nuclear techniques and the fight against pollution

The picturesque city of Salzburg was the scene of an important symposium, called to discuss one of the most pressing problems of our civilization — environmental pollution. Industrialization and urbanization, prerequisites of modern life, have a reverse side: contamination of water resources, atmospheric deterioration, soils poisoned by industrial toxicants. Pollutants are dispersed every day, threatening the health of man, endangering other forms of life, and jeopardizing the equilibrium of the biosphere in the long-term. What can be done to solve the problems which have already been created? In particular, what can nuclear science contribute to diagnosis and therapy?

The aim of the five-day symposium, on the use of nuclear techniques in the measurement and control of environmental pollution, was to take the first steps toward answering these questions. The meeting, convened by the International Atomic Energy Agency, brought together more than 170 experts from 32 countries and seven international organizations.

Prof. Vasilii Ferronsky, Director of the IAEA Division of Research and Laboratories, speaking on behalf of the Director General, summarized the situation in this way: "We are facing the problems of determining how much we can tolerate the threat of pollution, how long we can endure the dangers we face if the situation remains uncontrolled. Confronted by these harmful pollutants, we should trace their movement and accumulation affecting our supplies of water, air and food. For the sake of mankind we must be eager to find out the flow patterns, the ultimate location and fates of these pollutants in nature."

The Welfare of Mankind

Recent advances in nuclear techniques, such as neutron activation analysis, radioisotope X-ray fluorescence spectrometry, electron capture gas chromatography, mass spectrometry, and low-level counting, will make it easier than before to define the goals of environmental control, said Prof. Ferronsky. Turning to the participants in the symposium, he added: "With your active contribution, I am convinced that this first international meeting on the use of nuclear techniques on pollution problems will add to our understanding of the environment, and will become a landmark symbolizing one of the important uses of radioisotopes for the welfare of mankind."

The Mayor of Salzburg, Mr. Heinrich Salfenauer, drew attention to the fact that 1970 was being celebrated as European Nature Protection Year. "We in Austria, a typical tourist country visited for its recreational value, should especially focus our attention on this problem," he said.

Dr. Hans Lechner, Governor of the Province of Salzburg, also emphasized the importance of a scientific exploration of environmental problems. "We shall not overcome the pollution of water, air and soil by screwing back technical progress and industrial development," he said. "In this case, the alternatives would be to pollute, and starve. Other methods must be found, and avenues explored."

For the scientists present, this meant: measure what can be measured, hoping that the empirical data obtained and the scientists' own imaginations will lead to greater knowledge and understanding. In the context of the symposium, it meant that they should exchange information about nuclear techniques which enable the movement and behaviour of noxious substances in air, water and soil to be measured and analysed. Only a few experts doubted that the second part of the title of the symposium — "... control of environmental pollution" — would be most difficult of all to achieve.

But it was agreed that nuclear techniques do have essential advantages over other methods because of their sensitivity, selectivity and reliability. Often, however, they do not stand up to a cost comparison with other methods. So some experts suggested that in applying techniques the quality of the result should be taken into account in addition to the cost factor. Dr. Knut Ljunggren, of the Isotope Techniques Laboratory, Stockholm, Sweden, suggested: "There is no justification in regarding nuclear means of measurement, be they tracers, analytical methods or radioisotope gauges in any other way than in relation to competing methods of measurement and instruments."

Openness to all methods does not necessarily lead to the conclusion that nuclear analytical techniques will lose the race. On the contrary, nuclear techniques have another important advantage: they are able to trace pollutants back to their sources. And this, in the long run, could be an essential characteristic which could — and a good many participants hoped would — pave the way to effective control of environmental pollution.

