FALLOUT FROM NUCLEAR TESTS

U.S. ATOMIC ENERGY COMMISSION / Division of Technical Information

ONE
OF A SERIES ON
UNDERSTANDING THE ATOM

Nuclear energy
is playing a vital role
in the life of
every man, woman, and child
in the United States today.
In the years ahead
it will affect increasingly
all the peoples of the earth.
It is essential
that all Americans
gain an understanding
of this vital force if
they are to discharge thoughtfully
their responsibilities as citizens
and if they are to realize fully
the myriad benefits
that nuclear energy
offers them.

The United States
Atomic Energy Commission
provides this booklet
to help you achieve
such understanding.

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Director
Division of Technical Information

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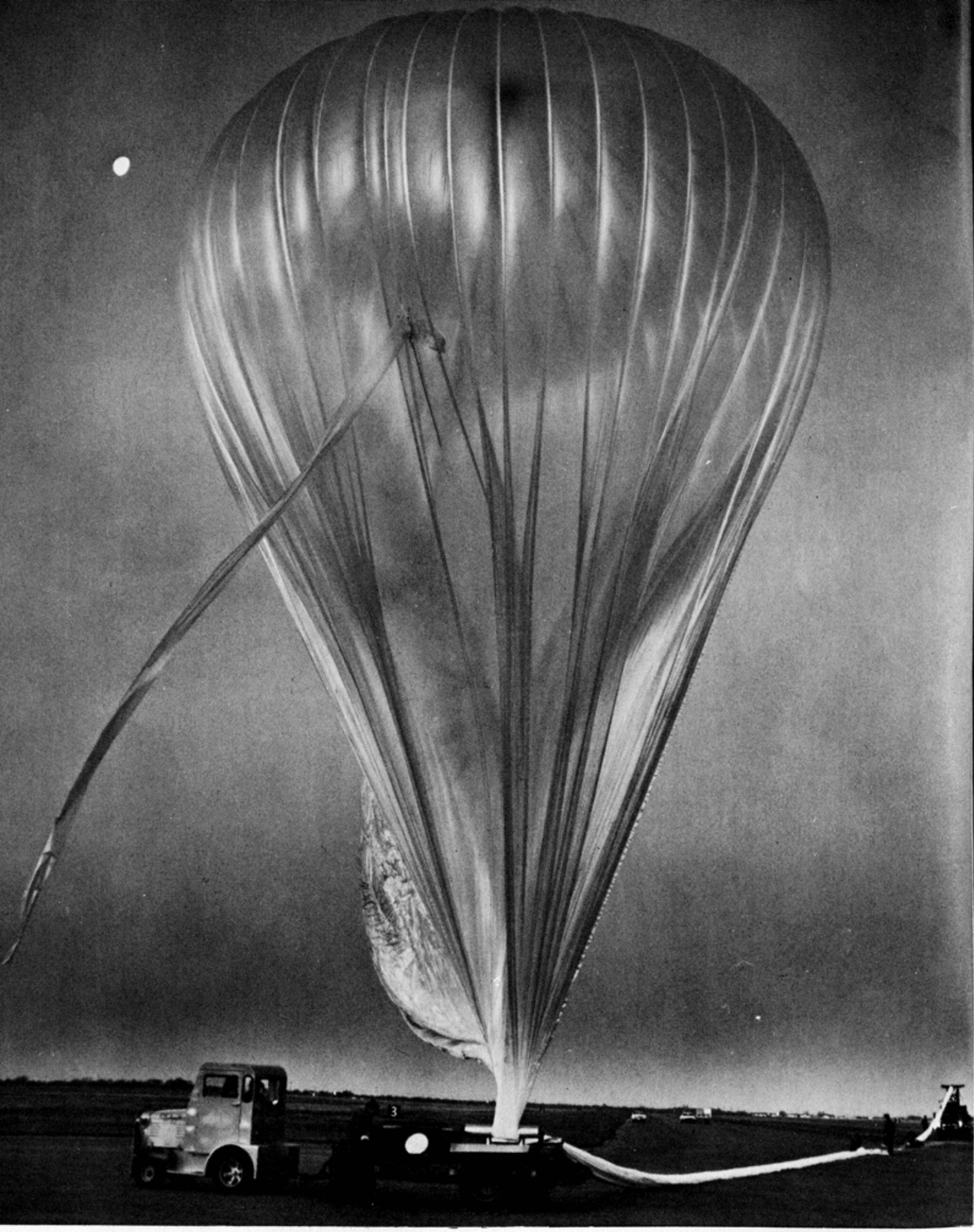


This high-altitude balloon is being prepared for launching at Goodfellow Air Force Base in Texas. The balloon carries air-filtering devices to collect atmospheric particulate samples, which are analyzed for various radionuclides. This information is useful in interpreting movement of radioactive debris from its point of injection into the atmosphere to its deposition on the earth's surface.

FALLOUT FROM NUCLEAR TESTS

By C. L. Comar

INTRODUCTION

The word "Fallout," destined for the vocabulary of all men, was coined in 1945. It refers to the radioactive debris that settles to the surface of the earth following nuclear explosions. Since most organisms living on earth can now be exposed to detectable radiation from a single nuclear explosion, there naturally has been great interest in the possible effects of fallout on living creatures, including man.

Apprehension and a degree of controversy have resulted from lack of knowledge of the nature of fallout, from its association with nuclear armaments, and the involvement of personal convictions. This booklet is intended to increase understanding by presenting information about fallout gained by scientists in recent years. It will summarize the important findings on which there is general agreement and indicate the areas of disagreement and those requiring further study. It is hoped this information will be useful as a basis for personal understanding of this difficult present-day problem.

FROM EXPLOSION TO DEPOSITION

Some basic concepts

Nuclear explosions result from the fission process* or from a combination of fission and fusion processes. In fission the nuclei of heavy atoms, such as uranium or plutonium, are split; in fusion the nuclei of two light atoms, such as hydrogen, are combined. Both processes involve the loss of mass, which is converted to energy. Both produce gamma radiation, neutrons, and great quantities of heat. In addition, fission produces radioactive fission products. Before the relation of all these to fallout can be discussed meaningfully, some definitions are in order.

We will be concerned with the power or *yield* of nuclear explosions. This is expressed in terms of energy released as compared to that released by the chemical explosive, TNT. For example, a one-kiloton nuclear device is one that produces the same amount of energy as does one kiloton (1000 tons) of TNT; a one-megaton device produces the same amount of energy as one million tons of TNT.

The basic phenomenon that causes concern in relation to fallout is *radiation.* Radiation is the transport of energy. This transport may occur without material carrier, as in the radiation of light rays from sun to earth or from desk lamp to desk. Alternatively, the energy may be carried by particles of atomic or subatomic size. The type of radiation we are concerned with, which can involve either mode of transport, is of a special nature in that it carries relatively large amounts of energy and has specific effects on biological materials.

The term *radioactive* describes the nuclei of certain specific elements that are unstable and undergo spontaneous disintegration; the property these nuclei possess is called *radioactivity.* The terms *radioactive elements, radionuclides* or *radioisotopes* are used to describe radioactive materials; nuclides are atomic forms of elements; isotopes are the various forms of the same element.†

*For an explanation of nuclear fission, see *Our Atomic World* and *Nuclear Reactors*, companion booklets in this series.

†For definitions of other unfamiliar words, see *Nuclear Terms, A Brief Glossary*, another booklet in this series.

Radioactivity liberates energy in the form of one or more types of radiation called *alpha, beta,* or *gamma* rays. *Alpha rays* consist of fast-moving helium nuclei that arise from the radioactivity of heavy elements, such as radium, uranium, or plutonium. *Beta rays* are streams of high speed electrons that can arise from the disintegration of any radioactive nuclei. *Gamma rays* are a penetrating type of radiation emitted by the nucleus of a radionuclide when it disintegrates. They are similar to X rays and ordinary light but are usually much more energetic.

Neutrons are particles that, along with protons, serve as basic components of an atomic nucleus. Neutrons travel outward from a nuclear explosion with high velocity and can then react with materials in the vicinity to make them radioactive. Materials made radioactive in this way are called *activation products.* In nuclear weapons experiments they may include radioisotopes of iron and zinc from towers supporting the atomic device. Perhaps the most important activation product from atmospheric nuclear explosions is radioactive carbon (carbon-14), formed from the reaction of neutrons with nitrogen atoms in the atmosphere.

In the fission process heavy atoms, such as uranium or plutonium, can divide in any one of 40 or more ways, leading to the production of 80 or 90 different primary radioactive products. All these undergo radioactive disintegration. In so doing some produce radioactive *daughters.* Thus, the mixture resulting from a fission explosion may consist of about 200 radioactive species of materials. Both the primary products and the daughters are generally referred to as *fission products.*

How fallout is generated in an explosion

In a nuclear explosion tremendous quantities of heat are produced in a relatively small quantity of matter within a few thousandths of a second. The casing and other structural parts of the exploded device, as well as the fission products and surrounding air, are raised to a temperature approaching that in the center of the sun, probably several million degrees. In such heat all materials are vaporized during the first few thousandths of a second. The high temperature creates what is known as a *fireball,* which expands rapidly, heating material in its vicinity, and then rises above the explosion point. Thus, right at the outset a nuclear explosion creates a mixture of gases, melted nuclear fuel, and perhaps some partially melted environmental materials. As the fireball cools the melted materials begin to solidify, and the gaseous materials condense and solidify. This produces the debris that is destined to fall back to earth. (It should be emphasized that the above does not apply to explosions conducted underground, which produce little or no fallout.)

