Under the subject of reactor physics, three questions were discussed:

(1) a study of the mechanisms which made possible the triggering, the continuation, the control and, finally, the cessation of the nuclear reactions; related to this subject were the changes caused by the reactions, the effect of propagation, the role of poisons, the role of water and the impact of temperatures

(2) the duration of the reactions and the measurements required for determining them and the changes in reaction intensity over the time period

(3) the possible value of thermohydrogeological studies were considered and also whether the repetivity of the phenomenon was exceptional or predictable.

### FUTURE RESEARCH

The future of the site and the steps which have already been taken to preserve it were discussed and it was agreed that additional sampling should be carried out so as to provide material for future research.

The desire of all participants at the meeting for a continuation of technical panels of this sort was made evident and it was requested that, if possible, the Agency should consider giving its support to sponsorship of the three specialised technical working groups.

The complete proceedings of the symposium are expected to be published by the Agency before the end of 1975.

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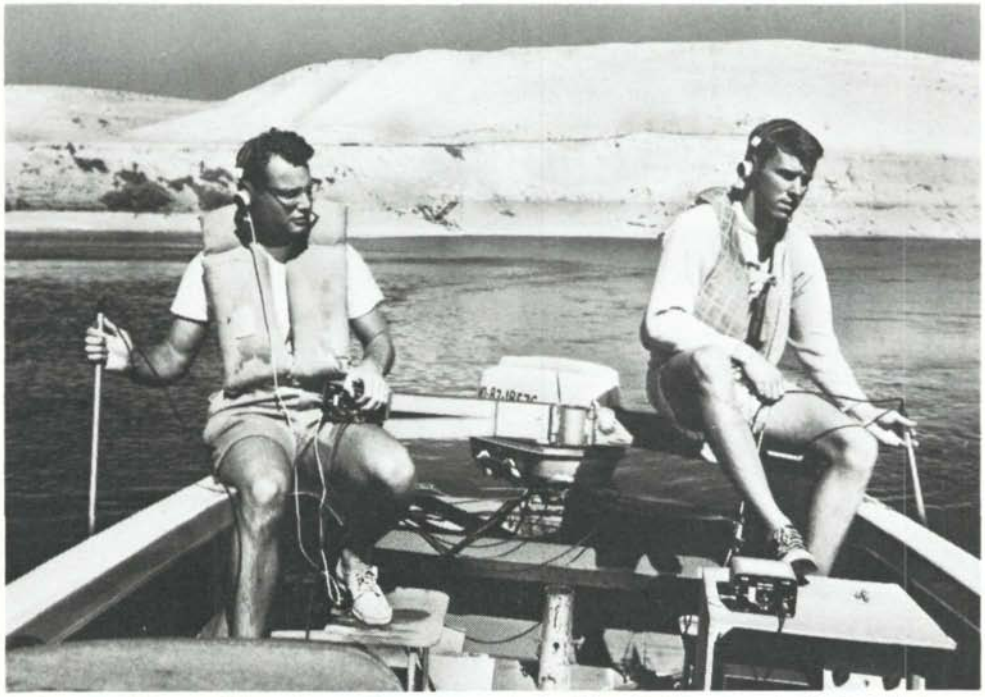
INTERNATIONAL SYMPOSIUM, OTANIEMI, 30 JUNE–4 JULY

The Symposium on "Radiological Impacts of Releases from Nuclear Facilities into Aquatic Environments" was attended by about 150 scientists and specialists from 26 countries and 4 international organizations. Thirty-three papers were presented in ten sessions.

