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FUNDAMENTAL CONSIDERATIONS IN DETERMINING SIGNIFICANT LEVELS OF RADIOACTIVE CONTAMINATION OF FOOD AND WATER

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The radioactivity of importance in sea water following an atomic explosion at altitude near sea level is principally due to fission products from the bomb which, with other materials, condense into small particles and fall into the sea. Some of this material will be retained in upper layers of water in solution, in suspension, or associated with organic materials. Radioactivity induced by the radiation from the bomb will be relatively unimportant, largely because of the extreme rapidity with which it is reduced by radioactive decay.

Fish living and feeding in waters containing radioactive materials will accumulate some of these materials in the various tissues of their bodies and on exposed surfaces such as the skin and gills. Observed levels of activity in sea water are too low to produce any harmful effects on the fish or on their food supply. In this connection, it may be observed that the levels of radiation required to produce observable effects on lower forms of life are generally much greater than for humans, and that the limits of radiation exposure considered acceptable for humans over periods of many years are much lower than those which would be acceptable for short periods of time.

The best guide that we have available for limitation of radioactivity in food and water is National Bureau of Standards Handbook 52, which contains recommendations of the National Committee on Radiation Protection limiting the quantities of radioactive material in the body. The maximum permissible concentrations in water, expressed as microcuries per gram, recommended in Table 3 of this handbook are considered to be applicable also to food. In setting these concentrations, it is assumed that they apply to the entire water supply of the individual (including the water contained in the food that he eats), and it is assumed that these values may be maintained throughout the remainder of his life.

The figures given in Handbook 52, based largely on occupational exposure, are considered adequate at the present time, since no one is exposed to radioactive materials at considerable fractions of these values throughout his early life. The possibility of a general increase in environmental levels of radioactivity from the widespread use of atomic energy for industrial purposes has led to consideration of the desirability of using lower levels for lifetime environmental exposure. These levels might be as low as one-tenth of those acceptable for occupational exposure to radiation or to radioactive materials.

In view of the above considerations we would limit the average concentrations of various radioisotopes in the total food and water supply of members of non-occupational groups to one-tenth of the values given in Table 3, NBS Handbook 52. As far as the welfare of a person eating a radioactive fish is concerned, the amount of radioactivity permitted over a period of several weeks or months, if uniformly mixed at this concentration through the total food and water intake, could be taken in a single eating of fish with no significant difference in effect. However, since methods of handling and distributing food make it impractical to determine the average concentration of radioactivity in individual diets, for administrative reasons it is desirable to reject individual fish or other items of food which contain levels of radioactivity materially above the accepted maximum permissible average level. Since it is sometimes impractical to detect every item which would be rejected on this basis, it is worth observing that occasional failure to detect individual items at much higher levels would not be expected to raise the average levels of radioactivity in the diets of individual consumers above maximum permissible levels.

For short periods of time the radioactivity in the diet may be much higher than the values discussed above without effects on the consumer. Attached are copies of Bulletin TB-11-8, issued December 1952 by our Federal Civil Defense Agency, suggesting total activities in water and food supplies which, it is believed, could be accepted for short periods of time in complete safety.

Since it is impractical under field conditions to determine the concentrations and the radioisotopic composition of radioactive materials on or in fish or other items of food, one needs some practical criterion for rapid screening of items requiring further examination from those which almost certainly meet established standards. Last April, as a result of conversations with the Federal Food and Drug Administration and other federal agencies, the Division of Biology and Medicine of the United States Atomic Energy Commission suggested that, as a temporary standard, individual fish be accepted if the gamma radiation, measured 5 cm from the surface of the fish, does not exceed 0.1 milliroentgen per hour. In terms of the response of G-M survey instruments commonly used in the United States, this corresponds to from 300 to 600 counts per minute with the tube shielded to exclude beta radiation. This value was based on the following assumptions:

(1) The radioactivity had been deposited on the outside of the fish after the fish was taken from the water;

