PROTECTION OF FOOD AND AGRICULTURE AGAINST NUCLEAR ATTACK

A guide for agricultural leaders

Agriculture Handbook No. 234
AGRICULTURAL RESEARCH SERVICE • U.S. DEPARTMENT OF AGRICULTURE

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PREFACE

If a nuclear attack were to be made upon the United States, all segments of our population and of our economic structure would be affected. Many of the problems created would be similar if not identical among the various segments. Some of the effects would be peculiar to each segment according to its needs and responsibilities.

Thus, agriculture would share the Nation's total difficulty and still be faced with special problems. The United States Department of Agriculture, in cooperation with other agencies of Federal and State governments, is responsible for helping to develop means by which farm people could cope with these special problems for their own protection and to maintain farm production in times of emergency. In fulfilling its responsibility, the Department participates in devising active defense and implementing actual protective programs, in conducting research to provide the knowledge on which these programs are based, and in keeping farm people and agricultural leaders informed about them.

One of the major parts of the defense plan being developed against nuclear warfare is aimed at reducing potential hazards from radioactive fallout. This handbook describes what is known about the effects of fallout on agriculture and what defensive measures can be taken against them. The information, including tables and denial times, is based on emergency conditions, not those prevailing in times of peace.

Some of the terms used may be unfamiliar because the widespread application of nuclear science is relatively new. However, many of them are rapidly becoming a part of the Nation's everyday vocabulary. A glossary is included in this publication to aid in a fuller understanding of such terms.

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The development of nuclear energy has created a new and uncertain element in man's world. On the one hand are the rapidly expanding horizons of progress made possible through the peacetime uses of this new form of energy. On the other hand is the possibility of damage or destruction of man and his possessions through the use of nuclear weapons if world peace cannot be maintained.

One of the important defenses against widespread destruction from nuclear weapons is a well-informed population, armed with as much knowledge as possible about protection and survival in case of attack. Agricultural leaders and farmers are responsible now, in time of peace, for developing a capability of the Nation to protect its people and the ability to produce food and other products necessary for existence.

Researchers are developing knowledge that will help to provide this protection and those in the U.S. Department of Agriculture are taking part. The study of nuclear weapons is relatively new and the usual techniques of research cannot always be applied because of obvious restrictions on the conditions of testing nuclear weapons. It is therefore understandable that not all of the needed information in this field is fully developed today. However, studies are extensive and the fund of knowledge is growing.

One of the problems that is being widely studied to help agriculture survive a nuclear attack is the effects of radioactive fallout and what can be done to prevent or minimize them. In approaching this problem, we can start with a brief description of the nuclear explosion itself.

NUCLEAR EXPLOSION

A nuclear explosion results in four destructive phenomena: (1) Blast, (2) light and heat radiation, (3) initial ionizing radiation, and (4) residual ionizing radiation. The first three are almost instantaneous at the moment of detonation, but the fourth (residual radiation, especially from detonations on the ground) produces its effects later, longer, and over a wider area, as fallout.

Area of Destruction

The area of destruction resulting from the blast, heat, and initial radiation will vary with the size of the weapon, the height of the explosion, and to some extent with the terrain and atmospheric conditions at the time of the explosion.

The size of the weapon is measured in terms of its total energy release compared with the energy released by TNT (trinitrotoluene, a nonnuclear explosive) when it explodes. For example, a 1-kiloton nuclear bomb produces the same amount of energy as the explosion of 1 kiloton (or 1,000 tons) of TNT. A 1-megaton bomb has the energy equivalent of 1 million tons (or 1,000 kilotons) of TNT. The earliest nuclear weapons released roughly the same quantity of energy as 20,000 tons (or 20 kilotons) of TNT. The energy release of the large bombs developed since World War II ranges from kilotons to many megatons.

Field tests have indicated that a 5-megaton nuclear bomb exploded on the surface of the earth would cause severe destruction to residential buildings out to about 6 miles from the point of detonation. Similar destruction from a 20 megaton device would extend out almost 10 miles. The heat from an 8-megaton bomb exploded on the earth's surface might set fires to easily ignitable materials during the first few seconds after detonation out to about 25 miles on a clear day. If it were exploded 2 to 3 miles above the surface of the earth, its heat would cause fires at somewhat greater distances.

