INTERNATIONAL SYMPOSIUM, SAN FRANCISCO, 17–21 NOVEMBER 1975

The symposium was jointly organized by the International Atomic Energy Agency and the US Energy Research and Development Administration. It was attended by 290 scientists and specialists from 12 countries and 4 international organizations.

Transuranium Nuclides in the Environment

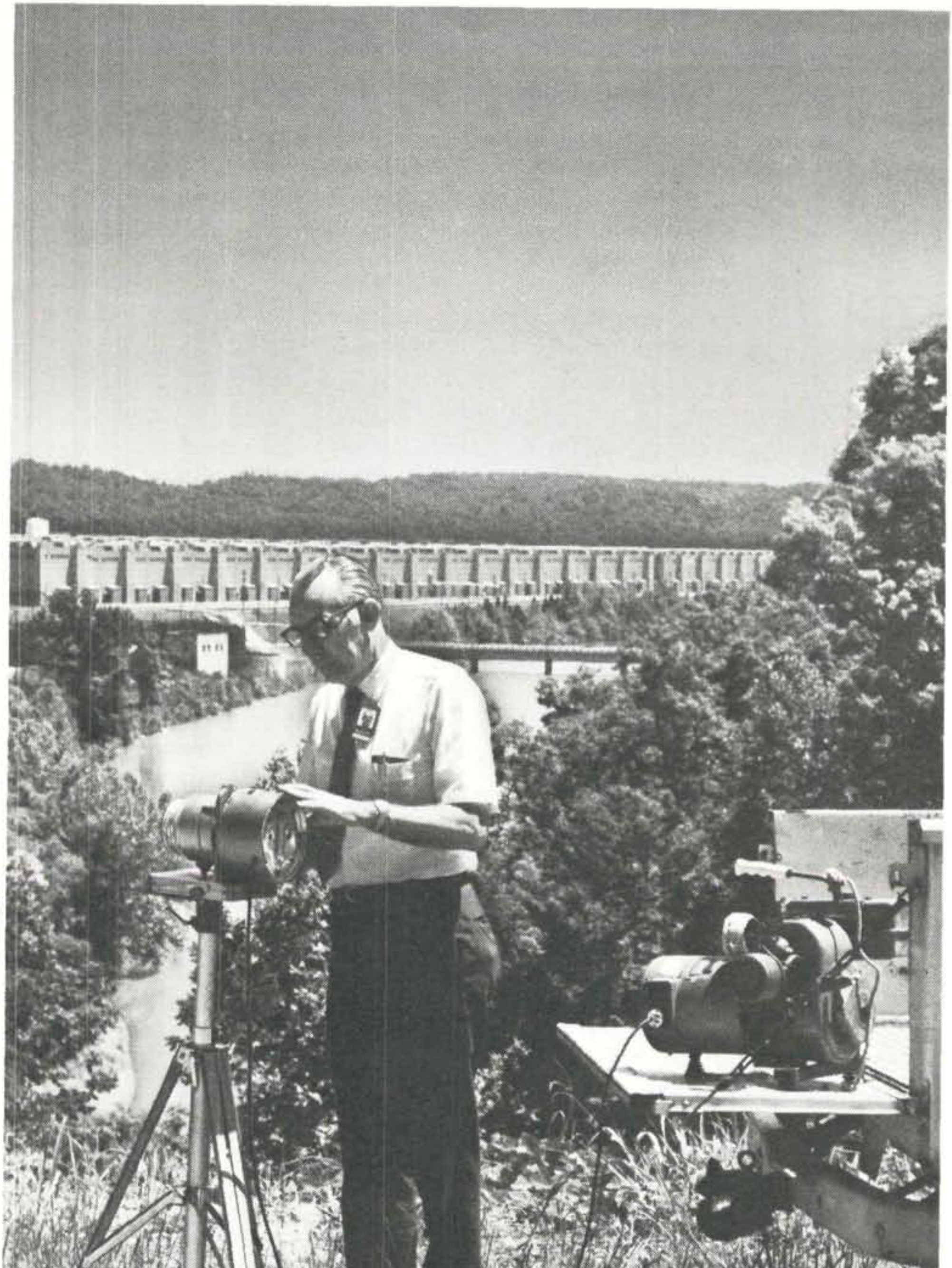
Projected development of nuclear power up to the year 2000 entails a substantial increase in the number of nuclear power reactors, of irradiated fuel reprocessing plants and of various other supporting facilities in the nuclear fuel cycle. In this period, transuranium elements, especially plutonium, will be produced in substantial quantities as by-products of the fission process and for use as fuel in present and future nuclear power reactors; these elements will have other peaceful applications as well. Growing world-wide interest and a natural desire to protect man and his environment have led to increasing concern in public, scientific and governmental sectors about the release of such radionuclides into the environment. Although releases of transuranium nuclides from existing nuclear facilities can be controlled to very low levels, it is essential, in view of their long half-lives and high relative radiotoxicities, that their fate in the environment be understood well enough to permit associated potential impacts to be assessed and hence effective control to be provided.

