



Isotope hydrology helps find water fit to drink

A programme of the Regional Cooperative Agreement for Research, Development and Training in Nuclear Science and Technology in Asia and the Pacific (RCA)

Clean drinking water is in short supply in Asia and the Pacific. More than one billion people live in conditions of 'water stress', where population growth, increasing per capita consumption, and competition between agricultural, industrial and domestic users are placing an overwhelming strain on limited freshwater resources. Furthermore, a vast proportion of these limited resources is too saline to drink or too contaminated to drink safely. Salinity is an increasing problem due to excessive irrigation and over-exploitation of groundwater generally (when the freshwater table gets very low, water from the sea flows inland to replenish it). Other contamination arises from industrial and agricultural pollutants such as heavy metals, sulphates and nitrates, from natural toxins such as arsenic, fluoride and polyaromatic hydrocarbons, as well as from a variety of microbial hazards, especially faecal coliform from sewage. The result? Two out of five people are drinking water considered unsafe by international standards. Finding, managing and protecting clean drinking water is therefore a major regional challenge.


The gravest drinking-water threat in many parts of the region is from arsenic. Arsenic occurs naturally but is poisonous above a certain level (10μg per litre of water, according to the World Health Organisation). Over a 5-20 year period, arsenic-rich water can cause skin discolouration; lesions on feet, chest and hands (pictured); cancers of the skin, bladder, kidneys and lungs; diseases of the blood vessels in legs and feet; and possibly diabetes and reproductive disorders.

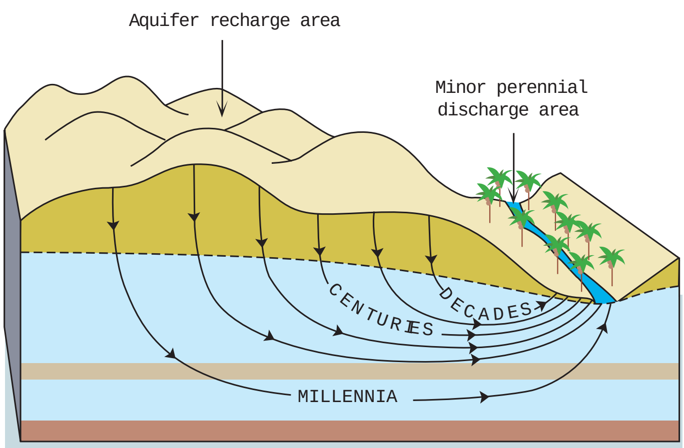
Millions of people in the region still drink water containing dangerous concentrations of arsenic. Worst affected has been Bangladesh, where the contamination of one in four shallow groundwater wells put 70 million people at risk. In a project run jointly with the IAEA and the World Bank, the RCA used isotopic investigative techniques to help locate deeper aquifers that could be used as an alternative and sustainable source of safe drinking water.

In response to this situation, the RCA has undertaken a long-term programme to help countries develop the skills and facilities to use isotopic (nuclear) tools and techniques, which allow very sensitive and often unique insights into the behaviour of water resources. This has greatly improved national and regional capabilities for assessing the quality of existing water supplies and for identifying alternative and sustainable sources of clean drinking water for the future. The programme, supported by the International Atomic Energy Agency (IAEA) under its Technical Cooperation Programme and initially in partnership with the United Nations Development Programme (UNDP), has involved technology transfer, human resource training and development, and investment in physical infrastructure.

Initially the RCA-assisted studies focused on the problems of freshwater supply and sustainability, the salinization and contamination of groundwater, and the evaluation of alternative groundwater resources for potential sustainable exploitation. Subsequent studies assessed the impact of industrialization and urbanization on the quality and quantity of water resources by targeting areas where local populations were considered to be at risk. These studies have had important results. Before they were undertaken, for example, most participating countries had no baseline data for toxic contaminants such as arsenic and fluoride. The studies revealed that these kinds of contaminants are more widespread in the region than previously thought.

Isotope techniques employ isotopes of the elements of water and of some dissolved salts as natural tracers. These have the advantage of directly providing information on processes undergone by the water itself without introducing any additional pollution. In addition, isotope measurements can provide information on how old the groundwater is and where it originally comes from; how it is recharged (from what sources, under what conditions, at what rates does it take days, months, years or millennia to replenish?); what its 'flow' patterns are; how it interacts with other aquifers and with surface water and sea water; its vulnerability to man-made pollutants, natural contaminants and saline intrusion; and how and where these impurities enter the groundwater and are then 'transported' by it elsewhere.

