The International Atomic Energy Agency's

LABORATORIES

Seibersdorf and Vienna

THE INTERNATIONAL ATOMIC ENERGY AGENCY'S

LABORATORIES

SEIBERSDORF AND VIENNA

Meeting the Challenges of Research and International Co-operation in the Application of Nuclear Techniques

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THE INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA)

The International Atomic Energy Agency, a specialized agency within the United Nations system, came into being in 1957 as the vehicle for international co-operation in the peaceful uses of nuclear energy. It plays a unique role in achieving and maintaining high levels of safety in nuclear facilities around the world and in verifying the exclusively peaceful uses of nuclear materials. It is the only worldwide intergovernmental organization dedicated to nuclear science and technology in support of sustainable human development, tackling pressing worldwide challenges, such as sufficient food, water and energy, good health care and a cleaner environment for a rapidly growing world population.

In assisting its Member States through a wide range of activities and programmes, the Agency sets standards, provides independent analyses and expert advice, and shares technologies particularly with developing countries. All these tasks have become more relevant than ever in a fast changing global environment.

The reputation and effectiveness of the Agency are largely a result of its scientific and technical competence and its objectivity. To support its manifold activities and co-operative networks, the Agency operates its own scientific laboratories in Seibersdorf and Vienna and a Marine Environment Laboratory in Monaco, to facilitate technical and scientific analysis and programme delivery. These world standard laboratories are unique in the UN system and help provide high quality services to Member States.

Vienna International Centre - Headquarters of the IAEA.


IAEA LABORATORIES
SEIBERSDORF

THE IAEA LABORATORIES AT SEIBERSDORF AND VIENNA

"The Mission of the IAEA Laboratories is to contribute to the implementation of the Agency's programmes in food and agriculture, human health, physical and chemical sciences, water resources, industry, environment, radiation protection and safeguards verification".

There are many facets of modern life that nuclear science and technology touch in some beneficial way. Whether we look to medicine or how to feed the world's population, examine a high-tech industrial facility or a simple village water supply, monitor environmental contamination or prevent environmental pollution, applications of nuclear knowledge are all around us, making life better for people.

None of these issues could be tackled without the appropriate scientific and technical support. The Agency therefore maintains a unique, multidisciplinary, analytical, research and training centre: the IAEA Laboratories, located at Seibersdorf near Vienna and at the Agency's Headquarters in the Vienna International Centre. They are organized in three branches:

- the FAO / IAEA Agriculture and Biotechnology Laboratory:
  Soil Science, Plant Breeding, Animal Production and Health, Entomology, Agrochemicals;
- the Physics, Chemistry and Instrumentation Laboratory:
  Chemistry, Instrumentation, Dosimetry, Isotope Hydrology;
- the Safeguards Analytical Laboratory:
  Isotopic Analysis, Chemical Analysis, Clean Laboratory.

Together with a General Services and Safety Section, which provides logistics, information, industrial safety and maintenance services and runs a mechanical workshop, the three groups form the "Seibersdorf Laboratories" and are part of the IAEA Department of Nuclear Sciences and Applications.

The Laboratories contribute an important share to projects fostering peaceful applications of radiation and isotopes and radiation protection, and play a significant part in the nuclear verification mechanism. All activities are therefore planned and implemented in close co-operation with relevant divisions and departments[1] of the IAEA. In specific sectors, the Laboratories also operate in conjunction with other organizations in the UN system, such as the Food and Agriculture Organization (FAO), the World Health Organization (WHO) and the World Meteorological Organization (WMO), and with networks of national laboratories in Member States.

[1] Department of Nuclear Sciences and Applications: Joint FAO / IAEA Division of Nuclear Techniques in Food and Agriculture, Division of Human Health, Division of Physical and Chemical Sciences; Department of Nuclear Safety; Department of Safeguards; Department of Technical Co-operation.

The IAEA Laboratories were first established in 1959 in the basement of the Agency's Headquarters, then housed at the former Grand Hotel in Vienna. They consisted of a handful of scientists, operating a small physics and chemistry laboratory and a support electronic workshop. In 1962, they moved into a more appropriate site built on land adjacent to the Austrian Nuclear Research Centre. This site is near the village of Seibersdorf, about 35 km south-east of Vienna. Today, the "Seibersdorf Laboratories" encompass an area of some 15 000 m^2 (more than twice the initial area) and a staff of about 180 people.

Research and International Co-operation for a Better Tomorrow

The Laboratories' activities have changed considerably over the years, especially during the last decade. Early work focussed on the preparation of radioactive sources and determination of radiation doses. Later, the activities were extended to applications of radiation and isotopes in health, agriculture, environmental and analytical chemistry, physics and electronics, and safeguards[2] analysis.

During the last ten years, the Seibersdorf Laboratories have increasingly assumed the role of an international reference laboratory, specialized in the above areas and water resources management. The new role of the Seibersdorf Laboratories has put increased emphasis on quality assurance and control of all its activities and in particular analytical measurements.

The larger agenda of the IAEA Laboratories reflects the Agency's growing responsibilities: it spans food and agriculture, water resources, human health, physical and chemical sciences, industry, environment, radiation protection and safeguards verification. The three individual laboratories listed above support the implementation of relevant IAEA programmes.

Analytical and Scientific Approaches

In areas where international acceptability of analytical results is of particular relevance, the Laboratories play a key role. Their analyses of nuclear and environmental samples from safeguards inspections, of radionuclides in air, soil, biota, fresh water and food, of isotopes in water, of trace and toxic elements in biological samples, and of food contaminants, guarantee credible and verifiable results.

Therefore, all radiochemical analyses as well as all analyses by nuclear and non-nuclear analytical techniques require strict quality control and quality assurance. To achieve this aim, scientists and technicians conduct intercomparisons and proficiency tests, and prepare, certify and distribute reference material to national laboratories

[2] "Safeguards" is the term used to describe the IAEA verification system of relevant materials in the context of non-proliferation of nuclear weapons.

to help them control the quality of their measurements. This External Quality Assurance Programme constitutes a vital service to Member States, establishing the Laboratories as an international reference centre. To strengthen this role, the Seibersdorf Laboratories themselves comply with the most stringent quality standards.

Specialized scientific and technical services help to implement IAEA technical programmes effectively, e.g. by measuring radiation doses for radiotherapy and industrial applications, maintaining, repairing and servicing nuclear instrumentation and providing diagnostic kits for detecting animal diseases. In supporting the Sterile Insect Technique (SIT) for insect pest control and eradication efforts, these services also include the build-up and maintenance of colonies of insects, such as tsetse flies and Mediterranean fruit flies.

Research and development aim mainly at filling knowledge gaps which prevent the practical application of a given nuclear technology, or fulfil the function of an international reference laboratory. The Seibersdorf Laboratories become involved only when research work cannot be carried out in a Member State. For example, research in soil science has improved the effective use of fertilizers in fields; a breakthrough has been the creation of a new banana variety with higher yields; and portable analysers designed at the Laboratories now assist in measuring environmental pollutants in the field.

Many of these activities are carried out in support of the IAEA Technical Co-operation Programme, which fosters international partnerships in development. To that end, the Laboratories undertake strategic research and development and other laboratory activities, provide technical advice and train scientists from Member States.

Several specialized networks of laboratories have been set-up and are co-ordinated by the IAEA. The Seibersdorf Laboratories participate in analytical measurements and permit national laboratories to validate their own measurements through IAEA standards or reference samples. These networks include:

- the ALMERA (Analytical Laboratories for Measuring Environmental Radioactivity) network, to provide radioanalytical support in case of an accidental release of radioactivity,
- the GNIP (Global Network of Isotopes in Precipitation), operated jointly with the WMO, to collect hydrological and climatological data from meteorological stations worldwide,
- the NWAL (Network of Safeguards Analytical Laboratories), to analyse the large number and diversity of samples requested within the IAEA Safeguards System,
- the SSDL (Secondary Standard Dosimetry Laboratory) network, to promote and maintain standards for dose measurements (dosimetry) in radiotherapy and radiation protection.

Portable XRF unit designed at the IAEA Laboratories.

Banana plants cultivated in the Laboratories' greenhouse.

In addition to networks co-ordinated by the IAEA, Laboratories staff play important roles within other international and regional standard setting organizations. These organizations include the International Committee for Radionuclide Metrology (ICRM), the European Safeguards and Research Development Association (ESARDA), various committees of the International Standards Organization (ISO) and the International Union of Pure and Applied Chemistry (IUPAC), EURACHEM, the Co-operation on International Traceability in Analytical Chemistry (CITAC), and committees of the Codex Alimentarius, the World Animal Health Organization (OIE), and the World Health Organization (WHO).

Training

Acquiring the necessary skills to use nuclear technologies appropriately, and safe handling and maintenance of sensitive instruments is a key factor in successful technology transfer. Therefore, the IAEA Laboratories place great emphasis on training scientists from developing countries in all fields covered by their activities. This is one of the key services the Laboratories provide to Member States.

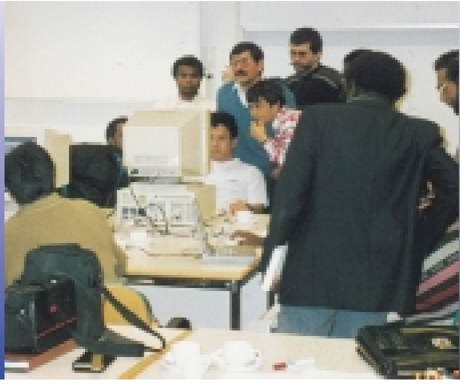
In-service training enables fellows to work alongside staff scientists for a period of one to twelve months in the application of specific nuclear techniques, for example in radiation mutation to develop crops tolerant to drought or high soil salinity, in gamma spectrometry for environmental radioactivity monitoring, or in isotope techniques to manage scarce water resources.

Six to eight training fellows typically participate in Group Training for a period of two to six months. The fellows receive technical tutoring, attend lectures and gain extensive hands-on experience under the supervision of the Laboratories' technical staff. For example, fellows learn how to repair, maintain and service nuclear electronic instrumentation.

Interregional Training Courses are held three to four times every year for some 20–30 participants. Over a five to eight-week period, they attend lectures and undertake practical exercises covering selected topics. Recent Interregional Training Courses dealt with measuring food contaminants and pesticide residues using nuclear and other techniques, monitoring environmental radioactivity and applying nuclear techniques to increase animal productivity.

Over the past four decades, more than 2300 scientists and technicians from 120 countries benefited from these training services at the Seibersdorf Laboratories.

Training scientists from Member States is one of the key services of the IAEA Laboratories.



RECENT HIGHLIGHTS

A new FAO/IAEA Training and Reference Centre for Food and Pesticide Control, made possible by generous donations from Sweden, Austria and the FAO, helps laboratories in Member States to meet international standards in analysing food samples for residues of pesticides, veterinary drugs and mycotoxins. Adherence to these standards is essential if countries want to participate in international food trade. The centre has a training programme for analytical chemists from developing countries, introducing them also to the Quality Assurance programme, a major activity of the IAEA Laboratories.

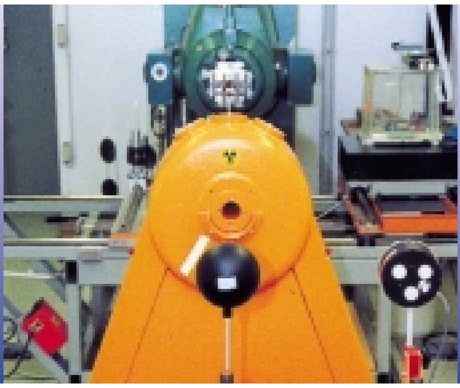
ALMERA, the network of Analytical Laboratories for Measuring Environmental Radioactivity, was successfully activated to support the International Study of the Radiological Situation at the Atolls of Mururoa and Fangataufa in French Polynesia where extensive testing of nuclear devices had occurred. The network, which presently consists of 53 laboratories in 26 countries, provided indispensable radionuclide measurements of environmental samples.

The exact calibration of dosimeters, used for monitoring people exposed to radiation in their working environment, is crucial for the radiation protection of workers. A pilot study, involving 30 national standard laboratories, successfully tested a recently developed TLD (thermoluminescent dosimeter) based system for dosimetry of low doses in caesium-137 gamma ray beams.

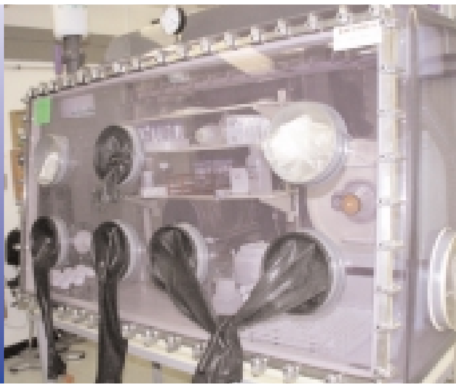
The capability of the Safeguards Analytical Laboratory has been significantly enhanced by new, high-sensitivity equipment (an inductively-coupled plasma mass spectrometer – ICP/MS). Donated by the government of the UK and specially modified in a French laboratory for work with plutonium samples, this instrument will permit great improvement in the quality of measurements of impurities in nuclear fuel materials.

