gave evidence of long-lived effects presumably due to radioactive debris. The effects were to increase the attenuation on the long great circle path so that for 8 to 12 days the diurnal variation of phase was that to be expected for signals which were received only over the short great circle path.

One surprising feature of the symposium was that several authors utilized observations which were originally made in 1922 as a source of data on the variations of very-low-frequency field strength with respect to distance. Although this should be taken as a compliment to that work, it also points out the necessity for new high quality measurements in this area.

The symposium was sponsored by the Central Radio Propagation Laboratory of the National Bureau of Standards. It is expected that a selection of the presented papers will be published in the Jan.-Feb. 1964 issue of Section D (Radio Propagation) of the *NBS Journal of Research.*

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Radioiodine: Its Nature and Effects

Radioiodine-131 is considered one of the most significant fission product elements because of its abundance in early fallout and in the gaseous effluent of certain nuclear industries, its high inventory in irradiated reactor fuels, its chemical, physical, and physiological characteristics, and its widespread use in clinical and therapeutic medicine. All these factors were considered at a symposium held at the Hanford Laboratories, Richland, Washington (17–19 June). In addition to the 75 Hanford scientists about 150 visiting researchers from Belgium, Canada, France, India, Japan, United Arab Republic, the United Kingdom, and West Germany attended.

Historically, the thyroid gland, which concentrates a substantial portion of any administered dose of iodine, was considered a radioresistant structure. Following reports of increased incidence of thyroid tumors in children as a consequence of exposure to x-irradiation early in life, the Federal Radiation Council recommended that a thyroid radiation dose to the general population from I^{131} in excess of 0.5 rem per year should call for some control measures. H. D. Bruner pointed out that the 0.5-rem dose has thus become a limiting case for normal peacetime operation.

The principal emphasis during the symposium was on the sources of radioiodines, their relative concentrations in the air-plant-cow-milk-man (child) cycle, and their possible effects. Principal subject areas were reviewed by leading scientists and each review paper was followed by reports of unpublished work from many laboratories.

In his review on the origin and disposition of radioiodine, J. Z. Holland (USAEC Division of Biology and Medicine) compared the relative biological significance of the several radioisotopes of iodine and concluded that even in cases of heavy environmental contamination with the shorter-lived radioiodines, the delays in the food chain would tend to reduce their relative importance with the result that longer-lived I^{131} is of unique importance. He pointed out that one may expect extreme irregularity in I^{131} distribution following a release incident. This results from the interaction of its relatively high abundance and short half-life with the bouyant rise imparted by the releasing event and the atmospheric eddies and rain clouds that act over periods of a few hours to days. Additional complications are introduced by the behavior of iodine precursors during release and by the chemical behavior of iodine. Iodine reacts with many materials, including many trace substances in the atmosphere, and it is readily oxidized and reduced through a wide range of valence states. The only conclusion which could be drawn at the present time regarding the partitioning of I^{131} between vapor and particulates, soluble and insoluble forms, and among elemental, reduced, and oxidized states is that none is clearly dominant over any great range of conditions.

L. Machta explained that three meteorological mechanisms can probably explain all incidents since September 1961 of higher-than-normal I^{131} levels in the milk surveillance network of the Public Health Service; these mechanisms are: low altitude transport of debris from atmospheric and vented underground tests in Nevada; subsidence within an anticyclone; and rainout of debris moving in the troposphere or even in the lower stratosphere.

The importance of grazing animals was stressed in relation to the biological disposition of radioiodine. The principal route of I^{131} into man appears to be by means of milk from dairy cows which graze in contaminated pastures. In this regard, it was reported by C. P. Straub that in a cooperative endeavor of the U.S. Public Health Service and the St. Louis Health Department, lesser amounts of I^{131} appeared in the milk from cows grazing in well-fertilized pastures. No appreciable contamination of milk with radioiodine was observed when stored hay and grain were fed to dairy cattle. Grazing animals, L. Van Middlesworth concluded, are very good early indicators of radioiodine contamination in the biosphere because they consume large amounts of exposed feed per gram of thyroid. Merrill Eisenbud predicted that for the foreseeable future direct measurements of the radioiodine content of milk would be the indicator of choice when it is necessary to appraise the public health significance of environmental contamination by I^{131}.

