RADIATION RESEARCH CONTRACTS

According to its Statute the IAEA has to fulfil a dual function - to help individual countries in solving their specific problems and to undertake tasks in the common interest of all its Member States. With this latter aim in mind the Agency has placed a number of research contracts with national research institutes. The purpose and scope of two of them is described below by the scientists responsible for their execution. The Agency has contributed to this work by putting at the institutes' disposal scientists from its own staff, apparatus and financial aid

BIOLOGICAL EFFECTS OF SMALL RADIATION DOSES

by Otto Hug

Professor Hug received his M.D. at Berlin University. He was Assistant at the Max Planck Institute of Biophysics, Frankfurt, and taught at the University of Frankfurt. In 1956 he joined the University of Ratisbon as Professor of Biology and is now a senior officer of IAEA's Division of Health, Safety and Waste Disposal

To establish the maximum permissible radiation doses for occupational and other kinds of radiation exposure, it is necessary to know those biological effects which can be produced by very small radiation doses. This particular field of radiation biology has not yet been sufficiently explored. This holds true for possible delayed damage after occupational radiation exposure over a period of many years as well as for acute reactions of the organism to single low level exposures. We know that irradiation of less than 25 Röntgen units (r) is unlikely to produce symptoms of radiation sickness. We have, however, found indications that even smaller doses may produce certain instantaneous reactions which must not be neglected.

Reactions on the Nervous System

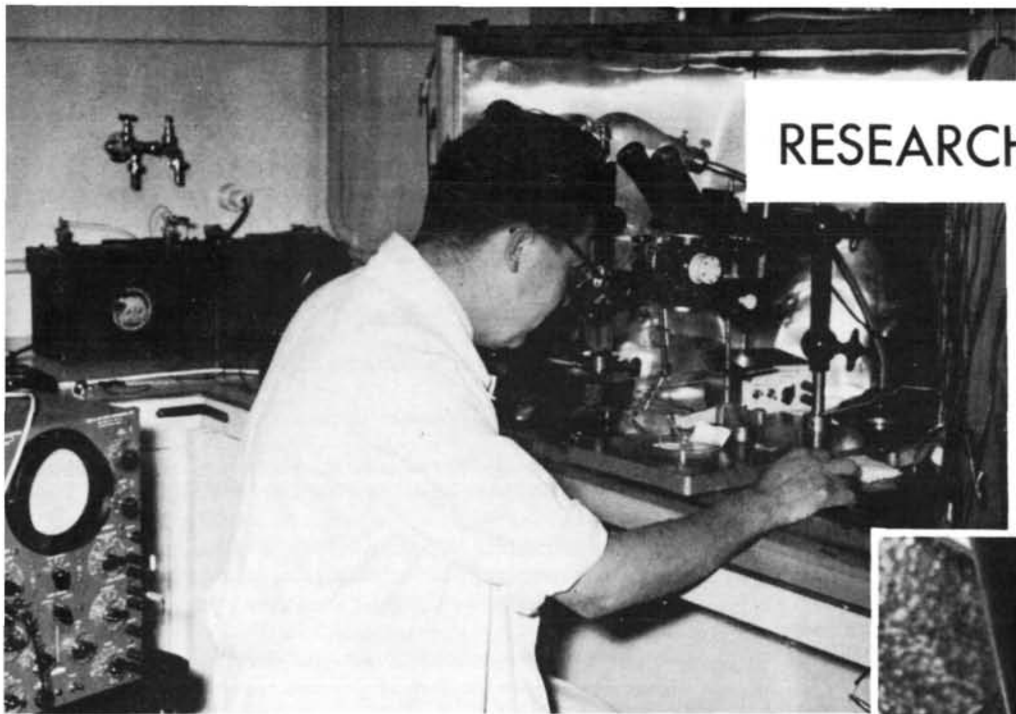
Recently, more and more observations have pointed to the fact that the nervous system plays an important role in such instantaneous reactions. This, to a certain degree, is in contradiction to the generally held opinion that the nervous system is considerably resistant to ionizing radiation. Indeed, irremediable structural or functional damage to the nervous system can only be produced by extremely high doses. Some earlier observations and a number of more recent ones show, however, that the sensory organs and the nervous systems of animals may react quickly and easily to low doses. Röntgen had stated that the kind of radiation discovered by him produced an impression of light in the human eye. This effect, later called "Röntgenphen", has been studied in detail. Unfortunately, this sensation, especially in bright daylight, is so weak that it cannot serve as a warning signal against radiation. But lower animals seem to be considerably more sensitive in this respect. We were able to demonstrate in particular that many invertebrates react with reflex motions to astonishingly small radiation doses. For example, snails retract their feelers, clams shut their shells, and actinia, those beautifully coloured sea lilies and anemones, retract their crown of tentacles. A few seconds after the beginning of the irradiation, small barnacles stop their rhythmic grasping actions. The behaviour of insects can be disturbed by irradiation as well. For instance, ants show a lively disturbance immediately after irradiation; they act wildly in an attempt to flee rapidly from an irradiated area into a "radiation-proof shelter". American scientists have recently reported certain disturbances in the behaviour of the water flea when subjected to radiation. Quantitative analysis of all these phenomena proves that they are reflex-like responses to ionizing radiation previously unknown.