Mururoa Atoll, French Polynesia.

Dosimetry calibration unit.



Glove box of the ICP/MS, used for Pu measurements.



THE FAO/IAEA AGRICULTURE AND BIOTECHNOLOGY LABORATORY

SOIL SCIENCE

PLANT BREEDING

ANIMAL PRODUCTION AND HEALTH

ENTOMOLOGY

AGROCHEMICALS

THE FAO/IAEA AGRICULTURE AND BIOTECHNOLOGY LABORATORY

Towards Sustainable Food Security

Many developing countries face enormous obstacles in meeting the need for food. Africa, for example, will require a tripling of current agricultural production over just three decades. But in many countries agricultural output is severely hampered by poor soils and practices, scarce water resources and low plant productivity due to adverse environmental conditions. Cattle production is affected by infectious diseases, under-nourishment and low fertility. Insect pests reduce global food output by about a third and inhibit international trade. They transmit diseases that severely affect humans, livestock and crops. In some developing countries, as much as 40 percent of all food produced is lost to insects or damaged by rodents, bacteria and mould.

Nuclear technologies can contribute significantly to alleviating these problems and to fighting hunger and poverty in developing countries. Applied in the appropriate way, they can foster sustainable food security and lead to substantial direct benefits to agriculture. The IAEA, as the only organization in the UN system applying nuclear technologies to meet basic human needs, has therefore joined forces with the Food and Agriculture Organization of the United Nations (FAO), whose mandate includes raising levels of nutrition and standards of living, improving agricultural productivity, and thereby enhancing the condition of rural populations. This successful co-operation is reflected in a Joint FAO/IAEA Programme on Nuclear Techniques in Food and Agriculture which includes both the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture (the "Joint Division"), based in the Agency's Headquarters, and the FAO/IAEA Agriculture and Biotechnology Laboratory (the "Agriculture Laboratory").

The Agriculture Laboratory works with the Joint Division in implementing the Joint FAO/IAEA Food and Agriculture Programme to address these food and agriculture challenges. Its international team of scientists specializes in research, development and the transfer of suitably adapted nuclear and complementary agricultural technologies. These techniques enable, for example, precise measurements to be made in soil and water management, important for crop output, breeding of more resistant and higher-yielding plants, identifying the presence of animal diseases and measuring hormone levels in animals to improve livestock production. They can reduce dramatically or even eradicate several insect pests, and also assist Member States to comply with international food trade agreements.

The Agriculture Laboratory's programme is established in agreement with the Joint Division. It focuses its activities and services on:

- Training of scientists from developing countries, emphasizing the transfer of nuclear and related biotechnologies,
- Strategic research and development and other laboratory activities in support of the Agency's Technical Co-operation Programme and Co-ordinated Research Projects, which encourage learning partnerships between scientific institutions throughout the world,
- Supply of materials to national and interregional projects,
- Provision of analytical and quality assurance services, and
- Expert services.

SOIL SCIENCE

Fertile Fields for More Food

Fertile soils and adequate water resources are essential to plant growth and thus sustainable agriculture. But in many parts of the developing world soils are deficient in key nutrients, such as nitrogen and phosphorus, and suffer from scarce or low-quality water supply. Both stable and radioactive isotope techniques can play a critical role in understanding soil-plant interactions and in helping to increase crop production through better soil and water management.

The **Soil Science Unit** supports the activities of the Joint FAO/IAEA Programme in developing and applying these nuclear techniques for measuring soil, water and plant processes. It studies ways of optimizing the use of water and plant nutrients in a manner which is environmentally sustainable. Its research findings and the methodologies used are subsequently transferred to Member States within the framework of IAEA Technical Co-operation and Co-ordinated Research Projects, and through laboratory-based training courses and fellowships. In addition, the Soil Science Unit carries out some 10 000 to 15 000 analyses each year of nitrogen and carbon isotope samples received from Member States that lack adequate facilities for crop nutrition studies. An External Quality Assurance Programme helps collaborating laboratories in Member States to set standards and evaluate their own analyses.

Soil scientists investigate rooting patterns at the Seibersdorf Laboratories.

NUCLEAR TECHNOLOGIES

- Emission and mass spectrometric analytical techniques for determining the stable isotopes nitrogen-15 and carbon-13,
- Phosphorus-32 based methods for measuring the efficient use of phosphate fertilizer and studying the fate of phosphate in soils,
- Neutron moisture probes and gamma gauges to measure soil-water balance and soil bulk density.

Activities and Achievements

Efficient Use of Fertilizers

Chemical fertilizers are a major cost for farmers in developing countries and, when used excessively, pollute the environment. Research has shown that less than 40 percent of the applied fertilizer can be taken up by the various crops. Over 60 percent is lost to the atmosphere, groundwater or remains unused in the soil. This finding has been confirmed in a number of FAO/IAEA studies. The nitrogen-15 isotope technology (^{15}N is the stable isotope of N) is arguably the best technique available to measure accurately the efficiency of nitrogen fertilizers. Many Member States have used isotope technologies to draw up recommendations for effective uses of fertilizers for major crops.

A Biological Alternative – Biofertilizer

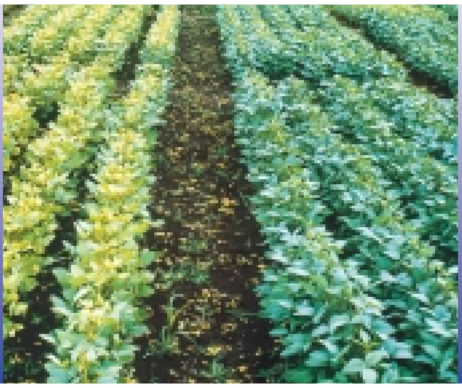
One way to improve soil fertility is to combine nature's gift of providing nitrogen in the atmosphere with nuclear technologies. About 80 percent of the atmosphere is nitrogen, which can be captured or "fixed" by leguminous crops through a symbiosis between the legume and a soil-borne, nitrogen fixing bacterium called Rhizobium.

The Soil Science Unit has pioneered and refined isotope techniques for measuring biological nitrogen fixation (BNF) and their transfer to developing countries. Using ^{15}N isotope tracers, efficient Rhizobium bacteria strains have been identified and nitrogen was monitored through the entire plant growth cycle. These bacteria, added to the seeds of legumes, such a soybeans, peas, beans, alfalfa and clover, stimulate the production of root nodules in plants which convert atmospheric nitrogen to a plant-usable form. The nitrogen fixed by the nodules not only promotes growth in the host legume, but also leaves soils more fertile for other crops grown subsequently in the fields. Fertilization by atmospheric nitrogen fixation is environmentally friendly, cheap and increases yields in legumes that are high in nutritional value.

Nodules on leguminous crops can fix N from the atmosphere.

Neutron moisture probe.

BNF increases yields.



Improved Water Use

Water scarcity limits crop production in many developing countries. How crops and pastures most effectively absorb the sparse amounts of water available in soils is an important issue in maximizing scarce resource use.

The Soil Science Unit is engaged in studies to refine isotopic techniques for monitoring the different sources of water available to crop plants, be it rain or ground water. These techniques are based on the different isotopic “signatures” found in water from different sources – the ratios of the oxygen isotopes (oxygen-16 and oxygen-18) and the hydrogen isotopes (hydrogen and deuterium) vary depending on the source of water taken up by the plant.

Renewables as Nutrients

A key element in sustainable agriculture is the use of renewable resources, such as animal manure, legumes or crop residues to maintain or improve soil quality and provide sufficient nutrients for crops.

Research and development at the Soil Science Unit has been instrumental in developing a ^{15}N technique for measuring the availability of nutrients from organic materials with the aim of reducing the need for mineral fertilizers. Nuclear methods, the direct ^{15}N technique and the ^{15}N isotope dilution technique, help to assess crop residues and locally available wastes, including radiation-sterilized sewage sludge, as ecologically sound nutrient sources.

PLANT BREEDING

Boosting Agricultural Production

Although conventional plant breeding methods have contributed considerably to increasing productivity of modern crops, advanced technologies must be employed to complement these methods and accelerate crop improvement. Plant biotechnology including nuclear techniques, tissue culture and molecular techniques can boost crop improvement, shorten the breeding process and help overcome some of the substantial agronomic and environmental problems that have not been solved by conventional methods.

INDUCED MUTATION

Plant scientists can induce changes or mutations in the DNA of plant seeds, buds or tissue by irradiating the plant material with gamma rays, X rays or fast neutrons. They then identify and select plants with the desired characteristics to breed improved, more robust or higher-yielding plants.

The Joint FAO/IAEA Programme develops and transfers nuclear and related methodologies and techniques to assist developing Member States in plant breeding research for crop improvement, especially as this relates to improved productivity under various environmental stresses.

The **Plant Breeding Unit** undertakes strategic research to develop methodologies for screening beneficial mutations, including low cost approaches and the use of unsophisticated equipment. Its team of scientists carries out experiments on mutation induction to increase and improve the genetic diversity of crops, such as rice, bananas and plantains and also on *in vitro* techniques to select and screen for desired genotypes of plants. Field trials are carried out in collaboration with national research centres and CGIAR[3] centres. The research results are transferred to Member States and may have an impact on agricultural policies in many developing countries.

A unique, cost-free service provided to Member States is the radiation treatment of plant material: since 1967 over 22 000 batches of seeds and *in vitro* cultures were irradiated for national crop improvement programmes.

NUCLEAR AND BIO-TECHNOLOGIES

- Cobalt-60 gamma source to induce mutations in plants,
- Molecular techniques, using DNA markers to detect the invisible genetic “fingerprint” of a plant and help to characterize the genetic diversity in crops,
- *In vitro* techniques to facilitate growth of millions of cells in a laboratory and allow the production of large populations of plants,
- *In vivo* and *in vitro* screening techniques for selecting mutants, e.g. tolerant to salinity or plant diseases.

[3] CGIAR – Consultative Group on International Agricultural Research.

Greenhouses of the Plant Breeding Unit at Seibersdorf.

Activities and Achievements

Science Imitating Nature

Mutations leading to increased biodiversity occur very rarely in nature. By using ionizing radiation, this natural diversity can be increased up to 10 000-fold and the development of new varieties significantly accelerated. A number of desirable characteristics such as disease resistance, drought tolerance, early maturing and better yield potential can thus be introduced, or an existing variety can be improved to make it more attractive to the consumer.

Plant biotechnology in combination with mutation induction and conventional breeding methods may open new frontiers for major crop varieties. Scientists at the Seibersdorf Laboratories are applying molecular techniques to identify DNA markers for salinity tolerance or susceptibility in rice mutants. This provides a rapid and reliable screening technique, particularly when large amounts of breeding material have to be tested. In addition, this DNA "fingerprinting" technique may be available as a service to directly support scientists in developing countries.

SUCCESSFUL MUTATIONS

Several mutants have been developed by national research programmes with support from the FAO/IAEA Programme:

In co-operation with the Malaysian University and the Malaysian Institute for Nuclear Technology Research, NOVARIA – a new mutant clone of Graine Naine, a popular Cavendish banana – was successfully developed using in vitro gamma radiation. The new banana type is characterized by early flowering, vigorous growth and good flavour.

An apple mutant variety induced by ^{60}Co radiation from "Golden Delicious" was developed and released in co-operation with the fruit experimental station Haidegg in Austria. This variety, named "Golden Haidegg", has a more intense fruit colour, can be stored longer and shows no russeting.

Development of Low Cost Tissue Culture

Mutation induction combined with tissue culture have made a significant contribution to plant breeding. To make this technology available to Member States, the Plant Breeding Unit has developed low cost tissue culture techniques that use cheap and easily available materials and simple laboratory equipment. The research demonstrated that the cost of micropropagation can be significantly reduced by taking advantage of natural sunlight, rather than relying on electric lighting in sophisticated growing rooms, and using locally available sugars instead of tissue-culture sucrose.

"Golden Haidegg" – apple mutant variety induced by radiation from "Golden Delicious".

In vitro shoots of bananas produced under artificial and natural light.

Major Crops

Bananas and plantains (*Musa spp.*) are among the world's major crops, reaching an annual production of some 80 million tons worldwide. They provide food and a source of income for hundreds of millions of people in tropical and sub-tropical regions.

Conventional methods to breed or improve different kinds of edible bananas and plantains are problematic because of the sterile nature of these plants. In collaboration with other laboratories in Member States, the Plant Breeding Unit is undertaking research to genetically improve several banana varieties using *in vitro* techniques to isolate mutants and screen for disease resistance. The aim is to produce banana plants which are resistant to fungal disease and require less or no pesticide spraying, a current practice which is costly and environmentally harmful.

Rice is a principal source of food for more than a third of the world's population. But the most widespread problem in rice-growing countries is saline soils. Of some 400 million hectares of salt-affected land in the world, 56 million are found in South and Southeast Asia, areas where rice production is highest. Every year, some 10 million hectares of potentially productive land are lost as a result of salinity or ineffective water management.

