safe management of radioactive waste that is generated from various nuclear applications. A key aspect of the IAEA programme is therefore directed to creating an awareness among national authorities of their responsibilities to effectively plan, develop, and implement national waste management programmes. Its activities are helping to establish the necessary infrastructure and to transfer appropriate technologies.

The IAEA's ability to make an effective contribution to the safe management of radioactive waste requires a continuous evaluation of national needs to ensure that the allocation of resources and efforts are balanced to achieve the maximum benefits and results. This is a dynamic process. New model projects to upgrade the waste management situation in selected countries are now being developed. They will be implemented and evaluated to determine if their components offer the right mix of packages for building infrastructures and transferring technologies, with the aim of making them applicable to the needs of a broad base of countries. ❐

Experts without frontiers: Building expertise for the transfer of nuclear technolgies

National and international experts recruited by the IAEA share their experience to strengthen skills in developing countries

by Robert Lauerbach and Alicia Reynaud

Arriving at Kenyatta airport, the physician was set for a relaxing flight back to Vienna. It had been an intensive two weeks of work in Kenya, finalizing procedures for an IAEA cancer radiotherapy project at the country's Institute of Nuclear Medicine. His Kenyan counterparts had organized a thorough work programme — they had even met in the evenings and on the weekend. The project — which was designed to strengthen the skills and practices in Kenya for the treatment of cancer — was now into its second year and nearing completion. He had been involved from the start, in the capacity of an expert recruited for a temporary assignment. His permanent job back home in Germany was to head the Institute of Nuclear Medicine at the University of Heidelberg.

Now, as he waited out a flight delay, his thoughts turned to his mission report. He was pleased by both the project's progress and support. Recommendations from his last mission had been well received at IAEA headquarters in Vienna, including financial support for a cobalt-60 radiotherapy unit that Kenya acutely needed to treat patients. As a radiotherapist, he knew the field well, the problems and pitfalls — and the benefits and rewards. This was his fifth assignment as an expert on a specific project of the IAEA's technical co-operation programme. Not all missions went as well as this one, but then no one ever said it would be easy...

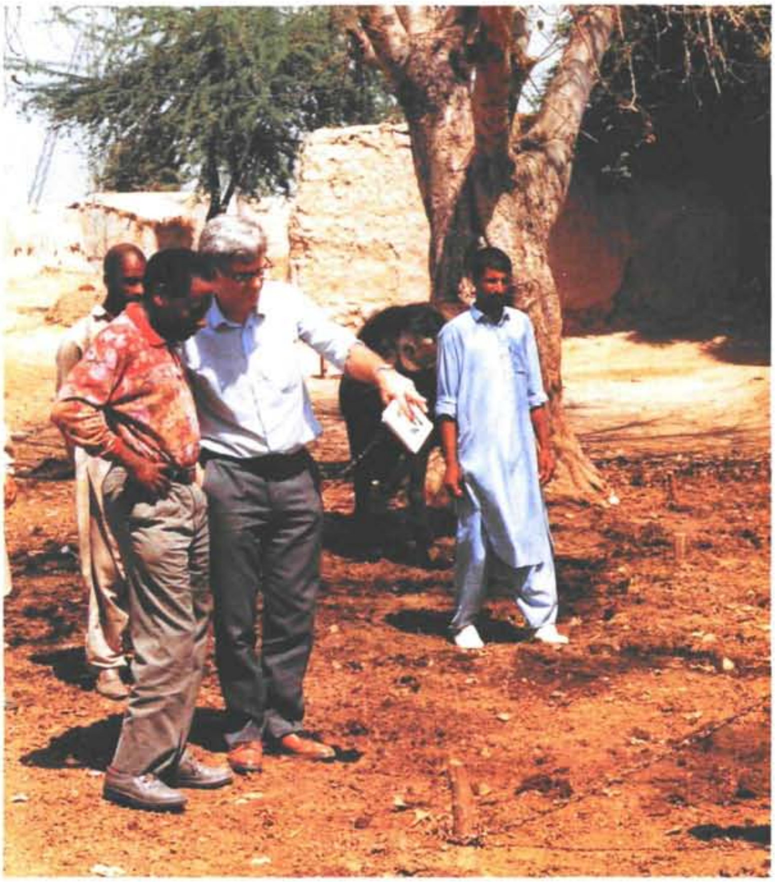
This short description of an expert assignment is a snapshot of the day-to-day life of hundreds of experts recruited by the IAEA each year. Over the last decade, the IAEA has planned and carried out nearly 18 000 expert assignments within the framework of its technical co-operation programme. The programme functions as the turntable for the transfer of nuclear technology to the developing world, assisting countries in achieving self reliance for the many applications of nuclear science and technology.

As the snapshot illustrates, the transfer of nuclear technology is more than the generation of energy in nuclear power plants. The IAEA's technical co-operation programme focuses on the safe application of radioisotopes and radiation technologies in food and agriculture, human health, hydrology and industry, and various other fields. These technologies are used, for example, to improve food crops, eradicate pests, determine groundwater resources, sterilize medical supplies, check airplane structures, monitor environmental pollution — and treat the ill.

There is a growing need to transfer these established technologies, still concentrated in certain countries, to countries where such resources remain in short supply. The major vehicles for technology transfer to the developing world are technical co-operation projects. Right now, there are more than 1000 such projects operational within the IAEA. Within them, the development of human resources is a key element for helping countries achieve scientific and technological self-reliance. The carriers of nuclear technologies are scientists and engineers who are ready to share their expertise with their colleagues in developing countries. Their missions take them across national boundaries, making them, in a real sense, "experts without frontiers".

Experts work within the institutional framework of nuclear energy's peaceful development. In practice, this means that special attention is devoted to safety and safeguard aspects. Nuclear technology's peaceful uses are

Mr. Lauerbach and Ms. Reynaud are staff members in the Experts Section of the IAEA Division of Technical Co-operation Implementation.



On assignment near the Pakistan and Indian border for a joint IAEA/FAO animal health inspection, an expert talks with local livestock owners.
(Credit: Feldman, IAEA)

monitored throughout the world by means of international agreements, such as the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), and international guidelines and regulations on the basic safety standards for radiation protection, for example. This has led to close interaction between the donors of the technology, the experts, financial contributors, recipient countries, and the IAEA.

In this article, the role that experts play within the context of IAEA technical-co-operation programmes is featured. Also reviewed is the provision of expert services, including the types of assignments, and the process of recruitment. Expert services have become one of the pillars of technical co-operation at the IAEA, alongside the provision of equipment and fellowships and the organization of training courses and workshops.

The provision of expert services

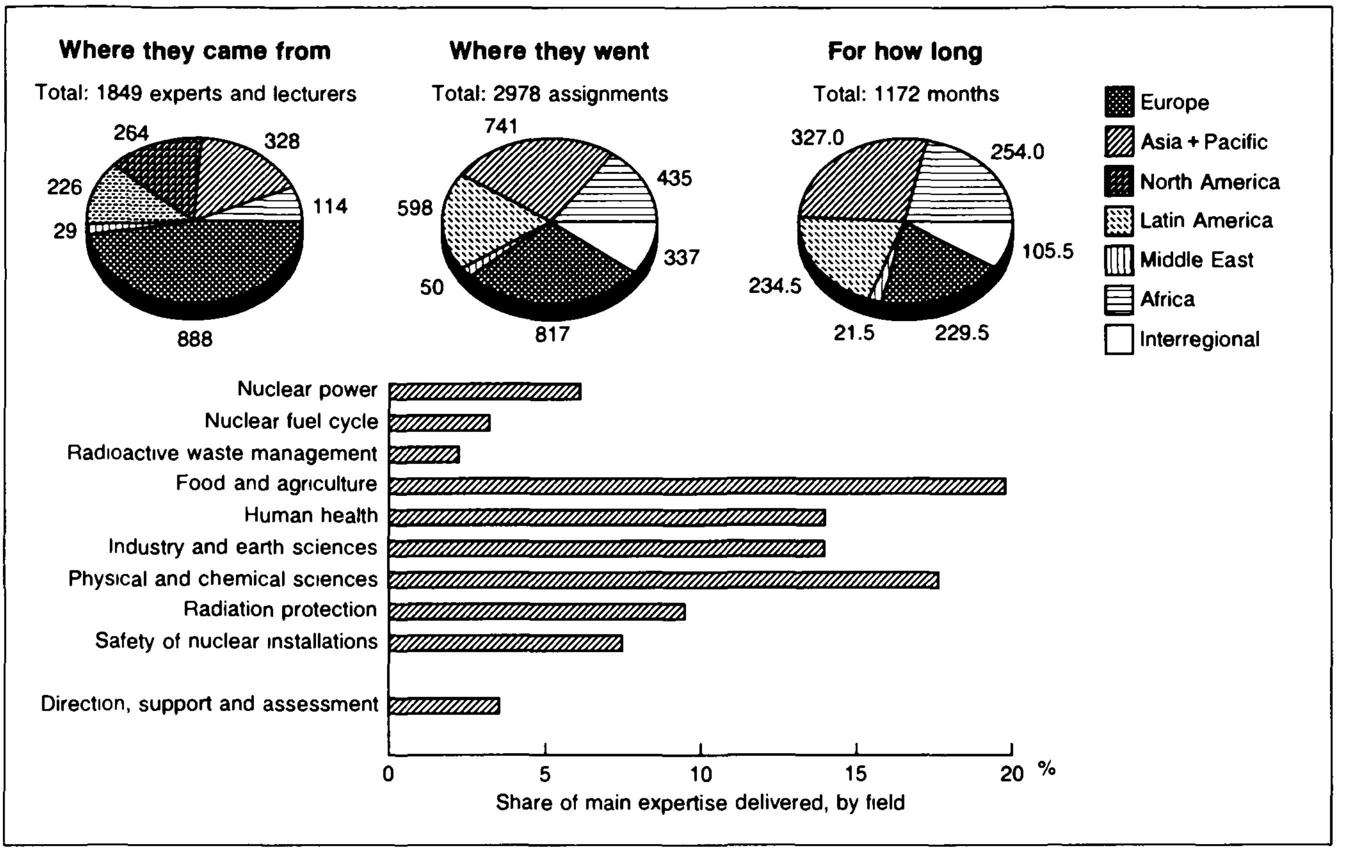
The IAEA has been providing technology transfer services through expert assignments since 1958. Typically, experts work on projects of their expertise and function as advisors, lecturers, or workshop participants. Recruited for a limited period only and ready to travel to other countries and continents, an expert is a special kind of person. He or she possesses the knowledge of a sophisticated technology, and has the ability to share it effectively with others.