Local and worldwide fallout

The characteristics of fallout resulting from a specific explosion are determined by two main factors: The height of the burst and the size or power of the explosion.

As far as height is concerned, the significant distinction is whether or not the burst occurs at so low an altitude that large quantities of soil or water are sucked up into the hot fireball. If so, condensation takes place on this material, and comparatively large and heavy particles or droplets with their attached radioactive material fall to earth relatively soon. This is called *local* or *early* fallout and takes place in the first 24 hours after the explosion.

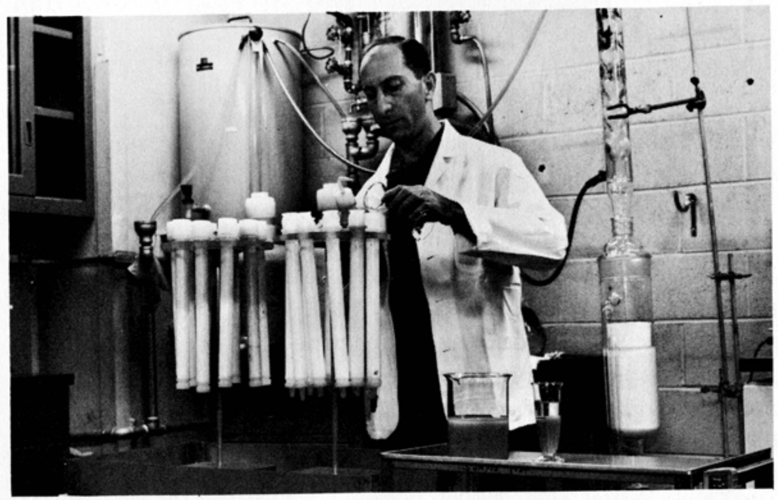
Bursts that occur at so great a height that dirt or water is not sucked up into the fireball produce little or no local fallout. Instead, the contaminated particles condense in very small, relatively soluble particles. These are widely dispersed and descend to earth ultimately as part of what is called *worldwide* or *delayed* fallout. Worldwide fallout is further subdivided into *tropospheric* and *stratospheric* fallout.

Behavior of worldwide fallout in the atmosphere

The distinction between the two types of worldwide fallout requires some consideration of processes in our atmosphere.

If you were to proceed directly upward from any point on the earth's surface, measuring the air temperature as you went, you would find that the air temperature first decreases with increased altitude. All at once it would become constant or even begin to increase. The level where this sudden discontinuity occurs is called the *tropopause.* From the earth's surface to the tropopause—a region of turbulence and rapid mixing—is the *troposphere.* This is the zone where our weather is formed, and our clouds, rains, and mists occur. Above the tropopause is the *stratosphere* where there is only slow vertical mixing but no turbulence. The tropopause occurs at about 50,000 to 60,000 feet in the tropics and at about 30,000 to 40,000 feet in the middle and polar latitudes. Movement and mixing between the stratosphere and the troposphere are most active in the regions of the *tropopause gaps,* which are discontinuities between the polar and tropical tropopauses.

Detonations of low-yield devices (of a few hundred kilotons or less) at or near the surface of the earth project their fission products no higher than the troposphere. Tropospheric fallout is washed down by rain or snow within a period of 1 day to 4 weeks. Since winds travel mainly in a west-east direction, tropospheric fallout reaches the earth in an irregular band roughly centered at about the same latitude as the detonation.



Measuring fallout concentrations in rainwater at one of 140 AEC collection stations around the world. Rain drains into ion-exchange column (right) from roof-top funnel.

PATTERNS OF GLOBAL FALLOUT MOVEMENT

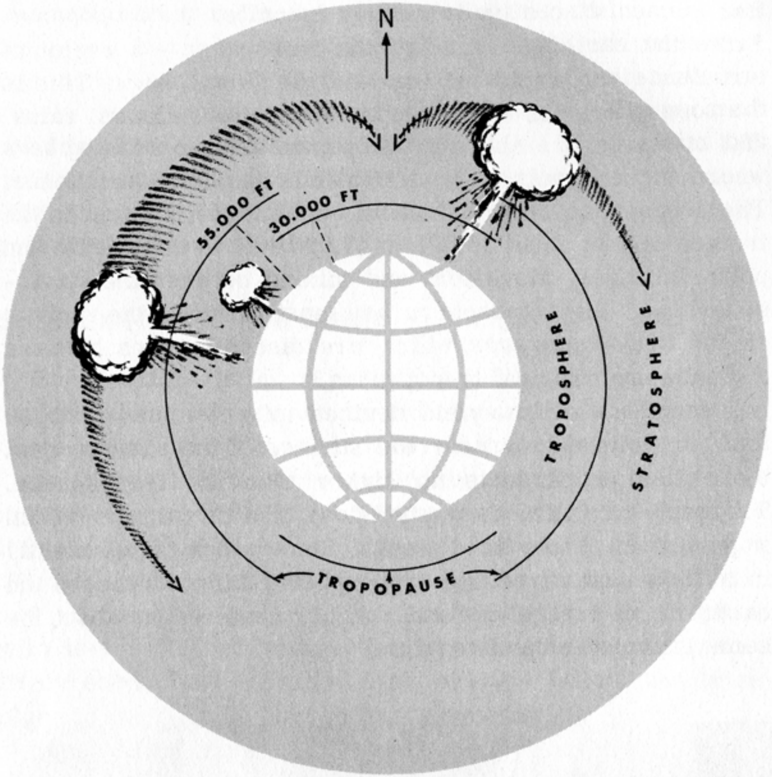


Figure 1 *The arrows in the diagram should be interpreted as representing the ultimate movement of debris that occurs only after constant mixing by random eddies, and not as simple one-way circulation.*

High-yield explosions (those measured in megatons) propel their fission products into the stratosphere. Meteorologists do not agree about exactly how, when, and where these radioactive particles descend from the stratosphere (in which mixing is minimal and precipitation nil) to the troposphere and then to the earth. Figure 1 presents, however, a simple diagram that conforms to the facts as they are now understood. It shows that debris injected into the stratosphere in the regions near the equator moves slowly toward both poles, but principally toward the pole of the hemisphere (northern or southern) in which the detonation oc-

curs. Months or years later it descends into the troposphere near the gap in the tropopause; this sinking (or vertical mixing) is accelerated in late winter or early spring and by some kinds of weather.

The experience from tests carried out so far supports this conception. Most of the nuclear testing was done in the Northern Hemisphere, and the greatest fallout occurred in the temperate latitudes of the Northern Hemisphere. Also there *has* been increased fallout in the late winter and early spring. Relatively rapid deposition occurred after Russian tests that were conducted north of 50 degrees latitude. On the basis of this experience, the half-residence time* for debris injected into the lower polar stratosphere is believed to be less than one year and to be dependent on the season of injection. Fallout from United States and British testing, which was done mainly at tropical latitudes, has come down much more slowly than that from Russian tests. The half-residence time in the equatorial stratosphere is now believed to vary from about 1 year, for debris injected into the lower levels, to 5 years or more, for debris injected into higher levels.

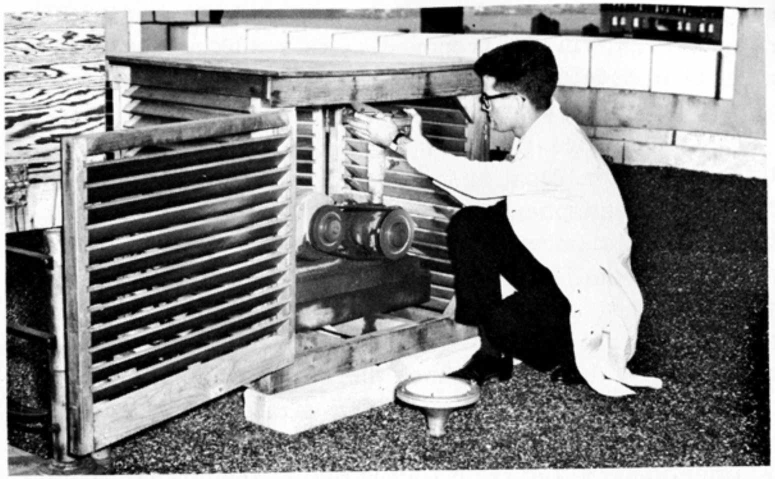
To summarize, then, we find that types of fallout can be classified on the basis of time following detonation required for it to reach the earth:

CLASSIFICATION	TIME REQUIRED
Local or early fallout	Minutes to 1 day
Worldwide or delayed fallout:	
Tropospheric fallout	1 day to 1 month
Stratospheric fallout	Up to 5 years or more

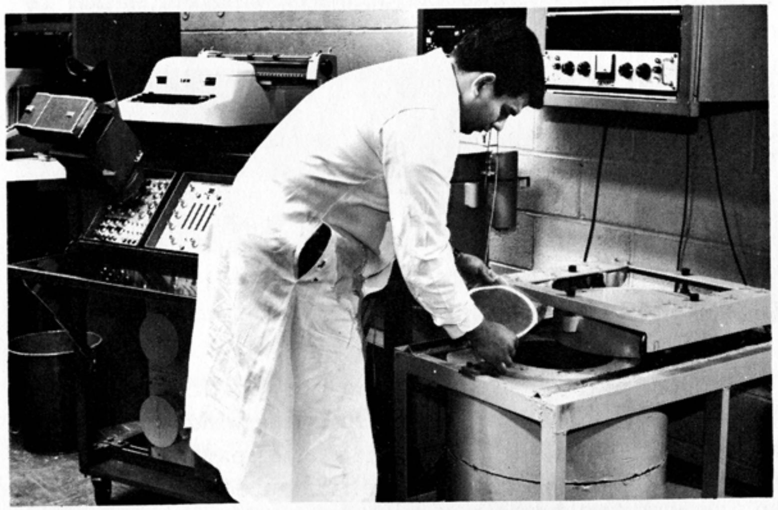
Effects of local fallout

The nuclear cloud containing the particles that will descend as local fallout is carried by the wind in directions and speeds depending on the size of the particles and air-circulation patterns at various altitudes. Most of the particles fall out under the cloud as it moves along. They are

*Half-residence time is the time required for half the debris to be transferred downward from the stratosphere to the earth.