Over the past years, nuclear and related technologies have played a crucial role in developing mutant rice lines that are tolerant to salinity. The Plant Breeding Unit has been advancing these technologies. Recent research included mutation induction coupled with the so-called anther culture technique and salinity screening at the seedling stage under greenhouse conditions.

Scientists grow genetically improved banana plants in the Seibersdorf greenhouses.

Plant breeding experts develop mutant rice lines tolerant to salinity.

ANIMAL PRODUCTION AND HEALTH

Improving Breeding Efficiency – Combating Animal Diseases

Animals provide milk, meat and hides as a source of income for millions of farmers, as well as draught power and manure to cultivate crops. But in many parts of the developing world livestock productivity is seriously constrained due to infectious diseases, malnutrition, poor reproductive performance and environmental stress. Nuclear and related technologies can alleviate these problems in both cost-effective and environmentally friendly ways.

The Joint FAO / IAEA Programme contributes to developing new strategies for feeding and breeding animals, determining the existence and prevalence of major livestock diseases and monitoring the efficacy of vaccination campaigns for disease control and eradication.

The **Animal Production Unit** bridges the gap between technological development and field application. It provides research and technical support, training and other services to scientists and veterinarians in Member States. The Unit also emphasizes standardization and internal and external quality assurance of analytical and diagnostic techniques.

NUCLEAR AND RELATED TECHNOLOGIES

- Radioimmunoassay (RIA) for measuring hormones and monitoring reproductive processes,
- Enzyme-linked immunosorbent assay (ELISA) and molecular-based technologies, e.g. polymerase chain reaction (PCR), for diagnosing infectious diseases.

The Animal Production Unit plays a key role in international efforts to tackle animal health issues. It is designated as

- the FAO / IAEA Central Laboratory for ELISA and Molecular Techniques in Animal Disease Diagnosis,
- the World Animal Health Organization (OIE) Collaborating Centre to advise on animal disease diagnostic issues, and
- the WHO Collaborating Centre for ELISA and Molecular Techniques in Zoonoses Diagnosis.

In these capacities, the Animal Production Unit supports various initiatives in the development of international guidelines for, and standardization of, diagnostic tests to detect animal diseases.

Activities and Achievements

Improving Breeding

By using the isotope-based radioimmunoassay (RIA) technique, reproductive and other hormones can be measured – in milk, serum or plasma – to give a better understanding of the reproductive physiology of livestock. RIA is an important tool used to determine when animals are ready for breeding, to diagnose pregnancy, to correct reproductive health disorders and to improve artificial insemination. The overall benefits are healthier animals, more milk and meat and higher income for farmers.

The Unit has provided RIA kits to laboratories in Member States for measuring the female reproductive hormone, progesterone, and its male counterpart, testosterone, in ruminants such as cattle, sheep, goats, buffalo, camelids and yaks. RIA kits, commercially available for testing human blood, were adapted for use in these domestic animals. Some 1500 adapted RIA kits are distributed every year to more than 50 counterpart laboratories around the world. To bring down costs and make these kits affordable for developing countries, new assay formats have been developed in co-operation with national laboratories.

APPLYING RIA

In Peru, the RIA technique was used successfully to improve productive performance of dairy cows; this involved the introduction of Zebu and European crossbreeds through artificial insemination and an improved pasture-production scheme. Progesterone RIA helped to improve and monitor the breeding programme, in which each cow now produces up to 10 more liters of milk daily.

In Mexico, a dairy co-operative using RIA was able to increase milk production by 63 percent, which in that case means an extra 10 million liters of milk per year.

RIA works through antibody/antigen interactions to measure the relative concentration of reproductive hormones in milk, plasma or serum.

Fighting Infectious Diseases

Millions of livestock die or are unproductive due to viral, parasitic or bacterial diseases. The control and ultimate eradication of these diseases is essential for improving economies in developing countries and lifting international trade barriers.

The Joint FAO/IAEA Programme supports international animal health projects by developing and transferring the nuclear-related technique, ELISA (enzyme-linked immunosorbent assay), and newer, molecular-based techniques (e.g. the polymerase chain reaction – PCR) for diagnosing diseases in cattle and for monitoring disease control programmes. Standardized ELISA diagnostic kits with new, improved assays, sustainable in adverse environmental conditions, were developed by the Animal Production Unit in collaboration with national laboratories for several major animal diseases and distributed to over 50 collaborating laboratories in developing countries.

- Rinderpest (or cattle plague) killed millions of cattle in Africa and West Asia some two decades ago. Following international vaccination campaigns within the Global Rinderpest Eradication Programme (GREP) and the Pan-African Rinderpest Campaign (PARC) to control and eventually eradicate this plague, ELISA tests and molecular methods are now used by laboratories in some 40 countries to measure vaccination efficacy or detect any remaining virus activity through sero-monitoring.

- Trypanosomosis is a livestock disease transmitted by the tsetse fly which severely restricts cattle rearing in Africa. ELISA helps to detect the trypanosomes in cattle and to survey intervention strategies. It was applied during and after the successful tsetse eradication campaign on Zanzibar island, United Republic of Tanzania, and will be used in other major campaigns to eradicate this disease and its insect vector.

- Brucellosis and foot-and-mouth disease are major debilitating livestock diseases in Asia, Latin America and Africa. ELISA kits, developed in Member States and standardized by the Animal Production Unit, assist national and regional control programmes and are already used by dozens of veterinary laboratories in Member States.

> The ELISA technique, analogous to RIA, is highly suitable for processing large numbers of samples because it is quick and relatively low cost. ELISA tests are used to diagnose a wide variety of diseases by identifying the disease agent itself and/or the antibodies produced against the agent.

ELISA kit.

ENTOMOLOGY

Controlling and Eradicating Insect Pests

In many parts of the world, insect pests have a devastating effect on food production and on human and animal health. Despite the use of chemical insecticides costing some US $32 billion every year, up to 40 percent of global food output is estimated to be lost due to insect pests. In addition, non-tariff barriers to international trade in agricultural commodities have to be overcome, often requiring a pest-free status. Concerns about environmental pollution, resistance to pesticides, residues in food and the preservation of biodiversity demand new and insecticide-independent strategies and technologies for combating major pests to secure enough food for a rapidly growing world population.

The Joint FAO/IAEA Programme is researching, developing and implementing such technologies and methods. The focus of activities is an environmentally friendly technology known as the Sterile Insect Technique (SIT). This nuclear-based method has been highly successful in pest management programmes all around the world to control and eradicate harmful insect pests, such as fruit flies, tsetse flies, screwworms and certain caterpillars.

THE STERILE INSECT TECHNIQUE - A BIRTH CONTROL FOR INSECTS

The success of this technique lies in the regular release by air of considerable numbers of sterile insects of the target species over large infested areas. The technique is applied using an area-wide concept which targets an entire insect population. The insects are reared in "fly factories" and then irradiated by gamma radiation, which renders them sterile but otherwise leaves them reproductively active. Mating of the released males with wild female insects produces no offspring. Continual releases cause a fall in the insect population leading to eradication.

The **Entomology Unit's** international team of researchers focuses its activities on two key insect pests: the tsetse fly and the Mediterranean fruit fly (medfly). The researchers develop mass rearing procedures, quality control protocols, radiation sterilization strategies, develop genetic sexing strains and provide sterile insects and other materials to field programmes and collaborating institutions. Its R&D work in these areas is unique and has an essential, major impact on the implementation of SIT in many Member States.

Insecticide spraying reduces the insect population before applying SIT.

Medflies.

Tsetse fly.

NUCLEAR AND RELATED TECHNOLOGIES

- The Sterile Insect Technique, as a key element in integrated area-wide eradication campaigns,
- Genetic methods for developing male-only strains in fruit flies,
- Molecular techniques, such as the polymerase chain reaction (PCR), for insect population analysis.

Activities and Achievements

The Tsetse Fly – a Scourge for Africa

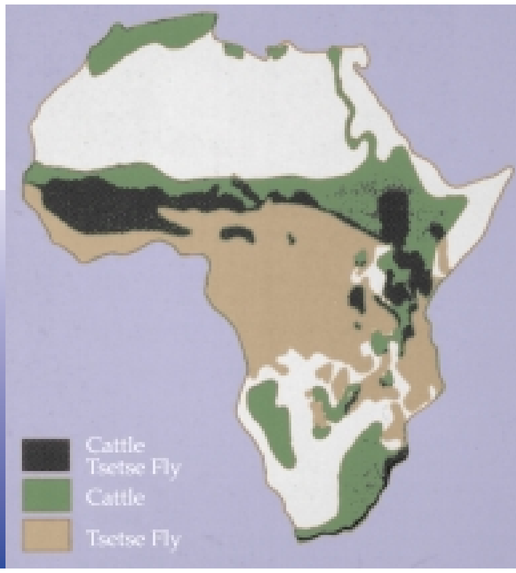
Tsetse flies infest almost two thirds of sub-Saharan Africa and transmit a parasitic disease – Trypanosomosis – which devastates livestock herds and spreads debilitating “sleeping sickness” amongst people. The Sterile Insect Technique may provide a lasting solution for effective tsetse control and eradication operations in Africa.

Research at the Entomology Unit led to a breakthrough in mass rearing of sterile tsetse flies, essential for any effective SIT programme. The rearing technology and procedures developed included a new feeding system, sex separation for sterilizing males only and a set of quality control protocols. Recent advances in automated rearing of tsetse flies considerably increase production capacity and reduce costs. The Unit’s R&D work played a crucial role in the successful eradication of the tsetse fly on Zanzibar island.

TSETSE ERADICATION ON ZANZIBAR

Within an IAEA technical co-operation project, the technology to mass produce tsetse flies was transferred to the Tsetse and Trypanosomiasis Research Institute (TTRI) in Tanga, Tanzania, and national staff were trained. From a “start-up” colony, established at the Entomology Unit, the Tanga fly factory was able to produce millions of sterile male tsetse flies which were released by air over the nearby island of Zanzibar. Following a period of continuous releases, the tsetse fly was eradicated and the trypanosomosis problem was eliminated. The lasting impact of this SIT campaign is increased livestock development and better agricultural land use on Zanzibar.

Over 10 million km^2 of sub-Saharan Africa are infested by tsetse flies. Tsetse eradication allows the introduction of productive livestock and agricultural systems.



In support of future eradication campaigns in other parts of Africa, the Entomology Unit continues to refine methods for tsetse SIT. It is the only laboratory in the world which can provide tsetse flies from six different species. New automated rearing of tsetse flies standardizes the rearing process.

The Mediterranean Fruit Fly

The medfly is among the most economically harmful insects, severely hindering world trade in agricultural products. It attacks over 250 species of fruit and vegetables in many parts of the world. So great is the potential damage that many countries impose strict trade barriers and prohibit import of fresh, potentially infested produce from endemic countries.

R&D in SIT technologies for area-wide medfly control and eradication is among the most advanced in insect pest management. The Joint FAO/IAEA Programme has supported successful SIT projects in Argentina, Chile, Costa Rica, Guatemala, Mexico, Peru and Portugal, USA (California), South Africa and the Middle East. In Chile, for example, eradication of the medfly has given a major boost to a multi-billion dollar fruit and vegetable export industry. Research work, training of scientists and the transfer of new technologies to Member States by the Entomology Unit have been crucial to these successes.

The Unit is now the acknowledged world centre for medfly genetic diversity and currently maintains some 80 genetically different strains of this insect. Its central role lies in the development of genetic sexing strains (GSS) of medflies, i.e. strains which allow the sexes to be easily discriminated during the rearing process with the result that only males are released.

TECHNOLOGY TRANSFER IN ACTION

In Argentina, the major temperate fruit production regions in Mendoza Province and various Patagonian Provinces have achieved the lowest medfly population ever using a GSS developed at Seibersdorf, and have now negotiated access, through Chile, to Pacific ports.

Israel and Jordan have joined forces in eradicating the medfly from the lower Jordan Valley (also known as the Arava or Wadi Araba) to increase the horticultural development of the area and enhance trade. A GSS is an essential component of this programme. Expanding the project to eradicate this major plant pest from the entire region, which causes substantial harvest loss in fruit and vegetables, is expected to lead to increased revenues of some US $330 million in Israel and some US $195 million in Jordan. In addition, the environment will benefit from this SIT campaign by eliminating more than 194 tonnes of pesticide used each year, which, besides being costly, leaves residues in water, soils, fruits and plants.

Medfly production facility in Mendoza Province.

Lower Jordan Valley.

Rearing system for medflies at the Entomology Unit. New mass rearing concepts are based on a Recombinant Filter System, leading to better quality of the mass reared insects.

By isolating a special mutation inducing temperature sensitivity, a GSS has been developed in which female eggs are killed by a minor temperature increase. Brown medfly pupae (below) are heat-treated males. Fly production costs are reduced considerably by producing males only.