Applied nuclear science and technology covers a wide range of subjects and requires a multitude of different specializations. *(See graphs.)* Five areas stand out. The applications of isotopes and radiation technology in food and agriculture have for a number of years been the single most important expert activity. They are followed by applications of physical and chemical sciences; human health activities, including the production of radiopharmaceuticals; earth sciences, covering activities such as the development of water resources; and industrial development, with emphasis on non-destructive testing techniques. For all these applications and technologies, safety-related activities in the field of radiation protection account for a large share of expert services. They are prerequisites for technology transfer and help ensure that an adequate infrastructure exists or is established in the recipient countries.

Who are the experts and where do they come from? The typical IAEA expert is a man, between 35 and 60 years old, with at least 10 years' relevant experience in the application of isotopes and radiation after his postgraduate degree in science or engineering. He is fully aware of the radiation protection rules and procedures within his specialization. His career is frequently related to national or international development and he is member of professional societies. He masters at least one or two of the United Nations languages and last, but not least, he is interested and enthusiastic to share his experience with others in the developing world.

But what about the women? Experience shows that they can easily match the standards of their male colleagues. However, there are not enough women who apply for expert posts. Only 6% of the IAEA's expert roster — a computerized list of expert candidates which comprises more than 5000 candidates — are women. It is one of the goals of the IAEA's technical co-operation programme to increase the participation of women. For this it relies heavily on the promotion of women at the national level and the encouragement of women by national authorities to apply for international posts.

The IAEA distinguishes between two major types of experts financed by its technical co-operation programme — those who work for projects other than those of their own country (who are called international experts) and those who work for their own country's projects (national experts). Depending on the project's scope and required work, the same person can serve as



IAEA expert assignments in 1993

a national or international expert. In recent years, the component of national experts has increased steadily. In 1993, it reached a level of 25% of all assignments. Such assignments are playing an increasingly important role in technology transfer.

Experts come from all parts of the world. In 1993 alone, the IAEA recruited experts from more than 100 countries and practically all IAEA Member States contributed to the exchange of expert services. During that year, the number of experts recruited and sent on mission reached a peak of nearly 1900. While the majority of the expert assignments is carried out by persons not belonging to the staff of the IAEA, about 20% are staff members. Normally, external staff obtain leave of absence from their employer to work for a limited time for an IAEA technical co-operation project.

About two of every three experts come from industrialized countries. The IAEA is encouraging experts from developing countries to play a larger role in providing expertise to other developing countries, preferably within the same geographical region. This is especially applicable for the Middle East and African regions, which do not yet supply a substantive number of expert services. On the other hand, Europe as a region, supplies nearly half of all expert services. Among individual States, the major providers are the United States and United Kingdom, followed by Germany and Canada. Among developing countries, India, Argentina, Brazil, and Hungary take the lead in the number of experts they provide. *(See graphs.)*

Where do the experts go and how long are they assigned? Most IAEA technical co-operation projects include what is called an "expert component" in their implementation plan. Currently, expert missions take place in some 80 countries in all parts of the world. The geographical scope is likely to increase, as experts are assigned to new IAEA Member States, notably to countries that have emerged from the former Soviet Union. Currently, the highest numbers of experts are recruited for assignments in Europe, followed by the Asia and the Pacific region, and Latin America. Recruitment for assignments to the Middle East and African regions is lower than one would expect.

Over the past 10 years, the average length of an expert mission has fallen from one month to two weeks. At the same time, the number of missions has more than doubled. This reflects the increasing self-reliance of developing countries, enabling the scheduling of shorter and more specialized missions. It is also reflects greater international co-operation, including more workshops, training courses, and co-ordination meetings, during implementation of technical co-operation projects.

The process for recruiting experts

The recruitment and fielding of experts for the IAEA technical co-operation programme is a complex task, entailing numerous administrative steps which involve multiple partners. These partners include the IAEA, the recipient and the donor countries, and often other international agencies such as the Food and Agriculture Organization (FAO), World Health Organization (WHO), and United Nations Development Programme (UNDP). In order to recruit and field the right expert at the right time, close interaction is required with governments, recruitment sources, project counterparts, UNDP offices, and most importantly, the expert.

The terms of reference for an expert assignment are summarized in a job description which serves as the base for recruitment. Upon receipt of a job description from the responsible project officer, the IAEA Experts Section approaches suitable candidates. This is done in accordance with the various procedures requested by the sending and receiving governments and based on the nature of the assignment. The sources involved in locating expert candidates to undertake assignments in technical co-operation projects may differ from case to case. Main contributors are the recipient country itself which has specific experts in mind; the IAEA technical officer responsible for a specific project, suggesting experts or institutions in which experts could be located; and the Experts Section's own roster of experts, a computerized file of more than 5000 expert names and their field of expertise.

In the case of a candidate who has never served on an IAEA project before, his or her curriculum vitae is sent to the relevant technical officer for evaluation and classification for the experts roster. Suitable candidates are then submitted to recipient countries for their approval, according to UNDP and government procedures. It is usually at this stage that the Experts Section informs the recipient government of the dates on which the expert would be available to carry out the proposed assignment.

Subject to official clearance by the governmental authorities concerned, or after receipt of such a clearance, depending on time available to complete recruitment arrangements, the Experts Section makes an offer to the expert. This might include a modest honorarium for the services to be delivered, as well as per diem rates and travel expenses. At this stage, the expert receives relevant information regarding visa and medical requirements, as well as briefing and reporting instructions.

Once appropriate clearances have been received and the offer is accepted by the expert, a contract is prepared between the expert, or the expert's permanent employer or sponsoring organization, and the IAEA. There are several types of contracts, depending on the function of the expert and the duty station. The average duration of a contract is two weeks; few contracts are longer than one month. For projects of a more lasting nature, 1-year contracts, with possibility of extension, might be offered to some experts.

Once the Experts Section has informed the local UNDP office and the counterparts of the expert's travel and related itinerary, its major work is done. Now it is up to the expert and the counterpart organization to make the mission a success. Due to the short contractual time, work typically begins at once. Direct communication between the expert and national counterparts usually clarifies the objectives and work plan before the trip begins. Both sides then can concentrate on the work at hand as soon as the expert arrives. Often, one expert assignment can only cover a small aspect of a technical co-operation project. Team and follow-up missions are characteristic for larger projects which, in the end, might have a stronger impact on national development.

At the end of a mission, experts file a detailed report with the IAEA. This helps assess the project's progress, identifies problem areas, and recommends action that needs to be considered.

Future directions

The IAEA's technical co-operation programme continually endeavors to strengthen its role as a catalyst and a vehicle for innovation in the provision of technical assistance, and to increase its responsiveness to the evolving needs of the developing world. During the past 2 years, it has been focusing on a policy review to stress nuclear technology transfer at the national level. From past work, basic infrastructures have been created in many countries upon which national development can now build. In this context, the further development and strengthening of radiation protection laws and procedures will play a major role. Additionally, model projects have been launched that are more closely oriented towards national development plans and the practical needs of end users.

Through these avenues and others for effective technical co-operation, "experts without frontiers" will continue to play a key role. They stand to remain a basic component for the transfer of nuclear science and technology to developing countries. ❐

Fellowships in nuclear science and technology: Applying the knowledge

Nearly 1200 scientists, engineers, and specialists receive training each year under IAEA-supported fellowships and scientific visits

by John P. Colton

Over the past three decades, the combined, co-ordinated efforts of people in dozens of countries have been responsible for the selection, placement, and training of more than 16 000 engineers, scientists, specialists, and technicians under the IAEA's programme for fellowships and scientific visitors.

The numbers alone tell only part of the story. Many of these "alumni" of this co-operative training programme today are managing institutions and agencies in their home countries where nuclear technologies are being used for peaceful applications. Others are in senior positions at international organizations, including the IAEA.

Since its initiation in 1958, the programme has passed through various evolutionary stages. Training today is strongly oriented towards practical learning related to the use of nuclear techniques rather than theoretical studies. Individual training for fellows, for example, is designed to provide an in-depth understanding of a particular technology, whereas the training of scientific visitors reflects the growing interest in the application and commercialization of applied nuclear technologies. The programme covers such subjects as physical and chemical sciences, the use of radioisotopes in marine biology and industrial applications, nuclear power and safety, radiation protection, agriculture, and health.

Over the past quarter century, donor countries have financially supported — at a total cost of more than US $120 million — the training of fellows and scientific visitors from more than 95 IAEA Member States.

Mr Colton is Head of the IAEA Fellowships and Training Section in the Department of Technical Co-operation. A more comprehensive report on the programme is featured in the 1994 edition of the *IAEA Yearbook*, available for purchase from the IAEA Division of Publications.

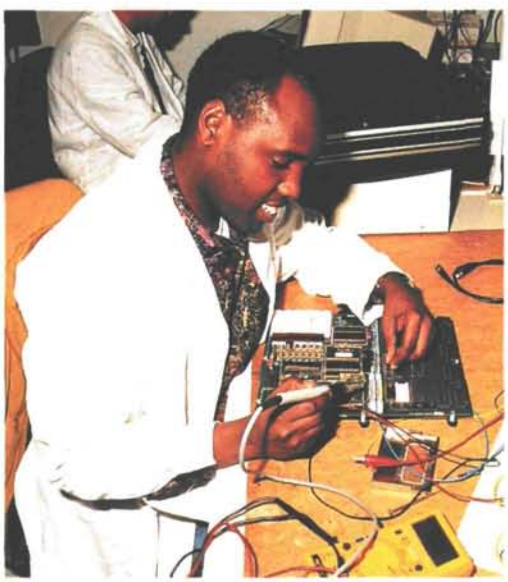
This article reviews the programme, from the standpoint of its historical development, co-operative framework among nominating and host countries, the selection criteria, and plans and expectations for the coming years.

Historical development and trends

Throughout the years, the experiences gained by IAEA trainees have fostered the transfer of scientific and theoretical aspects of nuclear technologies. As importantly, they have given managerial and leadership support to their home institutes and organizations. Interviews with hundreds of fellows and scientific visitors confirm the fact that one of the most important benefits of the training is the practical aspect — to see how something is accomplished, and to apply that knowledge for the benefit of others.

One does not have to look far to find managers who once received IAEA support during their time of education and training. A large number of trainees have become senior leaders in the national and international communities. Within the IAEA's own technical co-operation department, for example, a significant percentage of Directors and Section Heads are former IAEA fellows. Other IAEA technical departments also have senior officers who received technical training with the IAEA's assistance. Additionally, many heads of national atomic energy authorities and institutes have benefitted from the Agency's training programme during their careers. Also interesting to note is that several members of the IAEA Board of Governors and their primary staff members are among the distinguished alumni of the fellowship and scientific visitors programme.