Fission-product concentrations in ground-level air are measured at 15 stations at the same longitude, at intervals from Greenland to the southern tip of South America. From these measurements the mixing of fission debris in the atmosphere at different latitudes is studied. This photo shows a sampler on the roof of the AEC's Health and Safety Laboratory in New York City. This sampler filters dust from 10,000 cubic meters of air each week.



Materials filtered from air are examined for radioactivity in laboratory shown in this photo. Gamma radiation is measured with a sodium-iodide detector and electronic analyzer. Later the material is analyzed radiochemically.

subjected to further movement by the winds as they descend. Local fallout may begin near the detonation point in 5 minutes or less (from very low yield surface bursts), or it may not begin for 30 minutes or more (from high yield bursts). It may travel up to several hundred miles downwind in times ranging up to 24 hours. Thus, there can be considerable damage to life from local fallout in areas far removed from the effects of blast and fire.

The longer the time required for descent, however, the less the damage is likely to be. The reason for this is that all radioactive material loses its radioactivity with the passage of time by a process of disintegration or decay through which it ultimately becomes nonradioactive. The time taken for half the atoms in any quantity of a given radioactive material to disintegrate is known as that material's *half-life*. Half-lives vary from less than a millionth of a second to millions of years, according to the isotope concerned.

Local fallout consists mainly of a mixture of about 200 radioactive fission products each with its characteristic half-life. The radiation from any amount of local fallout continually decreases with time. As a rule of thumb it can be stated that for every seven-fold increase in time after the explosion the radiation decreases ten-fold. For example, assume that local fallout reaches a place 1 hour after the explosion and that its intensity at that time is measured as 100 units; 7 hours after the explosion the level will have fallen to about 10 units, and 49 hours after the explosion to about 1 unit. This accounts for the recommendation by civil defense experts that one should remain shielded from local fallout as long as possible.

Human beings exposed to local fallout must be concerned about the gamma radiation given off by the larger, coarse particles. These particles settle on surfaces, such as the ground, roofs, and trees, but do not enter enclosed spaces, such as houses or shelters, to any appreciable degree. Nevertheless, the gamma radiation from the particles can penetrate ordinary enclosures, and consequently very dense shielding is required to protect against it.

Those in a local fallout area also must avoid additional dangers from the possibility of exposed skin being burned by beta radiation, and must be sure not to take any fallout-contaminated air, food, or water into their bodies. In a nuclear war these dangers would be very grave.

Those responsible for nuclear tests have located test sites in places far removed from human habitation and have selected test times with due attention to weather conditions. Consequently, the local fallout from tests has produced relatively little hazard to human beings.

The principal concern regarding fallout from tests has properly been focused on worldwide fallout. Most of what we have to say in the remainder of this booklet will, therefore, relate to worldwide fallout.

WHICH RADIONUCLIDES ARE IMPORTANT?

Of the 200 or so radioactive nuclides produced in the fission process, only a few are known to represent a possible hazard to man through their appearance in fallout. Whether or not an individual radionuclide can be hazardous depends on several factors:

AMOUNT PRODUCED Obviously, the less there is of a given radionuclide, the less the potential hazard from it. The atoms produced most frequently are those with atomic weights between 80 and 108 (strontium-90 is in this group) or between 126 and 154 (cesium-137 and iodine-131 are in this group).

RADIOACTIVE HALF-LIFE The half-life of a specific radionuclide is the time required for one-half of it to undergo radioactive decay. Short-lived radionuclides predominate in local and tropospheric fallout. Radionuclides with intermediate half-lives such as strontium-89 (half-life of 51 days) can be important in the case of tests conducted in polar latitudes, because of the relatively short half-residence time of the debris in the stratosphere. In other stratospheric fallout, which is relatively slow in coming to earth, long-lived radionuclides are of most significance.

EFFICIENCY OF TRANSFER TO MAN The pathway by which radionuclides move into the body of man varies with the radionuclide and the circumstances of contamination. For example, some fallout radiostrontium may be deposited directly on the surfaces of plants that are commonly eaten by man; in this instance the food chain is simply plant-to-man. In other cases, the movement may be from soil to plant tissue to edible animal tissue to man. In the soil, the plant, the animal, or the man, metabolic barriers may prevent the radionuclide from reaching damaging locations. For example, some "rare earths" occur frequently as fission products, but their absorption from the gastrointestinal tract is so small in man (and animals) that these elements are of little importance in the food chain. Any unfissioned uranium or plutonium would likewise be poorly absorbed.*

METABOLISM IN THE BODY The radiation dosage delivered to the body by long-lived radionuclides deposited internally is directly proportional to the length of time that the radionuclide is retained. Thus, strontium-90, which is deposited in bone, like calcium, is removed slowly and is potentially more hazardous than cesium-137, which is deposited in soft tissues and is removed fairly rapidly.

The damage that a radionuclide can do may also be increased if it is concentrated in particular tissues. For example, practically all of the iodine-131 retained in the body is concentrated in the thyroid gland.

Based on these factors, the radioactive materials found in weapons-test fallout most likely to represent significant hazards to man are iodine-131, strontium-90, strontium-89, cesium-137, and carbon-14.

PATHWAYS TO MAN

Numerical relationships

Various units of measure have become customary for expressing the quantities of radioactive materials in the successive steps from nuclear explosion to deposition in man. In order to make clearer the relative magnitudes expressed by these units we have attempted to relate them in sequence

*Such poorly absorbed radionuclides may, under some circumstances, enter the body by inhalation or contribute significantly to the external gamma radiation, and so be hazardous.

PAST EXPLOSIONS AND STRONTIUM-90 LEVELS

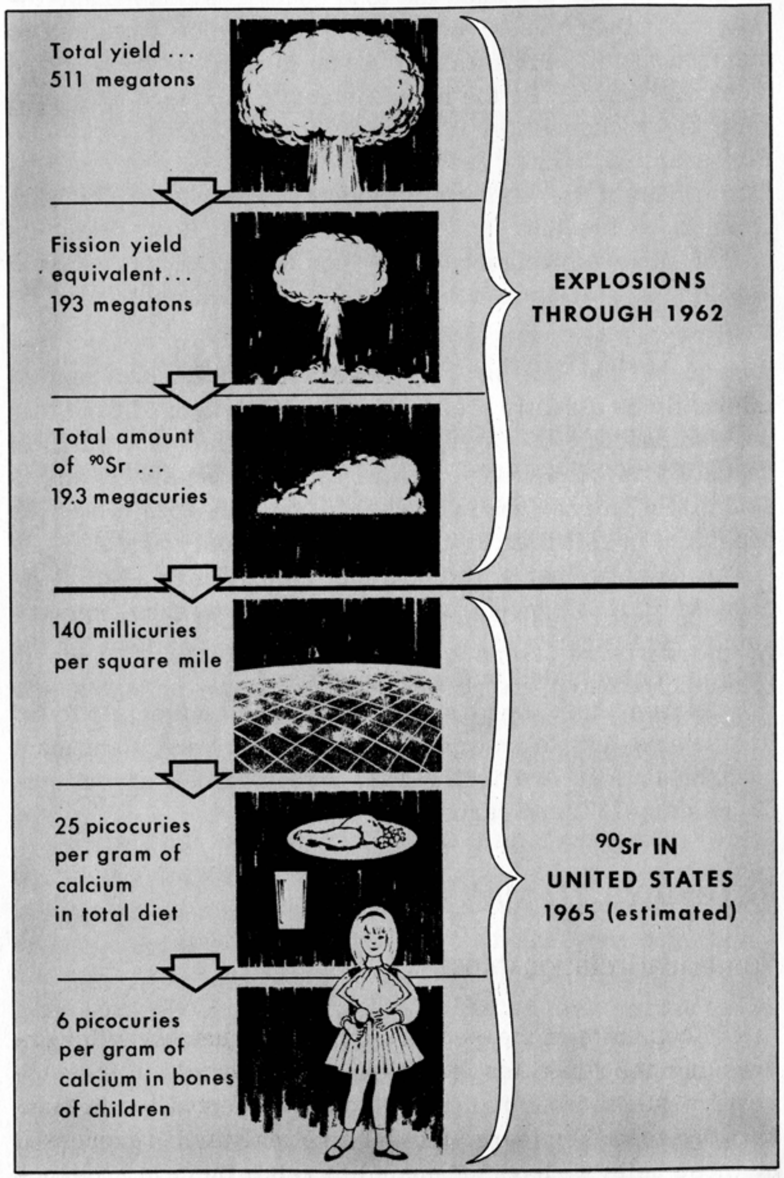


Figure 2 *These relationships are shown primarily to illustrate the units involved and they vary from time to time with conditions.*

diagrammatically, using strontium-90 as an example (Figure 2).