Extensive studies for many years have investigated the distribution and behaviour of these elements and potential detriments resulting from their release to the environment. More recently, scientists have begun to make projections for evaluating the degree of control necessary if such materials are to enter the complex chain of commercial activities associated with nuclear power production.

Ecological studies on removal of transuranium nuclides

A substantial number of papers dealt with ecological studies of mechanisms – physical, chemical or biological – related to removal of transuranium nuclides from accessibility to man by deposition and downward migration in soil, silt or sediments. Several papers discussed the distribution of transuranium elements in water, marine biota and sediments. The uptake by biota was noted, especially by benthic organisms in one instance. Deposition in sediments from silt-laden water was discussed as the predominant means of removal, with silt movement being the major transport mechanism for relocation of such nuclides. It was pointed out in one paper that, in terms of the fate of discharged activity in the sea, the sediment and seawater compartments are the most important, and that the fraction of the activity associated with marine organisms is very small, even though appreciable build-up of the concentration does take place. Another paper noted the author's belief that sediment erosion and back-diffusion mechanisms were operative

Releases of transuranium nuclides from nuclear facilities can be controlled at very low levels. Monitoring equipment to determine contaminants in air, water or on the surface is widely used around these facilities. The picture shows air sampling in Oak Ridge, USA. Photo: Union Carbide Corporation ▶



even in very deep oceans and postulated the translocation of americium (Am) and plutonium (Pu) back to the surface of the sediments and indeed to the water column by such feedback mechanisms.

The behaviour and characteristics of transuranium nuclides — generally plutonium — in soil were also discussed. Generally, plutonium, americium and other transuranics are leached downward into the soil over time, the actual profile depending on a number of factors (including soil topography type and chemistry, physical and chemical state of the transuranium nuclides over time, local hydrology, etc.) that were elaborated. Several authors pointed out other operative transport mechanisms such as movement by wind, uptake by plants consumed by animals and the ingested products deposited in a new location, and pelt contamination of small burrowing animals.

Pathways to man

Turning to the subject of pathways to man, a group of papers were presented, eliciting considerable discussion on such pathways, transport and dose estimation models. Specific pathways were covered individually in each of four papers. The first, noting the 'colloidal' behaviour of Pu, suggested that flocculation and filtration appear to be the primary factors contributing to Pu removal in (drinking) water treatment facilities. Another paper on the feed-chicken-man pathway indicated that chickens ingesting ^{238}Pu as the relatively insoluble dioxide absorb a very small percentage of Pu that, in the egg or in chicken flesh, appears to present little hazard to man. A third study reported on expected Pu resuspension and resulting dose from agricultural operations at an old field that contained Pu from a nuclear fuel processing facility effluent as well as from fallout. The calculated dose commitment received by the tractor driver was less than 1% of the dose received from natural background. Similarly, another paper reporting on the lichen-reindeer-man food chain in Sweden stated that the Lapps were not considered to have a higher dose commitment due to plutonium that other people, ant that foodstuffs other than reindeer meat and perhaps also inhalation were more important sources of intake of Pu in Lapps.

One of the major concerns today is the determination of health effects and projected risks associated with exposure to the transuranium elements and the derivation of the appropriate safety standards and recommendations. It was concluded that, on the basis of statistical analysis of available human data, there is little support for a marked increase in plutonium toxicity in the lung due to a "hot particle" effect; moreover, some published estimates of "risk per particle" appear to be too large by factors of at least 1000. The total exposure represented by the available human data is not yet large enough to substantiate, on a statistical basis, the value of 0.016 μCi for the maximum permissible lung burden. However, as a "best estimate" this value should not be too high by a factor of more than 15, or by a factor of more than 40 at the 95 percent upper confidence level. A closely related paper discussed the same uncertainties from the standpoint of animal data for inhaled transuranics and data on lung cancer in humans who had been exposed to sources of radiation other than the transuranics. The animal data suggested that the risk from a working lifetime exposure of 15 rems per year to the lungs from transuranium elements may be 5 times the risk incurred with a whole-body exposure of 5 rems per year, while the human data suggested the risk may be less. It was noted that risk estimates calculated directly from experiments involving inhalation of transuranic particles circumvent the "hot particle" issue. Another paper examined the distribution of radiation dose commitments within the body that can result from the lung deposition of Pu, Am and Cm, and presented the derived inhalation intake, for various particle sizes, to produce the same risk of cancer equivalent to that from whole-body radiation.

