Radiation for better health

In a variety of ways, nuclear techniques help countries strive towards the world's goal of health for all by 2000

by Mohamed Nofal

In a simple way, it can be said that health means absence of disease. Total absence of disease, an ultimate aim of medical science, is not yet feasible. Yet any programme aimed in that direction would try to create environmental conditions that prevent diseases, would attempt to diagnose them early, and would try to treat them in the most cost-effective way when they do occur. In many ways, health-related applications are playing an important role in helping countries work towards the target, as stated by the World Health Organization (WHO), of health for all by the year 2000.

Over the past three decades, the IAEA has built up a range of co-operative projects and programmes that basically cover:*

- *Nuclear medicine.* Radionuclides are used to diagnose and treat diseases and in medical research to understand their nature.
- *Nuclear analytical techniques.* These are used to estimate various trace elements in the body, in our diet, and in our environment. In contrast to nuclear medicine techniques — which probe our internal environment to find clues to diseases that afflict us — nuclear analytical techniques probe our immediate external environment, where changes may be the cause of some diseases.
- *Radiation biology.* This is concerned with altering the external environment by radiation or with eradicating diseases using external radiation. For instance, radiation sterilization of medical supplies destroys micro-organisms, an ubiquitous component of our environment that can threaten health. Radiotherapy tries to kill cancer cells that although internal are functionally extraneous to the human body's needs.
- *Dosimetry.* This deals with the reliable measurement of radiation doses given intentionally to alter the human environment internally or externally.

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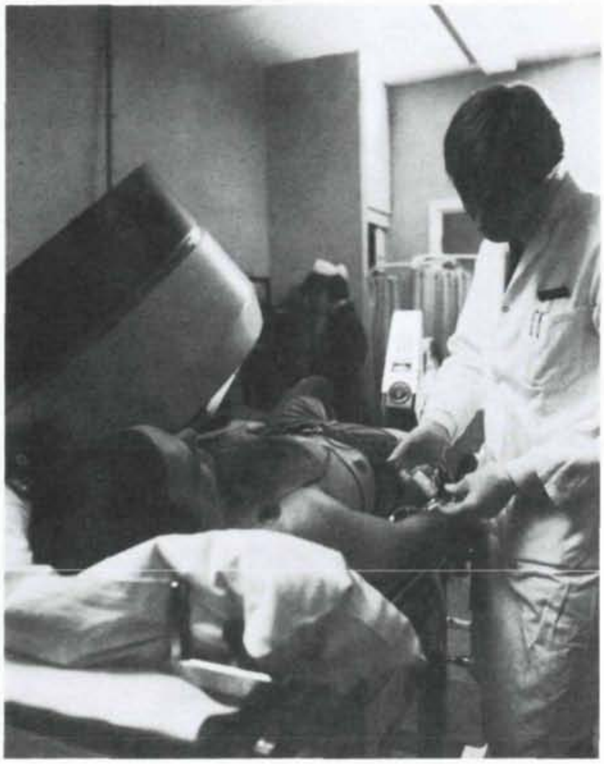
* Fuller reports on the IAEA's programmes in nuclear medicine and related fields appear in the *IAEA Bulletin*, Vol. 28, No. 2 (1986), and Vol. 25, No. 2 (1983).

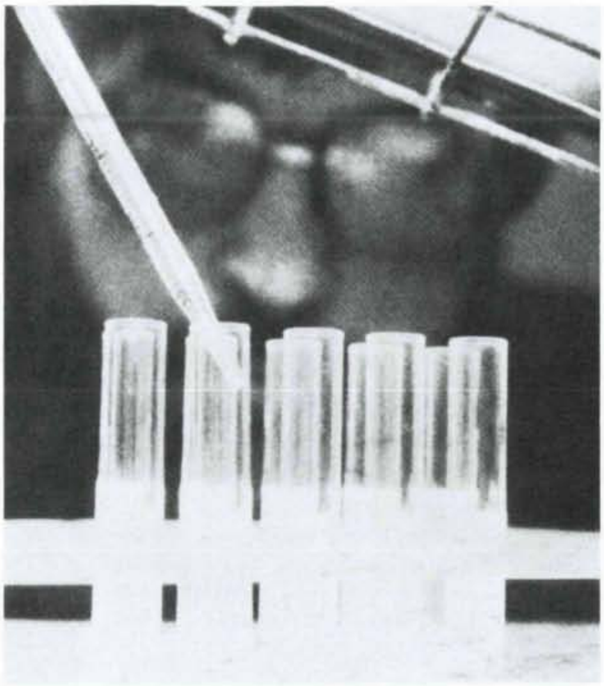


Patient being injected with a short half-life radioisotope used to provide visual display information on the heart rate and lung function. (Credit: UKAEA)

