RADIOACTIVITY IN FOODS

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There is little doubt that atomic energy will assume an important rôle in our civilization, and it is appropriate that future possible hazards should be evaluated. At the present time, it can be concluded that there is no reason for any change in our nutritional habits or food technology as a result of fall-out contamination. Research must continue, however, so that recommendations can be made to minimize the intake of radioactive contamination should this ever become necessary.

Although environmental contamination now existing is due almost entirely to fall-out from nuclear weapons, peacetime operations may become increasingly important as sources of radioactive contamination. In addition to fall-out, small quantities of radioactive materials may be released into the environment as a result of such operations as mining of uranium and thorium ore and fuel processing; reactor installations in power plants, submarines, ships, and aircraft (normal operations and accidents); and radioisotope applications in medicine, industry, and agriculture.

Determining Factors in Hazard of Radioisotopes

The relative hazard of radioactive materials will be governed by the amount released into the environment, physical half life, efficiency of transfer through the food chain to the human diet, degree of absorption by the body, and length of time retained in the body. By these criteria, the radioisotopes from fall-out of the greatest concern are iodine, barium, strontium, and cesium. Extensive data are available on the passage of these radioactive materials through food chains and subsequent implications.[1] Table 1 summarizes their characteristics from the standpoint of environmental contamination.

The radioisotopes of iodine collect in the thyroid gland and those of barium concentrate in bone. Since isotopes of both of these elements have short physical half lives, they can be dangerous only during certain periods, depending on the frequency and the nature of production of contamination. Experience has indicated that iodine-131 transmitted in milk may be important at short times after releases such as in reactor accidents. Strontium-89, which is produced in higher activities than strontium-90, may be more hazardous shortly after production, while strontium-90, with a much longer half life, becomes more dominant with time. The strontium radioisotopes, of course, are cumulative in bone. Cesium-137, which follows potassium in metabolism, is considered less of a hazard than strontium-90 because it is turned over relatively rapidly in the body, it is not selectively concentrated in any one part of the body, and it does not pass appreciably from soil to plant in the food chain.

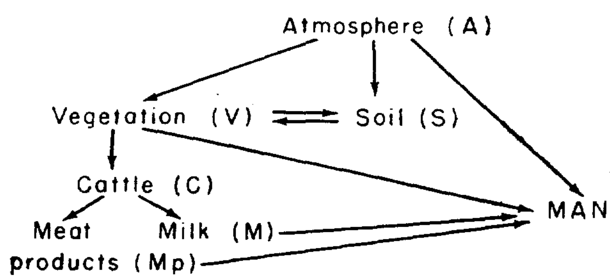

Diagram of main terrestrial food chains by means of which environmental radioactive contaminants reach the human population.

Radioactive contaminants are transferred to man by means of specific pathways through the main terrestrial food chains. These food chains are illustrated diagrammatically in the figure and the primary pathways of barium, iodine, strontium, and cesium are shown in table 1. As an example, strontium-90 is deposited from the atmosphere on the foliage of plants and on the soil. Transfer between soil and plant proceeds in both directions by normal root uptake and by washing from leaves or death

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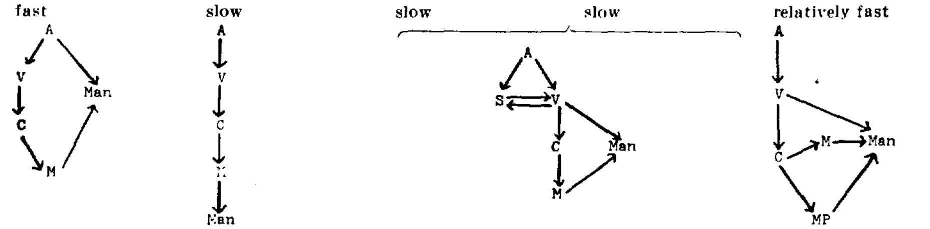
of leaves. Strontium-90 reaches the human body by direct consumption of vegetation and of milk from animals that have fed on the vegetation.