The programme has gone through various stages of development. During the late 1950s and early 1960s, countries principally were interested in having individual scientists receive



Scenes from IAEA-supported training of scientific fellows and visitors. **Training covers a range of nuclear applications in fields of electricity production, food and agriculture, health and medicine, and industry and earth sciences, for example.**

NORTH AND LATIN AMERICA: 1043/1396

***North America:* 0**/898

Canada: **0**/277
United States: **0**/621

***Latin America:* 1043**/498

Argentina: **115**/116
Bolivia: **23**/0
Brazil: **137**/116
Chile: **86**/45
Colombia: **57**/10
Costa Rica: **31**/10
Cuba: **120**/39
Dominican Republic: **22**/0
Ecuador: **82**/5
El Salvador: **17**/2
Guatemala: **57**/23
Haiti: **1**/0
Honduras: **0**/1
Jamaica: **4**/0
Mexico: **101**/94
Nicaragua: **15**/0
Panama: **20**/1
Paraguay: **17**/0
Peru: **62**/1
Uruguay: **31**/23
Venezuela: **45**/12

ASIA AND PACIFIC: 1701/683

Australia: **0**/134
Bangladesh: **131**/4
China: **329**/59
Democratic People's Republic of Korea: **30**/0
India: **3**/162
Indonesia: **186**/31
Japan: **0**/106
Korea, Rep. of: **116**/23
Malaysia: **130**/44
Mongolia: **82**/0
Myanmar: **35**/1
New Zealand: **0**/5
Pakistan: **149**/39
Philippines: **86**/7
Singapore: **11**/0
Sri Lanka: **49**/1
Thailand: **167**/62
UK (Hong Kong): **6**/4
Viet Nam: **191**/1

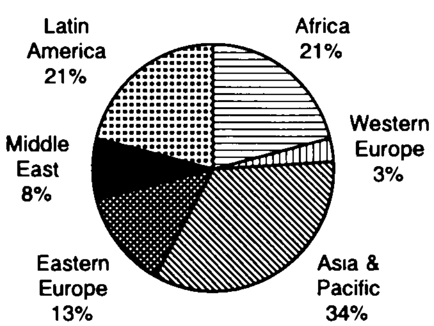
Regional Overview 1989-93: IAEA Fellowships and Scientific Visitors

The tables on this and the facing page provide a regional overview of the countries of origin and the training sites of IAEA-supported fellows and scientific visitors. The number of IAEA fellowships and scientific visits placed from each country (i.e. where fellows and scientists came from) is in bold face. The number of fellowships and scientific visits that each country, or institution, hosted (i.e. where the training was provided) is in normal typeface.

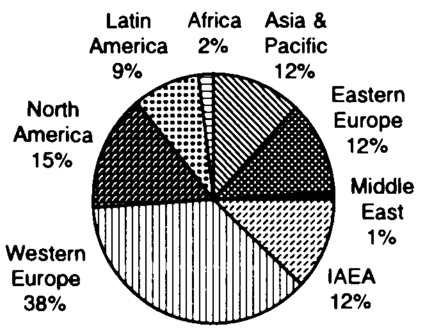
All told during the 1989-93 period, countries requested 4905 fellowships and scientific visits. During the same period, countries hosted the training of 5835 fellows and scientific visitors. (The numbers are not equal for various reasons, such as the fact that scientific visitors may average two to three visits in different countries.)

The graphs below illustrate the respective shares by region. Evident is that developing countries in a number of regions are hosting a significant number of training sessions.

Where fellows came from
(percent by region)



Where fellows were trained
(percent by region)



WESTERN EUROPE: **138**/2940

Austria: **0**/126
Belgium: **0**/106
Denmark: **0**/57
Finland: **0**/53
France: **0**/343
Germany: **0**/460
Greece: **29**/23
Iceland: **0**/4
Ireland: **2**/4
Italy: **0**/117
Monaco: **0**/7
Netherlands: **0**/113
Norway: **0**/18
Portugal: **24**/9
Spain: **1**/120
Sweden: **0**/93
Switzerland: **0**/25
Turkey: **82**/7
United Kingdom: **0**/516
European Nuclear Research Centre: **0**/36
IAEA: **0**/703

EASTERN EUROPE: **638**/690

Albania: **56**/0
Belarus: **4**/0
Bulgaria: **150**/15
Croatia: **3**/0
Cyprus: **10**/0
Czechoslovakia (former): **51**/59
Czech Republic: **10**/0
Former Yugoslav Republic of Macedonia: **1**/0
Germany (former GDR): **0**/20
Hungary: **79**/257
Poland: **101**/140
Romania: **127**/4
Russian Federation: **0**/52
Slovak Republic: **7**/0
Slovenia: **3**/7
Ukraine: **12**/7
USSR (former): **0**/90
Yugoslavia (former): **24**/39

AFRICA: **1012**/93

Algeria: **67**/6
Burkina Faso: **0**/7
Cameroon: **26**/0
Côte d'Ivoire: **18**/2
Egypt: **158**/47
Ethiopia: **44**/0
Ghana: **67**/5
Kenya: 49/8
Madagascar: **21**/0
Mali: **26**/0
Mauritius: 7/0
Morocco: **79**/4
Namibia: **2**/0
Niger: **23**/1
Nigeria: **134**/2
Senegal: **17**/1
Sierra Leone: **16**/0
South Africa: **0**/5
Sudan: **72**/1
Tunisia: **34**/2
Tanzania: **54**/2
Uganda: **24**/0
Zaire: **24**/0
Zambia: **39**/0
Zimbabwe: **11**/0

MIDDLE EAST: **373**/33

Afghanistan: **8**/0
Iran: **124**/2
Iraq: **19**/0
Israel: **0**/20
Jordan: **45**/1
Kuwait: **0**/2
Lebanon: **1**/0
Libyan Arab Jamahiriya: **83**/0
Saudi Arabia: **15**/1
Syria: **76**/7
United Arab Emirates: **1**/0
Yemen: **1**/0

academic training. Assistance was given to those countries who were creating a broad theoretical base in all scientific fields, but concentrating primarily on nuclear power applications and the fuel cycle.

In the intervening three decades, national needs and expectations have matured, and today's training programme focuses mainly on applied technologies. This is in keeping with overall IAEA policies requiring that its programmes are closely tied to national goals and objectives. And rather than importing general nuclear expertise, as used to be the case, countries now are interested in locally cultivating their own.

Significant modifications in the ways and means of implementing training also have taken place. The application format used to be simply a personal history form including a statement as to the type of training being requested. Most candidates had even been accepted by the host institutes before asking for IAEA assistance. Their own national nuclear authorities played little or no role in the entire nomination and placement process. Requests were reviewed by a small group of IAEA staff members and awarded mainly on the merits of each candidate's personal qualifications. In a few cases, the IAEA became involved with host countries, but in the majority of cases, the fellows were on their own when it came to, for example, obtaining visas, making travel arrangements, or corresponding with host institutes. Often, as they lacked institutional endorsement or support, the candidates had no work position to return to and had to find jobs once they returned to their home country.

The greater emphasis on locally produced expertise has helped to change this picture. National authorities now actively participate in the nomination process, determine the priorities of training and commit full support by salary continuation and re-employment rights. The host countries respond faster to proposals for training, assist with visa requests, qualify and monitor host institutes for adequacy and quality of training, and arrange most of the administrative support. The IAEA, for its part, has developed new procedures for review, evaluation, selection, placement, and training support. These modified procedures and support mechanisms assist the IAEA in implementing its goals of meeting the requesting country's needs in a timely, cost effective, and quality manner.

The IAEA technical co-operation process. The placement of fellowships and scientific visitors is part of the IAEA's overall process of providing technical assistance to developing countries. The IAEA responds to national requests for training assistance on a 2-year cycle. The requests are submitted by governmental authorities in the form of a technical co-operation project. The project document is reviewed and evaluated by the IAEA's Division of Technical Co-operation Programmes in consultation with technical officers (specialists in the technology) and the Division of Technical Co-operation Implementation (specialists in equipment purchase, placement of fellows and scientific visitors, and contracting experts). Recommended projects are submitted to the Board of Governors for approval following a review by the Board's Technical Assistance and Co-operation Committee. Once it approves the 2-year cycle programme, the Board authorizes project funding on an annual basis (i.e., the programme for 1993-94 has funds approved in December 1993 for 1994). The project normally consists of requests for expert services, equipment purchases, fellowships and scientific visitors, and training courses.

For the 1995-96 programme cycle, approximately 1000 new project requests were submitted, and it can be expected that about half of them will be approved. The component for fellowships and scientific visits normally represents about 20% to 25% of the total resources allocated to the project. For 1994, this component was budgeted at more than US $18 million including approximately US $8 million carried over from prior years. More funds typically are available because of the continuing nature of fellowship training and the possibility of carrying over funds.

Fellowships and scientific visitors: Selection and training

Support supplied through the IAEA' s technical co-operation training programme has played a key role in advancing the peaceful applications of the atom. Training normally takes the form of attendance at academic institutions, participation in research groups, on-the-job training in a specific technology, short visits to research facilities, or combinations of these. The host countries and their institutes are thus integral to the process of technology transfer.

Placement of fellows and scientists was relatively easy during the IAEA's early years, when most requests were for advanced university studies. The maturing of research and industrial institutions in developing countries, however, has shifted emphasis towards more specialized practical training. This interest in applied technology is seldom matched by existing university courses and therefore special arrangements have to be made with host institutions. While this has made placement more difficult and time consuming, the end result is that training becomes more valuable in terms of technology transfer.

Selection criteria. Applicants to the IAEA's fellowship programme must be well qualified and motivated. In addition, the IAEA evaluates applications to ensure that the objectives of the training are clearly identified; the type of training being sought is explained and that proposed host institutes are identified; the national supporting commitments are stated; and, that both the candidate and national authority assure that the benefits of the training will be implemented within the requesting country. An additional factor is language certification. Experience has shown that in approximately one-third of all cases, language is the major limitation to successful training. Language capability is so important that many countries have established their own minimum language levels which must be met before they will accept training candidates.

During the review, selection, and placement process, about 40% of the candidates will not be selected or will be withdrawn from the process. Typically, this is because requirements have not been met, the status of the applicant has changed, or a suitable host country has not been found. Main specific reasons include the lack of professional or language skills; equivalent training is available in the home country; the requests are not related to a technical co-operation programme; and, the request is outside of the Agency's sphere of responsibility.

