Some Activities of the IAEA on the Use of Radioisotopes and Radiation

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The use of radioisotopes and radiation will continue to expand. There is an immediate and obvious use for radioisotopes in industry, medicine, agriculture and other branches of science. Working with isotopes and radiation is on the other hand an effective way of acquainting a large number of people with radiation and radioactivity, including radiation protection. One of the advantages of radioisotope technology is that it can be used in small laboratories such as those in universities, enhancing nuclear training. Owing to the extreme sensitivity and detectability of isotopes they are also advantageous in studies of the distribution of many materials, e.g. dust, air, water and soil.

The programme of the IAEA in respect to the use of radioisotopes and radiation is concentrated mainly in the Department of Research and Isotopes. Some examples of IAEA activities in the application of radioisotopes will be mentioned in more detail, including isotope hydrology, physics, industrial applications, medicine and agriculture.

Hydrology

In the hydrology programme isotope techniques are important for environmental studies. At present the commonly used environmental isotopes are the stable isotopes deuterium and oxygen-18 and the radioisotopes tritium and carbon-14. The first three isotopes are part of the water molecule and are the closest to being ideal tracers of water. The latter water tracer is present in a dissolved form and therefore is subject to loss by precipitation, absorption and exchange.

Stable isotope measurements are very useful in determining the origin of water. For example, precipitation falling at a higher altitude is more depleted in deuterium and oxygen-18 than precipitation falling at a lower altitude. This fact can be used to determine whether groundwater is recharged by infiltration of precipitation falling on a plain or whether it originates from the infiltration of precipitation falling in the mountains and then travelling

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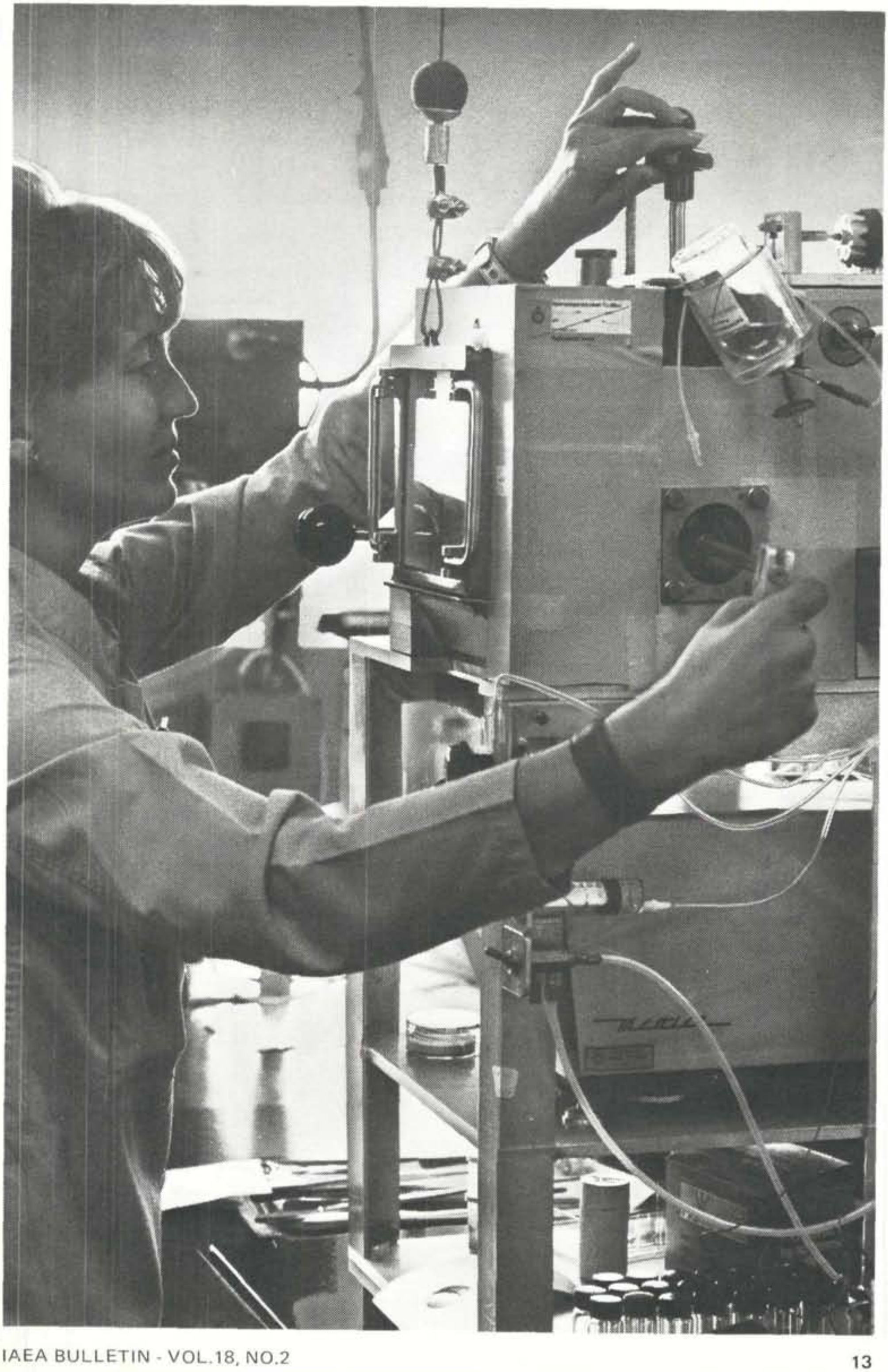
Technetium- 99m has quickly become one of the radionuclides used most frequently in nuclear medicine. The physical half-life of technetium- 99m is six hours, which is sufficient for a day's work. In order to meet the needs of Swedish hospitals a special isotope service at Studsvik laboratories has been established where the sodium pertechnetate solution is distributed in ready-to-use doses.
Photo: Ab Atomenergi