The relative importance of the various pathways depends on many factors, for example, the composition of the soil (calcium level) and the nature of plant cover. A heavy root mat will tend to trap fall-out strontium and delay its reaching the soil for dilution with soil calcium, while at the same time permitting absorption into the plant from the base of the stem. The agricultural management of crops and livestock, which includes the plowing depth, fertilizer practice, and type of feeding (barn or pasture) employed, is another factor to be considered. Also of great importance are dietary habits of the population and food technology. As an illustration, in the processing of frozen vegetables, washing them prior to freezing will remove some of the surface contamination. If nuclear tests are stopped, the soil reservoir will become increasingly important; therefore, the time pattern of contamination has to be taken into account. Although food-chain considerations are extremely complex, certain generalizations can be made. It is obvious that the pathways that require considerable time in passage to man (for example, via the soil) are of no significance for the short-lived radioisotopes,[2] iodine-131 and barium-140. It also appears that the present contamination of diets originates mainly from surface contamination rather than from the soil reservoir.

The movement of strontium radioisotopes from soil to man is interrelated and, to some extent, governed by the simultaneous movement of calcium. In all steps of the food chain from vegetation to human bone, calcium is preferentially utilized relative to strontium. Thus, it has been calculated that at equilibrium the strontium-calcium ratio in bones of young infants would be from 3 to 12% of that in vegetation, with values of 8 to 16% in the bones of persons over 6 months of age. Although milk is our primary source of calcium, the discrimination against strontium relative to calcium in passage from the feed of the cow to its milk tends to reduce the importance of milk as a source of strontium-90. While dairy products furnish some 80% of our dietary calcium, they may supply somewhat less than 40% of the total strontium-90 intake when steady-state conditions are established. Attention should also be given to contaminated water supplies as a possible source of strontium-90. In making estimations, the entire strontium-90 and calcium intake of the population must be considered.

TABLE 1.—*Comparison of Radioisotopes in Environmental Contamination*

	Iodine-131	Barium-140	Strontium-89	Strontium-90	Cesium-137
Physical half life	8 days	13 days	51 days	28 years	30 years
Metabolic behavior	collects in thyroid	like calcium, collects in bone	like calcium, collects in bone	like calcium, collects in bone	like potassium, collects in muscle
Removal rate from body	fast	slow	slow	slow	relatively fast
Main pathways in food chain*					
Samples for monitoring radioisotope levels	vegetation, milk, and thyroid	vegetation and milk	soil, vegetation, milk dairy products, bone, and aquatic food	soil, vegetation, milk dairy products, bone, and aquatic food	vegetation, milk, dairy products, meat, and whole body
Maximum permissible radioisotope concentrations, $\mu\mu c$ per liter†	3,000	200,000	7,000	80	150,000
Radioisotopes in milk, $\mu\mu c$ per liter‡	121	42	52	6.4	57
Comparative radiation dose to humans, rad	<0.04 to thyroid in 1955 and 1956	<10% of strontium-89 dose	approximately from 1 to 20% of strontium-90 dose	approximately 0.2 to 0.4 to skeleton over 70-yr. period from present tests§	approximately 0.001 per year from present levels

* A = atmosphere V = vegetation M = milk S = soil C = cattle MP = meat products.
† Recommended maximum permissible concentrations for specific radioisotopes in drinking water as derived from recommendations of National Committee on Radiation Protection and Measurements. These concentrations and milk values are quoted by Public Health Service.
‡ Levels found in United States from July, 1957, to July, 1958.
§ This estimation includes recent analytical data and concepts of nonuniform stratospheric inventories developed at May, 1959, congressional subcommittee hearings.

The soil reservoir probably will not be an important factor for cesium-137 because of the fixation of this element in the soil and its consequent unavailability to the plant. At the present time, about 60% of the cesium-137 content of the average diet is derived from dairy products, 25% from meat products, and the remainder from vegetables, cereals, and fruits.

Radioisotope Levels

The present levels of these radioisotopes in the biosphere (soil-plants-animal products–man) can be determined with reasonable accuracy by radiochemical analysis. For purposes of illustration, table

1 presents some of the average radioisotope values for milk in the United States for the years 1957 and 1958. In the early part of 1959, values for strontium-90 in milk from various locations in the United States all averaged well under 30 micromicrocuries ($\mu\mu c$) per liter. These values are below the recommended maximum permissible limits for lifetime exposure to specific radioisotopes in water. Discussion of maximum permissible levels is beyond the scope of this paper. It is urged, however, that scientists and laymen should develop a clear understanding of what is implied by figures given as maximum permissible levels and how these figures are derived.[1]