AMBROSE MASABA GIDUDU, UGANDA

Research Fellow at the Entomology Unit of the FAO/IAEA Agriculture and Biotechnology Laboratory

A graduate in botany and zoology of Makerere University in Kampala (BSc) and of the University of Montepellier in France (MSc), Ambrose Gidudu is a Ugandan research fellow at the Agriculture Laboratory. He is participating in a nine-month training programme at the Entomology Unit to study molecular biology techniques and genetic methods in tsetse fly research and in applying them in the Sterile Insect Technique (SIT).

The training he receives at Seibersdorf is particularly appropriate and of importance to his home country, as Ambrose has been involved in tsetse control programmes in Uganda since 1988. Like many other countries in sub-Saharan Africa, Uganda is infested by tsetse flies which cause acute and chronic sleeping sickness in people and "Nagana", animal trypanosomosis, in livestock. As the Acting Principal Entomologist at the Tsetse Control Division of the Ugandan Ministry of Agriculture, Animal Industry and Fisheries since 1996, Mr. Gidudu has planned and co-ordinated national and community based tsetse control programmes.

He is no newcomer to the IAEA, as he participated in fellowship training on tsetse fly rearing at the Entomology Unit in 1991 and served as Implementation Officer for an IAEA project on the control of tsetse flies on the Buvuma Islands in Lake Victoria from 1990 to 1992. This is where he will be able to contribute the know-how gained at Seibersdorf: using molecular biology techniques, Ambrose is learning to extract DNA from tsetse flies, to analyse this DNA in order to determine fly movement and detect if re-invasion of an area occurs. Upon returning to Uganda, Ambrose will carry out these analyses in the field within an IAEA-supported project that aims at eradicating the tsetse fly from the Buvuma Islands using SIT.

Mr. Gidudu finds that he is greatly benefiting from the fellowship programme and from contacts with other researchers. "This training has been a great chance for me to improve my scientific work and morale", he said. "Basic equipment from the IAEA will allow me to continue my work in Uganda. This will not only be beneficial for me personally, but, most important, for my country" he concluded.

AGROCHEMICALS

Safe Food in International Trade

Pesticides are applied worldwide to control contamination and improve agricultural output. However, they may leave residues in food, which, if exceeding defined levels, may be harmful to health and inhibit international trade. International agreements[4] provide a clear framework for harmonizing regulatory measures to ensure quality and safety in food and avoid non-tariff trade barriers. Implementing these international regulations and national legislation in Member States requires suitable laboratory facilities and adequately trained personnel to monitor the wide range of potential chemical and microbiological food contaminants. While this infrastructure is standard in the industrialized world, many developing countries still lack the appropriate capability to support such legislation.

The **Agrochemicals Unit,** operating within the Joint FAO/IAEA Programme, assists developing Member States in the control of food quality and safety by transferring appropriate techniques for the analysis of organic contaminants in food. It also provides quality assurance services for scientists in Member States in the safe use of agricultural chemicals and in monitoring the resulting residues, to ensure safe and good quality food.

Training is the key activity of the Agrochemicals Unit. The Unit is the central laboratory of the FAO/IAEA Training and Reference Centre for Food and Pesticide Control (TRC), established in 1998. With the opening of an additional training laboratory facility in 1999 – constructed thanks to donations from the governments of Austria and Sweden, and from FAO – a major training programme for analytical chemists from developing Member States has commenced.

NUCLEAR AND RELATED TECHNOLOGIES

- Radiotracers, i.e. radio-labelled (^{14}C) pesticides for validating analytical methods and protocols for determining residues in food samples,
- ELISA – enzyme-linked immunosorbent assay, e.g. for determining DDT residues in soils.

[4] For example, the WTO Application of Sanitary and Phytosanitary Measures, the WHO International Code of Conduct on the Distribution and Use of Pesticides, and the FAO/WHO Codex Alimentarius.

Activities and Achievements

Validating Methods

The challenge faced by many laboratories in developing countries is to use their limited instrumentation effectively, while still assuring reliable results. In its efforts to assist developing Member States, the Agrochemicals Unit is selecting and validating simplified methods and equipment that can be used in the analysis of pesticide and other contaminant residues in food and environment samples.

ELISA HELPS DETECT DDT

Success was achieved through a recent study organised by the Agrochemicals Unit, in which laboratories from 15 Member States tested a newly developed ELISA kit for detection of DDT and related compounds in soils. ELISA thus helped to determine whether the land was suitable for agricultural production.

The FAO/IAEA Training and Reference Centre for Food and Pesticide Control (TRC)

The TRC was established to strengthen the analytical capability in developing countries, assist in the control of food quality and safety, especially in relation to international trade, and bring the quality and use of pesticides up to international standards. The TRC also introduces and implements appropriate quality assurance and control systems to testing laboratories of Member States.

The Agrochemicals Unit contributes to activities of the TRC with laboratory-based training and quality control of methods for analysing pesticide residues, pesticide products and mycotoxins in food and feed samples.

Training is the most important task of the TRC. The aim of this programme is to assist Member States in establishing and operating national laboratories according to international standards, i.e. the principles of ISO Guide 25 and Good Laboratory Practice (GLP), to produce reliable and internationally acceptable analytical results. National officials involved in planning, decision making and supervision, as well as analysts working at the lab-bench participate in the programme and gain experience which they can use to improve conditions in their home countries.

The TRC has established a data base on the Internet including results of methods validation of analytical procedures, training manuals and links to useful sites. The data base is included in the homepage of the TRC *(http://www.iaea.org/trc/)*. Since access to the Internet can be difficult and costly for some developing countries, parts of the data base will also be made available on CD-ROM.

FAO/IAEA Training and Reference Centre for Food and Pesticide Control.

TRC'S TRAINING COURSES

- Planning and implementation of food control activities by chemical analysis,
- Introduction to ISO Guide 25 and GLP,
- Training of quality assurance officers and laboratory inspectors,
- Analysis of pesticide residues in food,
- Testing the quality of commercial pesticide products,
- Introduction to quality assurance and quality control measures in residue analytical laboratories,
- Application of nuclear and related techniques to analyse mycotoxins in food,
- Determination of veterinary drug residues in animal products,
- Analysis of radionuclides and toxic metals in food and environmental samples.

THE PHYSICS, CHEMISTRY AND INSTRUMENTATION LABORATORY

CHEMISTRY

INSTRUMENTATION

DOSIMETRY

ISOTOPE HYDROLOGY

THE PHYSICS, CHEMISTRY AND INSTRUMENTATION LABORATORY

Benefiting from Physical and Chemical Sciences

Implementing sustainable development in poorer countries and maintaining the quality of life in industrialized countries rely on many factors: adequate supplies of energy, food and water, appropriate education and training, participation in international trade, human health programmes and environmental protection. Nuclear technologies play an important role in achieving these aims. As part of its mandate, the IAEA advises Member States about new nuclear technologies and techniques and helps to develop national capabilities to support safe and effective nuclear applications which can contribute to enhancing the quality of life for millions of people.

A wide range of Agency programmes, spanning environmental pollution control, water resource management and safe and exact treatments in radiation medicine depend on state-of-the-art laboratory support. The IAEA maintains – as part of its Seibersdorf Laboratories – a Physics, Chemistry and Instrumentation Laboratory whose analytical and R&D work contributes to the peaceful applications of nuclear techniques in Member States.

The Physics, Chemistry and Instrumentation Laboratory (PCI) contributes to the Agency's programmes in physical and chemical sciences, industry, human health, environment and water resources by means of analytical, radiometric, instrumental and dosimetry measurements plus experimental research and development. Training of scientists from developing countries and assistance to Member States in all related fields are also among the key activities. To that end, the PCI Laboratory also manages a programme of Analytical Quality Control Services in close co-operation with the Agency's Marine Environment Laboratory in Monaco.

Gamma spectrometer for in situ radioactivity measurement.

Many developing countries suffer from water scarcity.

Working in co-ordination with the relevant divisions in the Agency's Headquarters, the PCI Laboratory covers a wide range of activities such as:

- Determination of trace and toxic elements relevant to human health, and of radionuclides in air, soil and water for environmental monitoring,
- Analysis of isotopes of hydrogen, oxygen and carbon for hydrological studies,
- Assurance of controlled radiation dosages in radiation medicine and industrial applications in Member States by supporting the IAEA/WHO Network of Secondary Standard Dosimetry Laboratories (SSDLs) and providing dosimetry services for medical centres and radiation processing facilities,
- Design, maintenance and repair of nuclear instrumentation,
- Technical advice and training in support of the IAEA Technical Co-operation Programme,
- Research and development in support of IAEA Co-ordinated Research Projects.

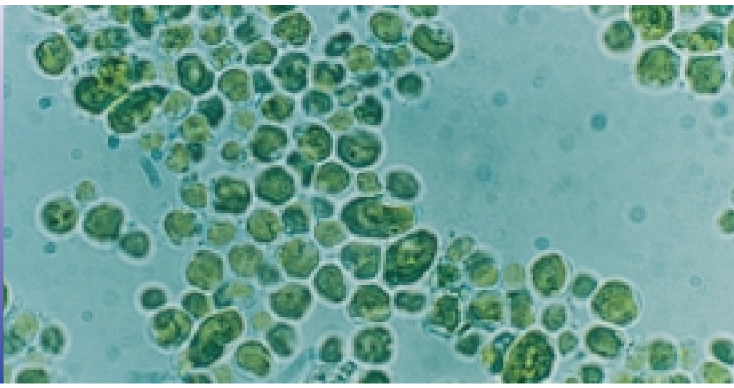
CHEMISTRY

Monitoring Environmental Pollution

Radioactive elements are present in the environment at nuclear weapon test and waste dumping sites as a legacy of the Cold War era. Moreover, residues of toxic elements and heavy metals, resulting from increasing industrialization, may affect the quality of air, soils, water and food. Mining of uranium and other ores, non-nuclear processing industries, or the use of agrochemicals also release radionuclides into the environment. Reducing harmful emissions and minimizing health risks require appropriate know-how, laboratory facilities for precise analytical and radiometric measurements and an assurance of the analytical quality in the laboratories performing these measurements.

Burning fossil fuels pollutes the environment.

The **Chemistry Unit** supports the Agency's programmes in environmental pollution monitoring and human health. The Unit has leading scientific and technical expertise in analytical measurements and radioanalytical chemistry and transfers these technologies to Member States. It applies a range of nuclear and microanalytical techniques to determine toxic and trace elements and radionuclides in environmental, food and other biological materials. A major goal is supporting Member State laboratories in implementing an effective quality



Algea are a bio-indicator of environmental pollution (microscopic view of algae reference material).

system for their analytical measurements, as they play a key role in monitoring environmental pollution and assessing the safety of food for both local consumption and export.

ANALYTICAL AND RADIOCHEMICAL TECHNIQUES

- Neutron activation analysis
- Atomic absorption spectrometry
- Inductively coupled plasma optical emission spectrometry
- Inductively coupled plasma source mass spectroscopy
- Alpha, beta, and gamma ray spectrometry

Activities and Achievements

Analytical Quality Control Services (AQCS)

For more than 30 years, the AQCS programme has been one of the Agency's key services to Member States. Analytical results often form the basis for decisions on economic, ecological, medical or legal issues. It is thus critical that laboratories be able to demonstrate the quality of their results. Through AQCS, the Chemistry Unit supports laboratories in developing countries to ensure the reliability of their analyses of nuclear, industrial, environmental and biological materials. Regional and global intercomparison exercises provide a unique opportunity for laboratories to compare and evaluate their performance on a global scale.

AQCS Highlights during the Past Decade

- 92 reference materials are available through AQCS,
- 9000 reference material units were distributed to laboratories in Member States,
- 16 worldwide intercomparison exercises assessed the measurement standards of analytical laboratories,
- 170 laboratories participated in proficiency tests to evaluate their performance.

Samples are treated in this freeze dryer to reduce their volume.

Homogenization of samples after freeze drying.

Analytical Measurements and the ALMERA Network

Analytical results of the Chemistry Unit have been a crucial part of investigating, amongst others, the radiological situation in and around the former nuclear testing site of Semipalatinsk (Kazakhstan), where milk and vegetation samples were measured for radioactive residues. They also contributed to determining environmental radioactivity released by nuclear accidents at Chernobyl and Tomsk 7, and the assessment of the residual radioactive contamination at the French nuclear test sites at the atolls of Mururoa and Fangataufa.

A special feature of these measurement activities is the network of **A**nalytical **L**aboratories for **M**easuring **E**nvironmental **R**adio**A**ctivity (ALMERA). Established in 1995, it provides emergency radioanalytical support in case of an accidental release of radioactivity. As the central co-ordinator of the network, the Chemistry Unit organizes proficiency tests, collects and disseminates emergency response procedures and prepares and distributes guidelines for sampling and analysis. The network laboratories have recognized and specialized skills in environmental radioactivity measurements. ALMERA presently consist of 53 laboratories from 26 different countries and is part of the Agency's Emergency Response activities.

