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Radioisotopes And Us

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We live in the atomic age. Radioisotopes and their radiations are a part of our every-day lives. We lived with radioisotopes long before we entered the atomic age. We cannot escape a close relationship with radioisotopes and with their radiations. The greater our knowledge of radioisotopes and their radiations, the better we can cope with the problems which they present. It is therefore desirable that all of us gain more knowledge of what these isotopes can do to us, as well as for us.

We need to know what radioisotopes are. An atom is composed of electrons and a nucleus; the nucleus, having most of the weight of the atom, contains protons and neutrons. Each kind of atom, whether it be oxygen, nitrogen, or carbon, contains a definite number of protons, which together with the electrons outside the nucleus determine the chemical characteristics of the element. However, the atoms of a given element may have different numbers of neutrons, resulting in atoms of different weights for the same element. Atoms of the same chemical element with different weights are called isotopes. Thus, carbon-12 and carbon-14 have weights of approximately 12 and 14 times that of a hydrogen atom. Hydrogen itself has three isotopes which have atomic weights of 1, 2, and 3. Most natural elements are mixtures of several of these isotopes. All carbonaceous material contains small amounts of carbon-14 along with larger amounts of carbon-12.

Some of these isotopes, particularly the heavier ones, are not stable. Sooner or later these atoms decompose with the emission of energy in some form and the production of a different atom. These isotopes are said to be radioactive because of this property of giving off radiation in the same manner that radium does. In some cases decomposition is rapid and the life of the isotope may be measured in seconds. Other radioisotopes are more stable so that millions of years are required for decomposition. Since the number of atoms breaking down in a given time depends on the number of atoms present, the rate of decomposition is an exponential function which approaches zero slowly. Consequently, the rate of decomposition of each radioisotope is measured in terms of its half-life, that is, the time required for one-half of the radio-active atoms to break down. A given quantity of radioisotope with a half-life of 3 hours will have only one-half its original radioactivity after 3 hours.

Iodine-131, an isotope very commonly used in medical diagnosis and therapy, has a half-life of 8 days, whereas potassium-40, which occurs naturally in human tissue, has a half-life of almost one and one-half billion years. Carbon-14, the radioactive form of carbon, has a half-life of 5700 years; strontium-90, an isotope produced by nuclear detonations, has a half-life of 28 years.

When these radioisotopes decompose, energy is released in some form which we call radiation. Nuclear reactions produce four kinds of radiation. Alpha particles, coming principally from heavy elements such as uranium, thorium and radium, consist of positively charged helium atoms which are heavy, highly charged, and low in penetrating power. They can be stopped by a sheet of paper or the outer layers of the skin. Alpha particles will not cause damage to tissue unless the particles are emitted inside the body; therefore, all such alpha-emitting substances must be very carefully kept from entering the body.

Beta particles, given off by many common radioactive materials such as carbon-14 and strontium-90, are much lighter than alpha particles and carry a negative charge. Beta particles, or high-speed electrons, may penetrate up to a third of an inch of body tissue, depending upon their energies. Beta particles may travel a few feet in air but are stopped by an inch of wood or a thin sheet of aluminum. Over-exposure to beta particles can cause skin burns.

Gamma rays are not particles like the first two, but are electromagnetic vibrations similar to radio waves, ordinary light, ultra-violet light, and X-rays. They can travel hundreds of feet in air and are stopped only by thick layers of lead or concrete. Energetic gamma rays can cause severe damage to all parts of the body; therefore, exposure to external sources of gamma rays must be avoided.

Neutrons are nuclear particles with no electrical charge. They can travel hundreds of feet through air or penetrate several feet of concrete. They are best stopped by compounds, such as water, containing large amounts of hydrogen. Neutrons also can cause severe damage to tissue.

Probably the greatest dividend of the atomic age thus far is the increased availability of radioisotopes. These are produced in atomic reactors where ordinary chemical elements are bombarded by neutrons. Radioisotopes are sold by an agency of the United States Government to properly qualified individuals and organizations for research and other uses. Radioisotopes are available now in plentiful amounts for saving lives, time, and money.