underground or as surface run-off to the plain. Information of this kind is valuable in studies of the water balance of an area. Such a study reported that the recharge to a coastal plain in Nicaragua originated from elevations higher than 280 m.[1]

Possible interconnections between aquifers may be studied when the stable isotopic composition of the water in the two aquifers is different. In Algeria, it was found that although the two aquifers were recharged by water from the same mountains, aquifers did differ in their stable isotopic composition[2]. This was due to the fact that the water in the lower aquifer was much older than that in the upper aquifer.

Variations in the environmental isotopic composition of water can provide an insight into the mechanisms of processes occurring in hydrological systems. Although there is an increasing tendency for using these techniques in hydrological investigations, their potential use as an additional hydrological tool has not yet been fully utilized.

X-ray Fluorescence

One example on the use of radiation is elemental analysis by charged-particle induced X-ray fluorescence. The principle is to excite the atoms of a substance to be analysed by the bombardment of energetic particles.

The development of high revolution semi-conductor detectors during the past few years has advanced greatly the usefulness of this technique. The detectors such as Si(Li) and Ge(Li) with energy revolutions of approximately 180 eV in the energy range 1—10 keV are able to separate individual X-ray lines. Multi-elemental analysis is then possible in which all the elements present can be identified at the same time. In CPXE (charged-particle X-ray emission) the sample is bombarded with fast ion beams (protons, alpha particles, or heavy ions) from electrostatic accelerators of 1—5 MeV.

The current Agency co-ordinated research programme in CPXE has nine members of which six are from developing countries. The members exchange experimental results, make intercomparisons of samples, report new techniques and meet together periodically at one of the centres engaged in this research. Among the research projects some will be mentioned as being of special interest:

- In parts of Yugoslavia, tooth decay is unknown. Analysis of the drinking water has shown not only a high concentration of fluorine but also of molybdenum. This poses the question whether molybdenum may also play an important role in preventing tooth decay.
- In cereal grain, measurements of sulphur content have been made in an attempt to correlate such values with certain sulphuric amino acids. If a correlation exists, the analysis could be made quickly and cheaply by CPXE instead of expensive and time-consuming biochemical methods.

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[1] Payne, B.R., Yurtsever, Y., Environmental isotopes as a hydro-geological tool in Nicaragua, Isotope Techniques in Groundwater Hydrology 1974 (Proc. Symp. Vienna, 1974), IAEA Vienna (1974) 1, 193—201

[2] Gonfiantini, R., Dincer, T., Dereköy, A.M., Environmental Isotope Hydrology in the Hodna Region, Algeria, Ibid, 293—314

– In archaeology the technique is being applied to the glazing material of pottery to correlate with other dating methods.

– In pollution studies CPXE has already been used to establish lead concentration in various materials from automobile exhaust **(Table 1)**[3]. The results are given in ppm and the comparison with other analytical techniques is good.