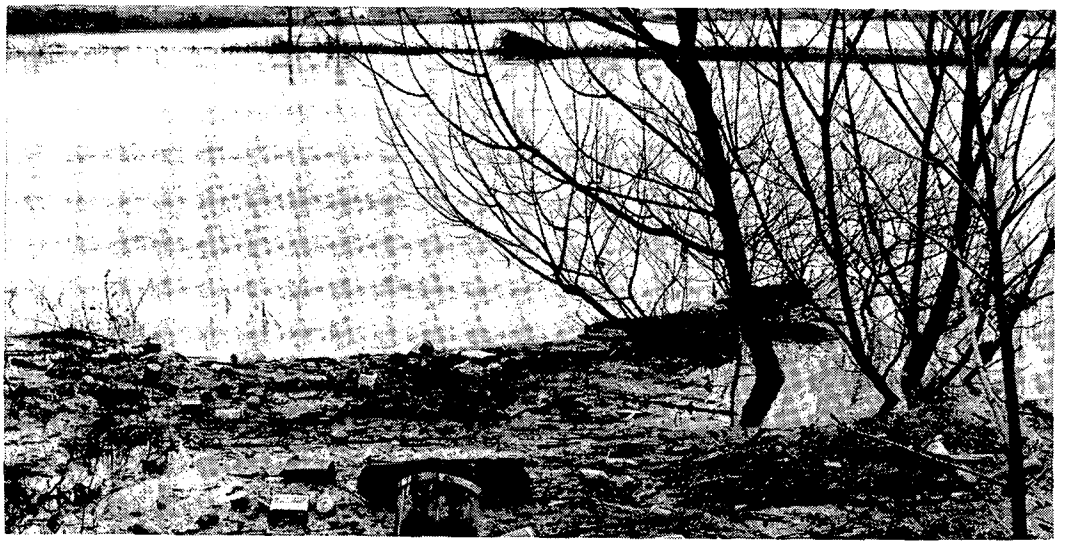
Another argument was used as well: that it is hardly possible to make a generally-applicable cost comparison. Rather, it is necessary to compare both the methods and the results obtained by the different techniques. "In environmental studies," Ljunggren writes, "especially those based on studies of ecological systems, the cost of obtaining a sample is often very high — therefore it seems reasonable to treat every precious sample to the best analytical procedure available rather than to try to minimize costs for analysis."

Promising results were demonstrated by a new branch of science, radioecology. Applying nuclear methods to investigate biological problems, interdisciplinary teams are doing systematic research on the environment. Success was reported in determining the means by which enrichment and other changes in a biologically interdependent area — a so-called ecological system — take place.

Pollutants often vary their behaviour and composition during their stay in a certain medium. Mercury affords a good example. Discussion about this metal was among the highlights of the symposium. Mercury, which has been known for years to be noxious in the form of vapour, has not until recently been regarded as one of the classical pollutants — such as carbon monoxide, sulphur dioxide, lead or DDT. But mercury pollution has now become a subject for concern in some areas.

Yugoslav research workers, however, measured the uptake of mercury in domestic animals and fish around a mercury mine and processing plant at Idrija, Slovenia, by means of neutron activation analysis. The animals tested showed no ill effects attributable to mercury intoxication, and these research workers said in their report: "Although occasional intoxications do occur among the human population, these are mainly in newcomers to the area. We tentatively suggest that there is some accomodation effect to increased levels of mercury" in the environment. Swedish radioecologists reported on the phenomenon of spontaneous mercury methylation: Organic radicals attaching themselves to mercury form a stable combination which is much more dangerous than inorganic compounds of mercury, or mercury in metallic form. Such metabolizing could also occur in relation to other elements, it was presumed. It was therefore proposed that a research programme should be initiated in relation to arsenic, antimony, cadmium and selenium.

Metabolic conversion in organisms can be identified only by nuclear techniques, it was argued. Since the chemical composition of the resultant products — the metabolites — is unknown, classical methods of obtaining evidence must fail. Such research on metabolites using nuclear methods may lead not only to information about the behaviour and transport of certain substances in a system, but to acquisition of fundamental knowledge about natural processes, since the "tracers" used for



The scene is in France: it could be almost any industrialized country. Nuclear techniques can be used in the battle against pollution. Photo: UNESCO/F. Bibal

"Nuclear energy, far from being a major contributor to the pollution of the environment, will *in fact diminish* pollution as it replaces other sources of electric power..." Extract from the addendum to the Agency's report to the Economic and Social Council of the United Nations for 1969—70. Here, the 500 MWe Trawsfynydd nuclear power station, Merioneth, North Wales, at dusk. Photo: UKAEA

the exploration of microchemical procedures themselves indicate the working of natural systems.

