# Health and the environment: Examining some interconnections

*Through IAEA-supported projects, researchers are investigating the effects of changing environmental conditions on human health*

by
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Sustainable environmental development, in all its forms, is more than a concept for protecting the fragile ecosystems of Earth. On a personal level, it is a prescription for better health. Billions of people the world over, for example, suffer health problems from industrial air pollution, exposure to toxic metals and wastes, and life-threatening parasites that quickly adapt to poor environmental conditions. As the Earth's health improves under policies of sustainable development, so too will the health of its people.

In various ways, the IAEA is working with national and international agencies to broaden scientific understanding of the interconnections between the environment and human health. Often nuclear and related technologies are applied in the search for answers to complex and puzzling questions. This article highlights some of that work, illustrating the dimensions of both the problems and the potential solutions.

## Air pollution: A nuclear "window" to an urban lung

Humanity has benefitted greatly from industrialization. In many countries, life has become more organized, comfortable, and productive. At the same time, industrialization has brought its curses — among them, urbanization, which has claimed the environment as its first casualty. In terms of impact on human health, air pollution is one of the most significant of all changes to the global environment that now so ominously threaten humanity. Pollution is the result of people plus economic activity, both increasing at a significant rate.

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For developing nations, the situation places them on the horns of a dilemma. They need to pursue industrialization vigorously to achieve growth in the economy. At the same time, they do not have the resources to build adequate industrial safety systems to keep pollution under control. Torn between these two conflicting needs — rapid economic growth and environmental protection — most developing nations give in to the pressures of economics. Only recently have governments started facing up to the associated dangers. Yet regulations governing environmental safety are not strictly adhered to in many of these countries.

Asia provides a striking example of this precarious situation. There are only 13 cities in the world with populations of more than 10 million. Seven of them are in Asia. About 1 billion people live in Asia's crowded, chaotic cities. Of the seven cities with the worst air pollution in the world, five are in Asia.

Air pollution is the worst of environmental insults because of the chance for its transboundary movement. It is caused mostly by combustion of fossil fuel in motor vehicles and power plants, smoke from wood stoves, incinerators, industrial chimneys, etc., and dust from farm products, construction sites, and mining, for instance. Pollutants are usually lead, sulphur dioxide, sulphuric acid and sulphates, oxides of nitrogen, ozone and photochemical pollutants, carbon monoxide, volatile organic compounds and finely dispersed organic matter including aeroallergens. All these pollutants beyond a certain concentration are hazardous to human health.

The health effects of air pollution have been well documented since the famous London fog incident in 1952. About 4000 excess deaths were attributed to the incident, which categorically established the direct correlation between high air pollution and mortality rate. Even at lower levels of pollution, raised mortality has been reported in many studies since the London case. Reports on air pollution episodes further show an increase in emergency hospital admissions for respiratory and cardiovascular diseases and in applications for health/risk benefits to workers. Pulmonary function tests in the laboratory show an increase in forced expiratory volume per one second (FEVI) during episodes of air pollution. Values of FEVI vary from region to region with different levels of air pollution.

The underlying mechanism of high mortality and morbidity due to air pollution is not yet clear. Air pollution may increase the lung permeability leading to pulmonary edema or water logging of lungs. Thus, gaseous exchange in the lung alveoli will be hampered causing oxygen starvation in the body. It is known that people suffering from acute and chronic respiratory diseases are more sensitive to particulate air pollutants.

The body's usual defense mechanisms — such as ciliated membrane and the immunoglobulin present in the mucous lining the airways — do not protect the lungs from pollutants in inhaled air. At best, large particles may be prevented from reaching the deeper parts of lungs by impaction to the mucous lined membranes in the upper airways. Subjective feelings of respiratory discomfort and the sensation of shortness of breath are familiar symptoms of acute exposure to polluted air.

Air pollution exacerbates preexisting disease conditions, minimizing the chances of recovery, and is particularly deleterious to patients with chronic conditions like bronchitis, asthma, and cardiovascular problems. Older people are at higher risk of being affected than the young.

Most of the hazard from air pollution is associated with so-called PM10 particles, which are small, fine particles that can penetrate deep into the lungs. They are produced mainly, but not only, in the exhaust emissions of motor vehicles. Recent estimates suggest they are killing about 60 000 people annually in the United States and about 10 000 per year in the United Kingdom. The situation in other countries is largely unknown, but available data suggest that the problem is likely to be very widespread.