Nuclear medicine

Today, more than 10 million nuclear medicine procedures are performed annually in the United States alone. About one patient in four admitted to a general hospital has a nuclear medicine procedure as a part of the diagnostic process. Not only has the number increased each year, but the variety of procedures is also widening rapidly. Many developing countries are expecting help from the IAEA to institute nuclear medicine facilities in their premier hospitals to support the specialized medical care they provide. Member States that already have some kind of facilities are requesting to update their nuclear medicine services. There were nearly 70 requests from Member States this year for help with their nuclear medicine programmes.

The demand points in two directions: On the one hand, it points toward both a horizontal and vertical spread of nuclear medicine. On the other hand, it points up the growing concern that the future practice of nuclear medicine will require instruments that are more expensive and more sophisticated, and that the needed radiopharmaceuticals and labelled compounds will also become more elaborate, expensive, and often proprietary in nature. The spiralling cost of nuclear medicine, and the basic infrastructural facilities required to sustain it, need a continuous effort on the Agency's part to nurture nuclear medicine in the developing world through technical co-operation support, research contracts, and educational efforts.



Radioisotopes are used to trace enzymes and proteins through a patient's fluid sample. Here, a scientist prepares fluorescent materials for use in medical radioimmunoassay testing.
(Credit: E.I. du Pont de Nemours & Co., Inc.)

In-vitro nuclear medicine. These are procedures that do not involve administration of radioactivity to the patient. Radiolabelled substances are added in the test tube to various clinical eluates obtained from the patient to estimate minute levels of hormones, vitamins, nutrients, and drugs circulating in the body. Radioimmunoassays (RIA), which use immuno-reactive reagents, are the main procedures in this class. Hundreds of biological substances of diagnostic importance can be estimated by them. They are one of the simplest, most inexpensive, and versatile tools in diagnosis.

Agency activities include helping to establish and upgrade laboratories, and to assist countries to develop the indigenous capability to produce reagents at the national or regional level. One project provides bulk reagents for the assay of thyroid-related hormones to nearly 14 countries in the Asia-Pacific region. These type of assays are most commonly done in developing countries, and costs per patient can be cut to one-tenth the usual cost by using bulk reagents instead of ready-to-use commercial kits. Countries already are in the phase of switching over to using bulk reagents that they make themselves or are developed in the region. This indigenous process has gradually led to a transfer of technology and regional self-sufficiency. A similar programme is being introduced this year for Latin American countries. The entire programme of *in-vitro* assays is supported by intense training activities in the quality control of procedures.

Other Agency work concerns new developments in the field of biotechnology, which have led to a great deal of sophistication in a variety of assay procedures. (Some examples are monoclonal antibodies, the use of magnetized particulate reagents to obviate centrifugation, and the use of solid-phase assay systems to make procedures simple and quick.) The programme encourages these techniques wherever possible through co-ordinated research programmes.

Over the past decade, assays were mainly used towards estimating blood levels of hormones. But the trend now is towards increasing their use in the diagnosis of communicable diseases. Immunoassays for serum hepatitis and AIDS (acquired immune deficiency syndrome) have become widely known, yet new assays for many other diseases far more common in developing countries are also being developed. IAEA-supported research programmes cover the development of RIAs for malaria, schistosomiasis, and tuberculosis.