Not surprisingly, communication has become increasingly important in the selection process in light of improved telecommunications capabilities. This fact elevates the nominating country's role, since it must monitor the status of its applicants to keep the IAEA promptly and properly informed, and to prevent time and resources from being wasted. Much effort, for example, has been expended in the past on placing some candidates, only to find out later that they were either no longer available for training, had accepted other opportunities, or had changed professional positions.

The requesting authorities and the fellow are notified as soon as the fellowship is awarded and again when an acceptable host institution indicates that it is prepared to supply the requested training. The IAEA then sends a letter of appointment to the candidate, providing information on the proposed study programme and other details concerning the stipend, allowances, and insurance coverage, for instance. Also sent is guidance concerning travel and visa arrangements and preparing for the stay in the host country.

Overall the time span between the IAEA's receipt of a nomination and the placement offer has been shortened considerably. The average time from receipt of the application until award, subject to successful placement of the fellowship is about two to three months, down from eight months in 1990. Placement negotiations with host countries are averaging four months, down from six in 1990. Thus, the average time from the receipt of the application until the start of training is approximately 10 months, significantly below the average 18 months in 1990.

Developing countries as hosts. Increasingly, developing countries are serving as the hosts for fellowship training and scientific visits. A number of these countries have established the technological base needed to supply quality training. Often, the training can be done at lower costs. Additionally, the training conditions in developing countries are frequently more representative of those in the trainee's home institute.

Future plans and expectations

By the year 2000, an estimated 100 IAEA Member States are expected to request technical assistance, including fellowships and scientific visits. In 1958, just after the IAEA came into being, only 11 countries received technical assistance. Today, 85 countries do.

Given the projected growth of requests, the number of IAEA fellows and scientific visitors that are trained each year should increase to between 1400 and 1600 by the end of this decade. If these projections hold, they will push the total number of IAEA-trained fellows and scientists to more than 25 000 by the year 2000. The type of training offered will remain predominately short and intense, and include applied on-the-job training. Advanced academic training will continue to be made available for those from lesser developed countries where there is a need to establish a firm base of human resources in support of technological development.

If past is prologue, the IAEA's support of training opportunities for scientists, engineers, specialists, and technicians from developing countries will remain a valuable component of efforts to effectively transfer the atom's many peaceful applications. In the process, it will help develop a good many of tomorrow's national and international leaders in the nuclear field. ❐

IAEA Board of Governors meetings

At its meetings in early December 1994, the IAEA Board of Governors considered matters related to the Agency's technical assistance and co-operation programme for 1995-96: safeguards; illicit trafficking of nuclear material *(see related item, page 61)*; and radioactive waste management.

Safeguards in the DPRK. On 11 November, the Board met in special session regarding the implementation of safeguards in the Democratic People's Republic of Korea (DPRK). The meeting was in response to developments related to the agreed framework that was signed 21 October 1994 in Geneva between the United States and the DPRK.

The Board authorized the IAEA Secretariat to act upon the UN Security Council request to the Agency concerning inspections in the DPRK, including monitoring the freeze of its graphite-moderated reactors and related facilities. The request was contained in a statement of the President of the UN Security Council on 4 November 1994. The Board further welcomed the fact that the DPRK will remain in the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) and that it will come into full compliance with the IAEA-DPRK safeguards agreement.

IAEA inspectors remain at the DPRK's nuclear complex at Nyongbyon. In mid-November, an IAEA technical team visited the DPRK for discussions with authorities there regarding the verification measures that are needed in accordance with established IAEA practices.

Technical co-operation. At its December meetings, the Board received a report from its Technical Assistance and Co-operation Committee on the provision of technical assistance to be undertaken during the 1995-96 period. The proposed programme covers assistance to more than 80 countries, as well as regional and interregional projects.

IAEA Director General sees new tasks ahead

The years 1995 and beyond will hold new tasks for the IAEA, in the view of the Agency's Director General Dr. Hans Blix.

In addressing the 49th General Assembly of the United Nations in New York on 17 October 1994, IAEA Director General Hans Blix said that new expectations and demands for both verification and safety-related services are being placed upon the Agency in response to global nuclear developments.

Dr. Blix noted that, in the context of the conference in April/May 1995 to review and extend the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), the IAEA would present detailed reports about the way in which it is strengthening its safeguards verification system. He said the IAEA will also report to the NPT Conference on its activities in support of the transfer of nuclear science and technology for peaceful purposes. In the safeguards field, the Director General cited several important developments which call for expansion of IAEA activities, including the successful negotiation of comprehensive safeguards agreements with States of the former USSR.

Among the new verification activities for the IAEA, Dr. Blix noted that the United States has begun a process for the eventual submission to IAEA inspection of all US fissile material no longer needed for defense purposes. He also said the IAEA has set up a working group to examine relevant issues related to the proposed cut-off agreement for the production of highly enriched uranium and plutonium for weapons purposes. He further pointed out the IAEA's technical advisory role regarding future verification arrangements for a Comprehensive Test Ban Treaty. New expectations in the international community further are leading toward a stronger global legal framework for the safe development of nuclear energy, Dr. Blix said. He noted that governments recently have adopted the International Convention on Nuclear Safety; that the IAEA Board of Governors earlier this month adopted new international basic radiation safety standards; and that consensus exists for a convention on the safe management and disposal of radioactive waste. He also described significant changes in the orientation of the IAEA's programmes for transferring nuclear science and technology.

In addition to his statement at the United Nations, Dr. Blix addressed a number of distinguished audiences in September and October 1994: the Council on Foreign Relations in Washington, DC; the Congress of the European Nuclear Society in Lyon, France; and the 38th regular session of the IAEA General Conference in Vienna, Austria.

Copies of the Director General's statements are available from the IAEA Division of Public Information.

Experts meeting on illicit nuclear trafficking

A group of some 96 experts from 46 countries and three international organizations attended a meeting to discuss measures against illicit trafficking of nuclear material and radioactive sources 2-3 November 1994 in Vienna.

The experts voiced widespread support for the IAEA to intensify its activities and to examine in detail additional actions at the international level. The meeting was called by IAEA Director General Hans Blix in response to a resolution of the IAEA General Conference. *(See related item on page 63.)*

The meeting shed much light on the issue of illegal trafficking of nuclear materials and radioactive sources. While confirming that the primary responsibility for preventing and responsing to such events rests with the governments concerned, the meeting urged that practical and effective complementary measures be taken at the international level — particularly by and through the IAEA — to address the problem of illicit trafficking.

Trafficking must first be combatted at its source, the experts noted. They proposed areas where the IAEA could intensify its activities. These included a number of measures to help States improve their national systems of accountancy and control and their systems of physical protection of these materials, and to develop a reliable base of information on incidents to assist decision makers and to better inform the public.

Taking into account the comments, suggestions, and proposals put forward and reviewed at the experts meeting, the IAEA Secretariat presented recommendations for action to the IAEA Board of Governors at its December 1994 session.

IAEA Director General Blix honoured

The European Atomic Forum has presented its 1994 Foratom Award to IAEA Director General Hans Blix. The Award, which was established in 1978, is presented every 4 years to individuals who have made major contributions to peaceful uses of atomic energy in Europe and the world at large. It was presented to Dr. Blix on 4 October 1994 at the Congress of the European Nuclear Society in Lyon, France, by Dr. Bill Wilkinson, President of the European Atomic Forum.

In presenting the Award, Dr. Wilkinson paid tribute to Dr. Blix's "courageous and effective advocacy of nuclear power as an environmentally benign source of electricity." He also commended him for the political impartiality, administrative and diplomatic skills, and ability to secure trust among national leaders. In his acceptance remarks, Dr. Blix thanked Dr. Wilkinson warmly for the honour represented by the Award, which he accepted not just personally but on behalf of the IAEA staff who worked with him in pursuit of the Agency's goals. He said he remained profoundly convinced of the many benefits for humanity of nuclear energy's versatile peaceful applications, including power generation. He stressed the increasing relevance of the international dimensions of the use of nuclear energy — the need for international verification of the peaceful nature of nuclear installations and the need for international rules and services to complement national measures to ensure safety in the use of nuclear power. In expressing confidence about nuclear power's future, he said that the advantages of nuclear power as a valuable part of the overall energy mix would become increasingly apparent.

International convention on nuclear safety

More than 50 countries have signed the International Convention on Nuclear Safety since it opened for signature in September 1994, with one, Norway, already depositing its instrument of ratification with the IAEA. The Convention — the first legal instrument that directly addresses the issue of safety of nuclear power plants worldwide — opened for signature on 20 September 1994 at the IAEA General Conference in Vienna.

The Convention applies to land-based civil nuclear power plants and obliges Contracting Parties to establish and maintain proper legislative and regulatory frameworks to govern safety. Through the Convention, States commit themselves to the application of fundamental safety principles for nuclear installations, and agree to participate in periodic peer review meetings to submit national reports on implementation of their obligations.

The Convention will remain open for signature at IAEA headquarters until its entry into force. This will be on the 90th day after the twenty-second instrument of ratification is deposited with the IAEA, which is the

Depositary of the Convention, including the instruments of 17 States that each have at least one nuclear installation which has achieved criticality in a reactor core.

Fifty-two countries have signed the Convention as of 15 November 1994. They are Algeria, Argentina, Armenia, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, China, Cuba, Czech Republic, Denmark, Egypt, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, Republic of Korea, Luxembourg, Mexico, Netherlands, Nigeria, Nicaragua, Norway, Pakistan, Peru, Philippines, Poland, Portugal, Romania, Russian Federation, Slovak Republic, Slovenia, South Africa, Spain, Sudan, Syria, Sweden, Tunisia, Turkey, Ukraine, United Kingdom, and United States.

Nuclear techniques in agriculture

Scientists engaged in agricultural and environmental research around the world met in Vienna 17-21 October 1994 at the International Symposium on Nuclear and Related Techniques in Soil Studies on Sustainable Agriculture and Environmental Preservation. The symposium was jointly organized by the IAEA and Food and Agriculture Organization (FAO) of the United Nations and took place at a time when the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture marked its 30th anniversary of service.

The symposium featured studies on soil/plant relationships in sustainable agricultural systems and research associated with environmental pollution problems. Specific technical topics included soil fertility, plant nutrition, water management, crop production, and environmental aspects related to nutrient and water management in crop production studies.