Another area of keen interest concerns the allowed health risk for ^{239}Pu, ^{241}Am and ^{244}Cm as compared to standards for penetrating radiation for occupational exposures. On the basis of an absolute risk prediction model, using certain derived organ distribution and risk factors, it was estimated that the excess cancer mortality for these transuranic elements, assuming maximum body burdens at the critical organ limits given by ICRP Committee II, would be higher by factors in the range of 1 to about 4 compared to that from dose at the current occupational limits for external whole body exposure to penetrating radiation. However, when compared to excess cancer mortality from ^{226}Ra under comparable circumstances, the excess mortality from these transuranic elements was estimated to increase by factors of 8 to 20. Noting that only major organs at risk had been considered, in view of the estimated excess cancer mortality, the authors urged that reconsideration of allowed body burdens for transuranics should not be delayed.

Panel Discussion

Continuing with this general theme, a panel then discussed the implications of plutonium for man and his environment. One panelist, in reviewing plutonium toxicity, concluded there was a reasonable basis for extrapolating animal transuranic bone toxicity data to man and that current permissible exposure limits for plutonium in bone seemed to be high by a factor of 5 to 10 in comparison to the radium limit. The lung limit could be even further out of line. In regard to extrapolation of risk estimates from the 10's of rads to the millirad or microrad range, while linear extrapolations are almost certainly conservative, the effects at these very low exposure levels may even be zero; in any event, these latter effects, if they occur, would never be separately attributable to transuranics as distinct from other polluting carcinogens. Another panelist, commenting on the "hot particle" problem, stated his belief that the majority of responsible researchers and others who have reviewed the problem consider that particulate plutonium is not more hazardous than the same amount of plutonium distributed uniformly in the lung; indeed, the data suggest the potential hazard increases as the dispersion throughout the lung becomes more uniform. Other panelists reviewed the various views on plutonium standards as seen in the United Kingdom, France and the United States of America. All called for care in examining the possible need for revision of current standards and emphasized the need for careful follow-up of exposure histories as well as a re-evaluation of the bases used to derive present limits.

Evaluation of environmental measurements

The concluding session of the symposium was devoted to evaluation of environmental measurements. One author, in reviewing the radiological significance of transuranium radioisotopes likely to be released to the environment during operation of the liquid-metal fast breeder reactor fuel cycle, estimated that the associated potential health consequences to current and future generations would be very small compared to risks associated with the production of energy by fossil fuels. However, it was noted that such estimation is subject to a number of uncertainties imposed by lack of knowledge, some of which cannot be greatly reduced until LMFBR facilities are designed and operated. In a related paper, the authors presented a simulation model of the environment, including man, developed to study evaluations of risks associated with radioactive releases from nuclear fuel cycle facilities, and initially directed towards releases of transuranium elements from the LMFBR fuel cycle. In general, the anticipated normal release of 0.36 mCi of alpha-emitting transuranic radionuclides per year per 1000 MWe power reactor would not result in a detectable health impact to the exposed population in the USA.

Conclusions

The Symposium made it clear that present standards of safety and practice for transuranic nuclides are still considered adequate and the numerical levels of these standards are probably correct within an order of about a magnitude. Moreover, it was evident that the extensive ecological studies of the past several decades have merely sketched out the bare framework of the intricate and complex ecological systems whereby the transuranic nuclides in the evironment become more or less available to man over their long temporal period of radioactive presence. In regard to risk evaluations of transuranics in man, animal data is likely to remain the prevalent evaluative tool as human data is scarce and likely to remain so. The Symposium stressed the need for expanded and more sophisticated efforts in ecological systems evaluation, and refinement and sensitivity analysis of human and animal data leading to a better understanding of the dose/effect relationship of the transuranium nuclides in man and the environment.