In-vivo nuclear medicine. The main forte of nuclear medicine is studying the function of various organs by using radioactive tracers. The most common *in-vivo* application is the imaging of organs. Radiopharmaceuticals that selectively localize in organs are administered to the patient and their distribution is mapped by using a variety of imaging devices. A gamma camera allows visualization of the entire organ in a few seconds, and if a computer is used along with it, dynamic sequential functional studies of various organs can be done. The entire field of imaging is rapidly expanding. Agency activities provide instruments and other accessory facilities in a few cases. They mainly, however, create the human resources by providing training and experts to interested Member States. As the instrumentation is sophisticated and complex, quality-control practices and maintenance support draw considerable attention through workshops, documents, and co-ordinated research programmes. Scientific symposia and seminars jointly organized by the IAEA and WHO have proved to be valuable channels, and sometimes hallmarks, of information exchange.

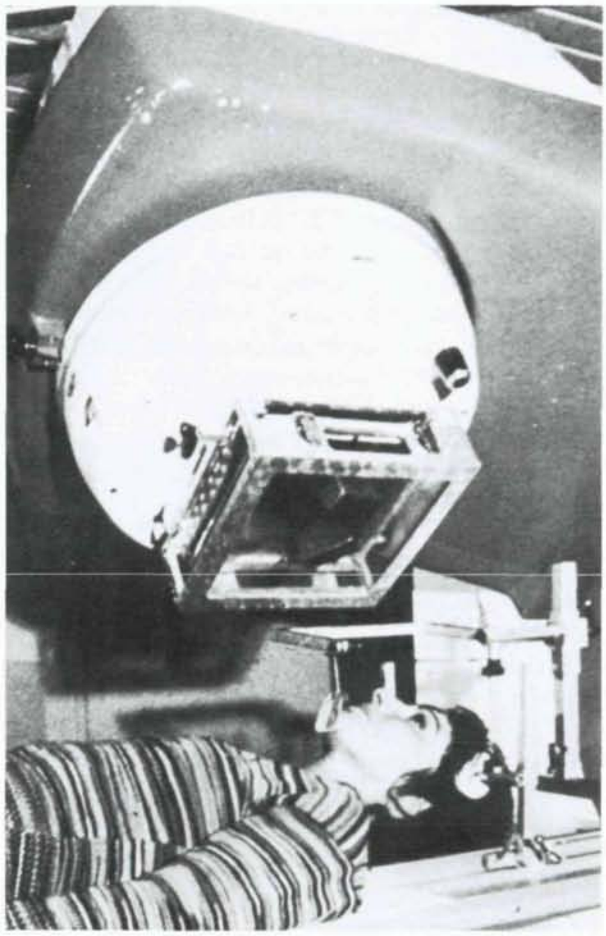
Radiotherapy

Radiotherapy of cancer patients to destroy rapidly spreading malignant cancer cells is well known. Under special circumstances, therapeutic radiation today may also be combined with other physico-chemical modalities — such as temperature (hyperthermia) or oxygen-tension (hypoxic cell sensitizers) — to enhance clinical advantages at relatively lower radiation doses. An international symposium jointly held in 1986 by the IAEA and WHO on radiotherapy in developing countries fostered a review of this important field of health care, and helped to identify needs in many countries.* Many technical co-operation activities are also building up a

* Proceedings of the symposium may be purchased from the IAEA. Reference STI/PUB/719. See the *Keep abreast* section for ordering information.

trained technical infrastructure of radiotherapists, radiologists, and medical physicists to help upgrade the radiotherapy of cancer.

The Egyptian Cancer Project, organized by the IAEA and the Egyptian Government in co-operation with WHO and financial support from Italy, is a good example of the use of radiotherapy to suit the needs and socio-economic conditions of developing regions. Major emphasis has gone to brachytherapy (close-range treatment) of the carcinoma of the uterine cervix (the neck of the uterus) with an intracavitary caesium-137 radiation source that is loaded by hand. Four project training courses have helped to pass on expertise in this speciality to 95 trainees from Egypt and some other African countries. (The Agency is planning a seminar in 1989 for Africa on organization and training of radiotherapy.) Radiotherapy applications are also being promoted in Asia and the Pacific under the Agency's technical co-operation programme known as the Regional Co-operative Agreement (RCA). A training course in Malaysia attracted specialists in radiotherapy and medical physics from 11 countries. While carcinoma of the uterine cervix was one focus, the RCA course covered a wider range of treatment techniques — for example, classical radiation sources of radium-226, newly developed californium-252, and remote "after-loading" devices that emit high doses.



