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NUTRITIONAL HAZARDS CAUSED BY RADIOACTIVE CONTAMINATION OF FOODS

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The scientific basis of the radiation hazard

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Radiation hazards have been known for more than 60 years. Only a few months after Röntgen's discovery in 1895, enthusiasts were burning themselves and their patients by liberal applications of the new X-rays. Soon the dangers of X-rays and radium became all too obvious, or so it seems to us. At the time, few people were much alarmed and no effective measures of control were organized until about 1920. More recently, some new radiation hazards have been identified and our assessment of the old ones has become keener. At the same time the subject has been confused by outbreaks of superstition, prejudice, ignorance and emotion, all serious obstacles to orderly argument and rational judgement.

Against this highly coloured background it is possible to pick out a few features relevant to the subject of this Symposium.

To begin, it should be made clear that radiation is everywhere. We all receive a measurable dose from cosmic rays and from radioactive materials present in the earth's crust, in building materials and even in drinking water. A further contribution comes from radioactive isotopes of potassium and carbon in our bodies. (See Table 1).

Next we should decide what is meant by the term radiation. For the present purpose, the word covers several different kinds of energy. Some are in the form of electromagnetic waves and some are kinetic energy (that is, energy of movement) of subatomic particles. The waves are either X-rays or γ-rays. These two kinds are identical in properties, but different in origin. X-rays are made in an electrical-discharge tube and γ-rays come from radioactive materials. Radioactivity is a spontaneous breaking up of the atomic nucleus, with the emission of electrons (almost invariably) and γ-rays (very commonly). The 100 or so chemical elements have among them about 1500 isotopes of which some 1200 are radioactive. The reason why radioactive materials are not commoner and more important is that most of them do not last very long. The breaking up of the nucleus usually transforms the radioactive atom into a stable one with no further emanations. The decay process goes according to an exponential law, quickly at first and then more slowly. The rate of decay can best be denoted by the half-life, i.e. the time needed for half of the atoms

Table 1. *Estimates of radiation background*, 1958

Source of radiation	Part of body considered	Dose received (mr)	Remarks
Cosmic	Whole body (indoors)	28/year in U.K.	At sea level (doubles for each 6000 ft. of altitude)
Rocks: sedimentary	Whole body (indoors)	40/year	
granite	Whole body (indoors)	70/year	
Radioactive potassium in the body	Whole body	18/year	
Radioactive carbon in the body	Whole body	2/year	
Wrist watch with luminous dial (0·4 μc radium at 1 ft. distance for 12 h/day	Wrist	6000/year	
	Gonads	12/year	
X-ray examination:			
Chest	Skin Bone marrow Gonads (male) Gonads (female)	250/film 20/film 0·3/film 0·1/film	
Digestive tract after barium meal	Skin Gonads (male) Gonads (female)	50,000/examination 20/examination 9/examination	
Pelvis	Skin Gonads (female)	20,000/film 200/film	
Pelvimetry	Gonads (female) Gonads (foetal)	1200/examination 2400/examination	
Mean/film*	Gonads (male) Gonads (female)	Between 35 and 350 Between 60 and 600	
Feet (shoe fitting)	Feet	At least 500/fitting	Depends on state of machine and other factors
	Gonads	?	
Seventy ordinary atomic explosions 1951–5:			
First transit	Whole body	3·5	In U.K.
Eventual total	Whole body	5	In U.K.
Hydrogen–uranium bomb (Bikini, March 1954):			
Total to March 1956	Whole body	2·5	In U.K.
Eventual total	Whole body	29	In U.K.
All atomic and hydrogen bombs to 1958: eventual total	Gonads Bone marrow	100 160	

*Obtained from sample surveys covering several thousand exposures in hospitals of different kinds. The gonad dose was estimated for each patient, by means of measurements with ionization chambers.

in a sample to undergo the radioactive change. Many isotopes have half-lives of a few minutes or less. The only ones found in the earth are those with very long half-lives (such as uranium) and their products, which sometimes decay in several stages before reaching stability as isotopes of lead.

Subatomic particles, including electrons, neutrons and a few others of lesser importance, can be made to move at high speeds, with correspondingly large amounts of kinetic energy. All forms of radiation—waves and particles—are rather alike in their biological effects; they are discussed by Brown (1959).

Fission and fusion reactions

The most prolific source of radiation of all kinds is the fission chain-reaction which occurs in uranium and in one or two other materials. Fission, a peculiar kind of radioactivity, is the breaking up of the atomic nucleus. It does not occur spontaneously to any useful extent but can be induced by quite a simple process. Uranium in its natural state is a mixture of two isotopes, ^{235}U and ^{238}U. ^{235}U undergoes fission fairly readily but ^{238}U does not. Suppose that we have a lump of pure ^{235}U. If we leave it lying about, a stray neutron from the atmosphere will run into it almost immediately. This neutron may be captured by a uranium atom which then undergoes fission, splitting into two sizeable pieces, each of them an atom of some lighter element, along with a lot of radiation (γ-rays, light, heat, ultraviolet rays and so on) and two or three neutrons. The average yield in ^{235}U is about 2·5 neutrons/fission. Each of these neutrons is capable of causing a further fission which, of course, increases the neutron population still further. We now see how a chain reaction is possible. Fortunately it is not as easily achieved as this simple explanation might suggest. Many of the neutrons escape into the surrounding air before being captured for fission and a good deal of skill is needed to make a chain reaction go properly. A chain can be made to go quickly, as in the atomic bomb, or slowly as in the nuclear reactor. The products of a chain reaction may be divided into four categories: (1) heat, used in nuclear power stations to make electricity; (2) neutrons, used at Harwell to make radioactive isotopes; (3) fission products, the fragments produced by the splitting of the uranium atoms, which are radioactive isotopes of other elements further down the periodic table; and (4) radiation, mainly electrons and γ-rays.