THE ALMERA NETWORK

was successfully activated to support the International Study of the Radiological Situation at the Atolls of Mururoa and Fangataufa in French Polynesia. Eleven laboratories of the network co-operated with the Chemistry Unit in providing crucial radionuclide measurements of some 200 environmental samples. The Study concluded that, although the terrestrial and aquatic environments of the atolls contain residual radioactive material attributable to nuclear tests, these are at generally low concentrations which are of no radiological significance.

Study teams collected rock and water samples in Mururoa and Fangataufa.

Food samples from the Chernobyl region were measured for radioactive residues.

Samples from Mururoa ready for environmental radioactivity measurements at Seibersdorf.

INSTRUMENTATION

Maintaining Nuclear Instrumentation

A large number of nuclear technologies have been developed in the second half of this century, finding their use in almost all aspects of modern life. These technologies are based on sophisticated instruments and equipment, requiring careful maintenance and repair. Many developing countries, however, lack adequate resources and skills for servicing modern instrumentation, which is an obstacle to taking advantage of these technologies. The IAEA instrumentation experts assist both other units at Seibersdorf and Member State laboratories in servicing their equipment or in repairing malfunctioning instrumentation. They transfer their know-how to scientists from developing countries through a comprehensive training programme. As a result, instrument failure has decreased by about 50 percent in developing countries over the past 10 years.

The **Instrumentation Unit** contributes to numerous IAEA activities in the field of instrumentation maintenance, servicing and repair. Particular emphasis is placed on assisting developing countries in maintaining and repairing nuclear instrumentation and electronic equipment. The Unit's team of experts also designs and constructs special electronic instruments or modules requested by Member State laboratories. In addition, training of scientists and technicians from developing countries receives particular attention. A major research activity of the Instrumentation Unit focuses on X Ray Fluorescence (XRF) spectrometry, used worldwide for the analysis of geological materials and for environmental pollution monitoring.

NUCLEAR TECHNIQUES

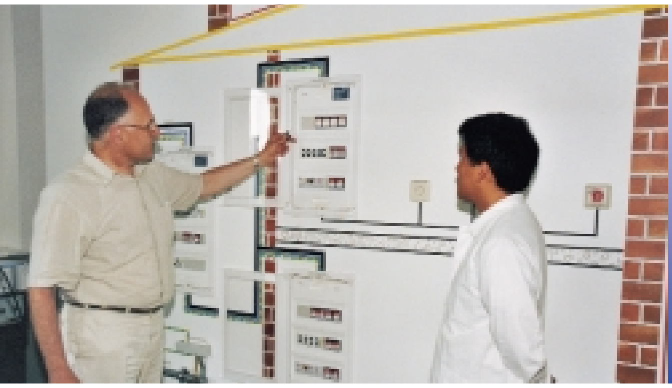
- X ray fluorescence techniques
- Accelerator-based analytical techniques

Activities and Achievements

Designing Nuclear Equipment

The Instrumentation Unit designs, modifies and builds nuclear instrumentation, which is not available on the market or needs to fulfil very specific requirements of Member States. The systems developed or adapted at Seibersdorf assist national laboratories, e.g. in determining levels of radioactivity or concentrations of hazardous elements in the environment.

Particular attention is given to training of scientists and technicians from developing countries.



NUCLEAR INSTRUMENTATION NETWORK FOR AFRICA

Twenty African countries have joined a network for service and maintenance of nuclear instruments, used in industrial applications, environmental pollution monitoring, human health and agriculture. The Instrumentation Unit supports this network through technical advice, training, fast provision of troubleshooting tools and spare parts, and a central computerised database with service manuals and suppliers' catalogues. The network also assists the member laboratories to share their own knowledge and resources in servicing and repairing nuclear instruments, helping them to become more self-reliant.

Research and Development

Research at the Instrumentation Unit focuses on XRF techniques. XRF is a simple and powerful method for analysing environmental, biological and geological materials. It has the unique advantage that it can be applied easily to samples of very different nature and requires no or only minimal sample preparation. Through research work, the Instrumentation Unit has improved the accuracy of different XRF techniques and designed new XRF instruments for microanalyses.

A model XRF training laboratory, recently installed at Seibersdorf and equipped with XRF spectrometers, provides technical back-up for some 100 XRF laboratories established worldwide under IAEA technical co-operation projects. This unique facility trains fellows from developing countries in maintenance and servicing of nuclear spectroscopy systems. Training of scientists and upgrading of XRF laboratories in several African countries has achieved better use of the XRF technique in environmental pollution control, geological analyses and in determining contaminants in food and other commodities for export. In addition, the XRF laboratory supports the analytical work of other in-house groups, such as the Chemistry Unit and its Analytical Quality Control Services.

A co-operation agreement with the Ruder Bošković Institute in Zagreb, Croatia, enables the Instrumentation Unit to use the Institute's particle accelerator for advanced analytical services, such as proton-induced X-ray emission, proton-induced gamma emission and nuclear reaction analysis.

Portable XRF unit designed at the Seibersdorf Laboratories.

XRF Setup.

VOAHANGY HARI-IALA RAZANABOLOLONA, MADAGASCAR

Training Fellow at the Instrumentation Unit of the Physics, Chemistry and Instrumentation Laboratory

Before joining a training programme at the PCI Laboratory's Instrumentation Unit in 1997, Ms. Razanabololona had gained several years of experience in working at the Maintenance and Instrumentation Department of the *Institut National des Sciences et Techniques Nucléaires* (INSTN) in Madagascar. She also served as project co-ordinator of the Agency's African Regional Co-operative Agreement (AFRA), and was responsible for the maintenance of medical and scientific instruments in Madagascar.

In 1997, Ms. Razanabololona was accepted for a six-month fellowship at the Instrumentation Unit to learn more about the design of microprocessor-based nuclear instruments; in particular, she was trained in multi-channel analyser designs, applied in most nuclear spectrometry systems. A Master's degree in nuclear physics from the University of Antananarivo, Madagascar, as well as previous training courses and fellowships on nuclear electronics in several countries provided the necessary academic and practical background.

"My training at the Seibersdorf laboratory has been very beneficial for my work in Madagascar", said Ms. Razanabololona. "Above all, it allowed me to acquire new skills which I will be able to use in maintaining and repairing nuclear instrumentation in my country. Besides, I got a lot of creative ideas for designing nuclear measurement instruments", she added. The training also helped Voahangy to prepare her thesis, and she soon expects to finish her studies at the University of Antananarivo with a Ph.D. in nuclear electronics.

DOSIMETRY

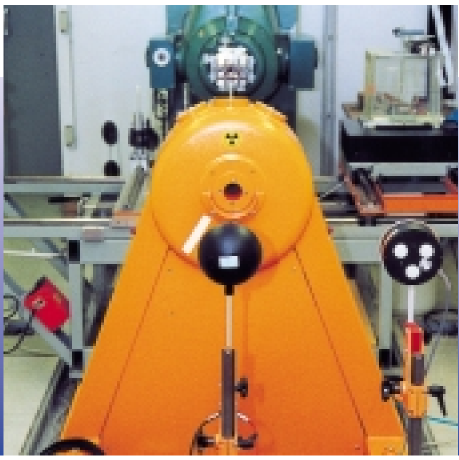
Assuring the Right Dose

Globally, one out of every three cancer patients receives radiation treatments. But radiotherapy will be ineffective if the dose is too low, or harmful if the dose is too high. Therefore, accurate dosimetry – the measurement of radiation doses – is a key field of concern for the IAEA. Radiation is also very important in modern industry: it is used, amongst others, in plastics processing, in the sterilization of medical supplies and in the preservation of food. Assuring the accuracy of these radiation doses is crucial to achieve the desired results.

The **Dosimetry Unit** operates in the framework of the IAEA Dosimetry and Medical Radiation Physics programme. It assists Member States in assuring controlled radiation doses in radiation medicine and in industrial applications. The Unit is the central laboratory of a network of Secondary Standard Dosimetry Laboratories (SSDLs), operated jointly by the IAEA and the World Health Organization (WHO). A training programme instructs medical radiation physicists from SSDLs in all aspects of dosimetry. Dose intercomparisons are organized to verify the dose measurements of radiation sources used in medical diagnosis, therapy and in industrial facilities in Member States. To operate the Dosimetry Laboratory at the highest possible standard, a Quality Assurance (QA) programme, based on the guidelines of ISO Guide 25 (General Requirements for the Competence of Calibration and Testing Laboratories), has been established.

RADIOLOGICAL EQUIPMENT AND TECHNIQUES

- Cobalt-60 therapy unit
- Gamma radiation sources
- Mammography diagnostic X ray unit
- X ray generators for calibrating ionization chambers and radiation detectors (for radiotherapy, diagnostic radiology and radiation protection)
- Thermoluminescent dosimetry (TLD)
- Electron spin resonance technique



left:
Cs-137 unit for radiation protection calibration.

right:
Cobalt-60 unit for radiotherapy calibration.

Both units are installed at the Dosimetry laboratory.

Activities and Achievements

The SSDL Network

Established in 1976, the joint IAEA / WHO SSDL network has been promoting and maintaining standards for dosimetry in radiotherapy and radiation protection. The SSDL network presently includes 70 laboratories and six SSDL national organizations in 58 Member States, about half of them being developing countries. The network also has 19 affiliated members.

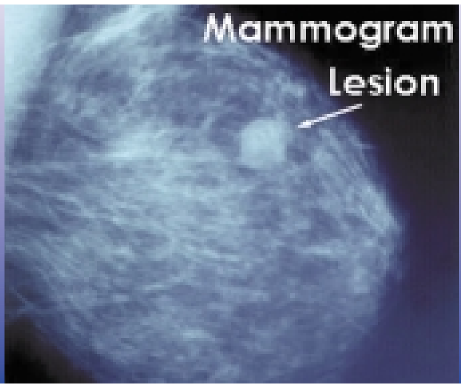
As the central laboratory of the SSDL network, the Dosimetry Unit facilitates links between national laboratories and the International Measurement System. One of the principal goals of the SSDL network is to guarantee that the dose delivered to patients undergoing radiotherapy is kept within internationally accepted levels. The Dosimetry Unit calibrates ionization chambers (i.e. detectors of the radiation level) and dosimeters from laboratories and hospitals in Member States to ensure that their equipment measures the correct dose.

Mammography has become a very common X ray diagnostic procedure for breast cancer. Indeed, it constitutes a substantial part of the overall radiation dose to which patients are exposed for medical purposes. To avoid any harmful side effects, the dose must be kept as low as possible. The installation of a mammography diagnostic X ray unit at Seibersdorf allows the scientists to develop radiation measurement standards for these X ray beams with the aim of producing an exact image while exposing the patient to a lower dose of radiation.

Dose Assurance

For almost 30 years, a dose quality audit service has been successfully organized by the IAEA Dosimetry programme jointly with WHO. It is based on mailed thermoluminescent dosimeters (TLDs) used to verify the accuracy of the radiation dose delivered by cobalt-60 therapy units and of high-energy photon beams of medical accelerators in Member States. This service has checked some 3000 radiotherapy beams worldwide and has considerably improved dosimetry practices in radiation medicine in developing countries.

The assurance of controlled radiation doses is crucial to effective radiation medicine.



ENSURING SAFETY: THE IAEA/WHO TLD POSTAL SERVICE

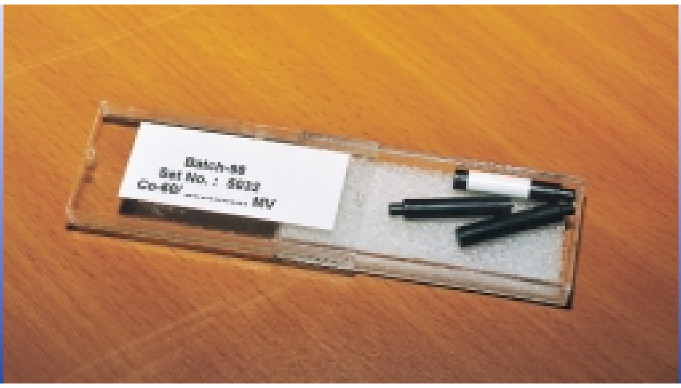
To verify the correct calibration of the radiation beam of therapy machines, hospitals receive a TLD detector – a small plastic tube, about 5 mm in diameter and 2.5 cm long, filled with a thermoluminescent powder. The medical physicist irradiates the detector at a specified dose and returns it to the IAEA for analysis and comparison. If the difference between the actual (as revealed by the detector) and the reported output of the machine exceeds the accepted limit of ±5%, the calibration of the equipment is verified and, if necessary, assistance is provided to solve the problem.