External beam radiotherapy unit. (Credit: CEA)

Nuclear analytical techniques

Human nutrition research. This is one area where nuclear methods have many important applications. Experts think that altogether about 15 essential trace elements — such as iodine, iron, copper, zinc, cobalt, and selenium — are required for good health in varying amounts. Agency programmes are promoting research to determine actual dietary intakes of trace elements in various countries, and to compare these with recommended dietary allowances. Total diet samples are being collected from 12 industrialized and developing countries. For the first time *ever*, a nutritional assessment is being made that includes *all* minor and trace elements (24 in all) that are considered to be of nutritional significance. Seventeen of the 24 elements are being determined by neutron activation analysis (NAA). The Agency has also developed new total-diet reference material, which has been certified for 22 elements with the help of 79 participants from 33 countries. NAA provided about one-third of the results reported. Preliminary results already provide interesting indications that, for many essential trace elements, actual dietary intakes in some countries fall well below the recommended dietary allowances.

Some effects of trace element deficiencies can be dramatically visible and widespread — in Asia alone, for example, more than 400 million people are estimated to be suffering from varying degrees of iodine deficiency. Most trace elements, however, exert their effects in more subtle, and less visible ways, and only relatively recently has the evidence started to emerge that deficiencies may be much more widespread than previously realized. Many countries are already fortifying selected foodstuffs with elements such as iodine and iron, and they are actively supporting research on copper, zinc, selenium, and other elements.

Health-related environmental research. In this field, too, efforts have focused on the use of nuclear-related analytical techniques. Emphasis has been placed on the study of toxic heavy metals, such as mercury, cadmium, lead, and arsenic. Human hair, for example, has been shown to be a useful first-level indicator of environmental and occupational exposure to several of these elements. Particularly for mercury, it is believed to reflect the total body burden. Other research programmes deal with methodologies for monitoring compliance with national and international regulations on maximum permissible concentrations of toxic elements in foodstuffs; and environmental pollution arising from solid wastes, such as coal fly ash and sewage sludge. Quality control forms an integral component of this work and is being promoted by development of new reference materials and reference analytical methods.

Radiation biology

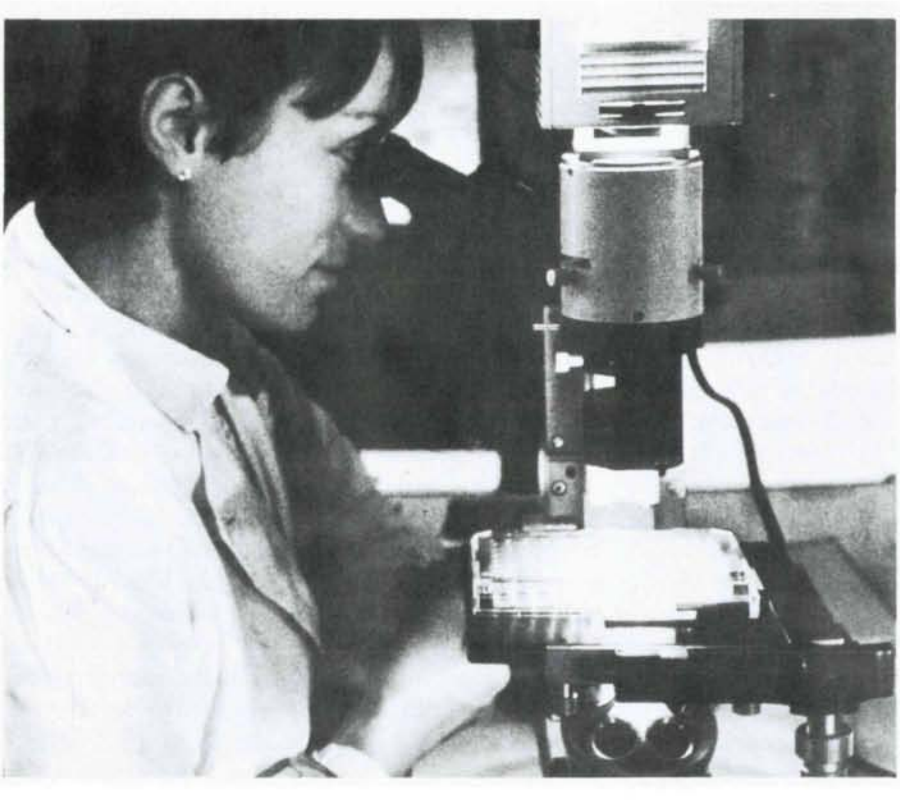
Developing countries have an acute shortage of sterilizing facilities in medical centres, one reason why the Agency is seeing growing demands to set up small-scale radiation sterilization facilities. Out of 135 large-scale gamma irradiators in 42 countries, 20 are located in developing countries, most of them implemented with the Agency's technical and research support. Medical supplies — syringes, needles, lancets, infusion tubes, catheters, catgut suture, scalpel, absorbent cotton gauze, bandages, pharmaceuticals and even tissue grafts — are needed at hospitals in every country. Inadvertent clinical use of items contaminated with micro-organisms can cause cross-infections, often with fatal consequences. Gamma rays from cobalt-60 are technically very effective, enabling "cold" sterilization of even heat-sensitive plastics after they are packaged. Unlike the conventional sterilizing agent, ethylene oxide, radiation leaves no toxic residues on treated medical items to cause health hazards.