Isotope measurements used in conjunction with data gathered by conventional hydrological methods (hydro-geological, chemical, biological, etc.) extend the application of this data to provide invaluable information about the source and movement of water in different environments both above and below ground, including rivers, lakes and aquifers. This isotope data can also help validate and improve the numerical models based on conventional analytical methods and assist in the overall planning and management of a water resource.



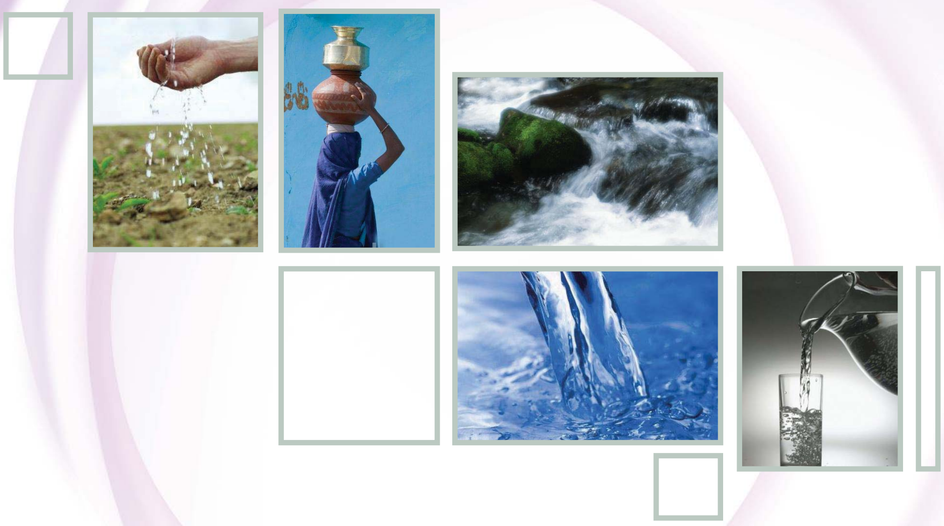
This conceptual model of Shijiazhuang aquifer in China illustrates the groundwater 'cycle' including recharge, discharge and pollution mechanisms.

The science by itself is not going to solve the problems without the participation of local, national and regional authorities. The RCA programme has also been helping to address this issue by encouraging the authorities to adopt a more collaborative and comprehensive approach to the collection of hydrological data. Interconnected problems can only be addressed effectively by coordinated and sustainable water management policies and practices based upon sound scientific evidence.

The RCA's work has brought isotope techniques to the attention of water resources managers and policymakers throughout the region. The demonstrated combination of nuclear and conventional hydrological techniques has produced more accurate assessments and predictions of groundwater behaviour, which in turn has enabled the development of better informed and more sustainable policies for using and managing the region's clean drinking water resources. The Philippines and Thailand, for example, have established protection zones for aquifers. Malaysia has enacted controls on the effects of mining activity on groundwater dynamics. Indonesia has set up a safe groundwater exploitation zone. Korea has characterized the flow paths of fluoride-bearing waters. India is now confident of selecting safe waste disposal sites and has prohibited the use of arsenic-contaminated shallow aquifers for drinking water. And Pakistan has investigated an arsenic pollution threat in the Indus Basin and developed a groundwater flow model for safe and sustainable management of Lahore aquifer to supply good quality water.

Isotope techniques are becoming essential tools in hydrological research, and the number of organisations adopting them in Asia and the Pacific continues to grow. Importantly the training, technical assistance and field studies facilitated by the RCA have given scores of local practitioners the skills and experience to ensure that isotope hydrology is here to stay.

Collecting water samples from a pond in Malaysia which has been created by the decomposition of waste from landfill.



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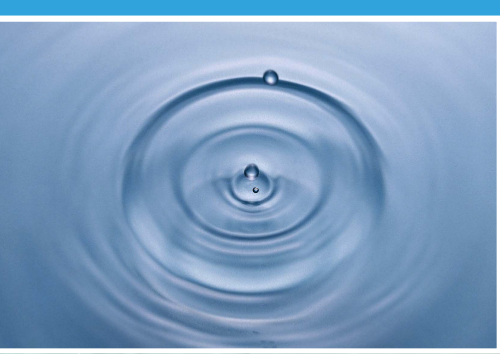

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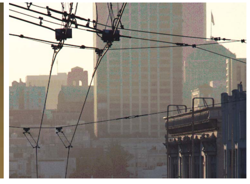