– Pollution studies have also started on samples of fish, mollusca and sea weed collected from different parts of the Black Sea.

TABLE 1. Lead contamination of several materials at several distances from a road (Low traffic)
(The results are given in ppm of dry material.)

Sample	Distance from the road (m)	Polarography	Atomic absorpt.	CPXE
Sand	0	1266	1030	939
Litter	0	531	625	523
	50	144	201	216
	100	110	132	189
Compost	0	451	332	372
	50	126	135	145
	100	42	49	88
Bryophytes	0	214	272	303
	50	130	129	136
	100	91	113	125
Spermatophytes	0	91	63	61
	50	33	29	31
	100	28	30	24

These examples illustrate the wide range of application of the CPXE technique. Further research work will extend the technique through standardization of target preparation and simplification of methods by which absolute concentrations can be determined.

Regional Co-operative Agreements

A quite different example for illustrating IAEA activities is the so-called Regional Co-operative Agreement. The International Atomic Energy Agency, as part of its overall function, has entered into agreements with Member States on a regional basis. The participating States are Bangladesh, India, Indonesia, Republic of Korea, Malaysia, Pakistan, the Philippines, Singapore and Thailand.

[3] G. Deconninck, G. Demortier, F. Bodart "Application of X-ray Production by Charged Particles to Elemental Analysis". Atomic Energy Review V. 13, No. 2, June 75, p. 367–412.

Member States party to this Agreement recognize that within their individual national atomic energy programmes there exist areas of common interest wherein mutual co-operation can promote more efficient utilization of available resources. Accordingly, in 1972 the Regional Co-operative programme was formally established whereby Member States agree, in co-operation with each other and the Agency, to promote and co-ordinate co-operative research, development and training projects in nuclear science and technology through their appropriate national institutions.

During the 19th IAEA General Conference held in September 1975, representatives of 15 Member States met for this purpose. The major topics of discussion centered on programmes and proposals to increase co-operation in areas of major importance to the region. These included increased food production, improved medical care, characterization of environmental pollutants and determination of the requirements for increased training opportunities for technicians associated with the growing nuclear programmes of the region.

Nuclear Methods in Environmental Research

In 1975 the Agency began a new programme component "Nuclear Methods in Environmental Research". The activity of the Agency in research on non-radioactive pollutants is supported for two main reasons.

The first reason is that nuclear methods are a powerful tool for environmental research, which should be used more intensively. In particular, it concerns a more effective utilization of research nuclear reactors for activation analysis of environmental objects. There are several aspects of this:

First, most of the inorganic pollutants, e.g. mercury, cadmium, arsenic, selenium, can be determined in complex matrices and in concentrations as low as one part per billion. In some cases organic contaminants can be detected, e.g. bromine-containing pesticides.

Second, the analysis of trace elements in environmental samples can be used for studies of pollution sources.

Third, one can deliberately tag objects of interest with activable tracers — either with stable isotopes or even with elements of a low natural abundance in the system studied. This technique has been applied for dynamic investigations such as migration of insects, atmospheric circulation, hydrologic studies, etc. An exclusive sensitivity of neutron activation analysis makes it often the chosen method.

Other nuclear methods also deserve consideration. Photonuclear activation analysis using linear electron accelerators and betatrons is feasible for determining such contaminants as lead and fluorine. X-ray fluorescence analysis including one method with excitation by radioisotopes or by protons from low energy accelerators is fast developing. Mass spectrometry has also found application in environmental studies.

The second reason for the Agency's interest in non-radioactive pollutants is the necessity for a comparison of probable impacts on the environment from nuclear and other sources of energy.

In 1975 the IAEA started a project within this programme on "Neutron activation analysis of pollutants in human hair, using research reactors". This topic was chosen because in the chain leading from sources of pollution to man it is man himself who is naturally the most important and final link. Moreover, the analysis of man's composition provides the most direct information on the gravity of the environmental situation. The composition of hair better reflects the body burden of many contaminants than most other tissues, including blood. Neutron activation analysis of hair has been found to be an effective analytical method. Human hair is easily obtained, kept and mailed. Historical samples may also be analysed.

The main objectives of the project are:

(1) to establish levels of contaminants (such as Hg, As, Cd, Pb, Se, Br, Sb, Cr, Mn, Zn and Cu) for the normal population in regard to different geographical and economical regions, and

(2) to reveal groups of population and individuals with increased levels of the contaminants and/or with abnormal ratios of contaminants and essential elements.