Radiation biology is also being applied to human nutrition research. The Joint Division of the IAEA and Food and Agriculture Organization (FAO) is supporting co-ordinated research on the use of nuclear techniques to augment the nutritive value of cassava, a staple food in many tropical countries.

Dosimetry

The IAEA/WHO network. In the field of metrology, very few countries have established primary standards for the measurement of ionizing radiation. Member States of the "Convention du Mètre" have the possibility to compare their national measurement standards with the International Bureau of Weights and Measures (BIPM) or ask for calibration if it is a secondary standard. However, only about half of the 47 Member States of the convention maintain national measurement standards for dosimetric purposes. As the use of ionizing radiation expanded worldwide, action was needed to solve problems created by lack of adequate calibration facilities. The IAEA, therefore, proposed that dosimeter-calibration laboratories should be set up whose work could be supported by existing primary standard laboratories, and co-ordinated by the IAEA and/or WHO. This network of Secondary Standard Dosimetry Laboratories (SSDLs) was established during the past decade, particularly for developing countries, and membership has now risen to about 60 laboratories, 46 of them in the developing world.

Most SSDLs have been set up to provide calibrations and to promote quality assurance in the dosimetry of radiation therapy and radiation protection. With the expansion of the therapeutic application of radiation in general, the requirement for accurate measurement of radiation doses will increase. Although lower accuracy is needed in radiation protection and in the very low range of dosimetric measurements encountered in environmental radiation monitoring, post-Chernobyl experience has shown the need for a better calibration and reliability of low-dose dosimeters. To this end a quality assurance programme has been initiated for the SSDLs. By using existing facilities, it can be ensured that measurement results obtained at different times,



Scientist observes cell cultures during production of monoclonal antibodies. (Credit: E.I. du Pont de Nemours & Co., Inc.)

Nuclear techniques can be used to evaluate and treat thyroid tumours, which can be caused by the deficiency of the trace element, iodine. The thyroid function can be assessed by *in-vitro* assays of related hormones, and its anatomical and pathological diagnosis can be helped by *in-vivo* methods, such as scintigraphy. When treatment is required, some of the thyroid tumours may be amenable to radiotherapy. (Credit: SEARO Regional Health Papers No. 10, World Health Organization Regional Office for South-East Asia, New Delhi 1985.)