# The Aquatic Environment

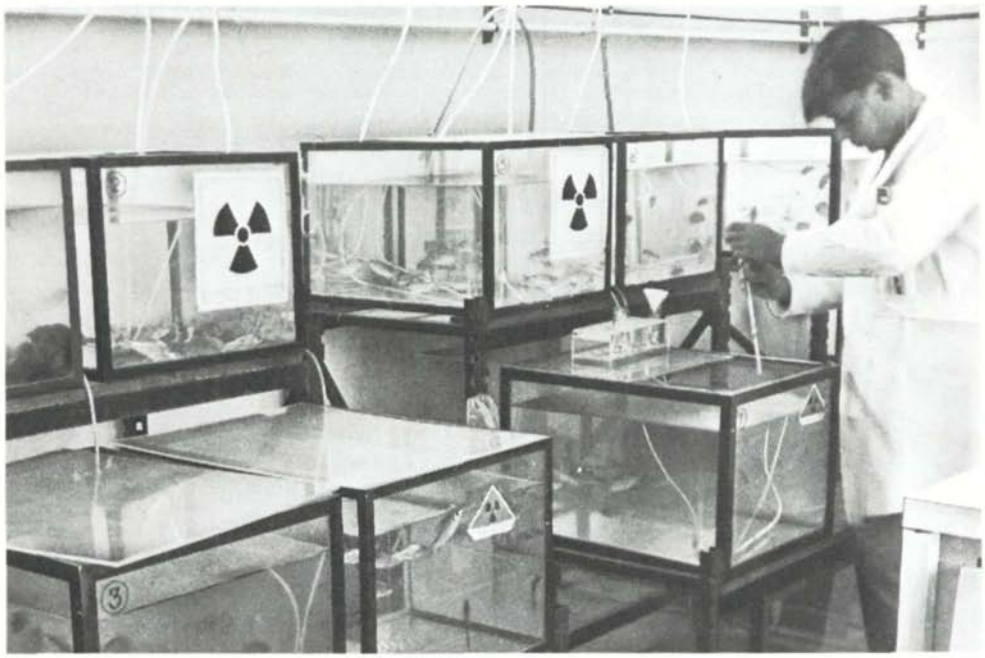
*The rapid increase in technological development and the broad societal benefit it has brought has been accompanied by a corresponding increase in environmental and societal problems. This has established a need to asses the impacts of new technologies, including nuclear industries. We are now entering an age which will see a rapid proliferation of nuclear power plants all over the world.*

*As long as man continues to utilize nuclear energy, some releases of radioactive materials to the environment seem to be inescapable consequences. The problem therefore is to limit and control such releases, so that adverse effects on man and his environment can be reduced to acceptable levels. We can now draw on three decades of experience of the environmental impact of radioactive materials. To review this experience and to survey recent results of studies related to the safety of releases of nuclear facilities into fresh water, estuaries and sea water, the International Symposium on "Radiological Impacts of Releases from Nuclear Facilities into Aquatic Environments" was held at Otaniemi, near Helsinki, Finland.*



Sonic tagged fish were followed by tracing equipment in the Colombia River near the Hanford Works in southeastern Washington State, USA, as part of a study to assess the effects of thermal discharges on river fishes. Photo: Pacific Northwest Laboratory

Aquariums in the radioecology laboratory for experimentation with aquatic biota at the Ezeiza Atomic Centre, Argentina.



## BASIC CONSIDERATIONS

In order to review the situation in relation to radiological effects it is necessary to consider the behaviour of radioactive contaminants in aquatic environments and the system for implementing requirements of radiological protection. In his invited paper, Preston (UK) first introduced the concept of acceptable dose and its application to environmental situations and critical pathway analysis. The establishment of potentially critical pathways at an early stage in the history of a discharge permits the most sensible deployment of resources on monitoring. Monitoring operations in the natural environment, in contrast to the monitoring of occupational exposure in the working environment, seldom permit the direct measurement of radiation exposure, and resort must be made to estimating exposure indirectly by using measurements of environmental contamination in conjunction with data from habits' surveys and the critical pathway analysis. This is done by comparing measured levels with the Derived Working Limits (DWLs). The DWL is a useful and convenient working standard against which to judge the significance of a measurement or series of measurements. The value used is usually a maximum exposure value or ingestion rate for the exposed individual, or the average of the critical group where one can be identified. It is in effect a maximum permissible exposure level and should never be achieved since, in pursuit of the "as low as readily achievable" policy, all authorized rates of discharge will be at some level lower than that needed to satisfy the calculated environmental capacity.