At present there are 17 scientists from 12 countries (Austria, Czechoslovakia, the Federal Republic of Germany, the German Democratic Republic, India, Iraq, Japan, Poland, the Philippines, the United Kingdom, the United States of America, and the Union of Soviet Socialist Republics) taking part in the project.

A special version of this project has been proposed to the Member States who are party to the Regional Co-operative Agreement for Research, Development and Training related to Nuclear Science and Technology in Southeast Asia and the Far East.

Radioisotopes in Medicine

Radioisotopes have been introduced very extensively into the field of medicine in the developed countries. It is the primary objective of the Medical Applications Section of the Division of Life Sciences to provide advice and assistance to developing countries as they attempt to incorporate these techniques into their own medical programmes.

The Agency programme has focused on three broad areas:

– the **in vivo** use of radioactive tracers, either for diagnosis in patients or for the study of the absorption and metabolism in normal subjects of various substances, for example, nutrients,
– the **in vitro** use of radioisotopes for assay of hormones, vitamins and other biological substances, and
– activation analysis for assay of trace elements in biological tissues.

One typical example of the medical programme is the series of Symposia held every four years on scintigraphic imaging procedures. This has been an area of especially rapid growth in nuclear medicine. Each meeting has been attended by several hundred nuclear medicine specialists from both developed and developing countries, and the published proceedings have become standard reference works for those who wish to keep abreast of important developments in this field.

Another example is the co-ordinated research programme, organized jointly with WHO, on the occurrence of trace elements in biological tissues as possibly associated with cardio-vascular disease. Neutron activation analysis techniques have been developed for analysing the trace elements of particular interest, and results have been obtained on tissues collected from several epidemiologically interesting regions. The collaboration of many laboratories has served to stimulate the improvement of techniques and the collection of data from diverse environments.

As a further example of the Agency's work in the medical field, many experts have served for periods of several months to a year or longer in establishing nuclear medicine services in hospitals in developing countries.

The Agency feels a special obligation to examine the relevance of procedures and the suitability of instruments as developed in the advanced countries for application in the developing countries. To this end, it is initiating a new programme which will attempt to examine in quantitative terms the importance of the information obtained by alternative nuclear medicine procedures, the design requirements for instruments to perform these investigations in the circumstances found in the developing countries, and strategies for maintaining the instruments once they have come into service.

Isotopes in Food and Agriculture

The Programme of the Joint FAO/IAEA Division of Atomic Energy in Food and Agriculture is designed to assist developing Member States to apply isotope and radiation techniques to the solution of problems related to food production and protection as well as minimizing pollution of food and the agricultural environment. Nuclear methodology complements other techniques in research and development applied to food and agriculture in that it frequently provides the most effective and sometimes the only means of answering specific questions. For example, in view of the present scarcity and high cost of many agricultural commodities, nuclear techniques can indicate the most effective utilization of fertilizer crops, as an aid to conserving fertilizer in the root zone for the plants, help ensure that pesticide applications result in minimal ecological damage, and help improve crops for higher yields, better quality, and disease resistance.

The Joint Division's programme has been drawn up on the basis of consultations between FAO and IAEA and is carried out on behalf of the two organizations. It involves co-operation with UNDP in regard to technical assistance, with WHO on food preservation and also with UNEP and WHO on pollution, entomology and pest control. Special emphasis is placed on co-ordination and support of research through a number of Co-ordinated Research Programmes, all of which are strictly problem-oriented. This assures a versatile approach and the activities are highly decentralized in that research is carried out entirely in national institutions, thereby strengthening their research capabilities. The IAEA Laboratory at Seibersdorf backstops these activities as needed. Currently, over twenty such programmes are in operation involving approximately 250 scientific institutions all over the world. Achievements to date show that the Joint Division's programme has stimulated or resulted in the development of several improved crop varieties, better mutation breeding techniques, more efficient ways of applying phosphorus and nitrogen fertilizers, more rational use of irrigation water, large-scale production of vaccines against lungworms in sheep and goats as well as of animal feeds based on non-protein sources of nitrogen, greatly improved techniques of applying induced male sterility to selected deleterious insect pests, better understanding of the processes of chemical pollution in food and agriculture as well as progress towards general acceptance and commercial use of irradiation as a means of food preservation.