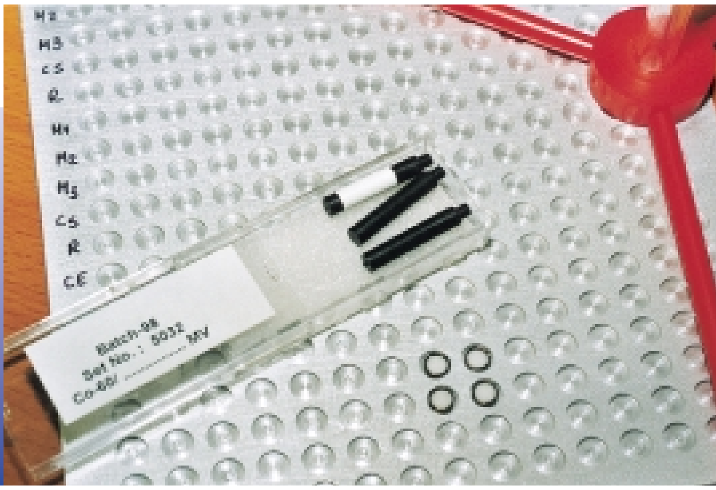
The Industrial Dose Assurance Service (IDAS)

Many industrial activities rely on irradiation, such as sterilization of food and medical products, decontamination of sludge to be used as fertilizer, and testing of industrial products. Radiation doses used in industrial applications are generally much higher than those in medicine.

IDAS is a special service provided by the IAEA Dosimetry programme to industrial facilities and research institutes in Member States involved in radiation processing. It provides an independent check of the entire dosimetry system of a facility. High dose audits for radiation facilities have been established using the electron spin resonance technique, and are servicing some 60 industrial facilities per year.

TLD detectors used in the IAEA/WHO TLD Postal Service.





ISOTOPE HYDROLOGY

Sound Water Management

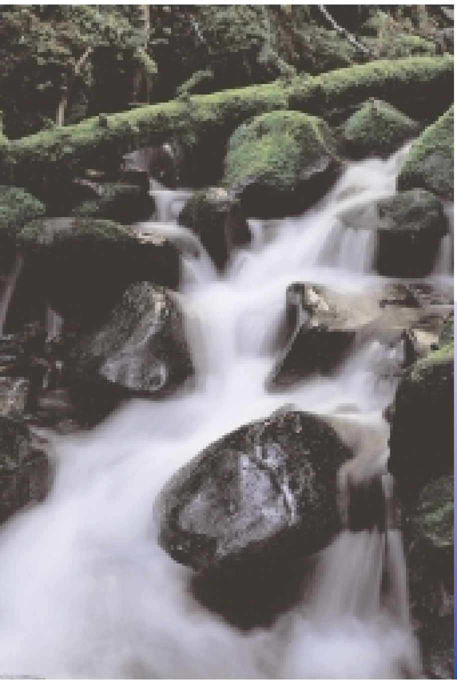
Water is one of the earth's most precious resources. As the global population increases, water is becoming dramatically scarcer and increasingly polluted. Renewable water resources are expected to drop by half by the year 2025. If water resources are not carefully managed, they could handicap economic growth and endanger human health and the environment. Isotope techniques, based on measurements of radioactive tracers or stable isotopes of the natural constituents of water (hydrogen and oxygen) can greatly assist in the sound development and management of water resources.

The **Isotope Hydrology Unit**, contributing to the IAEA programme on Water Resources Development, has been instrumental in developing and disseminating isotope hydrology techniques to laboratories and field projects worldwide. Its team of international experts assists Member States in using and managing their often scarce water resources. Methodologies developed by the Isotope Hydrology Unit help to assess water pollution in densely populated urban areas and to distinguish between renewable and non-renewable water resources in arid and semi-arid regions. A global network on precipitation assessment, jointly operated with the World Meteorological Organization (WMO), uses isotope techniques in studies of hydrology and its relation to global climate change. The Unit serves as a reference laboratory and sets international standards by producing, storing and distributing reference material for all isotope laboratories worldwide.

For technical reasons, the Isotope Hydrology Unit is the only laboratory not located at Seibersdorf. It is housed in the IAEA Headquarters at the Vienna International Centre.

NUCLEAR TECHNIQUES

- Isotopic analysis for deuterium, oxygen-18, carbon-13
- Electrolytic tritium enrichment
- Carbon-14 age determination
- Chlorofluorocarbons (CFC) tracer techniques



CFC measurement of water sample.

Measuring equipment for C-14 determination at the Hydrology laboratory.

Activities and Achievements

Measuring Isotopic Compositions

The key activity of the Isotope Hydrology Unit is measuring the isotopic composition of water, soils, and air using a number of analytical methods. Stable hydrogen and oxygen isotopes are natural constituents of water, while radioisotopes, such as tritium and carbon-14, were formed in the atmosphere as a result of nuclear bomb tests in the sixties and are produced by cosmic radiation. The Unit also measures chlorofluorocarbons (CFCs) in water and air samples. CFCs affect the ozone layer of the atmosphere and contribute to greenhouse gases. As these tracers have only been emitted as a result of industrial development since the middle of this century, they are a good indicator to determine the age of groundwater.

Analysing Water Samples

In support of dozens of technical co-operation activities, the Isotope Hydrology Unit analyses more than 3000 water samples and carries out about 1500 chemical analyses every year for countries without adequate facilities. So far, isotope hydrology laboratories have been installed or upgraded in 42 Member States with support from the IAEA.

The Unit's analytical work and the know-how transferred has helped several Member States to develop and improve the management of their water resources:

- *Venezuelan scientists were able to locate and exploit 50 new wells for the city of Caracas, thus reducing the water supply deficit by 25 million liters per day.*
- *A regional project, covering several African countries, is identifying renewable and non-renewable water resources beneath Egypt's desert and in Ethiopia's Moyale region, and using isotope data to assess groundwater resources around Dakar, Senegal, a rapidly growing city which suffers from severe water shortage.*
- *Nearly a dozen Member States are applying isotope techniques for geothermal energy projects, including water sample analysis, the use of tracers, hydrological modelling and computer simulations of reservoirs. Assisted by the IAEA, El Salvador is currently expanding its geothermal capacity, thus saving the country at least US $9 million in oil imports annually.*
- *The "Vienna Standard Mean Ocean Water" (VSMOW), developed by the Isotope Hydrology Unit, is worldwide the most important and most extensively used reference material for measuring oxygen and deuterium in water samples.*

Left:
Caracas, Venezuela.

Center:
Ethiopia's Moyale Region.

Right:
Geothermal Plant in El Salvador.

The Global Network of Isotopes in Precipitation (GNIP)

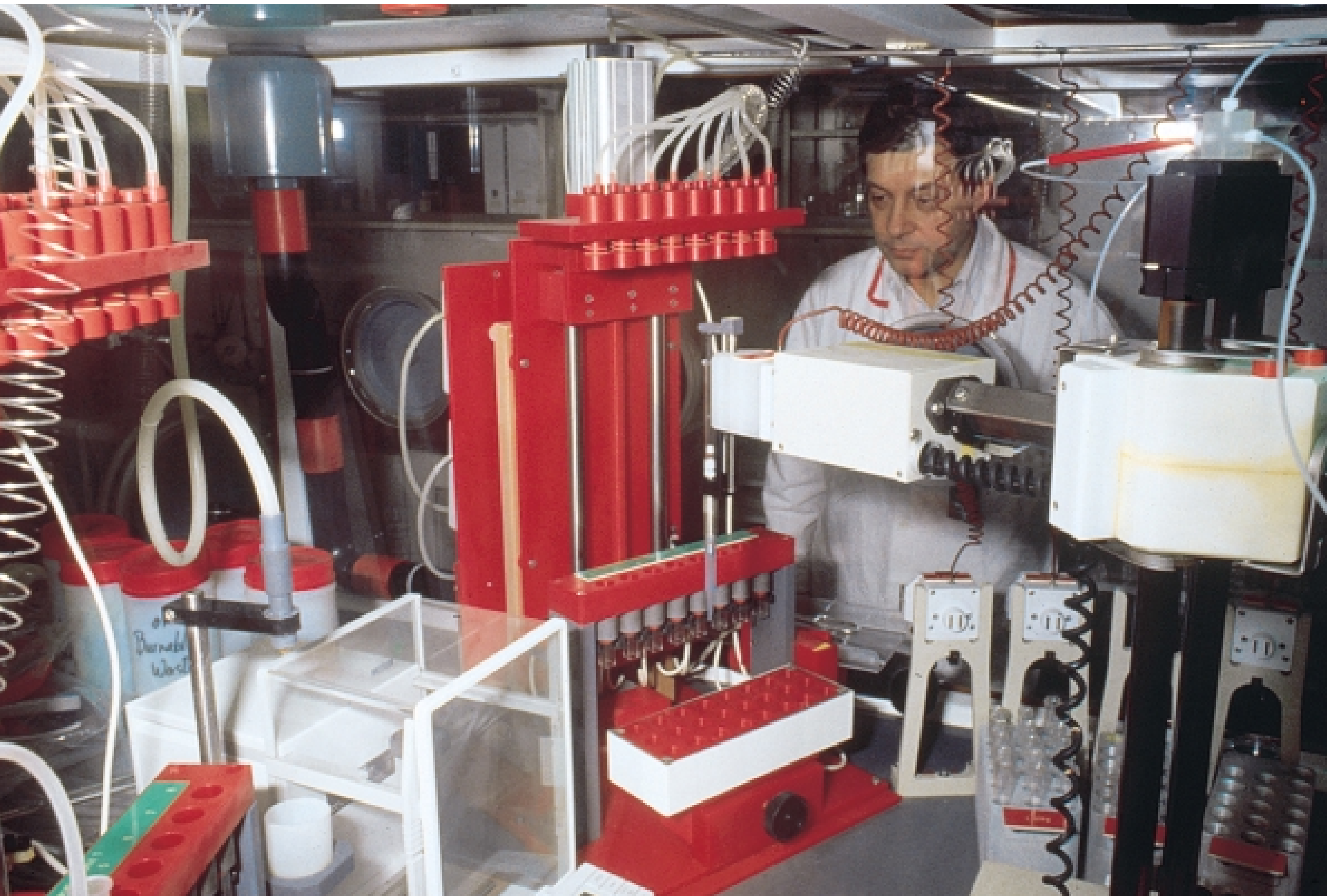
Initiated by the IAEA in 1961 and operated in conjunction with the WMO, this unique global network has been collecting hydrological and climatological data from over 500 meteorological stations around the world. These data provide information about the global distribution of isotopes in precipitation and contribute to a better understanding of global climate change and the greenhouse effect. Analytical results of precipitation samples are stored in the GNIP database maintained by the IAEA, and support scientific studies on climatological research and modelling. About one third of these analyses are done at the Isotope Hydrology Unit, which also serves as a reference laboratory and organizes regular inter-laboratory comparisons to ensure the analytical quality of the network.

THE SAFEGUARDS ANALYTICAL LABORATORY

CHEMICAL ANALYSIS

ISOTOPIC ANALYSIS

CLEAN LABORATORY



THE SAFEGUARDS ANALYTICAL LABORATORY

Safeguarding Nuclear Materials

Preventing the spread of nuclear weapons is a complex task requiring international co-operation and confidence-building at all levels – bilateral, regional and global. A global agreement, the Treaty on the Non-proliferation of Nuclear Weapons (NPT), that dates from 1970 and was made permanent in 1995, aims to prevent the further spread of nuclear weapons. It also seeks to promote nuclear disarmament negotiations among the five countries[5] formally declared and acknowledged as Nuclear Weapon States. The NPT currently has 187 State parties and provides – together with several complementary regional treaties – the foundation of legally binding non-proliferation commitments by countries around the world.

To verify that countries are meeting their obligations, the international community has entrusted the IAEA with establishing and implementing a strong and impartial inspection mechanism – the IAEA Safeguards System. Safeguards are a set of activities by which the Agency seeks to verify that a State is not using its declared nuclear material or equipment to develop or produce nuclear weapons. However, the revelations of a secret nuclear weapons programme in Iraq, after the 1991 Gulf War, and IAEA's discovery of the possibility of undeclared plutonium in the Democratic People's Republic of Korea (DPRK) in 1992, were a watershed in the history of IAEA safeguards activities. Since then, the Agency and its Member States have established and are now implementing new, more rigorous inspections and verifications under a Strengthened Safeguards System (SSS), which also comprises the search for undeclared nuclear activities and the confirmation of their absence. This new system is legally based on a "Protocol Additional to Safeguards Agreements", approved by the IAEA Board of Governors in 1997 and now in the process of being adopted by Member States.

Practically all countries around the world use nuclear technologies for a variety of peaceful purposes including electric power generation, industrial applications, and medicine. Currently, 68 developed and developing countries operate major facilities containing nuclear materials that are accounted for and safeguarded under agreements with the IAEA.

5 China, France, Russia, the United Kingdom and the United States.

Tokai Nuclear Plant, Japan.

Seals are used to guard material under safeguards from diversion or misuse.

A key element of the Safeguards System is physical inspections of nuclear installations by IAEA safeguards inspectors, who, amongst other verification measures, take samples from various measurement points of the fuel cycle. The SSS allows inspectors to also collect special “environmental” samples (such as dust, soil, water or vegetation) at or near nuclear sites. Precise and careful analyses of these samples are a valuable additional element to verify that the requirements of safeguards accounting are met.

The IAEA takes account of “special fissionable material” in any country under safeguards. This includes plutonium-239 and uranium-235 or 233.