The approach of systems analysis to environmental problems bears great promise of fruitful results. As a new art, making models of ecological systems with input and output calculations could lead to yet undeveloped ways of simulating procedures in nature. Computerized systems analysis using the catalogue of empirical data about the environment achieved by ecological research may soon contribute to a better knowledge of pollution problems.

Active or Activable?

The symposium showed that there is still a controversy about whether active or activable tracers should be used in activation analysis. Adding radioisotopes to the material to be investigated at least has the advantage of permitting direct measurement. Two schools of thought were seen to exist with regard to the abatement of the unlawful discharge of oil in waterways. Some experts suggested analytical measurements to prove the identity of an oil source, while others declared themselves for labelling the oil radioactively at source. Both methods, it seems, are applicable in practice. The analytical approach is possibly more likely to be applied in future.

With regard to more technical aspects, methods to improve the purity of filter materials, and standard reference materials for comparing elements were discussed. Radioisotope X-ray fluorescence spectroscopy was regarded as an appropriate tool for analysis of water for heavy metals such as zinc, cadmium and lead. This technique can be used for measuring concentrations of sulphur dioxide and lead in air, water and blood as low as ten parts per million. Dual-tracer techniques using mass spectrometry with sulphur hexafluoride as tracer, and radio-release methods, are also instrumental in pollution monitoring, the latter in particular being an effective tool for measuring pollution due to automobile exhausts.

Swedish scientists at the symposium also reported on the use of moss as an "environmental indicator", in particular for heavy metals. Moss retains these metals, apart from an insignificant washing-out by rain, since there is no exchange of nourishment with the ground. In this case, moreover, all types of analysis may be applied.

In the United States the application of isotopic techniques to problems of the environment began some 15 years ago. Studies have grown steadily, aimed more at obtaining an understanding of specific environmental problems rather than merely obtaining an evaluation of the potential value of a given technique. Also, more and more they are being initiated and conducted by the "environmentalist" and the sanitary engineer, rather than by the isotope technologist as in the past. William E. Mott, of the Division of Isotopes Development of the US Atomic Energy Commission, reviewed work performed with isotopes in areas of environmental pollution in the United States in the last five years. He dealt with isotopic tracers, radioisotope instruments, X-ray fluorescence analysis, radio-release methods, Mössbauer spectrometry and the radiation treatment of municipal and industrial wastes, and drew the conclusions that:

The technological base required for application of neutron activation analysis to pollution-related problems is well-developed and is being exploited on a broad front;

The potential of neutron-induced prompt gamma-ray analysis in pollution studies has yet to be evaluated;

Although innovators are at work, isotopic X-ray fluorescence analysis is relatively new and the range of basic techniques required to make it a versatile and important tool for pollutant measurement does not exist at present. But it is expected that it will have eventually a unique and important role in measurement and control of pollution;

Little work has been performed so far on the application of radio-tracers in municipal wastewater discharge. Important benefits could accrue from an expanded use of radio tracers in design and operational studies on wastewater treatment plants;

Isotopic and other nuclear techniques are, and will continue to be, of importance mainly in the realm of analysis and measurement;

Without cost reduction, and a change in wastewater management, the radiation treatment of municipal and industrial wastewater will play no important role in the immediate future.

By and large, Mr. Mott was optimistic about the abatement of environmental pollution. "Those skilled in the environmental disciplines will be applying, with the help and guidance of the isotope technologist, existing and established techniques to the solution of the pollution problems," he said. "Isotope techniques will be another basic tool in the work chest of the operational scientist and will continue to contribute in a very meaningful way to the control and abatement of environmental pollution in the 1970s."

Trace elements in the Air

American scientists from the University of Michigan, Ann Arbor, investigated the behaviour and variation of trace elements in air particulates over the heavily-industrialized area of Northwest Indiana and nearby rural locations. A set of 25 air-filter samples taken simultaneously was analysed for 30 trace elements by non-destructive neutron activation analysis. It appeared that some elements showed marked increases in concentration near large industrial complexes. Such nuclear techniques also permit the source of pollution to be traced: "Pollution elements such as Fe, Mn, Zn, Sb, Cr, W, Co, Sc, La, Ce, Th, Ca and Mg seem to be linked strongly to the local steel production and supporting industries," the scientists stated.