As indicated earlier, the yield of an explosion is measured in terms of the tons of TNT that would have an equal explosive effect. The total yield of all nuclear weapons exploded prior to the signing of the Test-Ban Treaty in 1962 is estimated at 511 megatons.

The total amount of fission products released in the production of 1 megaton of energy by nuclear *fission* is called 1 megaton *fission yield equivalent.* Since a nuclear device may produce a substantial fraction of its energy by *fusion,* the fission yield is frequently substantially less than the total yield. Thus, the 511-megaton total yield exploded prior to the treaty produced 193 megatons of fission yield equivalent.*

Amounts of radioactive material are measured in terms of a unit called the curie, which represents the rate at which the radioactive substance disintegrates and gives off alpha or beta particles. One curie was originally defined as the number of atomic disintegrations occurring per second in a gram of pure radium, but it is now established as an amount of radionuclide that undergoes 37 billion disintegrations per second. It is estimated that 1 megaton fission yield equivalent produces about 0.1 megacurie of strontium-90 (1 megacurie is 1 million curies). Thus, about 19.3 megacuries of ^{90}Sr were produced from the 193 megatons of fission yield equivalent produced in tests through 1962.

The amount of ^{90}Sr settling to earth is expressed in terms of millicuries per square mile (1 millicurie is one-thousandth of a curie). Under the conditions of testing through 1962, the 19.3 megacuries of ^{90}Sr that were produced resulted in an average level of about 140 millicuries of ^{90}Sr per square mile in the United States in 1965.

The amount of ^{90}Sr appearing in food and human bone is usually expressed in terms of picocuries per gram of calcium. (One picocurie, pc, also known as a micromicrocurie, is one million-millionth of a curie; 10^{-12} curie.) The amount of ^{90}Sr produced in tests through 1962 gave rise to

*The fission yields of all U. S., U. K., and U. S. S. R. atmospheric tests, by testing period, are shown in Figure 3.

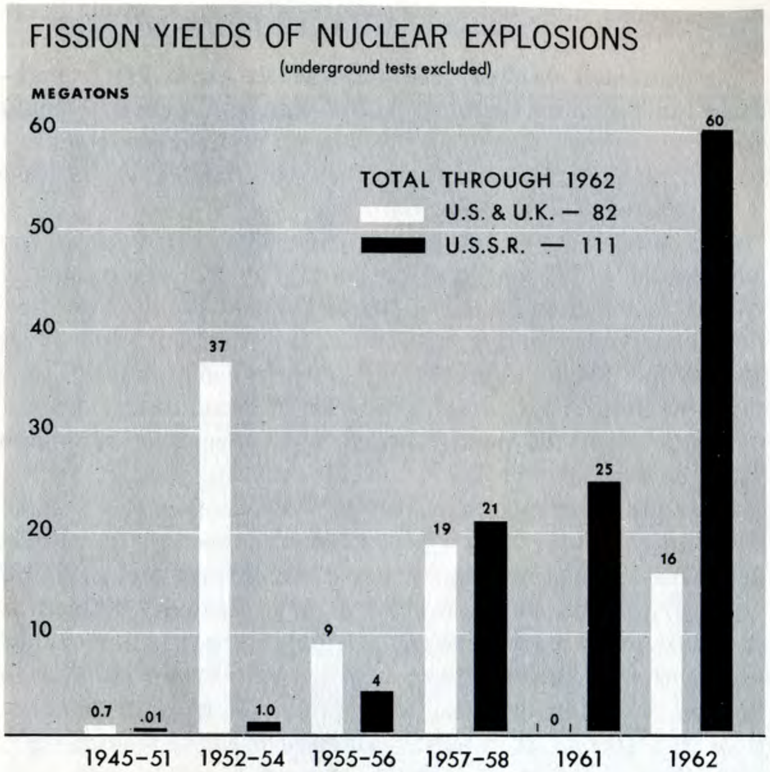


Figure 3

about 25 picocuries of ^{90}Sr per gram of calcium in total diet and about 6.0 picocuries of ^{90}Sr per gram of calcium in bones of children in the United States in 1965.

Movement of radionuclides

Radioactive materials in fallout reach the human population primarily in food, following a number of alternative pathways. There are several ways in which plants can become contaminated directly from the atmosphere. Fission products can stick to leaves, fruits or seeds. Radioactive material washed down by rain can be absorbed by basal parts and surface roots of plants. Heavy root mats can trap fallout and make it available to the plant.

Radioactive materials also can enter the soil and move into plants through the roots, just as any soil nutrient does, but for several reasons this process is inefficient. For one thing, radioactive substances may be diluted on entering the soil or may become unavailable to plants by being fixed to soil minerals. Furthermore, fission products in the soil move very slowly; this fact has two important consequences: Crops with surface roots tend to absorb most of the radioactivity, and most short-lived radionuclides lose their radioactivity before they can be absorbed.

Whether the pathway to man of any radionuclide is via surface contamination of plants or via the soil has a direct bearing on the amount found in food at any particular time. In the former case the amount varies directly with the rate at which fallout settles. We call the pathway of such a radionuclide *fallout-rate dependent.*

If the pathway is via the soil the amount of the radionuclide in food is cumulative, increasing whenever there is any fallout; even if the fallout rate becomes zero the

A biologist studies the root distribution of plants by injecting radionuclides into the soil and measuring plant uptake.

amount of this radionuclide in food does not decline sharply. Rather, it tends to level off, decreasing only gradually as radioactive decay and fixation in the soil take place. The pathway of such radionuclides is called *cumulative dependent.*

Radionuclides in or on plants may reach man directly by his consumption of foods of plant origin, or indirectly through his consumption of animal products. Grazing animals effectively collect contamination from plant material and concentrate it. Various factors, such as the metabolic behavior of specific nuclides and animal feeding and management practices, influence the relationship between the amount of radionuclides eaten by the animal and the amount deposited in its tissues and in secretions, such as milk, which are used for human food.

Man can also receive radioactive contamination from fisheries' products, but these are not important contributors of radioactive contamination to the human diet.

It is now time to consider the specific pathways followed by the most important radioisotopes found in fallout.

Iodine-131

Iodine-131, which has an 8-day half-life, is the radionuclide that produces the greatest radiation exposures within a short time (up to several weeks) after a nuclear detonation. This is because ^{131}I is produced by nuclear explosions in relatively large amounts, is transmitted efficiently through a food chain, may be deposited in a spotty pattern with areas of high contamination, and is concentrated within the body in a small gland—the thyroid.

Iodine-131 is of significance primarily in local or tropospheric fallout; almost all ^{131}I injected into the stratosphere disappears by radioactive decay before it can be returned to earth. Likewise, the ^{131}I that reaches the soil will decay before it can be taken up through the roots of growing food plants and be transmitted to man.

The pathway of ^{131}I through the food chain is shown in Figure 4. It is deposited on the surface of vegetation that is eaten by dairy animals, and is then secreted into milk, through which it reaches man.

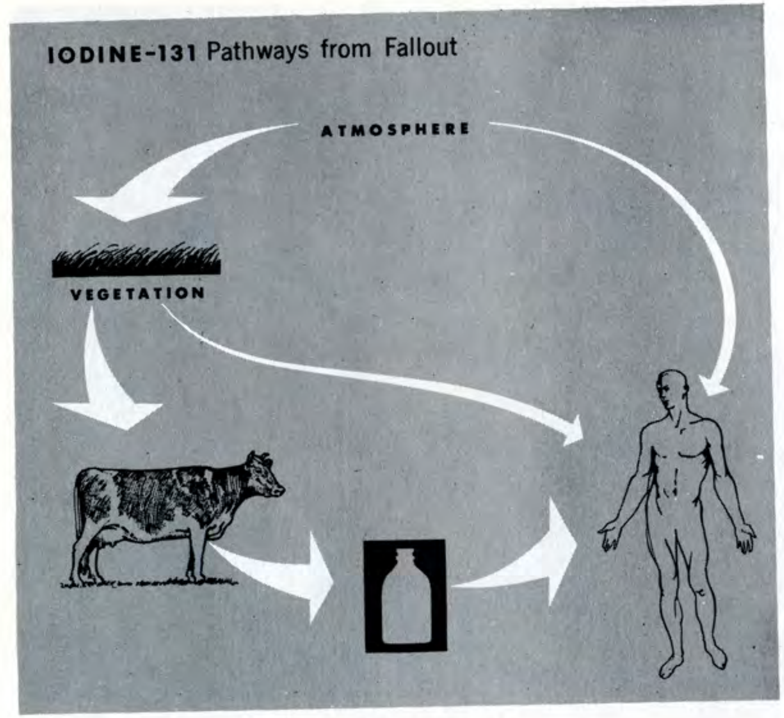


Figure 4

Man is also exposed to ^{131}I through his consumption of fruits and vegetables. Exposure via this pathway is minor, however, compared to that via dairy animals, because the surface area of fruits and vegetables consumed by a man is very small compared to the surface area of vegetation grazed by an animal, and because the contamination on fresh fruits and vegetables eaten by men usually is removed by washing or peeling.