To support its verification activities, the IAEA maintains a Safeguards Analytical Laboratory, as a part of the Seibersdorf Laboratories. Its principal function is the analysis of nuclear materials and environmental samples for verification purposes. The Safeguards Analytical Laboratory operates in co-operation with a Network of Analytical Laboratories (NWALs) in Member States.

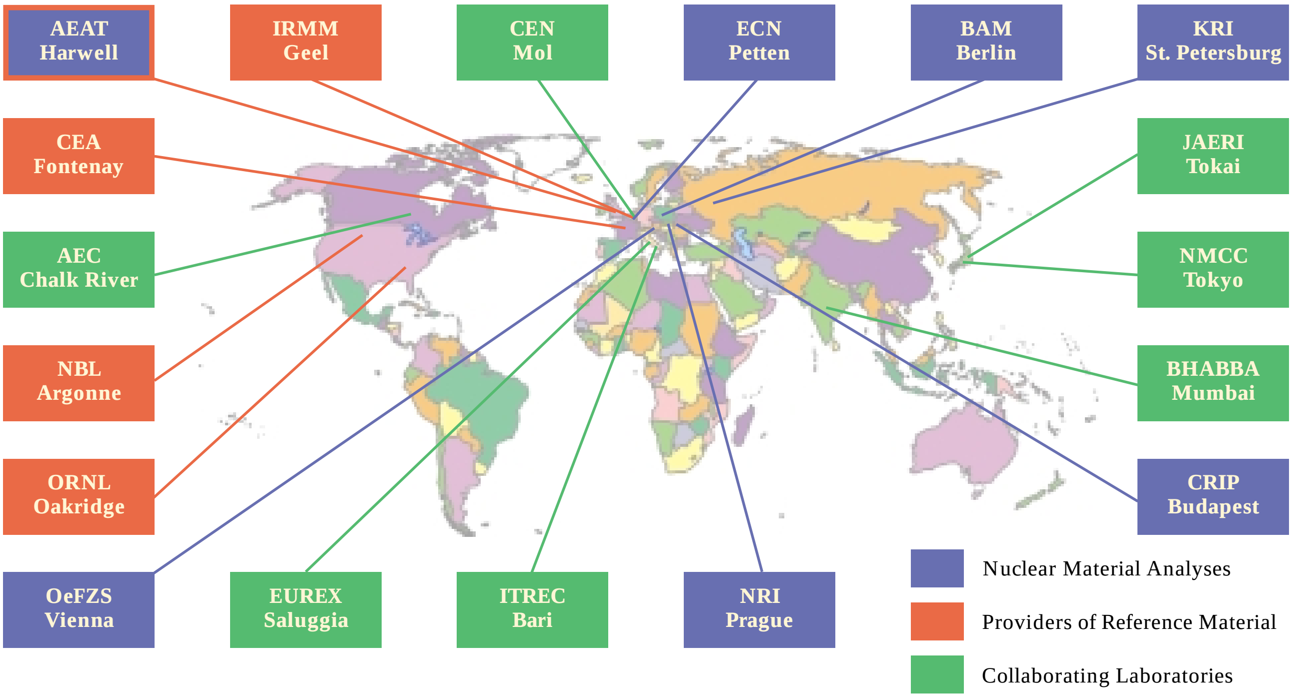
The Safeguards Analytical Laboratory (SAL) provides key analytical and related services to the IAEA Department of Safeguards, which implements the Strengthened Safeguards System jointly with Member States. Using highly advanced equipment and techniques, SAL’s international team of scientists complements on-site measures by examining safeguards inspection samples of nuclear materials and environmental samples. Between 1000 and 2000 samples of nuclear materials and about 500 environmental samples are received by the Laboratory every year. The paramount characteristics of SAL’s activities are: independence from any national influence; confidentiality and strict anonymity (samples are coded so as not to disclose their origin); an accuracy of 0.1% or better of its analytical results; and satisfactory response times (i.e. within 60 days after receipt of the samples). The results are reported to the Department of Safeguards which compares them with the nuclear plant’s declaration.

SAL operates three principal units: the Chemical Analysis Unit, the Isotopic Analysis Unit and the Clean Laboratory Unit. While the Chemical and Isotopic Analysis Units examine safeguards inspection samples of nuclear materials containing plutonium and uranium isotopes, the Clean Laboratory – recently established to support the SSS – analyses environmental swipes as well as water, soil and vegetation samples to search for any undeclared usage of nuclear installations. A Quality Assurance and Computer Services group supports their analytical work. Technical and administrative support for handling all nuclear materials samples is provided by the Safeguards Analytical Services (SAS) Office.

IAEA safeguard inspectors at work.

Co-operation with the IAEA Network of Analytical Laboratories (NWAL)

To accommodate the large number of inspection samples and the diversity of analytical requests, SAL co-operates closely with a worldwide network of analytical laboratories, nominated by Member States. The laboratories comply, like SAL, with IAEA quality assurance requirements. A comparison of results obtained by different laboratories gives additional assurance that the analyses meet the required high standards. In addition, SAL contributes to the preparation of standard materials for non-destructive analysis and reference materials, in co-operation with national and international laboratories.



Establishing an On-Site Laboratory in Japan

A new major reprocessing plant, under construction at Rokkasho-mura, Japan, will require strict verification of large amounts of processed reactor plutonium. In partnership with Japanese authorities, the Agency is setting up an On-Site Laboratory (OSL) at Rokkasho-mura for safeguards analyses. This will not only avoid the costly

Construction site of reprocessing plant and OSL, Rokkasho-mura, Japan.

transport of large numbers of samples to Seibersdorf, but it will also assure speedier verification results. Among SAL's new challenges is the equipment and operation of this OSL. Japanese and SAL experts jointly develop technical specifications and prepare procedures for safe operation. The Rokkasho-mura reprocessing plant and the OSL are expected to commence operation in 2005.

Technical Developments

SAL is keeping up with the latest technological developments by continuously improving its analytical methods and procedures. The automation of sophisticated analytical instruments, including robots, is one of these achievements. Mechanical and electronic workshops, equipped with new, state-of-the-art computer hard- and software, assist the analysts in these tasks. This has resulted in more accurate and precise destructive analytical techniques of nuclear fuel material and increased productivity, while simplifying the procedures for disposing of radioactive analytical wastes and substantially decreasing their volume.

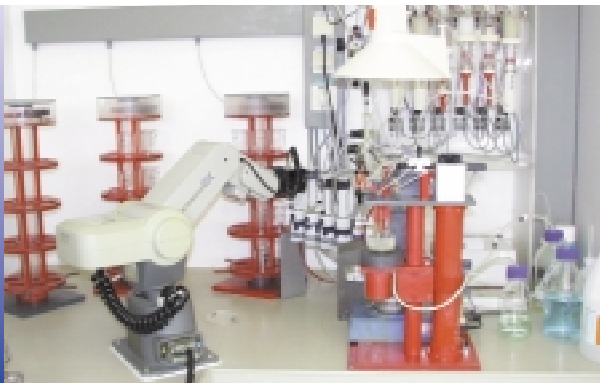
Training of Safeguards Inspectors

A comprehensive training programme, established jointly by SAL and the Safeguards Training Section, instructs new safeguards inspectors in the taking of samples, their careful handling and shipment to SAL, and in the use of installed and portable measuring instruments in nuclear plants. SAL analysts brief them on precautions to be taken when sampling nuclear materials and heavy water, and on the characteristics of typical methods of destructive analyses. Since 1995, the programme has been extended to train inspectors in environmental sampling. In a joint training programme with the European Atomic Energy Community (Euratom), more than 120 inspectors from both organizations were trained during the past two years.

Total Quality Management

Strict quality assurance and quality control throughout the analytical processes are essential for effective safeguards. Quality management begins with the planning of safeguards inspections, sample collection and shipment, and includes sample handling and analyses at SAL or collaborating laboratories of the NWAL, as well as reporting and evaluation of the analytical results. Both quality assurance and control measures are based on internationally recognized reference materials. For the analysis of environmental samples, reference and control materials need to carry trace amounts of uranium and plutonium with certified isotopic compositions. These needs are being addressed with the assistance of the Euratom / IAEA Co-operation Programme and the British and US Technical Support Programmes to IAEA Safeguards. In addition, several laboratories, e.g. the Institute for Reference Materials and Measurements (IRMM) in Belgium, assist SAL to characterize and validate certified reference and control materials. SAL's quality system is certified according to international ISO 9002 standards.

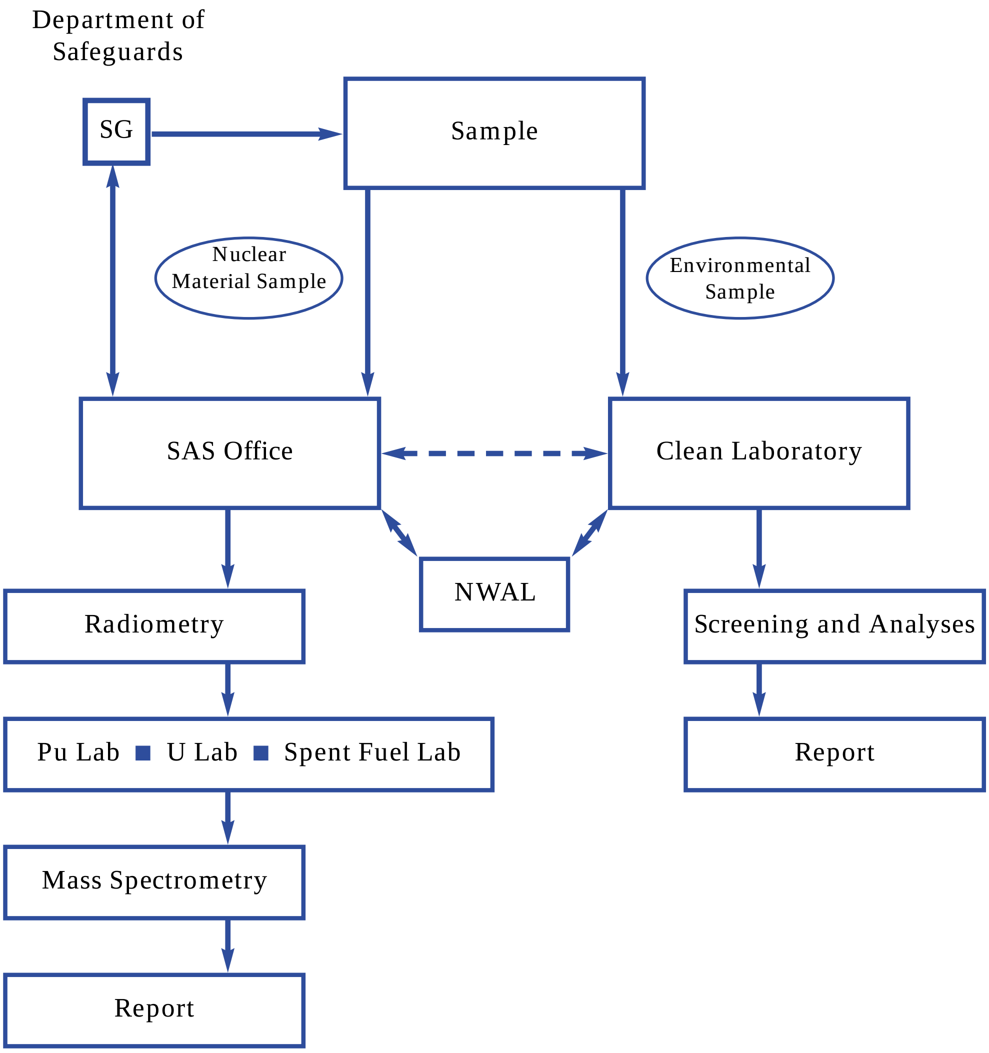
Training of safeguards inspectors at SAL.



Parts for the automated U-titrator produced at SAL's Mechanical Workshop.

Analysing Nuclear Safeguards Samples

General Sample Flow Within SAL



THE CHEMICAL ANALYSIS UNIT

The Chemical Analysis Unit combines routine analyses of samples for safeguards with development of analytical methods. This joint approach allows the Unit to remain at the forefront of contemporary chemical analyses for nuclear materials. Safeguards inspection samples are initially treated and their elemental assays (uranium, plutonium and thorium) determined by physical and chemical methods. These samples are then analysed by isotopic and isotope dilution methods in the Isotopic Analysis Unit.

MAIN METHODS USED FOR WET CHEMICAL ANALYSIS

- Automatic potentiometric titration
- Ignition gravimetry
- K edge X ray absorptiometry and fluorescence analysis
- Inductively coupled plasma / mass spectrometry

Activities and Achievements

The **Uranium Laboratory** handles all samples that do not contain plutonium or fission products (e.g. caesium-137). Mainly thorium and uranium elemental assays are performed and sample fractions for isotopic analyses by mass spectrometry are prepared. Typical samples include uranium oxide powders and pellets, alloy scrap materials, uranium hexafluoride (UF_6) and other materials from the nuclear fuel cycle. In addition, containers for UF_6 samples – used for safeguards inspections in the field – are regularly decontaminated.