One of the major sources of world-wide radiation at the present time is the fission of uranium and plutonium (a fissile material made artificially in a nuclear reactor) in atomic-weapon tests. Until 4 years ago fission was no great hazard. The present anxiety dates from 1 March 1954. On that day the United States Atomic Energy Commission exploded the first hydrogen bomb at Bikini in the Pacific. This device was made in three concentric layers. The core was an ordinary atomic bomb. Next to it was a layer of hydrogenous material containing large amounts of the two heavy isotopes, deuterium and tritium, in solid or liquid form. The outer layer was a thick shell of uranium metal. Detonation of the inner core raised the temperature of the hydrogenous layer to several million degrees centigrade, enabling fusion reactions to occur, with the evolution of much heat and many more neutrons. The neutrons passed through the uranium jacket, converting it into radioactive fission products and incidentally releasing further neutrons to keep the fusion reaction going. Tests of the same kind have been made since 1954 by Britain and Russia. When a bomb of this kind goes off a great quantity of fission products is released in a cloud which rises to about 50,000 ft. and then spreads like a mantle over most of the earth. It descends as radioactive dust for several years. By the time that this fallout reaches the ground, many of the short-lived radioactive materials have decayed, leaving three main constituents, ^{137}Cs, ^{90}Sr (both long-lived) and ^{89}Sr which has a half-life of 50 days.

Fallout

The amount of fallout deposited on each acre of ground depends mainly on the rainfall. Over the inhabited parts of the United Kingdom, the actual deposition of strontium is therefore three or four times greater in really wet places than in the dry regions. The method of estimating strontium fallout is sometimes misleading when it is not fully understood. The so-called strontium unit, as applied to soil, milk, food or other materials is the amount of ^{90}Sr present in the sample per gram of calcium. The strontium unit is therefore a calcium unit as well. Two patches of soil receiving exactly the same deposit of fallout may show very different results when the measurement is made in strontium units. A soil deficient in calcium will have a large number of strontium units. On the other hand a soil rich in natural or added calcium will have a very small score in strontium units. A similar trend will be seen in figures relating to milk or food products grown on the soil. Further confusion is sometimes caused when figures are quoted which include both ^{89}Sr and ^{90}Sr. ^{89}Sr is relatively harmless on account of its short half-life. Usually it is more abundant than ^{90}Sr in the fallout; a few days after a big bomb has been exploded, 90–98% of the strontium being deposited will be the lighter isotope. Reports of excessive concentrations of radioactive fallout in one place or another—in apparent defiance of the laws of meteorology—are nearly always the result of confusion over the points just mentioned. It should be emphasized, however, that milk and other animal products show a genuine difference in ^{90}Sr level between one region of the country and another. This is mainly because a cow on an upland farm will have to graze a bigger area to keep herself alive and make milk. Since the deposition of fallout is roughly the same on every acre, the bigger the area grazed by the cow, the more ^{90}Sr she will swallow.

Radiation hazard

Assessment of the radiation hazard is difficult, because little is known about the biological processes on which the hazard depends. If the world as a whole is considered, the incidence of radiation damage undoubtedly depends on the total amount of radiation delivered to the exposed population. Two possibilities deserve attention.

(1) There is the risk of distant genetic damage through the introduction of harmful recessive mutations which might spread unnoticed for many generations, after which no corrective measures could be applied. Irradiation of the gonads from external sources is, in Europe and North America, the largest influence at present. It appears

that the dose received by the population in these regions has now risen to roughly twice the natural background level. External irradiation of the gonads by fallout is, in Europe and North America, very much smaller, probably 1 or 2% of the average dose distributed in the practice of diagnostic radiology.

(2) There is the risk of leukaemia or bone cancer through the ingestion and deposition of ^{90}Sr. This hazard is very difficult to estimate. The majority opinion in scientific and medical circles is that the strontium hazard is appreciable, but not yet dangerous in comparison with other widespread sources of radiation in our own country. In the rice-eating countries of the East, the strontium hazard is very much greater* and (because X-ray services are less well developed) the hazard from diagnostic X-rays is relatively small.

Conclusion

The one conclusion which emerges from the study of these problems is that we do not know enough to make any accurate estimate of the dangers to be faced from radioactive contamination of food, now or in the future. A much greater research effort is needed to tackle this difficult situation before it becomes any worse, as it will do if large hydrogen bombs continue to be exploded. More work and less talk must be the policy.

*Vegetables and cereals generally contain much more ^{90}Sr/g calcium than do milk and other animal products. The intake of ^{90}Sr is therefore greater in countries where rice constitutes the main source of dietary calcium than in regions such as Europe and America where most of the calcium is provided by milk.

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Some reflections on the possible hazards to man of low doses of radiations

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Before any quantitative evaluation of a hazard can be made two basic types of information are necessary: firstly, the distribution in the environment of the hazardous agent; and secondly, the biological relationship between the frequency of occurrence of any particular harmful effect and the amount of the agent present in the relevant target tissue. A considerable body of information is now available on the distribution in the environment, and in man himself, of long-life fission products derived from megaton test explosions, in particular on strontium (^{89}Sr and ^{90}Sr) and caesium (^{137}Cs). If a similar amount of knowledge was available on the dose–response relationships for various harmful effects of radiation we would be in a very strong position from the point of view of estimating the hazard. Unfortunately,