Osterberg (USA) in his invited paper reviewed two past events, the Columbia River story and the fallout from the weapons' tests in the atmosphere, and stated that although neither of these led to major exposures to man, they would have been precluded in peacetime by the many environmental protection laws now in existence in the United States. Although at its peak the Hanford Laboratories released about 1000 curies of neutron-induced radionuclides per day into the Columbia River and the Pacific Ocean, no harmful effects have been observed. He observed that studies of world-wide fallout showed a larger dose to man than from nuclear power, but food chains in the ocean seem to filter out much of the radioactivity from fission products, so that they only appear minimally in the diet of man. Osterberg concluded that these past events appear encouraging for the future of nuclear power.

Several participants expressed great interest in the behaviour of radioactive contaminants and their stable natural isotopes in various components of aquatic ecosystems. They reviewed the subject matter in great detail and compared results obtained in different laboratories.

Interest was also focussed on the long-lived transuranic elements such as plutonium.

According to the results of a preliminary survey reported by Hetherington (UK), a large fraction of the plutonium discharged to the north-east Irish Sea is lost very rapidly from the water phase, but the residual few percent remaining in the water behaves conservatively thereafter and in a similar fashion to $^{137}Cs$.

Thompson (USA) reported that after more than 20 years of large-scale operations of fabricating and chemically recovering plutonium at the Rocky Flats Plant of the U.S. ERDA, no environmental hazard has been identified due to the release of small amounts of plutonium.

There was a general feeling that any potential impact would be minimized due to the fact that plutonium becomes strongly bound to bottom sediments and is thus removed from the direct pathway which could affect man. However, there are some problems requiring attention, particularly the significance of potential remobilization from sediments. The major areas of uncertainty probably lie in such areas as ocean mixing processes and sedimentation phenomena in shallow seas and deep oceans. Two papers were presented from the IAEA International Laboratory of Marine Radioactivity, Monaco: "Experimental Studies on Plutonium in Marine Biota" by S.W. Fowler, M. Heyrand and T.M. Beasley and "Adsorption-Desorption Characteristics of Plutonium and Americium with Sediment Particles in the Estuarine Environment" by C.N. Murray and R. Fukai. In these experiments, the gamma-emitting $^{237}Pu$ with a short half-life of about 45 days, which was produced in Japan and donated as a gift to the Monaco Laboratory, has been used.

## CRITICAL PATHWAYS

For the assessment of Population Dose Commitment, the identification of critical pathways would be extremely important. Regarding the estimates of public radiation exposure from liquid radioactive waste disposals, the most complete information available from United Kingdom sources was summarized by Preston in his invited paper. The individual dose commitment via the aquatic sector of the environment would be the limiting factor, and provided that this is kept within the ICRP dose limits, the total population dose commitment will be well within acceptable limits.

It is clear that reduction in dose commitment at either the individual or population level might be achieved by further expenditure on treatment of waste or by the choice of remote sites for fuel reprocessing in order to distribute the environmental load more evenly. The cost of extra treatment or of new site construction would need to be weighed carefully against the values of the benefits to be derived, or the costs to society of the relative risks. Furthermore, the risk associated with the transport of fissile materials and radioactive wastes caused by undue proliferation of fuel reprocessing sites would need to be assessed. These topics are all likely to require discussion internationally before satisfactory resolution of the problems involved can be achieved.

During a general discussion session, Dr. Knizhnikov from the Institute of Biophysics, Ministry of Public Health, Moscow, made the following statement regarding risk assessment:
"The words 'danger', 'danger from radioactive disposals' etc., have kept recurring during this symposium, and I should like to emphasize that the unnecessarily frequent use of such words is liable to give the public a false picture of the true state of affairs. Every human activity involves certain dangers and risks, and even inactivity itself is dangerous. An objective appraisal of the situation requires comparative studies, but I would estimate that the risk of cancer being produced by an irradiation dose of 5 rem/yr is equivalent to the risk incurred by smoking several cigarettes a day. Smoking one cigarette a day involves the same risk as irradiation by the limiting dose for individual members of the population. An hour spent in a smoky room, as for instance yesterday at the Government reception, involves a risk equivalent to that resulting from irradiation by the limiting dose for the whole population, but I think I can say that we are by no means opposed to attendance at such receptions. The dose and risk from a nuclear power station is at present several

actors of ten lower than this, but the public is nevertheless alarmed. I think there is a need or greater circumspection in referring to the danger from nuclear power station disposals."