In predicting the hazard of I^{131}, it is important to know the concentration ratios along the food cycle from air to milk to man. A number of useful relationships were reported. Under conditions of continuous low-level release: [(picocuries/kg grass)/(picocuries/m^3 air) = 4000 and [(picocuries/ liter milk)/(picocuries/kg grass)] = 0.1. The ratio of peak concentrations after a single contamination event involving I^{131}, taking as unity the thyroid of a human subject (on day 14) who had drunk milk daily, were: cow's total feed on day one, 400; cow's thyroid on day seven, 280; and cow's milk (per liter) on day four, 1.6. Considerable variation occurs, however, in the amount of I^{131} in the milk of different cows and the same cow at different seasons of the year. Milk from a cow labeled with radioiodine or a water solution of I^{131} resulted in comparable uptakes when fed to both man and animals.

R. J. Garner (Harwell) reviewed the effects of radioiodine and stressed the radioresistance of the thyroid gland of domestic animals; doses in excess of 5000 rads to the thyroid are required before any sign of damage may be expected. I. Doniach (London Hospital) reported that various investigators show a similarity in the biological action of x-rays and I^{131} on the thyroid. In the measurement of four different long-term effects, 1000 rads from x-rays has a similar quantitative effect to a calculated mean dose of about 10,000 rads from I^{131}. This is somewhat less than the 20-fold greater effectiveness of x-rays compared with I^{131} which was deduced from early changes with these two forms of exposure in sheep. S. Lindsay concluded that thyrotropic stimulation after subtotal thyroidectomy is a promoting factor in the development of both benign and malignant thyroid neoplasms in the rat and that it may also initiate the development of some malignant neoplasms. In an extension of these findings in animals, E. L. Saenger and co-workers reviewed the available data on the carcinogenic effects of I^{131} compared with x-irradiation in man. These workers concluded that thyroid carcinoma may develop rarely with x-ray doses of 2000 to 6000 r after a latent period of 10-to-35 years and that it is probable that x-ray doses of 100 r or greater to children's thyroids will increase the incidence of carcinoma. Irradiation of the adult thyroid with I^{131} cannot as yet be implicated as a carcinoma-causing mechanism. However, doses of I^{131} in children seem to increase the susceptibility of their thyroids to neoplastic change. According to Saenger and associates, the carcinogenic dose level of I^{131} for a child may not be below 600 rads, considering the differing dose rate between I^{131} and x-rays, fractionation of dose, and irregular distribution.

In a review of the important area of prophylactic and therapeutic measures for radioiodine contamination, F. W. Lengemann pointed out that the best policy is to prevent the entrance of I^{131} into the food chain since this is apparently the major avenue of contamination for those not occupationally exposed. Because milk appears to be the chief vector of I^{131} in the United States and some other countries, he proposed four means of limiting the access to the food chain by means of milk: (i) elimination of milk from the diet, (ii) use of ion-exchange columns to remove radioiodine, (iii) feeding of stored feed to milk-producing animals, and (iv) the substitution of stored milk or milk products for fresh milk. An added consideration was the use of thyroid-blocking agents at a number of places in the feed-milk-man cycle. In this regard, it was suggested that increasing the stable iodine in the feed of a dairy cow could reduce thyroid uptake by 50 to 80 percent in a person drinking such milk.

A highlight of the symposium was a very stimulating speech in which E. E. Pochin (University College Hospital, in London) posed the question: *What is a permissible dose?* "Perhaps it is more reasonable to look at what is a permissible risk," he said, and went on to cite some interesting comparative levels of risk in established industries today, based on fatal accidents per year or per million people employed. On such a basis, the nuclear industry ranks among the safest. "Although we still have a great deal to learn about quantitation of risks in radiation exposure," Pochin stated, "we have even further to go in attempting to estimate quantitatively the benefits that may be associated with any procedure involving radiation exposure." Pochin went on to say that the attempt to set radiation protection levels on a quantitative basis is a very necessary, but very ambitious undertaking. Many of the difficulties and also criticisms arise simply from the fact that no comparable attempt is being made to deal as quantitatively with many of the other hazards of life or work. This, in fact, may be one of the greatest values of radiation protection work—it may extend the practice of hazard evaluation into other fields and there promote studies of the justification for risks on a factual basis.

Shields Warren was the honorary general chairman of the symposium, and the session chairmen were S. A. Lough and H. D. Bruner (U.S. Atomic Energy Commission), A. H. Wolff (U.S. Public Health Service), B. M. Dobyns (Cleveland Metropolitan General Hospital), E. E. Pochin (University College Hospital Medical School, London), Stuart Lindsay (San Francisco Medical Center at the University of California), and C. L. Comar (Cornell University).

The symposium was under joint sponsorship of the U.S. Atomic Energy Commission and the Hanford Laboratories of General Electric Company; this work was performed under contract No. AT(45-1)-1350 between these two organizations. The proceedings will be published as the December 1963 issue of the *Health Physics Journal.*

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