***A need for biomarkers.*** Human exposure to carbon monoxide, for example, can be estimated either by measuring the carbon monoxide concentration in the air or by measuring carboxy hemoglobin in the blood. Similarly, exposure to lead in the atmospheric air can be estimated from the average lead concentrations in blood and urine of the exposed population. Such biomarkers can help physicians assess the risk of disease. At present, however, there are no biomarkers of effects on lungs from exposure to polluted air.

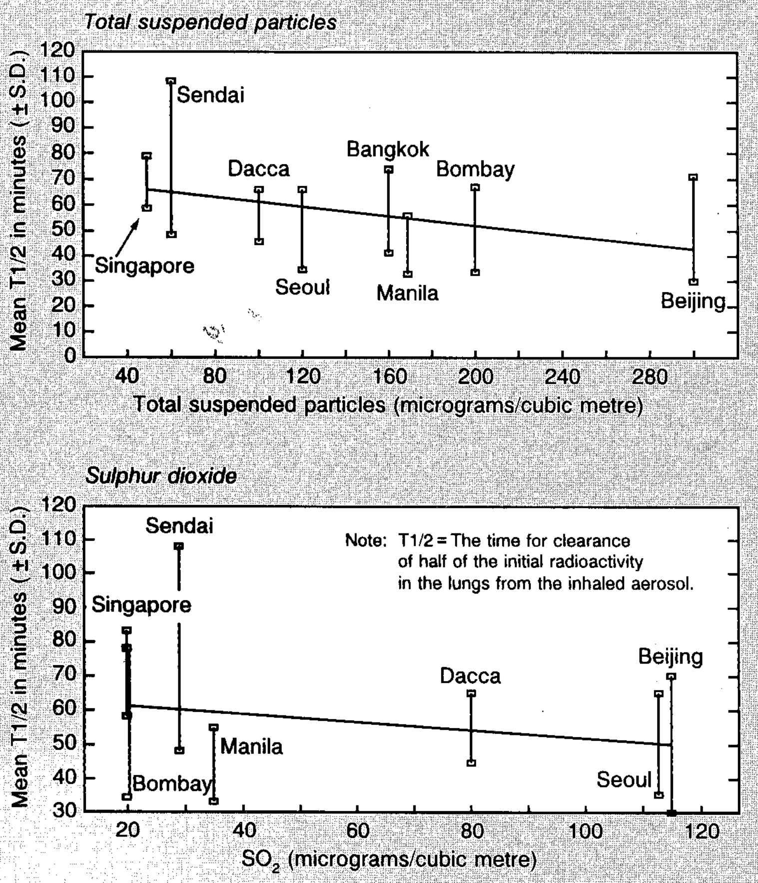
Nuclear techniques help fill this void, however, by providing tools for scientific investigation. They have been used in studies of lungs and airways for the past three decades. The data obtained, for example, enable significant sources of pollution to be identified, and quantified.

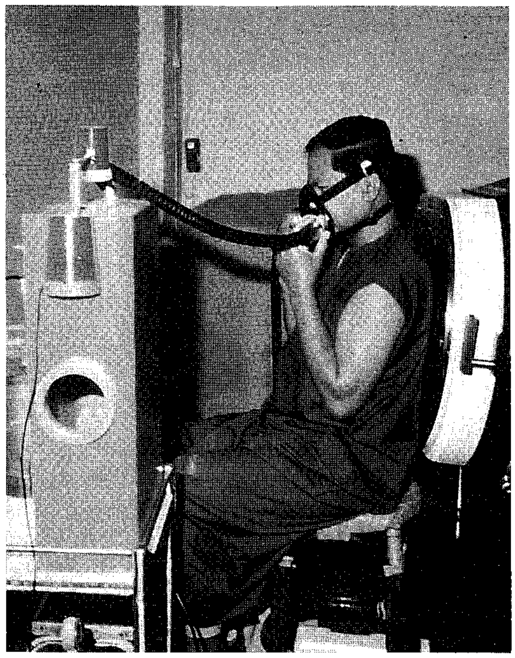
In other ways, the use of radionuclides as tracers help researchers study the respiratory functions of the lungs, namely blood perfusion and lung ventilation. Only recently have non-respiratory functions, such as mucociliary clearance and lung permeability, drawn the attention of clinical investigators. One such investigation involves imaging of the lungs using the aerosol scintigraphy technique with technetium-99m DTPA (diethylene triamine penta acetic acid). The technique — which is used to measure permeability of the alveolar-capillary membrane — is a very rapid, safe, and simple test that can be done in any nuclear medicine department. The patient inhales the aerosol from a delivery system for about five minutes, after which the clearance of radioactivity from the lung fields is monitored using a computerized gamma camera system. The measurements are used to determine the time for clearance of half of the initial radioactivity in the lungs. Any lung alveolar microvascular injury will alter the permeability and this will be reflected in the rate of lung clearance. The technique has been steadily applied to a wide variety of lung diseases characterized by diffuse inflammation of the lung resulting in alveolar microvascular injury.