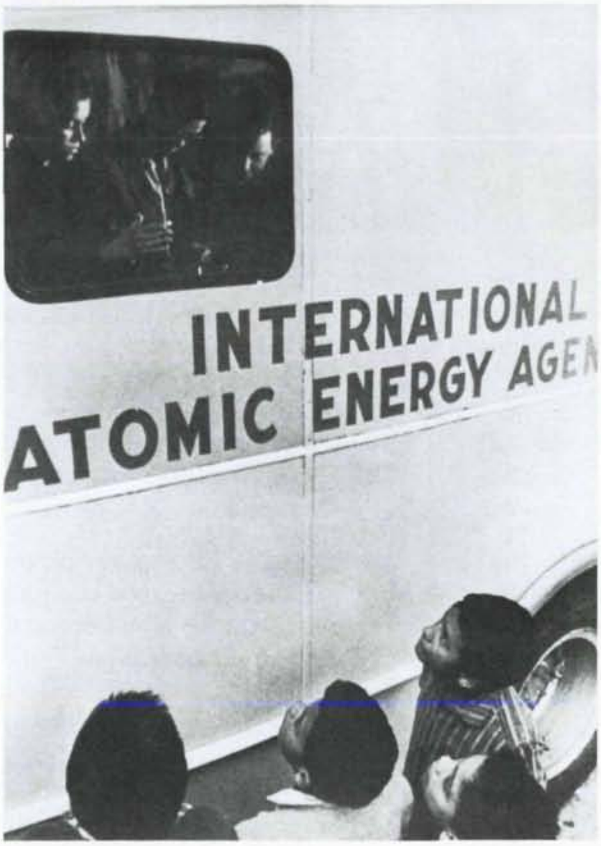
sites, and with different instruments can be compared so that competent authorities may draw proper conclusions. The Agency's dosimetry unit at the Seibersdorf Laboratories serves as the central laboratory in the SSDL Network. *(See the article on the Seibersdorf Laboratories for further information on the unit's work.)*

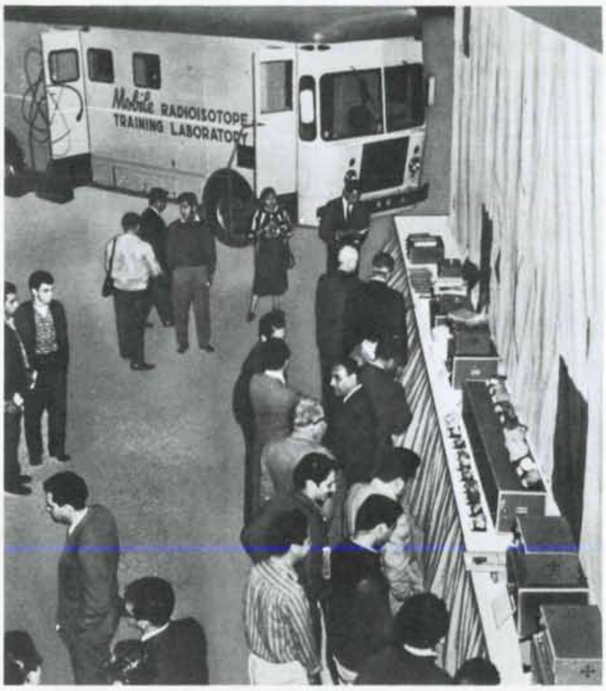
Dose intercomparison for radiotherapy. A postal dose intercomparison service for radiation therapy has been a joint undertaking of IAEA and WHO since 1970. Thermoluminescence dosimeters (TLDs) are prepared and calibrated at the IAEA and mailed through WHO to participating hospitals in developing countries. There they are exposed under defined conditions to a specified dose determined by the hospital laboratory. After their return to the Agency's laboratory, the TLDs are evaluated and the participants are notified through WHO on excessive deviations, their possible causes and proposed actions to be taken. Every year about 200 dosimeter sets are distributed and from these 100-150 sets are returned and evaluated. In total 650 hospitals have been served. On the average 70% of the hospitals have deviations within plus or minus 5%, which is an improvement from the results of the 1970s when only 60% achieved this result. However, 90% is believed to be a realistic goal, so this service will still be needed for quite some time. The service will be extended to all radiation qualities needed and will include use of a human-shaped phantom.

High-dose standardization and dose assurance service. The IAEA has also initiated the international dose assurance service (IDAS) for high-dose radiation and to promote dosimetry as a quality-control measure in radiation processing. Commercial and non-commercial irradiation facilities dealing with absorbed doses of gamma and electron radiation from 10 gray to 10 kilogray are invited to participate. Since June 1985 more than 200 dose checks have been done for 27 irradiation facilities in 18 countries. Results have been very good in general; however, overall deviations varied between minus 20% and plus 24%. It is expected that the standardization of radiation processing dosimetry will provide a justification for the regulatory approval of irradiated products and the basis of international clearance for free trade.

Pages from the past...