A ground breaking ceremony for construction of the new Clean Laboratory for Safeguards was held 14 October 1994 at the IAEA Laboratories in Seibersdorf, Austria. The Clean Laboratory, which is expected to be operational in late 1995, will be specifically dedicated to the analysis of environmental samples and measurements for safeguards purposes. Funding for the facility includes an extrabudgetary contribution from the United States of US $1.5 million. Participating in the ceremony were US Ambassador John Ritch III *(top photo, centre)*; Mr. Bruno Pellaud, IAEA Deputy Director General for Safeguards *(third from left)*; Mr. Sueo Machi, IAEA Deputy Director General for Research and Isotopes *(second from left)*; Mr. Wim Breur, Director of the IAEA Division of General Services *(left)*; Mr. Pier Danesi, Director of the IAEA's Laboratories at Seibersdorf *(second from right)*; and Mr. Stein Deron, Head of the Safeguards Analytical

Highlights of the 1994 IAEA General Conference

Prof. Alec Jean Baer of Switzerland, elected President of the IAEA General Conference (*Credit: Pavlicek, IAEA*)

High-level governmental representatives, including 20 ministers from 100 Member States of the IAEA, attended the 38th regular session of the IAEA General Conference 19-23 September 1994 in Vienna. Delegates elected as President of the Conference Professor Alec Jean Baer of Switzerland. Actions were taken in a number of key areas of global nuclear development. Topics addressed included those related to:

IAEA safeguards in the DPRK. Expressing their "continuing concern" over the DPRK's non-compliance with its safeguards agreement with the IAEA, Member States adopted a resolution urging the DPRK to co-operate immediately with the Agency in the full implementation of the agreement and to allow the IAEA to have access to all safeguards-relevant information and locations. It further strongly endorsed actions taken by the IAEA Board of Governors and IAEA Director General Hans Blix for their impartial efforts to implement the safeguards agreement. *(Also see Board item, page 60.)*

Monitoring and verification in Iraq. The Conference adopted a resolution that stresses the need for Iraq to co-operate fully with the IAEA in achieving complete and long-term implementation of UN Security Council Resolutions relating to Iraq. It notes that the IAEA, having completed the destruction of the Iraqi nuclear weapons capability, is now in a position to implement its ongoing monitoring and verification plan, and that the IAEA retains the right to investigate further any aspects of Iraq's past nuclear weapons programme, in particular as regards any new information obtained by the IAEA and assessed as warranting further investigations.

IAEA safeguards system. Pointing towards the 1995 Conference on the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) and the IAEA's essential role in applying safeguards under that Treaty and under regional nuclear-weapon-free zones (in Latin America and the South Pacific), Member States adopted a resolution on strengthening the IAEA's safeguards system. It expresses the conviction that IAEA safeguards can promote further confidence among States and thereby help to strengthen their collective security, and it underlines the central importance of effective safeguards for the prevention of nuclear energy's misuse for non-peaceful purposes and for the promotion of co-operation in its peaceful uses. It specifically requests the IAEA Director General to continue with the assessment, development, and, on a voluntary basis, the testing of measures for achieving a strengthened and more cost-efficient safeguards system, and to present to the IAEA Board of Governors in March 1995 proposals toward that end, together with an evaluation of their technical, legal, and financial implications.

Measures against illicit trafficking in nuclear materials. Expressing its deep concern over reports of illicit trafficking and its support for greater preventive measures, the General Conference adopted a resolution that invited IAEA Director General Hans Blix to take a number of actions to intensify the IAEA's activities supporting Member States in this area. They include establishing and upgrading national systems of nuclear material accounting and control; examining additional options available in the field of collecting, verifying, and analyzing data relating to incidents of illicit trafficking and the field of physical protection in conformity with the Agency's Statute; and preparing proposals in consultation with a group of experts designated by Member States and competent international organizations for consideration by the IAEA Board of Governors. *(Also see the item on trafficking on page 61.)*

African nuclear-weapon-free zone. Welcoming the progress made towards the conclusion of a treaty on an African Nuclear-Weapon-Free-Zone, the Conference adopted a resolution commending the African States for their efforts and requesting the IAEA Director General to continue to assist them in this regard.

South Africa's participation in IAEA activities. The Conference adopted a resolution inviting South Africa to resume participation in all activities of the IAEA. It specifically requests the IAEA Board of Governors to review the designation of South Africa to the Board. (As of 1977, South Africa was no longer the designated Member of the Board of Governors for the African Region). In taking the action, the General Conference particularly noted South Africa's dismantlement of its nuclear-weapons programme and its contribution to the evolution of an African Nuclear-Weapon-Free-Zone, and welcomed the new Government of National Unity as representative of all peoples in the country.

Application of IAEA safeguards in the Middle East. The Conference adopted a resolution that calls upon all parties concerned to consider seriously taking the practical and appropriate steps required for the implementation of the proposal to establish a mutually and effectively verifiable nuclear-weapon-free-zone (NWFZ) in the region, and invites all countries concerned to adhere to international non-proliferation regimes, including the Treaty on the Non-Proliferation of Nuclear Weapons, as a means of complementing participation in a zone free of all weapons of mass destruction in the Middle East and of strengthening peace and security in the region. It requests the IAEA's Director General to continue consultations with States of the Middle East to facilitate the early application of full-scope Agency safeguards to all nuclear activities in the region as relevant to the preparation of model agreements, as a necessary step towards the establishment of a NWFZ in the Middle East.

IAEA technical co-operation activities. The Conference adopted two resolutions in this area, one directed at strengthening technical co-operation activities and the other at financing technical assistance. The first resolution *inter alia* requests the Agency's Director General, in consultation with Member States, to present new initiatives to strengthen IAEA technical co-operation activities through the development of effective programmes aimed at improving the scientific and technological capabilities of developing countries in the fields of peaceful applications of nuclear energy and achieving sustainable development. The second resolution expresses concern about the decline in pledges and payments to the Agency's Technical Assistance and Co-operation Fund and requests the IAEA Board of Governors to re-establish an informal working group open to all Member States on the financing of technical assistance.

Technical assistance in the Middle East. The Conference decided to restore technical assistance to Israel and expressed its wish for closer co-operation between the IAEA and Israel in Agency activities in accordance with the Agency's Statute and objectives. (The provision of technical assistance to Israel by the Agency has been suspended since 1981 pursuant to a General Conference resolution.) Additionally, the General Conference, consistent with the Cairo Agreement of 4 May 1994 between the PLO and Israel, mandated the Agency's Board of Governors to identify, through its Technical Assistance Committee, technical assistance projects that could be implemented in the territories under the jurisdiction of the Palestinian Authority through appropriate international organizations.

Radioactive waste management. Member States adopted a resolution that stresses the vital necessity for the IAEA to continue to promote, co-ordinate, and strengthen international co-operation in the field of radioactive waste management. It specifically invites the IAEA Board of Governors and the Director General to start preparations for an international convention on the safety of waste management, and to continue the process of collecting relevant background information that would be useful in drafting the convention. It further calls for increased IAEA activities that assist Member

Dr. Chidambaram of India, the Chairman of the IAEA Board of Governors for 1994-95 (*Credit: Pavlicek, IAEA*)

IAEA Board of Governors for 1994-95

The IAEA's newly constituted Board of Governors for 1994-95 has elected the Governor from India, Dr. R. Chidambaram as Chairman succeeding Ambassador Ronald Alfred Walker from Australia. Dr. Chidambaram is Chairman of India's Atomic Energy Commission. His distinguished record of service also presently includes Chairmanship of the Nuclear Power Corporation of India Ltd. and of the Board of Governors of the Indian Institute of Technology, Vice-Presidency of the Indian Academy of Sciences, and Honorary Professorship in the Jawaharlal Nehru Centre for Advanced Scientific Research.

Elected Vice Chairmen were Mr. Yalçin Sanalan, President of Turkey's National Atomic Energy Authority and Mr. Nikolai Aleksandrovich Shteinberg, Chairman of the Ukrainian State Committee on Nuclear and Radiation Safety.

The 35 Member States on the Board for 1994-95 are Algeria, Argentina, Australia, Brazil, Canada, China, Colombia, Cuba, Egypt, Ethiopia, Finland, France, Germany, Ghana, India, Indonesia, Ireland, Japan, Lebanon, Mexico, Morocco, Pakistan, Philippines, Poland, Russian Federation, Slovak Republic, Spain, Switzerland, Thailand, Tunisia, Turkey, Ukraine, United Kingdom, United States, and Uruguay.

States, particularly developing countries, in strengthening waste management infrastructures and to consider further measures for enhancing global co-operation, including assessment of the impact of land and sea disposal of wastes.

Water resources and production. Two resolutions were adopted relating to this general subject. One resolution is directed at a plan for producing potable water economically. Noting the interest of a number of States in activities relating to seawater desalination using nuclear energy, and the conclusion of an advisory group on the need to establish a programme for identifying options and selecting demonstration facilities, the resolution calls upon Member States in a position to do so to provide expert services and extrabudgetary resources in support of these activities. It further requests the Director General to consult with interested States, and relevant international organizations in and outside the United Nations family, concerning desalination. The second resolution addresses the extensive use of isotope hydrology for water resources management, especially recognizing its valuable role in studying processes related to groundwater recharge, water salination, seepage, and water pollution, for example. It requests the Director General to direct the IAEA's available expertise and resources to a few concrete and cogent projects that would result in a visible impact in improved water resources management through isotope techniques, and urges the IAEA to work in conjunction with other concerned international organizations and solicit their co-operation in such projects.

IAEA budget and extrabudgetary resources for 1995. The adopted resolution approves expenditures for 1995 of US $211.5 million. This represents zero growth in real terms. The Conference further approved the target amount of US $61.5 million for the IAEA Technical Assistance and Co-operation Fund for 1995.

Staffing of the IAEA Secretariat. Two resolutions were adopted. One resolution, in taking note of ongoing efforts, requests the Director General with the assistance of Member States to increase the number of staff members from developing countries, particularly at the senior and policy-making levels. The other requests the Director General to continue efforts to rectify the existing imbalance in the representation of women in the professional and higher categories, particularly at the senior and policy-making levels, as well as in posts requiring scientific and technical qualifications, and from developing countries.

Nuclear safety and radiological protection. The General Conference also took note of a

At the IAEA General Conference, a special exhibit helped commemorate the 30th anniversary of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. Scientists M. Maluszynski and J. Richards *(left)* **briefed IAEA Director General Hans Blix** *(center)* **and FAO Director General J. Diouf** *(third from right)*. **Also attending were Mr. B. Sigurbjoernsson, Director of the Joint Division** *(second from right)* **and Mr. Sueo Machi, IAEA Deputy Director for Research and Isotopes.** *(Credit: Pavlicek, IAEA)*

number of reports on IAEA activities for strengthening nuclear safety and radiological protection. The measures include those related to the implementation of international conventions, including the International Convention on Nuclear Safety which opened for signature during the General Conference; provision of safety services; preparation of safety standards, including the newly adopted Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources; promotion of education and training; provision of technical assistance relating specifically to the safety of nuclear power plants in countries of Eastern Europe and the former Soviet Union; and safety principles for future nuclear power plants. Additionally, the work includes consideration by a Standing Committee of matters related to liability for nuclear damage.