For a variety of reasons, we can assume that this reaction to ionizing radiation has not been entirely lost during evolution, and that in man it is not restricted to the sensitivity of the eye mentioned above. It is the experience of radio-therapists that immediately after local irradiation of the abdominal region, disturbances of the normal intestinal and stomach motions may occur, such as a delay in the normal emptying of the stomach. They assume that the vegetative nervous system is involved.

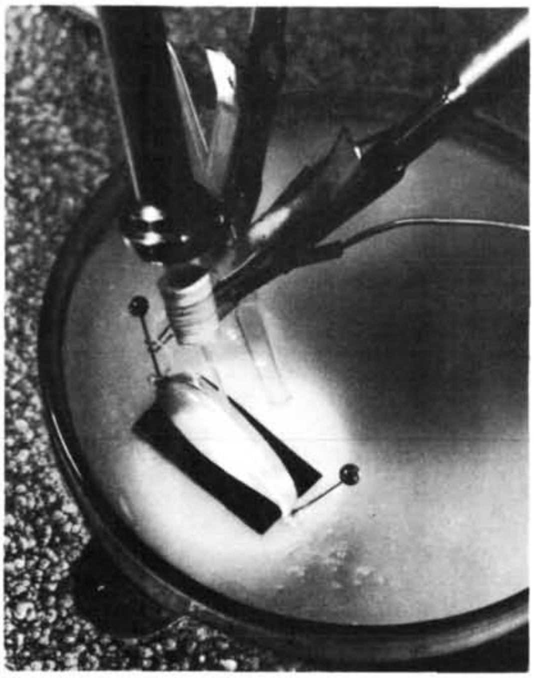
It is only recently that instantaneous reactions on the nervous system have been observed, and particularly in Russian scientific literature, reports have appeared describing phases of nervous over-excitability after irradiation, changes of normal reflex responses and disturbances of the electrical currents of the brain, measurable with an electro-encephalograph - all this due to very low radiation doses.

These are the scientific facts which led IAEA to place a research contract concerning the effects of small radiation doses on cells, in particular on nervous cells, with the Pharmacological Institute of the University of Vienna. This Institute appeared well suited to deal with the problem owing to the type of its previous research work. The Director, Prof. Franz Brücke, and his collaborator, Dr. Otto Kraupp, have long been interested in the functioning of the nervous system and in the influence of different drugs upon it. It was particularly fortunate that the electrical properties and functions of cells had been measured by a method specially developed at this Institute. From the above-mentioned observations we could expect that instantaneous reactions of cells to radiation would also lead to changes of their electrical status. Consequently, this method is now being applied to the research undertaken for IAEA. Different cells of plants and animals, ranging from algae to muscle fibres of mammals, were chosen as objects. Glass capillaries with a tip diameter of one half of 1000th millimeter and filled with a special solution