All uses of radioisotopes depend upon their ability to give off radiation. By following the radiation emitted by radioisotopes, we may trace similar materials which do not give off these radiations. A bell on one animal of a herd allows us to trace the whole herd by the sound coming from the bell. Sometimes the energy given off by radioisotopes is used for therapy or other purposes. Radioisotopes are saving millions of dollars each year. Libby (1957) estimated that in 1957 American industry saved four hundred million dollars through the use of radioisotopes, and that in 1962 the saving would be in the neighborhood of 5 billion dollars.

Radioisotopes are used extensively in industrial thickness gauges. How can the thickness of a film moving at high-velocity be measured without touching it? One solution is to place a radioactive source below the film so that its radiation goes through the moving strip and is registered by some detector on the other side. If the radiation is substantially absorbed by the film, the detector will register only a small amount of radiation. If the film for some reason becomes thinner, the electronic response of the detector increases because of the increase in radiation. In this way the thickness of the film can be determined with ease, and the thickness gauge may be made to control the whole operation automatically. Other important applications involve liquid level determination, wear of tools and machinery, radiography of metal parts, and nondestructive testing in general.

Radioisotopes in agricultural research are helping to increase our food supply significantly according to Libby (1956). The population of the world is increasing at the rate of 35,000 each day. Our food supplies must be continually increased. Radioisotopes are not used by farmers themselves, but are used in research to discover new and better methods of food production.

More than one billion dollars of fertilizer are used every year. If 1 per cent of this amount could be saved by more efficient use of this fertilizer, our food would cost ten million dollars a year less. This saving is being achieved through knowledge gained by means of radioisotopes. The loss due to insects during one year is approximately three billion dollars. Savings to American agriculture resulting from research using radioisotopes in studying the development of new and better insecticides amount to forty million dollars per year. The cattle industry in some parts of the world has suffered severely from the screw worm fly. This menace has been reduced by applications of radiation from radioisotopes with annual savings of twenty million dollars. Radiation in massive doses produces genetic changes in plants and animals. In the cross-breeding of strains of plants which are resistant to particular diseases, radiation has proven helpful. Through development of new disease-resistant strains of oats alone, 100 million dollars are being saved each year. We have not seen the end of benefits which radioisotopes are giving to us in the field of agriculture alone.

In the field of medicine radioisotopes are used for both diagnosis and therapy. The injection into the patient of small amounts of radioisotopes allows a physician to diagnose some physiological conditions more easily and more quickly than he could in any other way. For example, measurement of iron turnover rates, liver function studies, whole blood volume or total plasma volume, detection and localization of brain tumors, detection and localization of eye and skin tumors, and determination of kidney function are done easily and quickly by the use of radioisotopes. The use of gamma rays from cobalt-60 is well established in the treatment of malignancies. Iodine-131 is particularly useful in the treatment of thyroid tumors, since iodine is selectively absorbed by the thyroid gland. Other forms of cancer or leukemia may be treated with radioactive gold or chromium (Blahd et al., 1958). We can put no monetary value on the utility of radioisotopes in this area; human lives are being saved.

The use of radioisotopes is not without hazard to the human body. However, each individual is subjected to radiation at all times. The U. S. Atomic Energy Commission (1960) has published the following estimates of this exposure. The radiation from natural sources which the average person receives during the course of one year comes partly from inside the body and partly from outside the body, the total being approximately 100 millirems. The millirem is a measure of radiation dosage. The radiation from man-made sources which comes primarily from medical procedures of both diagnosis and therapy averages 160 millirems. Luminous watch dials, television tubes, etc. contribute 1 millirem and radioactive fall-out, 4 millirem. The total average annual exposure to radiation in this country is approximately 270 millirems, of which only 1.5 per cent comes from fall-out.

No one knows the effect on the human body of such dosages of radiation. Scientists have not yet been able to identify any specific effects that low levels of whole-body radiation have upon people. However, the effect of larger dosages of radiation is known (U. S. Atomic Energy Commission, 1960). If a person receives 500,000 millirems during a short period of time, the chances of his surviving are approximately 50 per cent, or, in other words, 50 per cent of the people who receive this dose will die. Some individuals may die from a dosage of 200,000 millirems. If 100,000 millirems are received at one time, the first signs of radiation sickness appear, and at 50,000 millirems the first identifiable signs of radiation effects appear in the blood picture. Workers in the atomic energy installations of our country are permitted to receive no more than 5,000 millirems per year.

On May 17, 1960 the Federal Radiation Council which was appointed by the President of the United States to advise him on matters concerning radiation and public safety reported in part as follows:

"(1) Acute doses of radiation may produce immediate or delayed effects, or both.