Air transport of radioactive materials

Experts from 17 IAEA Member States and three international organizations recently met in Vienna on proposed regulatory provisions for certain types of radioactive materials in air transport. They specifically reviewed a draft technical document for use in developing regulatory provisions for a new type of package which will be required for air transport of radioactive materials in excess of certain threshold quantities. The provisions are intended for inclusion in the 1996 revised edition of the IAEA Regulations for the Safe Transport of Radioactive Materials.

The meeting reached consensus on most of the proposed test requirements for the new packages, to be known as Type C. These tests include an impact test with an impact velocity of not less than 85 meters per second (most aircraft crashes have generally lower impact speeds than the proposed test criterion); a fire test at a temperature of 800 degrees Celsius for a period of one hour; a 200-metre immersion test designed to enable retrieval of the package from coastal waters or continental shelves; a puncture/tearing test; and a crush test. The proposed test criteria are partly supplementary and in every case more stringent than those of other existing package designs, taking into account the different and more severe environment of mechanical and thermal forces in aircraft crashes.

The IAEA's Regulations for the Safe Transport of Radioactive Materials have long been the basis for regulating national and international road, rail, air, and water shipments of radioactive material. They are subject to a continuous review and revision process to identify areas that can be further improved. In the case of air transport, the review process is designed to limit the probability of serious radiological consequences of accidents involving aircraft carrying packages of radioactive materials; to facilitate planning; and to ensure package recovery.

Radiation technologies in health care

As more countries use ionizing radiation for sterilizing tissues, blood, and other medical products, the need to pool international knowledge about the technology is becoming increasingly clear. At the 3rd European Conference on Tissue Banking and Clinical Application of Grafts, specialists in the field explored legal and ethical aspects, as well as questions of standardization and quality assurance. The conference was organized in Vienna 4-7 October 1994 by the European Association of Tissue Banks (EATB) in co-operation with the IAEA, and with the American Association of Tissue Banks and Asia-Pacific Association of Surgical Tissue Banking.

Scientific sessions focused on a range of technical topics, as well as on general standards for tissue banking and ethical rules that have been proposed by EATB in the interests of harmonization within Europe. Also presented was an overview of the IAEA's programme on radiation sterilization of tissues. The programme has led to the establishment of tissue banks in 13 countries in Asia and the Pacific region, and other banks now are emerging in Africa and South America. To further promote progress, the IAEA has harnessed the support of major world associations involved with the technology. Other applications reviewed at the conference included the use of radiation technologies for sterilizing packaged medical supplies and related products. Worldwide, more than 40% of these products presently are being sterilized using radiation technology, it was reported, with 180 gamma irradiators and about 20 electron beam accelerators in service.

Symposium on spent fuel storage

Safety, engineering, and environmental aspects of spent fuel storage were reviewed at an IAEA international symposium 10-14 October 1994 in Vienna. The symposium included reviews of national approaches to the safe storage of spent fuel; selection of different spent fuel storage technologies; and design, planning, and siting of storage facilities. The total amount of spent fuel accumulated worldwide at the end of 1993 was 140 thousand tonnes heavy metals (tHM) and projections indicate the amount may reach 330 thousand tHM by the year 2010. Considering that part of it will be reprocessed, the amount to be stored by 2010 would be about 215 thousand tHM, or more than twice as much as is now in storage worldwide. Storage problems necessarily are taking on greater urgency in a number of countries.

Spent fuel can be safely stored for long time periods, and some spent fuel now has been in safe storage for more than 30 years in some countries. The symposium reaffirmed the scientific consensus that present technologies for spent fuel storage give adequate protection to the population and the environment, and the continuing interest in studying whether further reductions in risk and greater radiological safety can be achieved. More than 120 participants from 34 countries and four international organizations attended the symposium.

Conference on radiation and society

A major international conference on radiation and society took place in Paris in late October 1994. The week-long conference was organized by the IAEA at the invitation of France and with support from the French Institute for Protection and Nuclear Safety (IPSN). Sessions took place at the new conference centre at the Louvre.

The conference drew the interest and participation of some 400 policy makers, nuclear experts, and the media from 51 countries and nine international organizations. Participants examined a number of case studies including the nuclear weapons legacy, cancer and leukaemia clusters, radioactive waste disposal and the environment, and Chernobyl health effects. They further examined various aspects of the interplay between experts advice, public and media perceptions, and the decision-making process.

Technical sessions covered various topics, including assessment of radiation exposure levels; assessment of radiation health effects; impact of radiation on the environment; perception of radiation risk; and managing radiation risk. Fora for the media and policy makers particularly looked at communication aspects of radiation risk, including discussions of controversial case studies.

More information may be obtained from the IAEA Division of Nuclear Safety or from the communication service of IPSN in Paris, France (telephone 33-1-46-5486-38, or facsimile 33-1-46-5484-51).

Strengthening radiation protection infrastructures

Representatives from IAEA Member States were recently briefed on the status of the programme for strengthening radiation protection, nuclear safety, and radioactive waste management infrastructures in countries of the former USSR. The programme was launched in 1993 as a joint phased initiative between the IAEA and the United Nations Development Programme (UNDP) for information exchange, preparation of country assistance packages, and their implementation.

The programme is now in its second phase and the briefing focused on assistance packages which have been developed for eight countries of the former USSR, namely Belarus, Estonia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, and Uzbekistan. The country assistance packages are based on information gathered to date from the forum held from 4-7 May 1993 in Vienna and from expert missions and input from local experts. They are aimed at strengthening these countries' legislative and regulatory frameworks; enhancing their regulatory and operational performance; strengthening their capacity for the mobilization and management of external resources; and fostering public awareness and confidence.

Additional financial resources are now being sought to bring the programme into the implementation phase. More information may be obtained from the IAEA Division of Nuclear Safety.

Croatia: Collaboration with IAEA

The IAEA has inaugurated the Laboratory for Nuclear Microanalysis at the Institute Ruder Boskovic in Croatia as one of its collaborating laboratories in the field of accelerator-based analytical techniques. This enables the IAEA to provide advanced analytical services and training, particularly in connection with a number of its programmes.

In Croatia, a beamline analytical facility has been constructed and installed on the existing Van de Graaf accelerator. The collaboration provides for the IAEA's cost-free use of the machine, together with supporting facilities such as sample preparation and an electronic laboratory. It further covers the proton microprobe, installed on the same accelerator and used for elemental concentration mapping on a micrometer scale. The beamline facility can also be used to provide advanced analytical services to scientists from IAEA Member States and their institutions. In addition, training and maintenance of accelerator equipment can be provided for developing countries possessing accelerator facilities. Applications include air pollution analysis and multi-elemental analysis of environmental samples; medical and biological applications; solid state and material analysis; and agriculture studies.

Argentina: Nuclear training course

Argentina hosted an IAEA interregional training course from 31 October to 2 December 1994 on quality assurace for nuclear power plant operations. Thirty participants from 12 countries attended. The training course provided participants with information on current methods and techniques that help in the attainment of safety and reliability of nuclear power plants. Lectures were provided by experts from Argentina, France, Mexico, Spain, United Kingdom, United States, and the IAEA.

Ukraine: Safeguards agreement signed

A comprehensive safeguards agreement between the IAEA and Ukraine was signed at the Agency's headquarters on 28 September 1994. The agreement was signed on behalf of the IAEA by Director General Hans Blix and on behalf of Ukraine by Mr. Nikolai A. Shteinberg, Chairman of the Ukrainian State Committee on Nuclear and Radiation Safety. The safeguards agreement was approved by the IAEA Board of Governors in September 1994. It covers all nuclear material in all peaceful nuclear activities within the territory of Ukraine, under its jurisdiction or carried out under its control anywhere. The agreement will enter into force upon the IAEA's receipt of written notification by Ukraine that Ukraine's statutory and constitutional requirements have been completed. The agreement would remain in force until superseded by an agreement between Ukraine and the Agency for the application of safeguards in connection with the Treaty on the Non-Proliferation of Nuclear Weapons (NPT).

Ukraine's Minister of Foreign Affairs had informed the IAEA in September 1992 of Ukraine's intention to adhere to the NPT as a non-nuclear-weapon State. Since that time, the IAEA has taken a number of measures necessary for the application of NPT safeguards in Ukraine, including technical visits conducted with a view to performing verification activities similar to those provided in NPT-type safeguards agreements. On 16 November 1994, the Ukrainian parliament voted to sign the NPT.

Yemen: New member of IAEA

The Republic of Yemen became a new member of the IAEA on 14 October 1994 by depositing its instrument of acceptance of the Statute. Yemen's application for membership had been approved by the IAEA General Conference in 1991. As of November 1994, the IAEA had 122 Member States.

Kazakhstan: HEU transfer to USA

The IAEA was informed in late November 1994 that a quantity of highly enriched uranium was moved from Kazakhstan to the United States where it will be subject to IAEA safeguards inspection. The IAEA was informed in advance of the transfer. Kazakhstan is a party to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) and as such has signed a safeguards agreement with the IAEA which will provide for inspections.

Italy and China: ICTP Prize awarded to Chinese scientist

The International Institute for Theoretical Physics in Trieste, Italy, has awarded its 1994 ICTP Prize in the fields of mathematics, nuclear physics, plasma physics, and other fields of physics to Dr. Chao-Jiang Xu from Wuhun University in China. The Prize consists of a medal, a diploma, and US $1000. ICTP Prizes are awarded annually in recognition of outstanding and original contributions within mathematics and physics. Candidates must be nationals of developing countries, working and living in developing countries.

The ICTP also has announced that information about its activities now is available over computer lines. Users of electronic mail, for example, should send a message to smr@ictp.trieste.it. The ICTP's conventional postal address, for those who prefer to write a letter, is P.O. Box 586, 34100 Trieste, Italy.

Canada: ASTM international workshop

Quebec will be the site of the third international workshop on dosimetry for radiation processing, being organized from 1-6 October 1995 by the American Society for Testing and Materials (ASTM). The workshop includes hands-on sessions at the Canadian Irradiation Centre and lectures by internationally recognized experts in the field. Participants are expected to include irradiator operators, quality assurance personnel, researchers, dosimeter suppliers, medical device manufacturers, and food processors. More information may be obtained from Mr. John Rickey, Far West Technology, Inc., 330 D S. Kellogg, Goleta, CA 93117 USA. Fax: 805-964-3162.