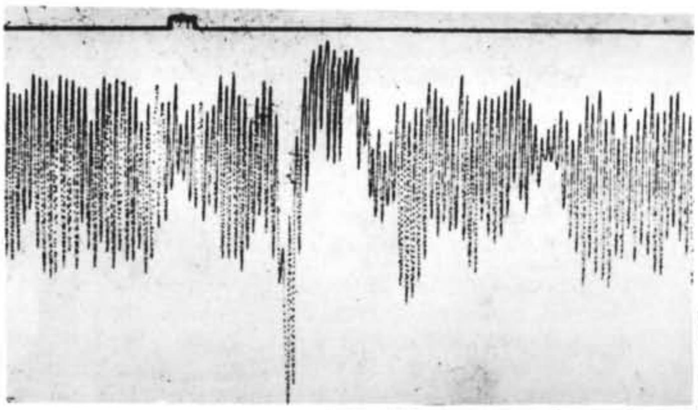
RESEARCH WORK FOR IAEA

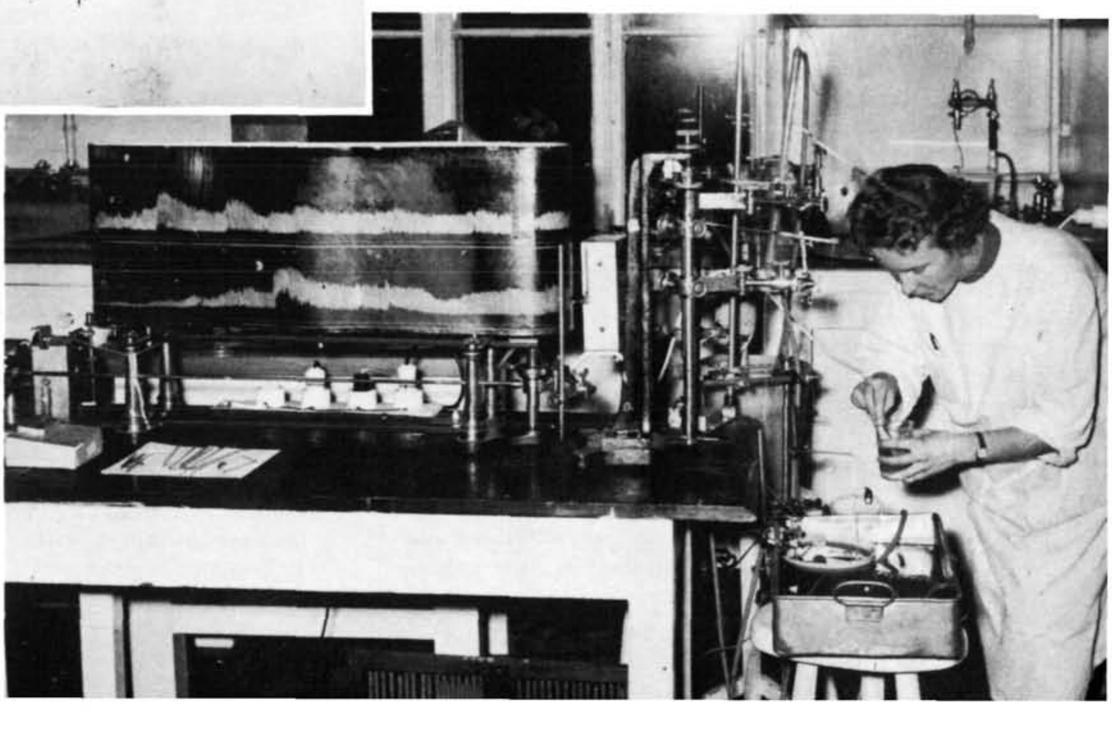


Lt: Equipment for measuring intracellular electrical potentials of cells. A strip of frog muscle, prepared in a petri dish, is placed under the microscope. Micro-electrodes are inserted into a single muscle fibre with a special micro-manipulator. The apparatus is protected from electrical interference by a metallic screen



Enlargement of frog muscle with micro-electrode inserted





Rt: Kymograph measuring tension and motion of rabbits' intestines. A strip of intestine is put into the constant temperature bath, the specimen being connected by a lever system to a stylus which records its motions on a moving blackened paper

Top: A section of a kymogramme showing a temporary contraction of the intestine, in the form of a high spike, after a short period of irradiation (marked on the base line)

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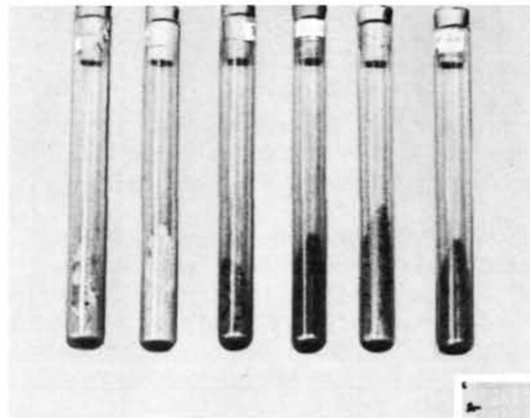
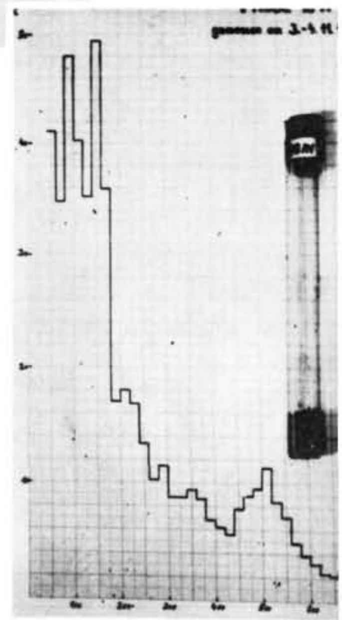