RCA's nuclear forensics tools in the fight against air pollution

A programme of the Regional Cooperative Agreement for Research, Development and Training in Nuclear Science and Technology in Asian and the Pacific (RCA)

Asia haze and global warming are topics that are grabbing the headlines and the attention of not only the politicians and decision makers but also the ordinary person in the street. But the air we breathe is not something confined to our town, city or country. It is circulating globally and what is discharged into the atmosphere can go around the world so what you are breathing in can contain pollutants from many sources and not just those from you neighbourhood. Of growing concern are the tiny particles of matter[1)] pumped into the atmosphere every day by cars, factories and power stations and even by the humble home fire which have been shown to be able to cause serious respiratory problems, cardiovascular damage, lung cancer, and death. They may also be damaging the earth's ecosystems and contributing to climate change.

To fight this problem, the RCA has undertaken an ambitious programme over the past 10 years to introduce and transfer highly sophisticated nuclear and other technologies to countries in Asia and the Pacific to monitor air particulate matter (APM), to identify the sources of origin of the individual minute specks of pollutant, and to 'map' their pathways through the air. Nuclear technologies have provided unique forensic tools that can analyse the microscopic particles of pollutants and unlock the secrets of their origin. Finding the source is the key to eliminating or reducing the pollution. But if national air pollution policies are to be effective, they will need to complement each other at a regional level too. Thanks to this project, many countries now have acquired these skills and facilities to use nuclear and other advanced techniques. The programme has been funded and implemented under the Technical Cooperation Programme of the International Atomic Energy Agency (IAEA) and in the first four years the United Nations Development Programme (UNDP) also provided financial support for technical equipment and for establishing sampling stations.

The following examples from Bangladesh and the Philippines demonstrate the way in which the technologies are now being used in the region and also the essential links that have been made with the local environmental agencies and government to ensure that practical use is made of the results from this highly sophisticated nuclear technology.

Bangladesh has been producing baseline data on air particulate matter (APM) in the city of Dhaka since the 1990s. The studies identified high levels of lead pollution as well as its possible sources. In response, the Air Pollution Authority introduced new control measures which have succeeded in cutting lead concentrations in APM to about one-third of the previous level.

The Dhaka City Corporation also conducted an urban transport project to improve the city's traffic and to reduce the air pollution from vehicle fumes. Nuclear techniques helped provide the data on APM which was then used by the project authority. The project, funded by the Bangladesh Government and with assistance from the World Bank, proved a great success. Similar projects are being undertaken in other cities such as Chittagong, Rahshahi and Khulna, thanks to the RCA programme. At the national level, the Department of Environment initiated an Air Quality Management Project, with US$ 5 million in funding from the World Bank, to introduce regulatory measures to mitigate the air pollution problem across the whole country.

The Philippine Nuclear Research Institute (PNRI) has participated in the RCA project from the start and has produced the first long-term database (going back to 1997) for fine and coarse particulate matter in Metro Manila. The source apportionment results confirm that vehicular emission has made a significant contribution to air particulates in the area. PNRI data have been reported in the National Air Quality Status Reports prepared by the Environmental Management Bureau since 2002, as mandated by the Philippine Clean Air Act.

PNRI stations have been co-located with Environmental Management Bureau stations, such as this one (pictured) at Valenzuela City, which together provide complementary data on air pollution. Results showed that the concentration of fine particulate matter was above United States Environmental Protection Agency standards, thus demonstrating the need to establish National Guideline Values. The PNRI has been made a member of the Metro Manila Airshed Governing Board, the area's policy-making body on air quality issues. The PNRI has also provided technical support on air quality monitoring to local governments in, for example, Puerto Princesa, Lipa City and San Pablo City.

This RCA programme has also contributed to major collaborative projects run by international organisations, such as the ASEAN project to reduce haze in the region. Perhaps the most significant of these collaborative projects is the Clean Air Initiative (CAI-Asia), initiated by the Asian Development Bank and the World Bank in 2004. RCA representatives have presented the results of their research at several CAI-Asia symposia.

The RCA programme itself is set to continue another phase over the next two years so that there can be further investments in the long-term local and regional information on air pollution, as well as source fingerprints, to make the region even better prepared to understand and tackle the complex nature and behaviour of air pollution.