## MARINE RESOURCES

The limiting consideration in monitoring and controlling radioactive waste disposal is the radiation dose commitment to man, and it is implicit that, provided the human radiation exposure problem is controlled, the consequential dose to aquatic organisms would cause a negligible risk of biological damage.

The evidence available seems to support the view that fish are the most radiosensitive component of aquatic ecosystems, and that damage to resources, if it occurred, would most likely stem from the direct effects of radiation on fish rather than effects produced in organisms at lower levels in the food webs. The elements most at risk in the life cycle of fish are the radiosensitive maturing and mature gametes and developing embryos.

From a consideration of stock recruitment mechanisms in exploited fish populations it is evident that any effects caused by low level radiation exposure would be compensated for by the density dependant responses of the population. A majority of aquatic animals have a very high natural mortality and a very high fecundity at the same time. From the genetics point of view, these factors make a substantial contribution to the selection pressure, i.e. to the early elimination of deleterious mutations which might otherwise affect population quality and size.

Blayrock (USA) stated at the end of his paper on dose estimation and prediction of radiation effects on aquatic biota, as follows:
"In conclusion we would predict that somatic or genetic effects produced on aquatic biota at the dose rates estimated for conversion, enrichment, fuel fabrication, nuclear power reactors, and reprocessing facilities would not significantly affect the exposed aquatic populations. Dose rate estimates for aquatic biota from milling and mining operations are much higher than estimates from other facilities in the nuclear fuel cycle. Additional information from long-term studies on aquatic populations exposed to chronic low-level irradiation would be necessary to fully evaluate the effects of such dose estimates. However, even at these higher dose rates (aquatic plants, 3.3 rads/day, invertebrates 1 rad/day and fish 0.06 rad/day) based on the information now available, radiation effects on aquatic populations probably would not be detected and the populations would continue without obvious detrimental effects."

## DEEP SEA DISPOSAL

Since 70 percent of the surface of the earth is covered by the oceans, the environmental capacity of oceans receiving releases from nuclear facilities may be considered much larger than that of the fresh water systems, and there have been proposals that this vast area should be considered as a part of the set of alternatives for disposal of radioactive waste. The sea disposal of packaged radioactive waste has been practiced in various contexts for almost 30 years and the IAEA is very much concerned about the safety aspects.

The concept of disposal of high-level solidified and encapsulated radioactive wastes into the deep sea floor was introduced at the symposium by Anderson, et al.(USA).

They concluded their paper as follows:
"Though we remain cautious, to date we have found no serious technical reason to doubt the possibility of successful seabed disposal of high-level nuclear wastes. We are now convinced that a means of assessing such disposal in a clear and rational manner can be developed and that the engineering requirements are not insurmountable. While we are not yet ready to seriously advocate the initiation of disposal of such wastes into the seabed, we are firm in our earlier conclusion that there are stable and otherwise 'useless' areas of the sea floor which deserve serious attention as possible disposal sites, and that a system for disposal of nuclear wastes into the seabed can be developed and assessed in a timely manner."

## GENERAL COMMENTS

The following general comments were also made during the meeting:

- Studies necessary to link the results of laboratory model experiments with those of field studies under natural environmental conditions should be encouraged; so should work which reflects actual events or work on the processes associated with hazards to man.
- Efforts should be made to achieve comparability of results obtained at different laboratories in different parts of the world.
- Environmental studies of plutonium and other transuranic elements with long half-lives and high radiotoxicities which do not have stable isotopes in nature should be encouraged.
- International collaboration between mathematicians, physicists, chemists, oceanologists, radiologists etc. will be indispensable to solve complex problems of ecology and environmental protection.
- In view of the large changes in national boundaries over the last 2000 years, not only sea disposal, but also long-term land disposal within national boundaries should be placed under international control.
- A number of participants expressed the wish that gamma-emitting $^{237}Pu$ with short half-life (about 45 days) should be made available at a reasonable price on a commercial basis for the purposes of biological experiments.