Pollution assessment of the air over the sea is difficult. But increased lead concentrations in polar ice samples and ocean surface waters, pesticides transported with wind-blown dust over the Atlantic and the Indian Oceans, and a general rise in ambient aerosol concentrations probably of man-made origin indicate that even the marine atmosphere is becoming more and more polluted. Experts from the US Naval Research Laboratory in Washington, D.C., obtained samples by aircraft flying at low altitudes 50 miles off the eastern seaboard of the US, on

a ship during an Atlantic crossing from the Caribbean to the Mediterranean, and at a shore station on the island of Hawaii. Samples taken along the Atlantic coast of the US showed the influence of polluted continental air masses in near-shore regions; an influx of African dust was found in the middle of the Atlantic. To determine the chemical composition and the origin of the particulate samples, different activation methods (neutron, photon and proton) were used.

Other means to study factors relevant to atmospheric pollution, especially larger-scale processes, can investigate radionuclides produced by the interaction of cosmic rays with components of the atmosphere. Depending on their physical characteristics, these radionuclides — with half-lives from minutes to millions of years — may become attached to atmospheric aerosols and serve as tracers of their behaviour.

Other radionuclides can be used to identify the origin of oil pollution of the sea caused by ships. Swedish scientists from the University of Lund labelled the oil on a ship with two radionuclides with different half-lives — for example, the iodine isotopes ^{125}I (half-life 60 days) and ^{131}I (half-life eight days). The activity ratio of the radionuclides in "pollutant" oil could then be determined, enabling a simple dating and identification to be performed. The reliability of such identification could be increased if three or more radionuclides were used.

Since the IAEA organized a panel on "Use of Activation Analysis in Studies of Mineral Element Metabolism in Man" in Teheran in 1968, much attention has been paid to studying the "normal" levels of various elements in animals and plants under assorted living conditions. Nevertheless, more than 70 per cent of the particulate contaminants in urban air, for example, are yet to be identified; it is not known whether selenium is harmful or necessary as a trace element in various life forms, whereas cobalt and molybdenum, at low concentrations, are desirable.

Detecting Pollutants in Man, animals and Plants

Participants in the symposium in Salzburg therefore felt it will be necessary to investigate trace levels of elements in man, animals and plants, and to determine their physiological role and the influence they have in the biosphere. The first such studies have already been made. Apart from studies concerning mercury uptake reported by Swedish and Yugoslav scientists, a French team from the Centre d'Etudes Nucléaires at Grenoble presented new results on the detection of pollutant elements retained by plants. Applying different nuclear techniques (using, for example, thermal neutrons from a reactor or 14 MeV fast neutrons from a generator), residues of pesticides such as Bordeaux mixture, organic fungicides based on zinc and manganese thiocarbonates, arsenic-containing insecticides and bromine-containing derivates were analysed. The method was good enough to carry out analyses on parts of a fresh fruit, or on products of the food industry. "It is becoming possible — without undue analytical work — to draw maps showing the fluorine concentration in different annual or perennial plant species and to determine the areas most affected," the scientists said.

Even small events may contribute to pollution. Peter E. Wilkniss and David J. Bressan from the US Naval Research Laboratory, Washington,

D.C., described pollution "under the magnifying glass." When a bubble of 1 mm diameter arrives at the surface of the sea a part of it, the "film cap," will protrude through the surface. At the moment it breaks, up to 20 fragments are generated, with diameters between 1 and 20 μm and an average salt mass of 10^{-11} g. Then the bubble cavity collapses, and up to four "jet drops" are ejected into the air from the bottom of the bubble. The top jet drop can reach a height of 12—15 cm above the water, has a diameter of 100 μm and has a salt mass of 3×10^{-8} g.

The bubbles are formed, the research workers reported, by gas production in biological processes in natural water; by sorption of dissolved gases on suspended particulates; in white caps on waves, caused by wind, and by the impact of snow or raindrops on water surfaces. What is startling is that they estimate that in this way 10^9 metric tons of inorganic salts are injected from the waters of the world into the atmosphere each year.

Unfortunately, by default of man this impressive natural phenomenon has become a powerful instrument of pollution. The bursting bubbles spread vast quantities not only of salt particulates but of noxious substances into the air, from aerated sewage plant tanks, contaminated rivers, lakes, estauries, bays, and especially surf areas in coastal waters, and the oceans themselves.