1)

The nose and throat are the body's first line of defence against the air particulate matter (APM) that we breathed in. However when the particles are less than 10 micrometres in diameter (referred to as PM10), they are small enough to bypass the nose and throat and make their way into the bronchi and lungs. If the particles are even smaller (less than 2.5 micrometres, or PM2.5), they can pass through the walls of the lungs themselves and enter other organs, causing cardiovascular problems including heart attacks. In short, the smaller the particle, the more dangerous it tends to be.

Fact Sheet

Nuclear Analytical Techniques

Nuclear techniques such as *ion beam analysis*(*IBA*), *neutron activation analysis*(*NAA*) and *x-ray fluorescence spectroscopy*(*XRF*) are extraordinarily sensitive and highly efficient; their capacity to identify - simultaneously - a wide range of elements quantitatively is unparalleled. For example, a technique known as *particle induced X-ray emission*(*PIXE*), one of the IBA techniques, can recognise in a one milligram sample of APM up to 27 separate elements(including the principal transboundary elements silicon, sulphur and lead): the keys to understanding its local, regional and world-wide sources of origin. PIXE is also very fast: samples require no preparation, and analysis takes only 10 minutes. Nuclear techniques also avoid the uncertainties associated with conventional methods of analysis. Chemical techniques, for example, in which samples are dissolved, can be compromised if a sample fails to dissolve completely, or if the reagents and vessels used in the dissolution process lead to contamination.

Analytical Data Base

Accurate, comprehensive data enables more effective mitigation strategies. Each country that has participated in the RCA programme now has its own database of information collected over the last 10 years, especially for fine (PM2.5-0) and coarse (PM10-2.5) APM. These databases have already been used by many national environmental authorities as a basis for devising new air pollution policies and strategies. Specific measures to reduce the concentrations and impact of particulate pollution include banning lead in petrol, removing old buses from service, and eliminating the use of small two-stroke engines. The effectiveness of these measures has been assessed too. Finally, the databases are used to provide information critical to air pollution models, that is air shed models and advanced receptor models. These models will provide a greater source resolution, better quantification of the source contributions and estimates of the influence of distant, trans-boundary sources on the airborne particle concentrations at the receptor site.

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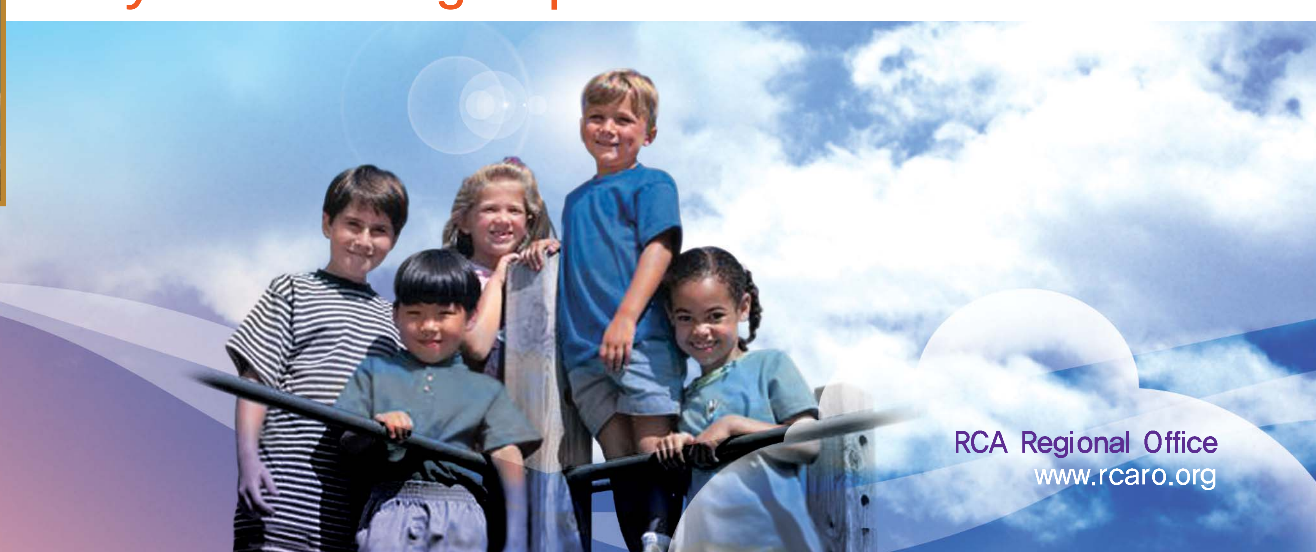
Nuclear analysis of airborne particles provides a key to alleviating air pollution