The major technique applied is the Davies and Gray potentiometric titration, which delivers routine results with a precision and accuracy of below 0.05% or better.

OTHER FUNCTIONS OF THE URANIUM LABORATORY

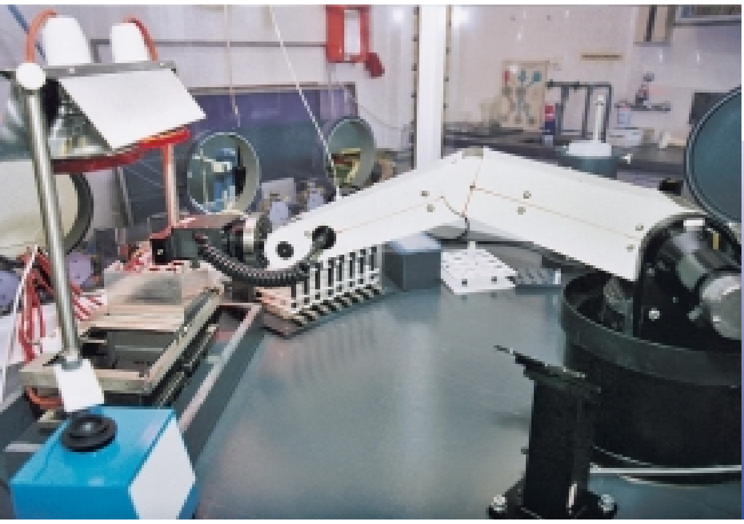
- Density measurements of uranium solutions and heavy water samples,
- Preparation of heavy water standards and density standards,
- "Spiking" of uranium samples (i.e. the addition of uranium tracer isotopes for isotope dilution analysis),
- Preparation and characterization of control and reference materials and standards.

The **Plutonium Laboratory** performs the treatment and analysis of all samples containing plutonium without fission products. Depending on their nature and the requested analysis, the samples are analysed for plutonium and / or uranium compositions, prepared for isotopic analysis or conditioned for a radiometric measurement or an impurity analysis.

ANALYTICAL TECHNIQUES

- Davies and Gray potentiometric titration
- MacDonald and Savage potentiometric titration
- Controlled potential coulometry
- Isotopic dilution techniques

The **Spent Fuel Laboratory** carries out all chemical treatments of samples containing fission products. Because of their high radioactivity, only very small (microgram to milligram) portions are shipped to SAL. Samples of this type are usually analysed by isotope dilution mass spectrometry. Within SAL's strict quality control programme, all chemical preparations and measurements are accompanied by control sample analyses and blank control materials.



Zymark Robot for separation of U, Pu and fission products in spent fuel samples.

OTHER ACTIVITIES OF THE SPENT FUEL LABORATORY

- New procedures for improved precision and accuracy of the measurements,
- Improvement of existing automation, in particular the robot system for processing spent fuel samples,
- Design of a new robot unit, to serve as a demonstration unit for on-site automated sample processing at the OSL in Japan,
- Adaptation of the Resin Bead technique to perform reliable analyses of nanogram amounts of uranium and plutonium in samples,
- Handling of “hot swipe samples”, i.e. highly radioactive swipe samples, in co-operation with the Clean Laboratory Unit.

The **Inductively Coupled Plasma/Mass Spectrometry Laboratory (ICP/MS)** is a facility set up to enhance the Unit’s ability to determine impurities (e.g. metal ions) in nuclear material samples. The high resolution and sensitivity of an ICP / MS instrument – donated by France and the UK – and the associated analytical procedures allow better “fingerprinting” of samples (i.e. an accurate differentiation between samples of similar composition). The method is especially effective to determine a sample’s origin. This type of information may be requested, e.g. when nuclear material from illicit trafficking activities is analysed. In addition, the ICP / MS supports the Clean Laboratory in effectively determining minute impurities in analytical reagents.

THE ISOTOPIC ANALYSIS UNIT

The activities of the Isotopic Analysis Unit complement those of the Chemistry Analysis Unit: uranium and plutonium samples from safeguards inspections, prepared at the Chemistry Analysis Unit, are measured here mainly by two nuclear techniques – mass spectrometry and radiometry. A thermal ionization mass spectrometer (TIMS), installed in 1998, enables the analysts to improve existing measurement procedures. The detection limits of uranium and plutonium samples in mass spectrometry are such as to permit the analysis of picogram (10^{-12}) amounts of these materials. Advanced analytical methods for measurements of “alternative nuclear materials” (curium, americium and neptunium) are also available. There is growing interest in Member States to include the verification of these alternative nuclear materials in the safeguards process.

Nuclear material samples are handled in the glove box of the ICP/MS.

ICP/MS instrument.

MAIN METHODS USED FOR ISOTOPIC ANALYSIS

- Mass spectrometry
- X ray fluorescence analysis
- Alpha spectrometry
- Gamma spectrometry
- Liquid scintillation spectrometry

Activities and Achievements

The **Mass Spectrometry Laboratory:** Special measurement methods are used to analyse uranium and plutonium samples for their isotopic compositions and element concentration while other elements, i.e. magnesium, lutetium and erbium, are analysed to verify the accuracy of the calibration of storage tanks. These methods produce the most accurate results achievable.

The **Radiometry Laboratory:** Radiation emitted by uranium and plutonium samples is measured by several high sensitivity methods:

- Alpha particle spectrometry
- Gamma ray spectrometry
- X ray fluorescence
- Liquid scintillation counting.

Low level gamma counter for gamma ray spectrometry.

The mass spectrometry laboratory is equipped with three mass spectrometers, including this Finnigan MAT 262 RPQ+ which is used for measuring plutonium samples.

Seibersdorf–Vienna

THE CLEAN LABORATORY UNIT

In operation since 1996, the Clean Laboratory plays an important role in the new Strengthened Safeguards System and enhances SAL's overall analytical capability. The Laboratory's team of experts analyses environmental samples taken from within a nuclear facility or its vicinity, to verify the absence of undeclared or clandestine nuclear activities. One of the most powerful methods which has emerged in this work is the identification and analysis of microscopic particles collected in swipe samples. The Clean Laboratory uses highly sophisticated measurement methods based on scanning electron microscopy to measure the uranium and plutonium content of such particles. A high sensitivity instrument – a secondary ion mass spectrometer – allows the isotopic analysis of these particles. These ultra-sensitive analytical methods can provide a complete picture of the elemental and isotopic composition of uranium and plutonium from particles 100 times smaller than the width of a human hair.

MAIN METHODS USED FOR ISOTOPIC AND ELEMENTAL ANALYSIS

- Pulse counting thermal ionization mass spectrometry
- Scanning electron microscopy
- Secondary ion mass spectrometry

Activities and Achievements

Clean Rooms to Avoid Contamination

A special feature of the Clean Laboratory Unit is its "Class-100" clean room facility. "Class 100" implies a very high standard of cleanliness that can be found, e.g. in the computer-chip industry. Environmental samples from safeguards inspections are received here, screened and prepared for distribution to laboratories of the NWAL. In addition, special kits used by safeguards inspectors for environmental sample collection are assembled and certified in the clean rooms. The clean room facility is essential to minimize the risk of any cross contamination that might lead to incorrect safeguards conclusions.

Clean Laboratory Building.

Sample analysis in "Class-100" clean room at Seibersdorf.

Analysing samples

The Seibersdorf experts analyse some 500 environmental samples every year. The samples are measured by:

- Low background gamma spectrometry
- Radioisotope-excited X ray fluorescence spectrometry
- Alpha / beta counting
- Scanning electron microscopy.

Selected samples are chosen for measurement by isotope dilution thermal ionization mass spectrometry, using a highly sensitive instrument equipped with pulse-counting detection. The ultimate sensitivity of this method is in the femtogram range (10^{-15} grams) for uranium and plutonium. All samples requiring even more exhaustive analyses are sent to NWALs for further processing.

Clean sampling kits

One of the main activities of the Clean Laboratory Unit is the preparation of clean sampling kits for collecting environmental samples. In 1998, for example, several hundred of such sampling kits were prepared in support of inspections by the IAEA Action Team in Iraq. A different type of kit has been developed for sampling inside hot cells of a nuclear installation, where sub-samples must be taken with remote manipulators and shipped back to the IAEA in special lead-lined containers because of their higher radiation level.

A kit for the collection of swipe samples consists of all the supplies needed by an IAEA inspector in the field: clean swipe cloths, plastic minigrip bags, clean room gloves, sample data form, pen and labels.

SUPPORTING SERVICES

GENERAL SERVICES AND SAFETY SECTION

HEALTH PHYSICS

GENERAL SERVICES AND SAFETY SECTION

Technical, maintenance and general support services provide the necessary infrastructure and ensure a safe and smooth operation of the Seibersdorf Laboratories site. They are grouped in the General Services and Safety Section (GESS) and include a

- Maintenance Unit
- Mechanical Workshop Unit
- Radioactive & Toxic Materials & Waste Group
- Library
- Procurement, Computer Support, Training and Fellowships Logistics crew.

Since 1995, five new facilities, encompassing a total space of 2700 m^2, have been constructed under the co-ordination of GESS, including an extension of the Entomology facilities, the Clean Laboratory, an electrical transformation plant, a multi-service building, and the FAO / IAEA Training and Reference Centre for Food and Pesticide Control.

The **Maintenance Unit** is responsible for the upkeep of the entire laboratory infrastructure and installations, such as heating, cooling, water, electricity, compressed air and telephones. It is also responsible for landscaping and the maintenance of the external site areas.

Mechanical Workshop of the IAEA Laboratories.

The **Mechanical Workshop** provides assistance to all units of the Laboratories, to the Department of Safeguards, and to other Agency divisions in constructing, maintaining and repairing mechanical equipment. A special feature of the Workshop are the skills of its craftsmen, who design, construct and test very specialized equipment that is not commercially available. These instruments are required for safeguards inspections, research work of individual units or for Technical Co-operation Projects in Member States. To ensure the correct installation of sophisticated equipment for safeguards inspections, highly specialized staff from the Workshop participate in field missions and train safeguards inspectors and plant operators in their use.

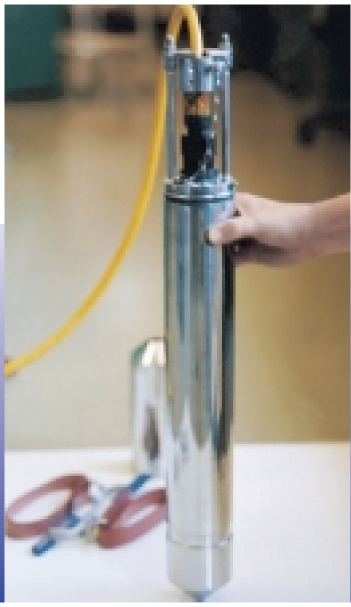
The **Radioactive & Toxic Materials & Waste Management Group** controls radioactive, hazardous and toxic materials and ensures their proper transport to and from the Laboratories' site, delivery, handling, storage, accounting and disposal. About 200 chemicals which have to be kept accountable, are handled in the Laboratories. A computerized system keeps track and controls their flow. Particularly nuclear materials, handled mainly for the Safeguards Analytical Laboratory, are subject to very strict accountability. Special care is taken to comply with IAEA Safety Standards and with Austrian and international regulations for the handling and transport of both toxic and radioactive materials (such as the International Air Transport Association's Dangerous Goods Regulations or the European Agreement Concerning the International Carriage of Dangerous Goods by Road).

CANDU Bundle Verifier.

Designed at the Mechanical Workshop, it allows the immersion of a collimator between the fuel rods of a nuclear plant without disturbing its operation. This device has been installed in nuclear power plants in Argentina, Canada, India, the Republic of Korea and Pakistan.

Spent Fuel Attribute Tester.

More than 25 such testers, developed at the Mechanical Workshop, have been installed worldwide for measuring gamma radiation in the spent fuel assemblies of nuclear reactors.



The **Library** of the IAEA Laboratories is operated in close co-operation with the Vienna International Centre main library. It holds a stock of more than 5000 books and several scientific periodicals for use by staff and visitors.

A **Training Facility** is housed in one of the wings of the Seibersdorf Laboratories; it is completely dedicated to training course activities and includes a modern auditorium for up to 100 people, a laboratory for practical exercises, an electronic training laboratory and meeting and study rooms for fellows and trainees.

Training Auditorium.

HEALTH PHYSICS

To ensure the safety and protect the health of those working with radiation sources, a Health Physics Unit provides advice on radiation protection and monitors all operations in which radioisotopes are handled; this includes also decontamination and waste management. The IAEA Radiation Protection Services Section supervises this activity. The staff of the Unit also provides expert advice on many aspects of personnel monitoring and environmental surveys for several Technical Co-operation projects.

In addition, the Health Physics Unit is responsible for the training of the Laboratories staff in radiation protection. Fellows from Member States receive training during an introductory course on radiation protection services, organized by the Agency each year.