Man also inhales some ^{131}I, but this route of exposure is relatively unimportant.

It is apparent, then, that only one item of the diet, fresh milk, is an important source of contamination from ^{131}I.

Very few measurements of milk were made to find levels of ^{131}I resulting from nuclear tests prior to 1957, and only limited studies were made during 1957-59. After the ^{131}I from the 1958 tests could no longer be detected, none was found until Russia resumed testing in 1961. Average mea-

A technician conducts radiochemical analysis of milk samples at a laboratory in Montgomery, Alabama.

surements of ^{131}I in milk in relation to testing periods since 1961 are shown in Figure 5. Note how rapidly the level responds to resumption or cessation of tests.

It must be noted that the levels charted represent monthly averages for the entire United States and that there were wide variations from one section of the country to another. Both in the autumn of 1961 and in the summer of 1962, for example, average monthly values exceeding 700 picocuries of ^{131}I per liter of milk were observed at some collection stations. Daily values were observed as high as 2000 picocuries of ^{131}I per liter at some stations, and it is possible that individual dairy herds had maximum daily levels two to four times as great as the area average.

After the cessation of tests late in 1962 the widespread ^{131}I levels in milk rapidly decreased and remained at non-

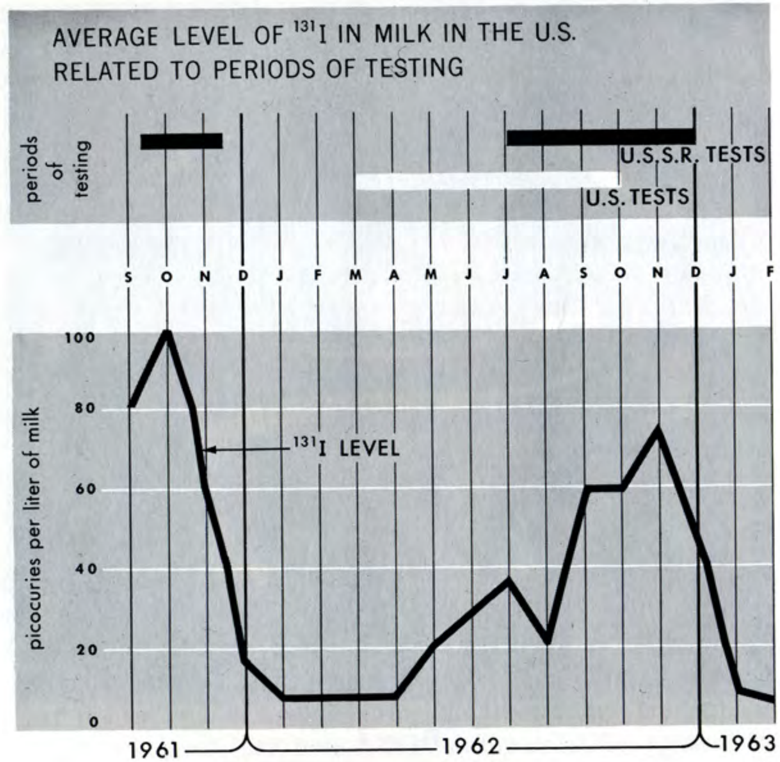


Figure 5

detectable levels. There is suggestive evidence that some of the ^{131}I observed in the United States starting in the fall of 1961 may have originated in the escape of radioiodine from underground explosions at the Nevada Test Site.

Strontium-90

Two radioisotopes of strontium are produced by nuclear explosions: Strontium-90 with a half-life of 28 years, and strontium-89 with a half-life of 51 days. Particular attention is always paid to ^{90}Sr because, of all radionuclides, it represents the greatest potential long-term hazard; in the body, it moves with calcium and is incorporated into bone, where, because of its long half-life, it remains as an inter-

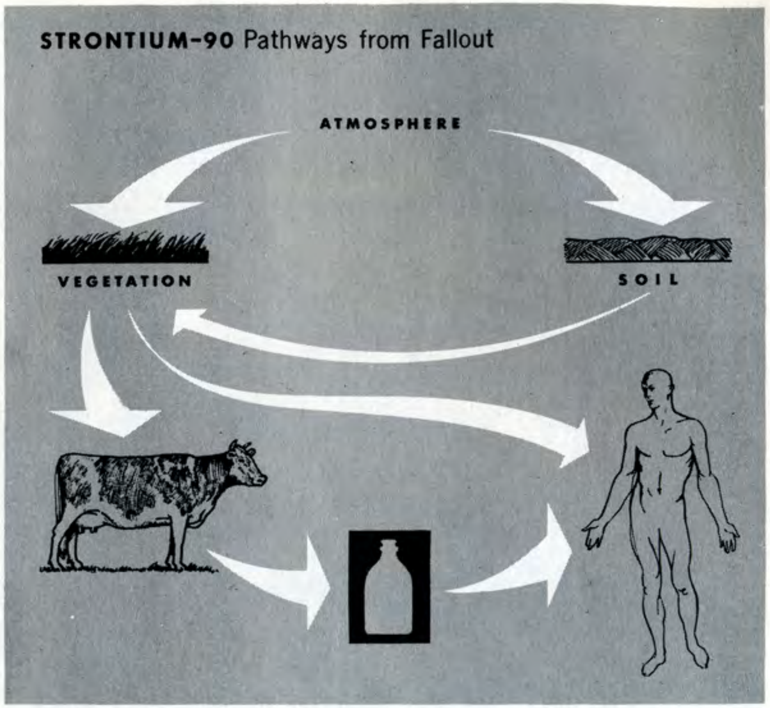


Figure 6

nal source of radiation.* Much of what we will say about the behavior of ^{90}Sr, however, applies as well to ^{89}Sr.

Figure 6 shows that ^{90}Sr reaches man primarily through his consumption of dairy products and foods of plant origin. Both surface contamination of plants (fallout-rate dependent) and contamination of the soil (cumulative dependent) are involved. The relative importance of these two routes varies with time, because of the influence of the amount of testing on soil contamination. In some areas in 1958 as much as 80% of the ^{90}Sr in food originated as surface contamination. As testing ceases, however, the fallout rate drops, and the soil reservoir makes a greater relative contribution. Examples of this situation were observed in 1960 and 1965,

*Half of any quantity of ^{90}Sr taken into the body will remain radioactive after 28 years; half of the amount remaining at 28 years will emit radiation for the next 28 years, and so on.

during testing moratoriums when the general level of ^{90}Sr in food dropped slowly because of the lessened contribution from the surface route.

The movement of strontium radionuclides from soil to man is interrelated with and to some extent governed by the simultaneous movement of calcium. For this reason levels of ^{90}Sr are often expressed in terms of *strontium units* (picocuries of ^{90}Sr per gram of calcium).

In assessing the ^{90}Sr hazard, the total intake of both ^{90}Sr and calcium must be taken into account. For any single food two factors must be considered: How contaminated it is with ^{90}Sr and how much calcium it contributes to the diet. For example, consider two foodstuffs, *A* and *B: A* contains 10 strontium units and contributes 0.1 gram of calcium to the diet in a given time; *B* contains only 1 strontium unit but contributes 1 gram of calcium to the diet in the same time. The potential harm from ^{90}Sr in these two foods would be equal, each adding 1 picocurie to the diet, even though foodstuff *A* had 10 times as many strontium units as foodstuff *B*. Thus, one cannot judge the relative ^{90}Sr hazard in foods merely by comparing their strontium units; one must consider the individual's whole diet, and its calcium content.

Much research has been done on the relative movement of strontium and calcium in the food chain and on other factors governing the amount of strontium that will finally be deposited in the human population. This research has revealed two factors that serve to limit the ^{90}Sr hazard.

A technician analyzes strontium-90 in samples of food.

First, it is evident that calcium is preferentially utilized over ^{90}Sr in practically every step of the food chain from vegetation to human bone, thus providing a biological barrier against ^{90}Sr.

Second, it has been learned that the common practice of washing plant foods or discarding their outer layers serves as a mechanical barrier against ^{90}Sr.

Milk has been the most important single item used for analysis and evaluation of food contamination, including contamination with ^{90}Sr, for several reasons: in the United States, dairy products are the largest source of dietary calcium; milk is produced regularly the year round; it is convenient to handle; it can be obtained from various geographical areas; and it contains the most important radiocontaminants. It must be emphasized, however, that the study of milk as an indicator food does not mean that milk is a preponderant factor in determining total ^{90}Sr intake. As a matter of fact, because a dairy cow puts 10 times as much calcium as strontium into the milk in proportion to the amounts ingested, the calcium in milk will be the *least* contaminated of all food sources of calcium. Thus, while dairy products supply about 75% of our dietary calcium, they contribute less than 50% of the dietary ^{90}Sr. This is shown in data from the Atomic Energy Commission's Health and Safety Laboratory on the ^{90}Sr contribution of various foods to a typical U. S. diet in 1964:

FOOD	PICOCURIES OF ^{90}Sr/DAY	PERCENT OF TOTAL
Milk	15.5	47.6
Flour and cereals	7.3	22.5
Root vegetables	1.6	5.0
Leafy and other vegetables	3.3	10.1
Fruits	2.3	7.2
Meat, fish, eggs	1.0	3.1
Water	1.5	4.5
Total	32.5	100.0

At present, the strontium units in milk do not vary greatly from those in total diet. The trend in levels of ^{90}Sr contamination is well indicated by these averages for strontium

units in milk from New York City, obtained also from the Health and Safety Laboratory:

1954	1.4	1958	7.6	1962	12.1
1955	2.7	1959	11.0	1963	25.6
1956	3.9	1960	8.0	1964	23.2
1957	4.5	1961	6.7		

Note how the levels decreased in 1960 and 1961, showing the effect of the test moratorium, and increased again in 1962 and 1963 showing the effect of the 1961 and 1962 tests.