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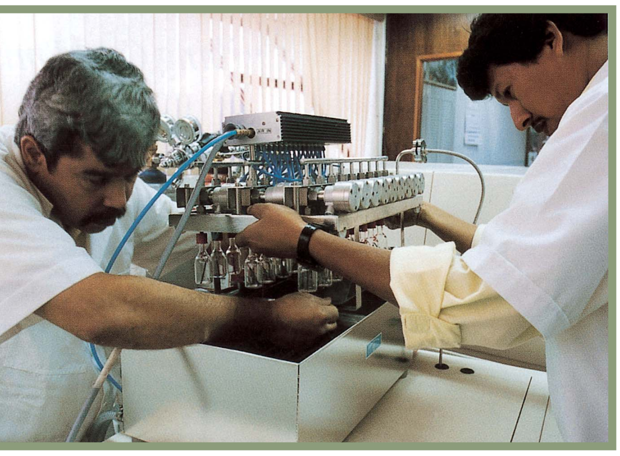
New materials from natural polymers: using nuclear technology to improve Nature's gifts

A programme of the Regional Cooperative Agreement for Research, Development and Training in Nuclear Science and Technology in Asia and the Pacific (RCA)

Countries in Asia and the Pacific are making great headway in deploying nuclear technology to develop an astonishing variety of advanced materials for use in medicine, agriculture, environmental protection and a wide range of industrial applications. The RCA has played a pivotal role in introducing this technology, known as radiation processing. Since 1997, and with support from the International Atomic Energy Agency and additional funding from the United Nations Development Programme, the RCA has run an ongoing technical cooperation programme to help participating countries acquire the skills and establish the infrastructure to undertake radiation processing research and development. Recently the programme has been focussing on one of the most exciting and innovative areas emerging in materials science today: the use of radiation processing to 'redesign' Nature's own materials.

Firstly, though, how does radiation processing work? Essentially, when a material is exposed to ionizing radiation from a radioactive source emitting gamma rays, such as cobalt-60, or to a beam of highly accelerated electrons, the energy of the radiation alters the material's molecular structure. Certain physical, chemical and/or biological properties of the material can be altered too, for example its strength, viscosity and biodegradability. Under controlled conditions, different effects can be achieved depending upon the 'base' material used, the 'dose' of radiation it absorbs, and the particular processing techniques employed. Molecules can be broken down ('degradation'); they can be made to stick together ('cross-linking'); or they can have different molecules stuck on to them ('grafting'). In other words, by carefully modifying a material's molecular structure, it is possible to redesign that material for a very specific, tailor-made purpose.

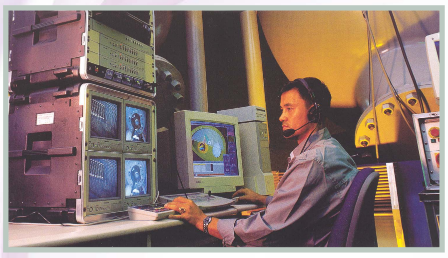
Radiation processing has several advantages over conventional chemical methods for developing new materials. In the first place, it's simpler and faster. It can also be controlled with much greater precision. And it's much 'cleaner': this is because radiation processing changes the molecular structure of materials without requiring chemical catalysts or extreme physical conditions such as high temperatures and immense pressures; it neither uses toxic chemicals nor generates noxious fumes. Furthermore, irradiated materials do not themselves become radioactive (just as a patient x-rayed for a bone fracture does not become radioactive). Radiation processing therefore offers the potential of a fast, efficient and toxin-free alternative to conventional methods of developing and manufacturing new materials and products.



Perhaps the technology's most promising use, which the RCA programme has been promoting recently, is the application of radiation processing to natural polymers. Polymers are large molecules consisting of long chains of repeated blocks of atoms, and they are found throughout nature: the cellulose in plants and trees; the starch in bread, corn and potatoes; chitin in the shells of shrimps, crabs and other crustaceans; agar, carrageenan and alginates in seaweeds. These and other natural polymers may prove to be the perfect 'base' resource from which to develop new materials. They are abundant, inexpensive, biodegradable, locally available and renewable. They also have some remarkable inherent properties. Chitin, for example, is naturally waterproof, and hard yet flexible.