(2) When processed for food, all of the radioactivity deposited on the outside of the fish would be retained in the outer two inches (5 cm) of flesh;

(3) The radiation is measured at about two weeks after the explosion from which the radioactivity came;

(4) The composition of the radioactive material at the time of measurement is that given in an article by H. F. Hunter and N. E. Ballou, "Fission Product Decay Rates," published in Volume 9 of Nucleonics, page C-2, November 1951;

(5) The gamma radiation received by the counter from the surface of the fish is as great as would be received from material of the same activity per unit area spread on a plane circular disc 20 cm in radius; (This assumption makes the problem amenable to normal methods of computation. The actual response of the instrument will depend on the size of the fish. This is one of the limitations on accuracy inherent in a practical method of field monitoring.)

(6) The level of radioactivity, measured in microcuries per gram of fish, if distributed as assumed in (2) above, should not exceed the value computed for this mixture of radioisotopes on the basis of the recommendations given in NBS Handbook 52.

Examination of the relative maximum permissible concentrations of the fission products concentrating in various body tissues show that at 14 days or later the tissue receiving the highest radiation dose from the ingestion of the radioactivity will be the bone. Nearly all of the dose to the bone is due to deposition of the three radioisotopes Sr^{89}, Sr^{90} and Ba^{140}. At 14 days, the respective concentrations of these radioisotopes in residual fallout material are about 3.8%, 0.03% and 13.5%, while the respective maximum permissible concentrations in water listed in Table 3 of Handbook 52, measured in microcuries per gram are 7×10^{-5}, 8×10^{-7} and 2×10^{-3}. If G is the concentration of the gross or total fission product activity in the total supply of food and water which would result in the ingestion these materials at the maximum rate permitted under the recommendations of Handbook 52.

$$\frac{0.038}{7 \times 10^{-5}} G + \frac{0.0003}{8 \times 10^{-7}} G + \frac{0.135}{2 \times 10^{-3}} G = 1$$

$$G = 1/950 = 1 \times 10^{-3} \text{ microcuries per gram.}$$

On the basis of assumption (2) above this would correspond to 5 microcuries per square centimeter of surface. On the basis of assumption (5) above, it is estimated that this would result in a radiation level of about 0.1 milliroentgen per hour at 5 cm from the surface. (This is computed by the use of integral calculus, using the following additional information: The average gamma energy emitted per disintegration from this material is approximately 0.35 million electron volts. The intensity of the gamma radiation at a distance r from a point source of radiation is given approximately by the equation, $I \cong 5.6\, CE/r^2$, where I is measured in mr/hr, C is measured in microcuries, r is measured in centimeters, and E is the average gamma energy per disintegration measured in millions of electron volts.)

Since the conclusion of the recent series of weapons tests in the Pacific Proving Grounds, any radioactive material which might be acquired by fish in this vicinity would be acquired before the fish are taken from the water. Thus far, we have been unable to obtain any fish with sufficient radioactivity from this source to permit an approximate empirical determination of the external radiation level which would correspond to maximum permissible average concentrations in food and water discussed above. However, on the basis of the uptake of the various fission products by fish under other conditions, the Division of Biology and Medicine, U.S.A.E.C., estimates that the criterion of 0.1 milliroentgens per hour at 5 cm is unnecessarily restrictive for this case.

The radioisotopes Sr^{89}, Sr^{90}, and Ba^{140} which limit the quantities of fission products which may be permitted on the outside of the fish after they are taken from water are relatively unimportant in considering the radioactivity which may be permitted in the flesh of the fish, since these radioisotopes are not retained in the flesh. The radioisotopes taken up by the flesh, of which Cs^{137} is an example, have very much higher permissible concentrations in food and water, of the order of 1×10^{-3} microcuries per milliliter. From a fish weighing 50 to 100 pounds, the gamma radiation from a maximum permissible concentration of these radioisotopes in the flesh is estimated to be several milliroentgens per hour, measured at a distance of 5 centimeters from the fish. The actual radiation level will, of course, depend upon the size of the fish.