"(4) The delayed effects from radiation are in general indistinguishable from familiar pathological conditions usually present in the population.

"(5) Delayed effects include genetic effects (effects transmitted to succeeding generations), increased incidence of tumors, lifespan shortening, and growth and development changes.

"(6) The child, the infant, and the unborn infant appear to be more sensitive to radiation than the adult.

"(7) The various organs of the body differ in their sensitivity to radiation.

"(8) Although ionizing radiation can induce genetic and somatic effects (effects on the individual during his lifetime other than genetic effects), the evidence at the present time is insufficient to justify precise conclusions on the nature of the dose-effect relationship at low doses and dose rates. Moreover, the evidence is insufficient to prove either the hypothesis of a "damage threshold" (a point below which no damage occurs) or the hypothesis of "no threshold" in man at low dosage.

"(9) If one assumes a direct linear relation between biological effect and the amount of the dose, it then becomes possible to relate very low dose to an assumed biological effect, even though it is not detectable. It is generally agreed that the effect that may actually occur will not exceed the amount predicted by this assumption."

The Federal Radiation Council takes the position that exposure to radiation is undesirable. If there are reasons for radiation exposure, the reasons should be balanced against the possible risks involved.

Some of the concern about fall-out presently felt by the people of the world could be avoided if these hazards were properly evaluated. For example, the Northwestern National Life Insurance Company of Minneapolis (1961) took an actuarial approach to the problem of fall-out as a hazard of modern living. Assuming the most extreme figures which have been proposed for the hazard of fall-out from all past atomic tests, this Company calculates that the hazard represents the same risk to the average American as drowning in his own bathtub.

The effects of an atomic bomb are usually classed as (1) blast, (2) thermal, (3) initial radiation, and (4) fission products. The U. S. Atomic Energy Commission (1961) estimated that a 50-megaton bomb can cause severe damage to frame homes at a distance of 14 miles from ground zero, and to reinforced concrete structures at a distance of 8 miles. The thermal effects from a 50-megaton bomb exploded at the surface or below 50,000 feet in the air could extend for 70 miles from ground zero. On a clear day a person could receive first degree burns at this distance if the person were not shielded from direct exposure to the explosion itself.

The fall-out effects are more complicated and less predictable. As the bomb explodes the nuclear fuel produces a wide variety of chemical elements, many of which are radioactive. These are called fission products. If the fireball touches the ground, dirt and debris are lifted into the ball and may become radioactive by reaction with neutrons. Because of the intense heat of the nuclear reaction, this material rises in about 10 minutes to about 60,000 feet. There it is cooled and carried away by the winds of the stratosphere. These particles fall to the earth during the next hours, days, weeks, months, and years. This, of course, is what we call fall-out.

This fall-out is in the form of a solid—fine particles—and thus needs to be treated as dust. Since it is radioactive—giving off alpha, beta and gamma rays—it should be avoided. The alpha and beta particles will cause damage if the dust is inhaled or consumed. The gamma rays will cause damage to body tissue at greater distances. The hazard from fall-out can be decreased in several ways.

(1) Distance. Since the intensity of radiant energy decreases as the square of the distance from the source, these particles should be kept away from us. One should stay indoors as much as possible during periods of maximum fall-out; clothing should be shaken or brushed to remove the dust; floors should be swept carefully; and food supplies should be protected from contamination.

(2) Shielding. The debris which comes from an atomic bomb and falls to the ground will be giving off alpha, beta and gamma rays. The first two of these will not penetrate many feet of air, but gamma rays are much more difficult to stop. Consequently, thick layers of dirt and/or concrete are desirable. However, even wooden walls offer much protection from penetrating radiation.

(3) Time. Since this dust is radioactive, it is continually destroying itself. In 49 hours it is only 1 per cent as dangerous as it was in the beginning.

Peacetime testing of atomic bombs has been achieved in this country without significant increase in the radiation to which we are all normally exposed. If any enemy should attack this country with atomic bombs, the fall-out levels will be higher than any seen in peacetime . We should acquaint ourselves with radioisotopes so that we can protect ourselves from their radiations more adequately.

As we live with the radioisotopes and their radiations in the future, we must face their hazards and evaluate them properly in terms of the benefits they give us and the risks we run in their use.

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