Countries participating in the RCA programme have produced great results already. Prime examples are the radiation processing of chitin to produce hydro-gels and of polysaccharides (such as starches and cellulose) to produce what are termed 'oligomers'. Hydro-gels are basically water-soluble, super-absorbent materials, but they are now being custom-designed for a remarkable variety of uses: antibacterial dressings for wounds and burns; biodegradable adsorbents for removing heavy metals from rivers and lakes; biocompatible coatings for delivering drugs into the body; controlled release agents for pesticides and herbicides; skin moisturisers and other cosmetics; and biodegradable packaging. Oligomers are being developed for medical uses, because of their anti-bacterial and anti-fungal properties, as well as to promote plant growth and extend the shelf-life of fruits, vegetables and eggs.

By facilitating the transfer of radiation processing technology, the RCA programme has helped countries of the region develop the capabilities to design new and exciting products and deliver them to an eager market. Indeed, over the last ten years, interest in this groundbreaking technology has grown faster in Asia and the Pacific than in any other region in the world, bringing with it the potential for significant benefits to industry, economic growth, health, agriculture and the environment. All the countries that have participated in the programme are actively engaged in researching and developing new materials, patenting their discoveries, or bringing new products to market for sale domestically and internationally. By promoting the use of natural polymers, the programme is also encouraging affordable, sustainable and environmentally-responsible development. As research teams across the region continue to experiment with new possibilities and explore new applications for their work, materials science in Asia and the Pacific looks set for a promising future.



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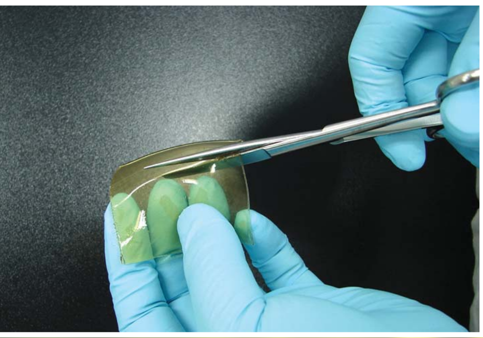

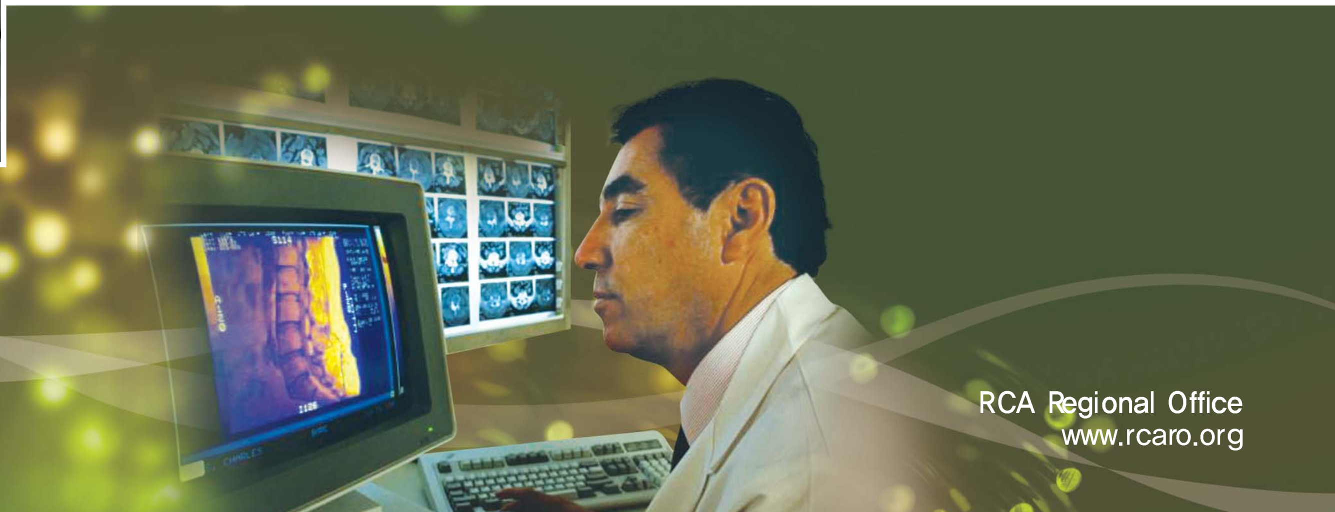

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'Distance assisted training' strengthens Regional skills in nuclear medicine

A project of the Regional Cooperative Agreement for Research, Development and Training in Nuclear Science and Technology in Asia and the Pacific (RCA)

A groundbreaking training programme is set to vastly improve the skills and expertise of nuclear medicine technologists (NMTs) throughout Asia and the Pacific and even to transform their status and recognition within the medical community. The unique 'distance assisted training' (DAT) programme, developed under the auspices of the RCA, is cost effective, highly adaptable to diverse teaching and learning environments, and designed to support sustainable in-country distance education practices. The programme was officially released in late 2005 and has been commended internationally as a seminal achievement upon which other training materials for developing countries should be modelled.