Rt: Samples from the biosphere – from water, plants and soil – in which fission products have been concentrated. Below: Graph showing the measurements of radio-activity obtained by gamma-spectrometry



Lt: A sample being put into a well-type scintillation counter. A large part of the radiation from the sample hits the crystal – visible as a white ring within the heavy lead shield – producing small flashes of light, called scintillations. The rate of scintillations is a measure of the amount of radio-active substances in the sample

Rt: Instrument for measuring radio-activity at very low intensities. An automatic camera photographs the readings every hour are being used as electrodes. Under a stereo-microscope these electrodes are introduced into a single cell by means of a special manipulator. In this way one can measure the electrical potentials existing between the interior of a cell and its surroundings. These potentials, representing a characteristic phenomenon of life, are sustained by complicated metabolic and diffusion processes, especially at the cell membranes. In the resting cell the potential is almost constant (resting potential). In cases of spontaneous actions or stimulations, typical spikes occur (action potentials).

So far changes of potentials had been observed only during irradiation with very high doses. Under the research project, we are examining whether or not low doses of irradiation may also change the resting or action potentials. The irradiation is being carried out with an X-ray apparatus as used for therapeutic superficial irradiation of the skin.

Another Approach

At the same time, we are trying by another method to approach the same goal, namely the detection of biological instantaneous reactions. The clinically observed actions of radiation on the intestine are being experimentally investigated by a special technique for testing drugs. When a piece of rabbit intestine is preserved under conditions as physiological as possible, the muscles of the intestinal wall keep their tension for a long time and show rhythmic contractions corresponding to the natural peristalsis in the living animal. Tension and motion can be registered by means of a Kymograph. In that way, we found that X-irradiation raises the tension of the intestine. It is now our aim to find the minimum necessary dose and dose rate for this effect and to analyze quantitatively the dependence of this effect on both these values.

During our investigations we developed another useful test for small radiation doses; we measured the through-flow of an artificial blood solution through the blood vessels of an intestinal loop. It was observed that a few seconds after irradiation the flow rate diminishes, and returns to its normal level only when irradiation ends. This phenomenon can also be registered with a Kymograph.

Our observations so far lead us to believe that the instantaneous radiation reactions of the mammalian intestine are also reflex-like stimulus responses and that the same rules are valid as those governing the reactions to mechanical, chemical, optical and electrical stimuli.

As usual, many new problems which await clarification have arisen in the course of our work and on the basis of the results so far achieved: Are these highly sensitive reactions produced by direct stimulation of the nerves, or receptors in the intestinal wall, or by substances freed or produced under irradiation in other cells? Can these substances be isolated and determined? Could these instantaneous radiation effects be diminished or suppressed by certain substances, such as those already known for their radiation protective properties? All these questions are not merely theoretical, but have a direct bearing on protection against radiation.

DISTRIBUTION OF FISSION PRODUCTS IN THE BIOSPHERE

by Thomas Schönfeld

Dr. Schönfeld, who is a Ph. D. of Vienna University, holds the position of Assistant Lecturer at the First Chemical Institute of the University. He is directing the research project described in this article

Protection against ionizing radiation given off in nuclear transformations is one of the foremost safety problems in all atomic energy operations. While every effort is being made to prevent reactors, processing plants and all other installations from releasing radioactive materials into the biosphere - air, water and earth - under any foreseeable conditions, small amounts of it are actually released into man's living space. Undoubtedly, this will continue to be so, at least for the time being. For example, low activity liquid wastes from some chemical processing plants are decontaminated in special processes, but traces of fission products remain in the liquids finally discharged on the ground or to nearby waterways. In some installations low and medium activity liquid wastes are even released on the ground or into swamps without prior decontamination. It is also to be expected that in accidents larger amounts of fission products may occasionally be released.

To make the routine release of small amounts of fission products safe and to be able to estimate the possible effect of larger releases in accidents, a considerable amount of information is required.