Dietary levels of strontium-90, which are expressed as micromicrocuries of strontium-90 per gram of calcium, have been estimated at approximately 0.4, 2, 4, 5, and 7 for each year from 1953 to 1957 respectively. It is estimated that the maximum levels from tests to date will occur from 1962 to 1965 and that the average maximum level in the diet of persons living in the United States at that time may reach about 24 $\mu\mu c$ of strontium-90 per gram of calcium. Recent considerations indicate that much of the present strontium-90 in milk may not have come through the soil but found its way into the plant by foliar absorption or other processes. This has important implications: (*a*) if there is no further testing, the levels may fall fairly rapidly, (*b*) the contamination of food when only the soil route is operative should be much lower than at present, and (*c*) this would explain why levels in non-milk foods are not greatly lower than in milk foods as is expected because of the dairy cow's preferential use of calcium.

Milk from numerous areas has been analyzed to determine the local variation in dietary levels of strontium-90. The highest values observed were about five times the mean value, while milk from cows fed on vegetation grown in low-calcium soils were approximately twice the mean value. There appears to be less variation in the levels found in the human population, presumably because the individual consumes food that originates from many areas. It is not yet possible, however, to express variability in precise statistical terms.

The most direct and important evidence comes from analysis of tissue samples from the human population. Typical values, calculated and expressed in terms of radiation dosage rather than concentration of radioisotopes, are given in table 1. A scale of values to indicate expected response of man to radiation is presented in table 2. It can be noted that present and anticipated levels of radioactivity in man, based on the effects of nuclear tests to date, are below those known to produce any observable effects. However, indiscriminate testing of nuclear weapons, either by many nations or at higher rates, could lead to levels of strontium-90 in the food chain that would be of definite concern. The most difficult issue, particularly because of its moral overtones, is whether present levels (also of carbon-14)[3] will produce absolutely no incidence or will produce only finite incidences of genetic or somatic harm in the world population. This is a complex and controversial matter relating to linearity of response and patterns of threshold versus non-threshold behavior at low levels.

Low-level monitoring, which detects excess radiation before health hazard levels are reached, will become important as a public health function to give advance warning of any peacetime operational difficulties. Public reassurance will be provided by monitoring at natural radiation levels before and after nuclear installations are placed in operation.

Summary

Although at the present time there is no indication for a change in our dietary habits, broad-scale research on the problem of radioactivity in foods and its implications must continue for future public welfare. Even if testing of nuclear weapons is halted, peacetime applications of atomic energy will release some radioactive materials into the environment. Therefore, close supervision of the dietary levels of radioisotopes and understanding of possible effects on man are necessary for evaluation of atomic energy benefits versus biological cost.

TABLE 2.—*Effects of Radiation on Man*

Radiation Dose, rad	Source and Conditions	Observations
3,000-6,000	3.6 μc radium or x-radiation to skeleton	Bone sarcoma
300	0.4 μc radium	Minimal nondeleterious bone changes
90	0.1 μc radium	No observable effects
50-60	(suggested as levels that would double leukemia incidence)	
7-15	Natural background	No observable effects
10	(recommended upper limit of radiation from any man-made source)	
0.2-0.4	(estimated dosage from strontium-90 from tests to time of writing).	
0.05	(estimated dosage from cesium-137 from tests to time of writing)	

References

1. Report of United Nations Scientific Committee on Effects of Atomic Radiation, General Assembly, Official Records: Thirteenth Session, Supplement No. 17 (A/3838), 1958. Environmental Contamination from Weapon Tests, HASL-42, United States Atomic Energy Commission, Technical Information Service, Oak Ridge, Tenn., Oct., 1958. Nature of Radioactive Fall-out and its Effects on Man, Parts 1 and 2, Hearings before Special Subcommittee on Radiation of Joint Committee on Atomic Energy, Congress of United States, United States Government Printing Office, May 27-29, June 3-7, 1957.

2. Russell, R. S., and Ellis, F. B.: Movement of Strontium 90 Through Food Chains, Soils and Fertilizers **21**:269-273 (Oct.) 1958. Comar, C. L.; Russell, R. S.; and Wasserman, R. H.: Strontium-Calcium Movement from Soil to Man, Science **126**:485-492 (Sept. 13) 1957.

3. Totter, J. R.; Zelle, M. R.; and Hollister, H.: Hazard to Man of Carbon-14, Science **128**:1490-1495 (Dec. 12) 1958.

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