The increasing sophistication of nuclear medicine demands increasingly high levels of knowledge and technical expertise from NMTs. In 1994 it was estimated that some 3,000 technologists in Asia and the Pacific had received inadequate training. Since then there has been considerable new investment in the technology and a corresponding increase in the number of technologists, yet many of them continue to struggle even with the basic concepts. To address this shortfall in expertise, the RCA initiated a project to develop a comprehensive new training programme. The project has been substantially funded by the Australian Government, coordinated at Westmead Hospital in Sydney, and implemented by the International Atomic Energy Agency (the Agency). A second objective of the project, since many NMTs' qualifications are not recognised internationally, was to provide technologists with a more sustainable career path by offering them a fully accredited course. There are now some 7,000 NMTs in the region, and it is estimated that 5,000 could benefit from this project.

Students in China demonstrate their practical skills during a workshop. Student assessment is based on assignments, final examinations, and on-site demonstration of skills.

During pilot studies, some 250 students from Bangladesh, China, India, Korea, Malaysia, Pakistan, Philippines, Sri Lanka and Thailand completed the basic stage of the programme, and 130 also completed the advanced topics. Each student received a special record of achievement from Westmead Hospital.

From an initial pilot scheme of only a few subjects, the DAT programme evolved over years of careful development and rigorous international review into a comprehensive syllabus of 25 subjects at basic and advanced levels. The complete programme now runs for 600 hours (six hours a week over two years for in-service training) and includes workshops and other 'hands on' experiential learning techniques to reinforce students' understanding of theoretical principles and to build their confidence in on-the-job problem solving. By giving technologists a common standard of conceptual knowledge and clinical practice, the programme will enhance the quality and consistency of nuclear medicine services throughout the region.

The unique 'distance assisted training' approach was developed as a solution to two longstanding challenges. Firstly, NMTs in Asia and the Pacific come from diverse cultural backgrounds, speak different languages, have varying levels of education, do not all operate the same medical equipment, and often work in remote areas where there are few opportunities for formal training. Secondly, countries in the region need to be able to deliver the training themselves, integrate it into existing programmes, and develop additional courses in the future. In short, to meet these criteria a new training programme had to be adaptable and sustainable. The DAT approach combines detailed course materials designed along 'distance education' principles, with an adaptable course framework and assessment methods that can be easily integrated into the countries' training infrastructure and development programmes.

To date, the DAT programme has already been made compulsory for NMTs in Thailand and all course materials have been translated into Chinese and Korean. Eleven other RCA Member States have confirmed their intention to implement the programme, pilot studies have been undertaken in Africa and Latin America, and interest has been expressed in introducing the programme into Eastern Europe.

The DAT programme is available to national authorities that accept responsibility for conducting it according to prescribed guidelines. An application form and further information are available from the RCA office, IAEA Vienna, PO Box 100, A1400 Vienna, Austria.

A local assessor in the Philippines evaluates a student's skills in positioning a patient for a clinical study using a gamma camera.

In nuclear medicine the patient is administered a small quantity of a radioactively-labelled compound which permits images to be acquired on a gamma camera. The images depict the functioning of the organ or tissues under investigation. Their uses include bone scans in patients with suspected cancer, studies of blood supply to the heart in patients with chest pain, even studies of the brain in patients with clinically-identified brain disorders.

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Restoring health and saving lives: global benefits from RCA's trail blazing

A project of the Regional Cooperative Agreement for Research, Development and Training in Nuclear Science and Technology in Asia and the Pacific (RCA)

Every year millions of people around the world undergo surgery during which tissue graft materials are used to assist in the treatment of their condition and help them to return to a healthy life. Tissue graft materials include skin, bone, nerves, tendons and even cornea.

For decades these procedures were almost prohibitively expensive for developing countries, because the materials such as sterilized bone, skin and other tissues were not available locally and had to be imported from developed nations at high, and ever increasing, expense. For example the cost of 30 grams of bone chips to fill a hole in a bone cavity caused by a tumour cost some USD 3,000 in the mid 1990's and the cost of a major bone for an arm or leg cost USD 10,000. Such high costs put this type of treatment out of the reach of the majority of patients in developing countries.