Perhaps the most important information required for assessment of the exposure of the population to ^{90}Sr comes from direct analysis of human bone. Numerous studies have been made, both in the United States and abroad, utilizing bone samples from the bodies of persons who have died. The most meaningful values have come from analysis of bones of children up to about 4 years of age;* contamination of older persons is generally low because of dilution with

A chemist separates strontium-90 as a strontium carbonate solution from a solution prepared from milk ash. Strontium must be chemically separated prior to counting.

*This is because young children form new bone as a part of their growth, and therefore make more use of calcium, and any strontium isotopes associated with it, than older persons.

bone of low ^{90}Sr content formed in earlier years. Enough samples have been studied so that there is reasonable confidence in the results. Moreover, there has been general agreement in results obtained by various laboratories, and the values in bone have been quite close to those expected from knowledge of the behavior of calcium and strontium, and of the values found in the diet. For example, in the New York City area strontium units in the bones of young children averaged 2.1, 2.7, 2.4, 3.1, 3.3, 5.6, and 6.2 for the years from 1958 to 1964, respectively. These values are about one-fourth of the strontium-calcium ratios of the diet as can be inferred by comparing them with the strontium-unit values for milk. This is consistent with the findings that the strontium-to-calcium ratio in human bone is about one-fourth of that in the diet.

Cesium-137

Cesium-137 has a half-life of 30 years and behaves in biological systems much as potassium does. Figure 7 illustrates the behavior of ^{137}Cs in the food chain. It is important to note that cesium tends to be retained in soils, so that very little is available to plants through their roots. Therefore, direct contamination of plant materials (which are fallout-rate dependent) has provided the most important ^{137}Cs pathway to man.

The potential biological effect of ^{137}Cs is much less than that of ^{90}Sr because ^{137}Cs is removed from the body more rapidly. It is estimated that it takes only 70 to 140 days to eliminate about 50% of the ^{137}Cs that may be in the human body at a given time.

Data for 1964 indicate that about 35% of the ^{137}Cs in the human diet in the United States comes from milk, 25% from meat, 20% from flour and cereals, 10% from vegetables, and 10% from fruits.

Since ^{137}Cs gives off gamma rays, it has become possible to measure the amounts of it in normal human beings by use of sensitive detection instruments known as "whole body counters."* The person to be examined is placed within a steel room to shield out natural radiation; within a few minutes, readings can be obtained on the total amount of cesium-137 and also of naturally radioactive potassium present in the subject's body. In 1959-60, values from hundreds of individuals in the United States and West Germany averaged about 60 picocuries of cesium-137 per gram of potassium. This decreased to about 34 in 1961 and increased to 40, 90, and 92, for 1962, 1963, and 1964, respectively. The range of values for individuals was from about one-half to three times the average values. Additional studies of special populations, such as Eskimos and Laplanders, have revealed levels considerably higher than the maxima in the other groups.

*For more information, see *Whole Body Counters,* another booklet in this series.

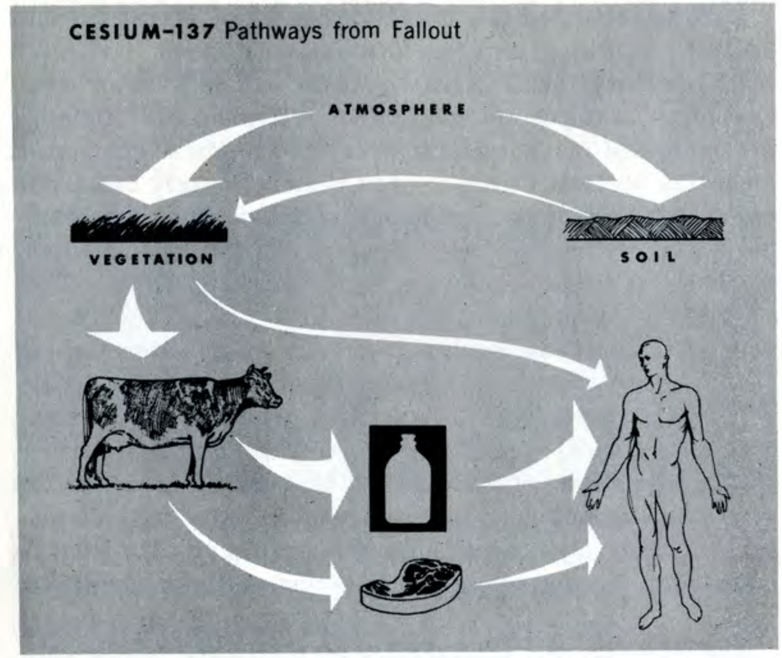


Figure 7

Carbon-14 and other radionuclides

Fission radionuclides other than strontium, cesium, and iodine are not known to contribute significantly to internal human radiation exposure from fallout.

But radionuclides can also be produced by activation with neutrons following a nuclear explosion. Of these, carbon-14 (half-life about 5800 years) is of the greatest importance. Carbon is an important constituent of living matter, forming the backbone of practically every biochemical compound. Since the earliest times, ^{14}C has been constantly created in the atmosphere by the action of cosmic radiation. As a component of carbon dioxide it is utilized by plants in photosynthesis and thus becomes incorporated in all living things.

The atmosphere, the terrestrial biosphere, humus in the soil, surface ocean waters, and deep ocean waters are all reservoirs of carbon. Carbon moves between these reservoirs at varying rates. A carbon dioxide molecule may descend from the atmosphere to earth in a few years, but it apparently takes approximately 1000 years for a carbon atom to be transferred from deep ocean water to the atmosphere. The rates of exchange between reservoirs must be taken into account if one is to understand the movement of ^{14}C.

The amounts of ^{14}C in the human population can be estimated from measurements of the troposphere. The specific activity of ^{14}C (amount of ^{14}C per total carbon) in the population will probably lag, by about a year, behind the specific activity in the atmosphere from which crop plants build food.

It is estimated that the amount of ^{14}C introduced into the dynamic carbon reservoirs by weapons testing in 1965 was almost double the amount of ^{14}C that has always been present naturally; this 70-to-100% additional ^{14}C is expected to fall to about 60% in 7 or 8 years, and to about 3% by the year 2040.

There are some radionuclides that are more significant in relation to seafoods than in the terrestrial foods, because some marine organisms concentrate certain fission products, such as cerium-144, and certain activation products, such as zinc-65, iron-55, iron-59, and cobalt-60. The hazard from these sources, however, is insignificant. For example, measurements of zinc-65 and iron-55 in fishery products from the Pacific Ocean, the most contaminated ocean, indicate that they contribute less radiation to someone eating them, even in large quantities, than the exposure from strontium-90. And ^{90}Sr in seafood, you recall,

has been shown to be only a small fraction of the daily intake of ^{90}Sr.

In concluding our discussion of pathways by which radiocontaminants reach man, it is of interest to compare the daily intake of various radionuclides, both natural and man-made, during 1964:

RADIONUCLIDE	PICOCURIES/DAY	SOURCE
Potassium-40	2500	Natural
Cesium-137	90	Nuclear tests
Strontium-90	25	Nuclear tests
Cerium-144	14	Nuclear tests
Lead-210	4	Natural
Radium-226	2	Natural
Plutonium-239	0.1	Nuclear tests

Of course, appraisal of possible biological effects on the population must take into account many other factors besides the amounts of radionuclides ingested. Some of these factors are discussed next.

BIOLOGICAL EFFECTS

Thus far, we have been concerned with amounts of radioactive materials in the human diet. It is necessary now to go one step further and think in terms of radiation dosage actually reaching the tissues, since it is this that determines biological effects. In order to deal with this subject, we must review some terminology and basic principles.

Units of measure

The unit of absorbed radiation dosage is called the *rad* (radiation absorbed dose), which is equivalent to the absorption of 100 ergs of energy per gram of tissue. Another unit is the *roentgen* (r), which is based on the amount of ionization produced in the tissues. For our purposes the roentgen may be considered approximately equal to the rad. Still another unit used to take into account the relative biological effect of different types of radiation, is the *rem* (roentgen equivalent, man). For practical purposes, when data are expressed in rems, we can assume that the biological effect is equivalent to that resulting from the same number of rads or roentgens of X rays or gamma rays.

The following examples will place in perspective the meaning of the rad in terms of biological effects:

Man in his lifetime (70 years) receives 7 to 10 rads from the natural environment. There is some belief that a very small portion of the number of cases of cancer and genetic abnormalities can be attributed to this radiation, but with our present knowledge this effect is virtually impossible to verify.

A few hundred rads of whole body irradiation delivered within a few days will kill any mammal.