The IAEA's mobile radioisotope laboratory served as a touring training centre in the 1960s, drawing keen interest in the countries visited. Here, the laboratory is in Mexico where among the stops was the University of Guanajuato.



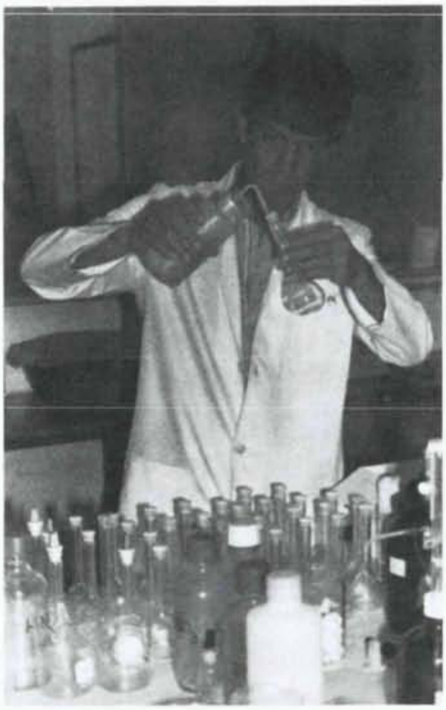


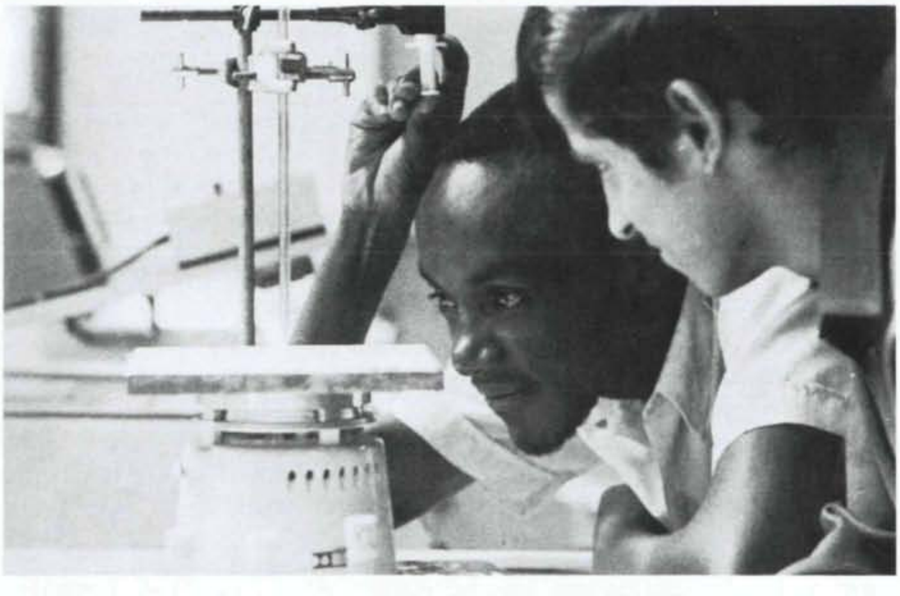
The IAEA has supported insect control projects applying radiation techniques in many countries, including Nigeria where the BICOT project has eradicated the tsetse fly from a target agricultural zone. The project, in co-operation with the Food and Agriculture Organization (FAO), has recently been expanded.

About 20 countries sent samples of rice grains and stalks from plants to the IAEA's Seibersdorf Laboratories under a research project in the 1960s to analyse fertilizer use with nuclear techniques.

In 1966, at the Research Institute for Tropical Metabolism of the British Research Council in Jamaica, childhood diseases from malnutrition were studied using nuclear equipment provided by the IAEA.

Since the 1970s, the IAEA and World Health Organization (WHO) have supported a network of laboratories to promote reliable dose measurements in radiation applications for medical, industrial, and other purposes. Shown here is a laboratory technician at the Secondary Standard Dosimetry Laboratory (SSDL) in Ecuador, one of more than 50 laboratories of the IAEA/WHO network of SSDLs.





Training young scientists in the application of nuclear techniques has been a key component of the IAEA's services over the past 30 years. Shown here is a student at the Makere University in Kampala, Uganda learning from an Agency scientist.