To address this situation the RCA took the initiative and designed a project to help national health authorities in Asia-Pacific countries build up the regional and national infrastructure for production of tissue graft materials that were sterilized using nuclear radiation. This was implemented with the financial and technical support from the IAEA. A key aspect of the production of tissue graft materials is sterilization. All tissues for grafting have to be carefully sterilized to both reduce the risk of the host body rejecting the grafted tissue and also to prevent any disease or infection being transmitted to the recipient. In the past, steam and chemical methods were used, but these methods had limitations because of either physically or chemically affecting the tissue or leaving potentially dangerous chemical residues. Radiation sterilization, mostly using gamma rays from a Cobalt-60 source, is better than these processes because it can sterilise without producing these negative side effects.

The radiation sterilization of the tissues was but one aspect of the bold RCA approach. It was recognised that to make an effective impact an holistic approach had to be taken. The project needed to address the whole process and set about the development of the facilities and the expertise to collect, sterilize and store tissues and the establishment and use of local 'tissue banks' to reducing costs and making tissue transplant treatment more widely available to those in need locally and regionally.

A tissue bank is just like a blood bank, except that instead of blood, it procures and stores human and/or animal tissue allografts such as musculo-skeletal tissues (bone, tendon, cartilage, ligament), soft tissues such as amnion and skin, and others including cornea, heart-valve and nerve tissues - all the tissues used in orthopaedic and plastic surgery.

Importantly the project developed a total quality assurance system and regulatory guidelines to ensure that these tissue banks could operate at the highest international standards. It also channelled advice, expertise, training and infrastructural support (such as the installation of specialised equipment) to the participating countries so that they could provide for their national needs. The project produced a draft curriculum on tissue banking - the first of its kind in the world - and at the same time this met the international standards laid down by the European Association of Tissue Banks (EATB) and the American Association of Tissue Banks (AATB).

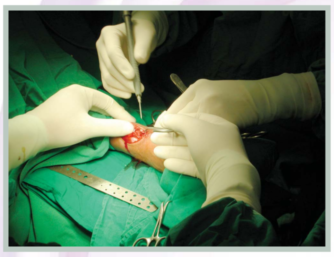
Practical Hands-on Session for the Tissue Convocation Ceremony of 1st Batch, 16 October 1998.

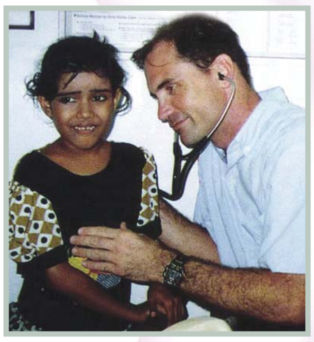
In partnership with the Singapore Government, the RCA converted the original draft curriculum into a multi-media course, which formed the basis of a one-year distance-learning IAEA/NUS Diploma Course in Tissue Banking for tissue bank operators, with certification by the National University of Singapore (NUS). This course has subsequently provided training to a total of more than 130 tissue bank operators from 14 Asia-Pacific countries. By reducing the dependence on imported tissue, there have been savings of millions of USD. By introducing radiation sterilization techniques and making tissue graft materials much more widely available local surgeons have been trained and have new skills in the utilisation of grafting techniques. This has all had a huge impact on national health care in the region and the added value from the human benefit is incalculable.

However these achievements are just the tip. There have also been global spin-offs from this RCA initiative. The multi-media curriculum was taken up in Latin America and translated into Spanish. Tissue Bank Training Centre in Singapore was reconstituted as an *International* Training Centre to make the tissue bank curriculum available globally. The RCA, with IAEA funds and expertise, converted the multi-media course into an online curriculum for internet delivery and tissue bank operators have been trained in Latin America (Brazil, Chile, Cuba, Peru, Uruguay), Europe (Greece, Slovakia, Poland, Ukraine) and Africa (Zambia, Libya, Egypt, Algeria).

Bank Operators during first Diploma Course held in November 1997.

The impact of this RCA project has been far reaching and has achieved a global impact. The success owes much to the resolve of the participating RCA countries to cooperate, collaborate, and demonstrates the power and progress that can come from the synergy.





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[IAEA/NUS Multi-Media Curriculum developed in April 1998 by NUH Tissue Bank with funds from the Singapore Government]

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