Enrichment Processes

Special problems arise from the fact that enrichment processes operate in the biosphere. Even if the concentration of a certain radio-element at the point of release, e.g. into a stream, is below the tolerance concentration, high concentrations in food for humans may arise by absorption processes in aquatic organisms which are in some way part of the food chain. Strong enrichment in aquatic organisms has, for example, been observed for radioactive phosphorus, itself not a fission product. Hazards due to enrichment processes might also occur where weakly contaminated water is used for irrigation. Obviously, processes of this kind must be studied carefully to make certain that a release of radioactive products in a given set of circumstances is not harmful.

Useful knowledge about various aspects of fission product behaviour in the biosphere has already been obtained, but many important questions remain unanswered.

Considering the large increase in the construction of reactors planned for the near future, which will lead to a corresponding increase in the amount of fission products to be handled, it is necessary to intensify the efforts in this direction. In May 1958 a research project on "the factors controlling the distribution of fission products in the biosphere" was started at the First Chemical Institute of the University of Vienna under a contract with the International Atomic Energy Agency. The First Chemical Institute is headed by Professor Hans Nowotny. The project is carried out within the Department of Radiochemistry headed by Professor Engelbert Broda.

Methods of Investigation

The project will contribute to one of the objectives of the IAEA - the establishment of standards of safety for protection of health and minimization of danger to life and property. Various methods of investigation are already being applied or are in preparation as part of this research project. The distribution of some fission products, present throughout the biosphere from nuclear test explosions, is being determined to elucidate the factors governing this transport and enrichment. Further data on the uptake of fission products by certain organisms or mineral substances may later be obtained by experiments on a laboratory scale or by release of small amounts of fission products into a certain ecological environment under controlled conditions.

Detection methods of high sensitivity are required for determining the fission products in the biosphere. At the First Chemical Institute in Vienna gamma-spectrometry has been employed since the beginning of the investigation and a low-level beta-counter will soon be completed. With a gamma-spectrometer (supplied by IAEA) samples from the biosphere, such as plant ashes or residues from the evaporation of river water are measured directly. Since gamma-rays of different energies are registered separately with this instrument, gamma-emitting radioisotopes are detected individually through the characteristic energies of their radiations.

Features of beta-counter

The essential feature of a low-level beta-counter is that the background count due to cosmic rays and to the radioactivity of the surroundings is a low one. This is achieved by heavy shielding against radiation coming from the outside and by cosmic ray counters arranged around the beta-counting tube itself. With the help of these counters and a so-called "anti-coincidence" circuit, some counts in the beta-counter are automatically recognized as due to cosmic rays and are not registered. The low background value obtained in this manner permits the detection of very small activities in the material under investigation. The sensitivity of such a counter surpasses that of a gamma-spectrometer considerably. However, measurements are more difficult, since each radio-element to be determined must first be isolated by chemical techniques. Radiochemical separation methods suitable for the samples to be investigated by the research project are now being selected and checked.

In the project under way at the First Chemical Institute in Vienna particular attention is being paid to fission products with half-lives of several months. These have so far been investigated much less thoroughly than the long-lived isotopes caesium 137 and strontium 90. First results about the distribution of some of these fission products - zirconium, ruthenium and rare earths - in rivers and lakes and in vegetation have been obtained.

SAFETY WITH ISOTOPES

The world is warned at regular intervals of the possible dangers in all work connected with radioactive materials. Atomic radiation is indeed a double-edged sword. The benefits of its controlled use are enormous, and the possibilities of use apparently limitless. But every scientist knows - some of the pioneers learnt it from tragic experience - that handled with insufficient care and knowledge, radioactive substances can be a source of great harm.

Recent research has, however, made it possible to determine, with a fair measure of certainty, the effects of ionizing radiation in given conditions and decide on measures to minimize, if not altogether to eliminate, the risk of accidental or excessive exposure. But much of this knowledge belongs to specialized branches of study, and all of those handling radioisotopes in medicine, industry, agriculture and diverse other fields cannot be expected to go through the relevant specialized disciplines. The need thus arises for a brief and simple code of practice or at least a general guide for the safe handling of radioactive substances. And such a code - if it were to be thorough and dependable - could be evolved only from a pooling of knowledge and experience acquired in different fields of work and in different countries.

A panel is set up

It is with this awareness that IAEA set up a panel of thirteen scientists from ten countries to go into the question and formulate an agreed set of do's and dont's for radiation workers and others concerned. Their recommendations were recently published in the form