Japan: Radiotherapy seminar

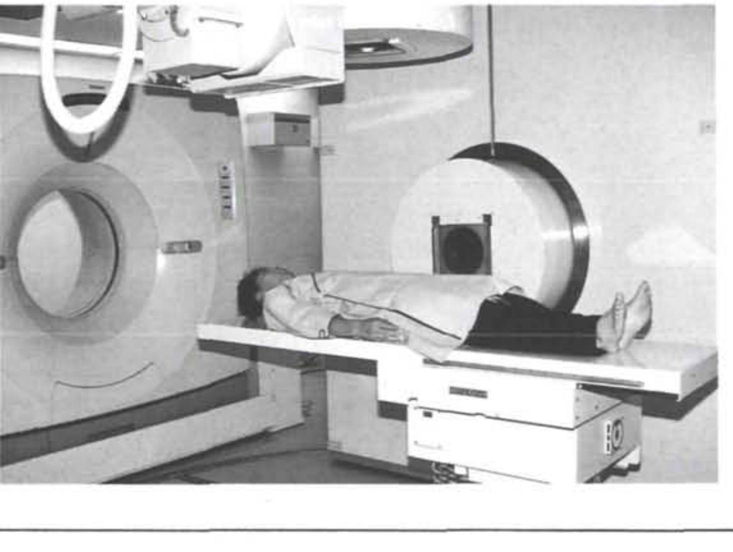
Scientists in Japan have started clinical applications of the world's first heavy-ion accelerator, called HIMAC, dedicated for medical uses, specifically radiotherapy of cancer.

Scientific reports that highlighted HIMAC's development and clinical use were presented in November 1994 at the International Seminar on Applications of Heavy Ion Accelerators to Radiation Therapy of Cancer. The seminar — which was attended by 160 specialists from 19 countries — was organized in co-operation with the IAEA by the National Institute of Radiological Sciences (NIRS) in Chiba, Japan. In parallel with the seminar, the IAEA held a consultants' meeting to obtain recommendations regarding its future activities concerning the application of heavy charged particles in cancer treatment.

Technical sessions at the seminar covered topics related to particle radiotherapy of cancer; beam delivery of the irradiation system and radiation dosimetry; treatment planning; the role of experimental biology for radiation therapy; and clinical results and protocols for the treatment of specified human tumours. Particular emphasis was placed on the design of future facilities for heavy charged particle radiotherapy. Participants underscored the need for enhanced international co-operation in the field. Areas where greater co-operative work is needed include research on the physics and biology of heavy charged particles, and the intercomparison of clinical results to enable more effective and safer radiotherapy of cancer patients. In response to expectations expressed at the seminar, NIRS offered to open the HIMAC facility for international research, as well as for the treatment of patients.

Austria: IIASA soils project

The Austrian-based International Institute for Applied Systems Analysis (IIASA) has launched a new project to develop alternative strategies for limiting the impact of toxic heavy metals on humans and the environment. Although air and water quality have improved markedly in the last two decades, IIASA notes that soil quality has become progressively worse. The nature of soil structures causes toxic chemicals and other persistent organic material to reside longer than in air or water. The IIASA project will study conditions in various regions of the world, with the aim of developing a model applicable in setting policies and in determining effective strategies for controlling soil contamination. More information may be obtained from IIASA in Laxenburg, Austria, A-2361.



Inside the HIMAC facility at NIRS in Chiba, Japan, where three dimensional heavy-ion radiotherapy of cancer patients has been initiated. *(Credit: NIRS)*

NUCLEAR PLANT AGEING. Some 47 technical experts from 20 Member States met in Vienna from 5-9 September 1994 to review draft guidance reports on the assessment and management of ageing of major nuclear plant components. The components include the reactor pressure vessel, vessel internals, pressurizer, and primary piping of pressurized-water reactors (PWRs); the reactor pressure vessel, vessel internals, and metal components of boiling-water reactors (BWRs); the pressure tubes, calandria and calandria supports, and primary piping of Candu reactors; and PWR and Candu steam generators. The reports are expected to be finalized in mid-1995.

WASTE MANAGEMENT SUPPORT. The IAEA Waste Management Section has established a special group responsible for helping developing countries upgrade their waste management infrastructures. Called "Support to Developing Member States", the group will conduct services for direct assistance and co-ordinate technical co-operation activities in waste management. It was established in recognition of the increased need for technical assistance and support in the field of radioactive waste management among developing countries.

NUCLEAR COMMUNICATIONS. A new publication from the IAEA's Division of Nuclear Fuel Cycle and Waste Management looks at key aspects of nuclear activities and public information. Entitled *Nuclear Communications: A Handbook for Guiding Good Communications Practices at Nuclear Fuel Cycle Facilities* (280 Austrian schillings), the book provides a compact source of information for nuclear professionals, identifying and addressing key questions that members of the public may have about different aspects of the nuclear fuel cycle. See the *Keep Abreast* section of this *IAEA Bulletin* for ordering information.

NUCLEAR PLANT SAFETY REVIEW SERVICES. Missions are being planned throughout 1995 for safety reviews of nuclear power plant operations in IAEA Member States. Under the IAEA's Operational Safety Review Team (OSART) programme, 1995 missions include those scheduled in Kazakhstan, France, Japan, Ukraine, Lithuania, Argentina, Sweden, Switzerland, and the United Kingdom. Under the Assessment for Safety Significant Events Team (ASSET) programme, eleven missions for 1995 had been requested as of December 1994, including the first mission incorporating a new ASSET service, peer reviews of plant safety analyses that have been conducted according to ASSET procedures. The year 1995 will see completion of the 100th ASSET mission since the service began. More information about these and other safety services may be obtained from the IAEA Division of Nuclear Safety.

INTERNATIONAL NUCLEAR EVENT SCALE. National officers of countries participating in the IAEA's International Nuclear Event Scale (INES) met in Vienna in late October 1994 to review the system's operation. INES is used to classify significant safety-related events occurring at nuclear facilities on a seven-level scale. The INES meeting noted that the system is proving effective in facilitating common understanding and prompt communication of events. At the same time, they noted that there are some inconsistencies among the participating countries in the application of the INES rating and procedures, a factor expected to be addressed in 1995. Fifty-four countries are participating in the INES information system, which was jointly developed by the IAEA and Nuclear Energy Agency of the Organization for Economic Co-operation and Development and has been in worldwide use since 1992.

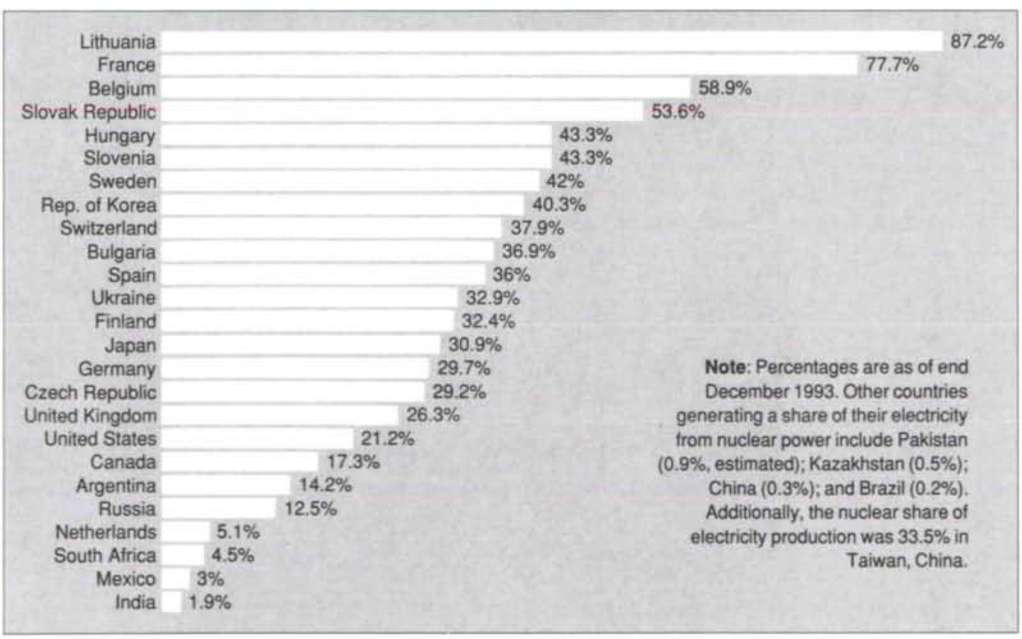
WHO STUDY OF IRRADIATED FOOD. In a detailed new study, the World Health Organization (WHO) concludes that irradiated food produced in accordance with good manufacturing practices can be considered safe and nutritionally adequate. The study is entitled *Safety and Nutritional Adequacy of Irradiated Food* and is the most comprehensive compilation on the subject ever issued by the global health organization. Worldwide, some 40 countries have approved the use of irradiation for various kinds of food, and about 30 of these are applying the technology on a limited commercial scale. More information about the study may be obtained from WHO's Food Safety Unit, 1211 Geneva 27, Switzerland. Fax: 791-0746.

Nuclear power status around the world

	In operation		Under construction	
	No. of units	Total net MWe	No. of units	Total net MWe
Argentina	2	935	1	692
Belgium	7	5 527		
Brazil	1	626	1	1245
Bulgaria	6	3 538		
Canada	22	15 755		
China	2	1 194	1	906
Cuba			2	816
Czech Republic	4	1 648	2	1 824
Finland	4	2 310		
France	57	59 033	4	5 815
Germany	21	22 657		
Hungary	4	1 729		
India	9	1 593	5	1 010
Iran			2	2 392
Japan	48	38 029	6	5 645
Kazakhstan	1	70		
Korea, Rep. of	9	7 220	7	5 770
Lithuania	2	2 370		
Mexico	1	654	1	654
Netherlands	2	504		
Pakistan	1	125	1	300
Romania			5	3 155
Russian Federation	29	19 843	4	3 375
South Africa	2	1 842		
Slovak Republic	4	1 632	4	1 552
Slovenia	1	632		
Spain	9	7 105		
Sweden	12	10 002		
Switzerland	5	2 985		
United Kingdom	35	11 909	1	1 188
Ukraine	15	12 679	6	5 700
USA	109	98 784	2	2 330
World total*	430	337 820	55	44 369

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

Nuclear share of electricity generation in selected countries



POSTS ANNOUNCED BY THE IAEA

SECTION HEAD (94-052), Department of Research and Isotopes. This P-5 post requires a Ph.D. in physics and 15 years of experience in a physics-related field and thorough knowledge of and demonstrated experience in the management of staff and scientific projects. Also required is a broad experience in plasma physics, with emphasis on thermonuclear fusion research, as attested by relevant publications and familiarity with scientific and technological problems of developing countries.
Closing date. 20 January 1995.