The aerosol scintigraphy technique has been applied by researchers participating in a recent IAEA co-ordinated research programme (CRP) on aerosol inhalation imaging of lungs. The researchers specifically looked at the effects of urban air pollution on lungs. People from 10 Asian cities — Dhaka, Beijing, Bombay, Bandung, Sendai, Seoul, Lahore, Manila, Singapore, and Bangkok — volunteered for this study. All non-smokers, they did not have any respiratory symptoms, had normal chest radiographs, and were given standard spirometric pulmonary function tests. The aerosol delivery system used in the study was designed and fabricated by the Bhabha Atomic Research Centre (BARC) in Bombay and was tested and validated for carrying out aerosol inhalation studies. The study also included compilation of annual air quality data from the 10 cities that covered total suspended particles (TSP), sulphur dioxide ($SO_2$), nitrogen oxides (NOx), carbon monoxide (CO), and ozone.

The study's results showed that there is an indication of altered lung function, i.e. lung permeability, with respect to concentration of pollutants in the air. This was most evident concern-

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



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

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.

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<br>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.

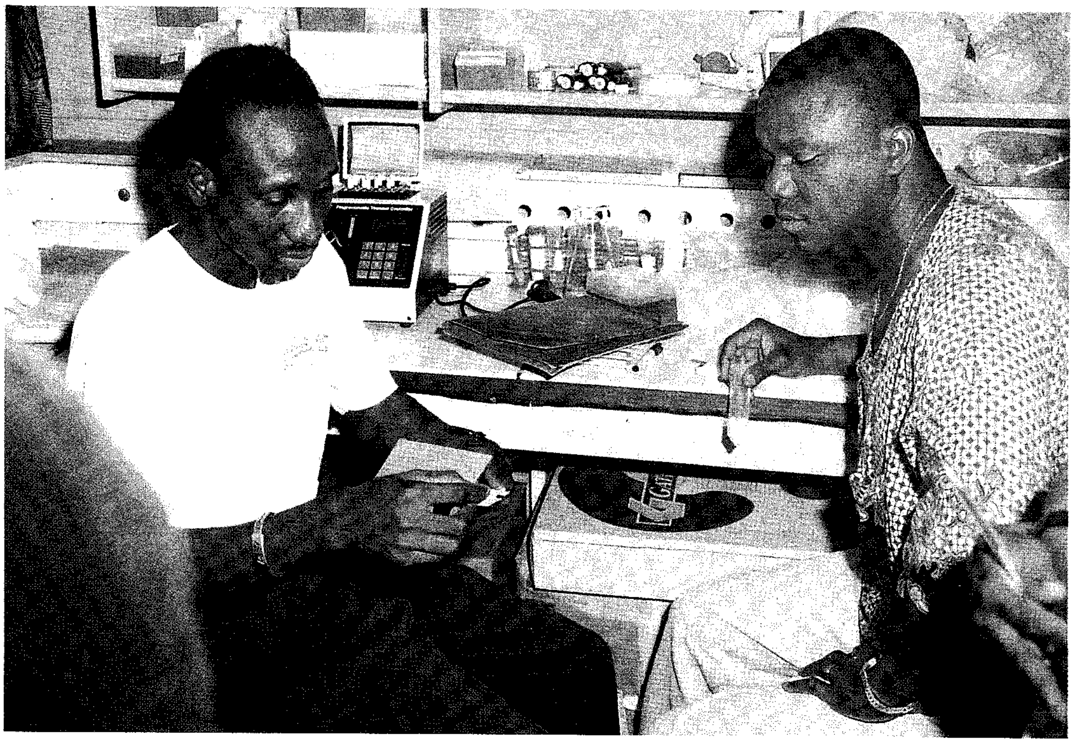
Effective diagnosis can contribute to the control of disease. In laboratories dealing with diagnosis of communicable diseases, the first analysis of clinical material is usually done by microscopy and culture. Both techniques lack sensitivity and specificity. Moreover, culture methods are, in general, 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)***