Several million rads will sterilize food completely—that is, kill all the microorganisms on and in it.

Somatic and genetic effects

Radiation can affect either exposed individuals or their descendants. Effects on the exposed individuals themselves—such as induction of leukemia or bone tumors and shortening of life—are called *somatic effects*. Effects on exposed persons' offspring conceived after the exposure are called *genetic effects*.

We will see later that human radiation exposure from fallout is less than that from the natural environment. Furthermore, the radiation dosage from fallout is for the most part delivered over the entire lifetime of the individual. The importance of this is that a given exposure delivered over a long period of time produces less somatic effect than the same amount of radiation delivered instantaneously or in a short period. A man exposed to a single burst of 600 rads would probably die, whereas if he received 600 rads over a lifetime, the effects would be scarcely noticeable, if they were at all. The reason is that the body has some capacity to recover from radiation effects, if given time. There is evidence that genetic damage is similarly decreased when radiation dosage is spread over a long period.

There is no direct evidence as to the effects of radiation at the low levels and long exposure times common to natural and fallout sources. Studies that would give the

On March 1, 1954, fallout from a nuclear detonation at the Pacific Proving Ground was swept off its predicted course by unexpected winds at high altitudes. Debris was deposited on Rongelap, an inhabited atoll east of Bikini. The islanders were evacuated, given care and medical treatment on other atolls, and repatriated in June 1957 after radiation had subsided to acceptable levels. The new buildings in the photograph were built by the U. S. Government for the returning Rongelapese.

required information are practically impossible to conduct. They would require large numbers (millions) of experimental animals, long periods (decades) of time, and sensitive criteria of damage.

Since adequate evidence is not available, one has to depend on inadequate substitutes, such as the health and longevity records of persons with many years of occupational exposure to radiation, including X-ray technicians and radiologists, and on vital statistics for populations living in areas where environmental radiation is greater than average. Such studies are being made, but as yet there are no definite answers.

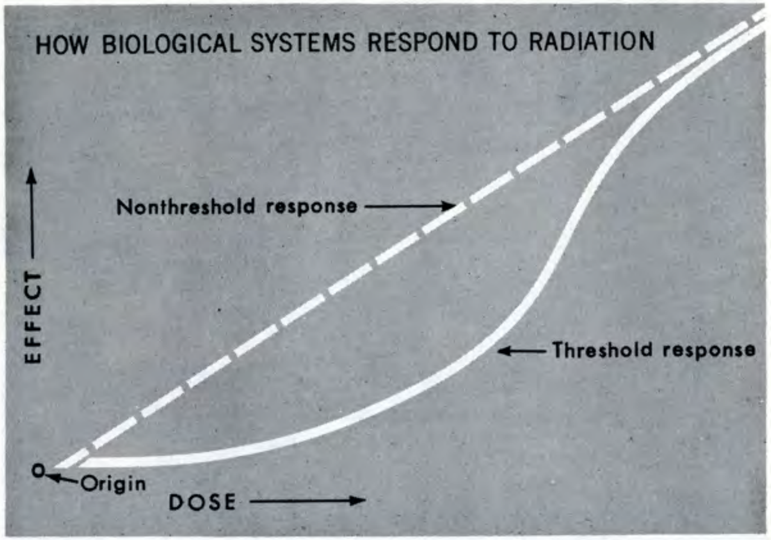


Figure 8

Threshold and nonthreshold response

A fundamental question is whether there is a level of radiation exposure below which no harm results; this question is also important for toxic chemicals and other agents. By plotting the doses against effects, as in Figure 8, an S-shaped curve often is obtained, indicating the effect is zero until a specific dose (the threshold) is reached. This is called a threshold response. Theoretically, any dose lower than the threshold would have no effect. It must be remembered, however, that if more sensitive methods become available for detecting the effect, the threshold may be lowered or even approach zero in which case no threshold will be apparent.

Another type of relationship is also possible: This is represented graphically by a straight line running through the origin. This is a linear or nonthreshold response and predicts that any dose, however small, will have a measurable effect proportionate to its size.

There is general agreement among scientists that genetic effects show a nonthreshold behavior; that is, that any dose of radiation will produce some genetic effect, although it

may be minor or delayed for generations. There is scientific controversy as to whether somatic effects are threshold or nonthreshold.

It would seem prudent, in the interest of safety, to assume that any amount of radiation will produce some measure of harm, both somatically and genetically, until there is evidence to the contrary. This is, in fact, the assumption on which all official radiation protection guides for the general population are based.

Background and fallout dosages

If we assume that any amount of radiation produces harm, then we must agree that the radiation from our natural environment must have been producing harm to mankind for centuries. Perhaps this background radiation can serve as our best yardstick in attempting to estimate the harm that may come from fallout.

Man is exposed to external radiation from cosmic rays and from natural radioactive materials in the ground, the air, and structures in which he lives and works. The principal sources of natural external radiation are uranium and thorium, their decay products, and potassium-40. Man is also exposed to internal radiation from radionuclides always present in the body, such as potassium-40, carbon-14, and members of the radium and thorium families.

It is estimated that the typical radiation dosage to individuals from natural sources is about 0.1 to 0.13 rad per year. In some areas of the world—parts of India and Brazil, for example—natural radiation exposure may be ten times that amount. It would be interesting to know the consequences of the higher dosages on the health of the populations involved, but studies that have been made of these peoples are incomplete and inconclusive.

Nor can precise values be given for the absorbed radiation dosage from fallout. By using the same principles for estimating dosages from naturally occurring radionuclides and from fallout, however, we can make a valid comparison that will favor neither one nor the other.

Table 1 on page 32 shows such a comparison. Values are given for bone, bone marrow, and reproductive cells, since exposures of these tissues are related, respectively, to in-

Table 1

AVERAGE RADIATION DOSES TO INDIVIDUALS IN THE UNITED STATES DURING NEXT 70 YEARS (ROENTGENS)

Site	From Background	From Tests Through 1962
Bone	9	0.46
Bone marrow	7	0.22
Reproductive cells	7	0.13

Source: Federal Radiation Council

duction of bone cancer, leukemia, and genetic abnormalities, the most serious effects believed to be traceable to radiation. The dosages given take into account exposure from radionuclides of strontium, cesium, and carbon.*

It can be seen that the dosage from background radiation is at least 19 times the maximum estimate of dosage from fallout.

The next task is to estimate as best we can just how much harm such exposures can cause.

Consequences

The estimated numbers of cases of gross defects, leukemia, and bone cancer that might result from radiation exposure and other causes are shown in Table 2.

The data indicate how great the uncertainty is as to the consequences of radiation exposure. They also indicate that, even if maximum estimates are accepted, the effects induced by fallout are far less than those from other causes. The 1963 International Test-Ban Treaty considerably reduces the possibility of major additions to worldwide fallout.

*Thyroid doses from ^{131}I are not included because peak dose rates persist only for a short time. Doses to the thyroid during and immediately following periods of testing have been estimated to average between 0.1 to 0.2 r per year in infants and between 0.01 and 0.02 per year in all age groups. It is likely, however, that there was much geographic variation and that in some limited areas of the United States the average doses were many times the national average.

Table 2

ESTIMATED NUMBER OF GROSS DEFECTS, LEUKEMIA, AND BONE CANCER CASES IN THE UNITED STATES

Conditions	Time span	Causes other than radiation	Caused by Radiation	
			Background	Fallout*
Gross physical and mental defects	Children of persons now living	4,000,000 to 6,000,000	no estimate given	20 to 500
Leukemia	In next 70 years	840,000	0 to 84,000	0 to 2,000
Bone cancer	In next 70 years	140,000	0 to 14,000	0 to 700

Source: Federal Radiation Council.
*Tests through 1962.

PREVENTIVE AND REMEDIAL MEASURES

Should individuals change their dietary habits?

We see from the foregoing tables that the biological effects of fallout do not appear to be significant compared to other risks of everyday life, but that there may well be *some* effects. The question then arises: Is the hazard so significant that individuals should modify their dietary habits in an attempt to reduce the intake of radioactive contamination? Experts agree this should *not* be done. Since the risk from fallout at present levels is so low, the chance of doing harm by modification of diet far outweighs the chance of doing any good.

As far as the chance of doing good is concerned, note that it is usually futile to try to reduce radioactivity intake significantly by alterations in diet. An excellent example is presented by milk, which has been widely publicized as a carrier of strontium-90. Paradoxically, even though milk is the largest single source of ^{90}Sr in the diet, reducing milk intake tends to *increase* the body burden of ^{90}Sr. This is because milk calcium is always less contaminated with ^{90}Sr than plant calcium, and if milk intake is reduced the body gets proportionally more of its calcium from plant sources.

But the most important consideration is the adverse nutritional effect than can result from misguided action. This

A local health worker picks up a gallon sample of raw milk in one of the farm areas monitored by the Public Health Service.

is illustrated dramatically in a letter received by a Federal agency:

Dear Sir:

... approximately six months ago, due to radiation fallout, our three sons stopped giving their baby children cow's milk, in fact, any kind of milk. These kids range in ages from six months to three years of age. Already they are beginning to show the effects of the lack of milk in their diets ...

Governmental remedial measures

Although the present situation does not warrant action by *individuals*, there are actions that are appropriately being

taken by *government* officials and scientists who are authorized to assume responsibility in two interrelated areas: (1) The development of remedial or preventive measures to reduce the exposure of the population to radioactive contamination, and (2) establishing the radiation levels at which the remedial measures would have to be placed in effect.