REACTOR ENGINEERING SAFETY SPECIALIST (94/053), Department of Nuclear Energy and Safety. This P-4 post requires an advanced degree in nuclear engineering or in a field of related sciences as appropriate to the duties of the post. Also required are at least 10 years of experience in matters related to engineering safety of nuclear power plants, safety analysis, including fire safety, the use of computer codes, and safety research.
Closing date: 20 January 1995.

NUCLEAR POWER PLANNER/ ECONOMIST (94/054), Department of Nuclear Energy and Safety. This P-4 post requires a Ph.D. or equivalent degree in energy technology/economics, or computer sciences/operations research in the field of energy. At least 10 years of experience, at a national or international level, related to energy systems, including energy and electricity demand/supply analysis and planning. Also required is extensive experience in the development and use of databases and models on personal computers related to energy and electricity supply technologies, preferably including economic comparison and treatment of health and environmental aspects.
Closing date: 20 January 1995.

UNIT HEAD/SYSTEMS ANALYST (94/055), Department of Safeguards. This P-4 post requires a university degree, preferably in computer science and at least 10 years of relevant experience. Also required is familiarity with techniques and practices of structured system analysis, design and programming, demonstrable programming, analysis and design experience for large mainframe systems, and management experience. *Closing date: 20 January 1995.*

SYSTEMS ANALYST (94/056), Department of Safeguards. This P-4 post requires a university degree, preferably in computer science and at least 10 years of relevant experience. Also required is knowledge of data processing, in particular techniques and practices of structured system analysis, as well as design and programming. *Closing date: 20 January 1995.*

FRENCH TRANSLATOR (94-061), Department of Administration. This P-3 post requires a university degree or equivalent. Applicants must have at least 3 years relevant experience, with a demonstrated aptitude for translation work, and the ability to handle difficult technical material. *Closing date: 10 February 1995.*

UNIT HEAD (TWO POSITIONS) (94-063), Department of Safeguards. These P-5 posts require an advanced university degree in chemistry, physics, engineering or electronics/instrumentation or the equivalent. At least 15 years combined research, industrial, and safeguards experience in the nuclear fuel cycle, processing of nuclear materials, nuclear material accounting and/or destructive/non destructive analysis. The posts also require experience in safeguards related activities including inspection planning, execution, data analysis and preparation of inspection reports and statements. *Closing date: 10 February 1995.*

SAFETY ASSESSMENT SPECIALIST (94-062), Department of Nuclear Energy and Safety. This P-4 post requires an advanced degree (Master of Science) in nuclear engineering. Also required are ten years of experience in the area of nuclear safety including quantitative techniques and component behaviour. *Closing date: 10 February 1995.*

PROCEDURES AND PERFORMANCE MONITORING ENGINEER (94-064), Department of Safeguards. This P-4 post requires a university degree in electrical or industrial engineering, with specialization in computer sciences. Also required is demonstrated managerial and organizational abilities, technical competence in the field of electronic data processing and of electronics and safeguards instrumentation, technical competence in the programming of interactive database applications. Demonstrated capability in the preparation of technical and management reports, and 10 years of relevant professional experience including some in an international environment. *Closing date: 3 March 1995.*

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

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

Reports and Proceedings

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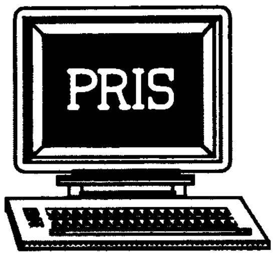


Database name

Power Reactor Information System (PRIS)

Type of database

Factual

Producer

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

IAEA contact

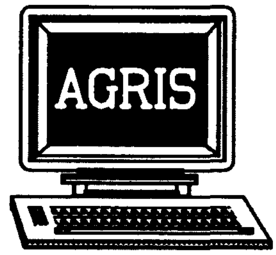
IAEA, Nuclear Power Engineering Section, P.O. Box 100
A-1400 Vienna, Austria
Telephone (43) (1) 2360
Telex (1)-12645
Facsimile +43 1 234564
Electronic mail via BITNET/INTERNET to ID: NES@IAEA1.IAEA.OR.AT

Scope

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

Coverage

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



Database name

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

Type of database

Bibliographic

Producer

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

IAEA contact

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

Number of records on line from January 1993 to date

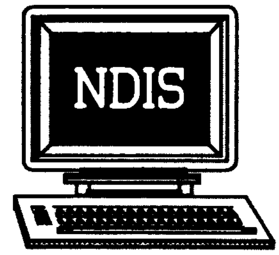
more than 130 000

Scope

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

Coverage

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



Database name

Nuclear Data Information System (NDIS)

Type of database

Numerical and bibliographic

Producer

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

IAEA contact

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

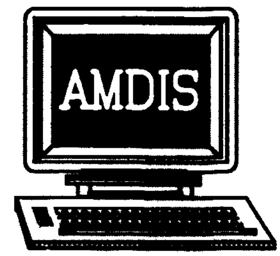
Scope

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

Data types

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

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



Database name

Atomic and Molecular Data Information System (AMDIS)

Type of database

Numerical and bibliographic

Producer

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

IAEA contact

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

Scope

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

Coverage

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

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

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

Database name
International Nuclear Information System (INIS)

Type of database
Bibliographic

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

IAEA contact
IAEA, INIS Section, P.O. Box 100, A-1400 Vienna, Austria
Telephone (43) (1) 2360 2842
Telex (1)-12645
Facsimile +43 1 234564
Electronic mail via BITNET/INTERNET to ID: ATIEH@NEPO1.IAEA.OR.AT

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

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

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

IAEA UPCOMING CO-ORDINATED RESEARCH PROGRAMMES

Improvement of ruminant livestock productivity in developing countries through the use of progesterone radioimmunoassay to increase the efficiency and quality of artificial insemination services
To improve the quality of artificial insemination (AI) services in developing countries through the identification of causes of inefficiency and the implementation of appropriate changes to rectify them. The programme will serve as a vehicle for instituting better training and professional development of AI technicians, as well as for educating farmers on the importance of oestrous detection and improved husbandry practices.

Improved diagnosis and control of foot-and-mouth disease in South East Asia using ELISA-based technologies
To strengthen the capability of the national veterinary services in Asia to contribute effectively to foot-and-mouth disease control by establishing the capacity to use ELISA-based systems for its diagnosis and monitoring.

Randomized clinical trial of radiotherapy combined with mitomycin C in the treatment of advance head and neck tumours
To enhance efficacy of radiotherapy and thus improve cure rates and survival, to increase the competence of the participating parties in the field concerned and to encourage a wider use of this multimodal approach in the oncological practice particularly in the developing countries.

Application of isotope techniques to investigate groundwater pollution
To develop methodologies for monitoring so that inputs to planning, decision and policy making for water resources utilization can be more definitive.

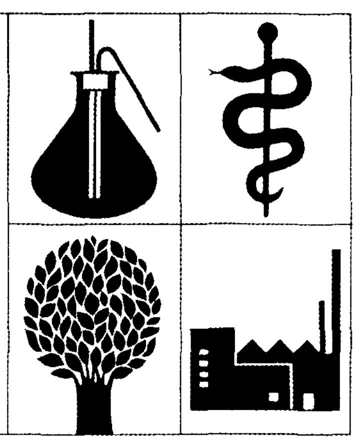
Radiation protection in diagnostic radiology in Asia and the Far East
To provide a detailed knowledge of the collective doses in the participating countrie by a comparison of these doses among countries, and to identify priorities for improvement at the national level.

High temperature on-line monitoring or water chemistry and corrosion (WACOL)
To set up the recommendations in the implementation of measures for the development, qualification, and plant commissioning of methods and equipment for on-line monitoring of significant water chemistry parameters under all operating conditions.

The use of irradiated sewage sludge to increase soil fertility, crop yields, and preserve the environment
To develop technologies for efficient and effective use of decontaminated sewage sludge as an organic fertilizer for increasing and sustaining soil fertility and crop production.

Improvement of new and traditional industrial crops by induced mutations and related biothecnologies
To develop mutagenic approaches for new species and selection procedures for agricultural and industrial requirements, to induce mutations leading to new product compositions and/or qualities, and to diversify the agricultural crop options, facilitating better crop rotations in a more sustainable pattern.

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



IAEA SYMPOSIA & SEMINARS

MARCH 1995

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

APRIL 1995

FAO/IAEA Seminar for Africa on Animal Trypanosomiasis: Vector and Disease Control Using Nuclear Techniques, ***Tanzania*** (3-7 April)

MAY 1995

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

Symposium on Environmental Impact of Radioactive Releases, ***Vienna, Austria*** (8-12 May)

JUNE 1995

Symposium for Crop Improvement, ***Vienna, Austria*** (19-23 June)

AUGUST 1995

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

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

Seminar on the Advancements in the Implementation of the New Basic Safety Standards (Experience in Applying the 1990 Recommendations of ICRP), ***Vienna, Austria*** (14-18 August)

SEPTEMBER 1995

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

OCTOBER 1995

International Symposium on Electricity, Health and the Environment: Comparative Assessment in Support of Decision Making, ***Stockholm, Sweden,*** (23-27 October)

NOVEMBER 1995

Regional Seminar for Asia and the Pacific on Radiation Dosimetry: Radiation Dose in Radiotherapy from Prescription to Delivery, ***Bangkok, Thailand*** (27-28 November)

94-04761

IAEA BULLETIN

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

IAEA MEMBER STATES

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

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

1959
Iraq

1960
Chile
Colombia
Ghana
Senegal

1961
Lebanon
Mali
Zaire

1962
Liberia
Saudi Arabia

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

1964
Cameroon
Gabon
Kuwait
Nigeria

1965
Costa Rica
Cyprus
Jamaica
Kenya
Madagascar

1966
Jordan
Panama

1967
Sierra Leone
Singapore
Uganda

1968
Liechtenstein

1969
Malaysia
Niger
Zambia

1970
Ireland

1972
Bangladesh

1973
Mongolia

1974
Mauritius

1976
Qatar
United Arab Emirates
United Republic of Tanzania

1977
Nicaragua

1983
Namibia

1984
China

1986
Zimbabwe

1991
Latvia
Lithuania
Yemen, Republic of

1992
Croatia
Estonia
Slovenia

1993
Armenia
Czech Republic
Slovakia

1994
Former Yugoslav Republic of Macedonia
Kazakhstan
Marshall Islands
Uzbekistan

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

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