It is prudent that knowledge be obtained and preparations made to cope with any foreseeable contingencies. The fact that such work is under way, however, should not be interpreted as meaning that existing conditions justify alarm.

In general, any remedial measure, to be useful, must fulfill certain requirements:

(a) It must be effective, that is, it must reduce the amount of contamination.

(b) It must be safe, that is, the health risk from its use must be less than that from the radiocontaminant.

(c) It must be practical.

(d) The responsibility for the application must be defined. In general this means responsibility is assigned to some unit of local, state, or national government.

(e) The impact on the public must be considered; for example, the measure should not be one that, by creating panic, could lead to malnutrition.

Remedial measures that have been proposed for iodine-131 are cited below. Iodine-131 is selected as an example because, if remedial measures are ever required, they will be needed first for this radionuclide.

Remedial measures for ^{131}I are relatively simple because of its short half-life, and because it reaches the public primarily in a single identifiable food, milk.

Measures proposed to be put into effect should ^{131}I in milk reach stipulated levels are:

(a) *Use of stored feed instead of pasture for dairy cows*. The practicability of this procedure depends first upon availability of stored feed at the needed time. The peak of ^{131}I concentration in milk usually is reached within a few days after deposition. Unless animals are transferred to stored feed within that time, the procedure will be of little avail. Obviously the plans must be made ahead of time so that they can be put into effect promptly.

(b) *Use of evaporated or powdered milk for young children and pregnant and lactating women.* This would be effective in reducing dosage, but there undoubtedly would be a demand by other persons who also would wish to stop using fresh milk. The feasibility of the measure would depend on available stores and production capacity for evaporated and powdered milk.

(c) *Use of stored milk products.* The feasibility of this would depend upon the availability of sufficient stores of refrigerated, frozen, or canned milk.

(d) *Pooling of milk.* Theoretically, the ^{131}I level in milk from regions of high contamination can be reduced by pooling it with milk from regions of low contamination. This would be difficult because of the need to assay milk supplies and the magnitude of the transporation problems involved.

(e) *Addition of stable iodine to human diet.* Increased levels of stable iodine in the diet will reduce the ability of the thyroid to absorb ^{131}I. However, the consensus of medical opinion is that this would create health risks if followed on a population-wide basis.

Strontium-90 decontamination is a much more difficult problem and as yet no preventive or remedial measures have been proposed that fulfill the criteria of effectiveness, safety, and feasibility. Research is being continued, however, into such possibilities as soil control, liming of soils, removal of ^{90}Sr from milk by ion exchange or membrane partition, and addition of stable calcium to dairy rations and human diets.

When should remedies be invoked?

It is necessary that an official body stipulate the level or range of radiocontamination that will signal the need to consider invoking preventive or remedial action.

In the United States this crucial and most difficult task has been assigned the Federal Radiation Council. The Council was created in 1959 and includes representatives from all national agencies with an interest in radiation. Its functions include advising the President on radiation matters affecting health, and giving guidance to all federal agencies in the formulation of radiation standards.

Iodine-131 again is an appropriate example, since there has been considerable controversy about ^{131}I levels in milk. In 1961, the Federal Radiation Council established an average daily intake of 100 picocuries of ^{131}I, or an annual intake of 36,500 picocuries as the upper level of so-called Range II, above which the application of control measures should be considered. Although these guidelines were presented with qualifications that restricted their application to normal peacetime industrial operations, there seemed to be an understanding in the minds of most individuals that they should also apply to fallout.*

In the summer of 1962, concentrations of ^{131}I in milk in some areas of the country approached the specified levels, and at least one state undertook to reduce ^{131}I levels in commercial fresh milk by arranging for farmers to use stored feed instead of pasture for their herds. In response to this situation the Federal Radiation Council issued an official statement on September 17, 1962, from which the following excerpts are taken:

> In some localities in the United States average annual intake values of radioactive iodine have approached the upper level of Range II, and, in one locality, have slightly exceeded Range II. This has led to actions and proposed actions involving countermeasures or preventive health measures. The Federal Radiation Council does not recommend such actions under present circumstances.
>
> The Council believes, based on competent scientific advice, that any possible health risk which may be associated with exposures even many times above the guide levels would not result in a detectable increase in the incidence of disease.
>
> The Radiation Protection Guides are not a dividing line between safety and danger in actual radiation situations nor are they alone intended to set a limit at which protective action should be taken. As applied to fallout, guides can be used as an indication of when there is need for detailed evaluation of possible exposure risks and when there is need to consider whether any protective action should be taken under all the relevant circumstances.
>
> Radiation exposures anywhere near the guides involve risks so slight that countermeasures may have a net adverse rather than favorable effect on the public well-being. The judgment as to when to take action and what kind of action to take to decrease exposure levels involves consideration of all factors.

*Guidelines for action specifically applicable to fallout contamination have been developed by the Council (Federal Radiation Council Reports No. 5 and No. 7, April 1964 and May 1965).

Traditionally, the United States has been assured of a wholesome food supply through the efforts of legislative and regulatory agencies. Such agencies maintain appropriate vigilance with regard to radioactive contamination, and it is fair to state that any food that is permitted to be marketed can be eaten without concern about deleterious effects from radiation.

WHERE WE STAND

Some people have expressed concern because scientists apparently disagree about the potential hazard of fallout. Actually the extent of disagreement on this question is far less than the very extensive area of agreement.

For example, there is a considerable body of accepted knowledge about the movement of radioactive materials from the site of production through the atmosphere and the food chain to the human population.

There is also sufficient agreement on the following matters to place them in proper perspective in relation to other hazards of life: (1) the levels of radiation to which the population will be exposed from given amounts and patterns of nuclear testing, and (2) the maximum biological effects that can be expected from a given degree of environmental contamination.

The consensus of informed individuals is that the present or anticipated levels of radiation exposure from fallout due to nuclear tests (through 1962) do not constitute a hazard that warrants anxiety.

There is also general agreement that fallout from nuclear testing contributes in a small way to worldwide radiation exposure and that the cost to society as a whole is probably not zero. Consequently, no action that increases the production of fallout or radiation exposure should be taken except after a decision that the benefit to society of the action is well worth the biological cost that society has to pay.

There are some matters about which scientific uncertainty still exists, mostly because of lack of evidence. These require continued research and attention. They include:

(1) The significance of local regions of high fallout that might result from combinations of circumstances, such as high rainfall, low soil calcium, and particular food chains;

(2) The possibility that certain segments of the population—the unborn, the sick, the young, the aged—could be more sensitive to radiation than the population at large, and that some individuals could be unusually sensitive to radiation;

(3) The most effective measures for reducing exposure from environmental contamination;

(4) The precise effects of changes in the design and yield of weapons and in the choice of test sites; and

(5) The behavior of strontium-90 and cesium-137 in the environment and in the human body over periods of a human generation or more.

Scientists and administrators in private institutions, governmental agencies, and international organizations are well aware of these matters and are actively engaged in research to reduce the uncertainties.

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Fallout and Agriculture, 23 minutes, sound, color, 1960. Available from, and produced by, Motion Picture Service, Office of Information, U. S. Department of Agriculture, Washington, D. C. 20250, and Film Service Libraries of all state colleges of agriculture.

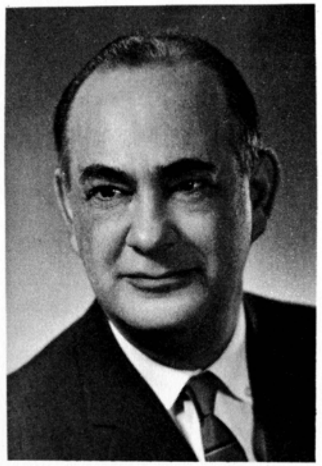
World-Wide Fallout from Nuclear Weapons, 40 minutes, sound, color, 1963. Available from, and produced by, the Defense Atomic Support Agency, The Pentagon, Washington, D. C. 20301.

Available for loan without charge from the AEC Headquarters Film Library, Division of Public Information, U. S. Atomic Energy Commission, Washington, D. C. 20545, and from other AEC film libraries.

Offsite Monitoring of Fallout from Nuclear Tests, 29 minutes, sound, color, 1958. Produced by the U. S. Public Health Service. This technical film, for high school and college level audiences, explains radiological safety activities of the U. S. Public Health Service in the area surrounding the Nevada Test Site. It describes the training of PHS Commissioned Reservists from state health departments, universities, and industry; monitoring and public information responsibilities of PHS zone commanders; methods of collection and laboratory analysis of environmental samples.

Atomic Tests in Nevada, 25 minutes, sound, color, 1955. Produced for the U. S. Atomic Energy Commission by the Lookout Mountain Air Force Station. This nontechnical film, for all audience levels, explains the reasons (in 1955) for continental testing of nuclear weapons and describes testing procedures at the U. S. Atomic Energy Commission Nevada Test Site with detailed information on measures taken to protect the public.

Tracing Airborne Radioactivity, 29 minutes, sound, black and white, 1962. Produced by the Argonne National Laboratory. The principle of air being able to cleanse itself of poisonous substances, including those that are radioactive, is covered in this film. Atmospheric fallout and the methods now being used to determine and study such fallout are examined. Fallout studies are discussed that relate man and his environment.



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