In general, the height of the explosion can be considered in one of three classifications: (1) Air bursts, (2) surface bursts, and (3) subsurface bursts, the last one consisting of underwater and underground bursts. Obviously, whether the blast occurs high in the air, at or near the surface of the ground or water, underground, or underwater affects the area of damage.

Elements of the terrain such as mountains and hills also affect the blast and fire damage area. For example, a surface explosion surrounded by high hills or mountains might damage a more limited area than one on a broad flat plain. Wind direction or velocity and rain also influence the extent of fire damage.

Fallout Formation

When a nuclear explosion occurs close to the ground and the fireball touches the surface, large quantities of earth are vaporized or melted by the intense heat of the fireball, and thousands of tons of earth are pulverized by the blast. As the fireball rapidly rises, the ascending currents of air carry much of the pulverized earth upward into the fireball and the developing mushroom cloud, where some of the particles are vaporized, some are liquefied, and others remain in the solid state. Part of the vaporized radioactive residue of the weapon condenses in or on the liquefied or solid particles of earth. These particles thus become sources of radiation.

According to estimates, about one-half of the material from a surface nuclear detonation will return to the earth's surface as fallout within 16 hours. In about 24 hours most of this local fallout, which accounts for approximately 80 percent of the total radioactive debris, will have settled. The remaining 20 percent of the radioactive material goes high into the troposphere or passes through the tropopause into the stratosphere.

When a high-yield nuclear device (megaton) is detonated, the radioactive products resulting therefrom move through the troposphere, the tropopause, and end largely in the stratosphere. In case of an aerial burst, the fraction of the radioactive products that enters the stratosphere will be larger than that from a surface burst. Some radioactive materials are scattered on the ground locally and some are left at various altitudes as the atomic cloud ascends. The bulk of the radioactive fission products, however, are thrust into the stratosphere where they become dispersed in the stratosphere with a greater concentration in the hemisphere in which the device was detonated.

The atomic material in the stratosphere follows the winds at this extremely high altitude and travels around the world until it finally descends. The return of this radioactive material to the earth is rather slow, carried principally by rain descending into the troposphere.

The residence time in the upper atmosphere ranges from months to several years. Because of this long residence time, the radioactive fallout would contain mostly the long-lived isotopes. The radioactive fallout is composed of long-life, medium-life, and short-life isotopes.

When the smaller atomic devices are exploded, the radioactive materials remain in the upper area of the troposphere. The residence time of radioactive fission particles at this level is measured in weeks or months. The pattern of distribution is not world-wide but largely confined to the hemisphere in which it originates, generally following the wind patterns passing through the point of origin.

Area of Severe Fallout—Surface Detonations

Of the fallout that reaches the earth's surface in the first 24 hours, the greater portion is in the general vicinity of ground zero (point of the earth's surface directly under the detonation). It extends from this point to possibly as far as 1,000 miles or more downwind, the distance depending upon wind speed. This downwind direction may differ by as much as 180 degrees from the direction of the surface wind and may carry the debris at speeds of 75 miles or more per hour. The initial height of the particles, their size, shape, and density, together with the upper air winds and precipitation, will largely determine when and where they will reach the earth's surface. This fallout is a source of radiation that can be hazardous to man and animals in the area where it reaches the earth's surface.

It takes time for fallout to drop from the radioactive cloud, even close to the burst. The earliest arrival time outside the totally devastated area might be nearly 30 minutes after detonation. Some areas within the pattern of severe contamination might not get the fallout for as long as 24 hours after the explosion. At any particular location it could continue to fall for hours.

RESIDUAL RADIATION AND FALLOUT

About 90 percent of the energy of a nuclear explosion is released through the blast, light and heat, and initial radiation. The remaining 10 percent of the bomb's energy is expelled as residual radiation in fallout. Arbitrarily, residual radiation is said to begin about 1 minute after the explosion. It continues at a diminishing rate for years.

Fallout

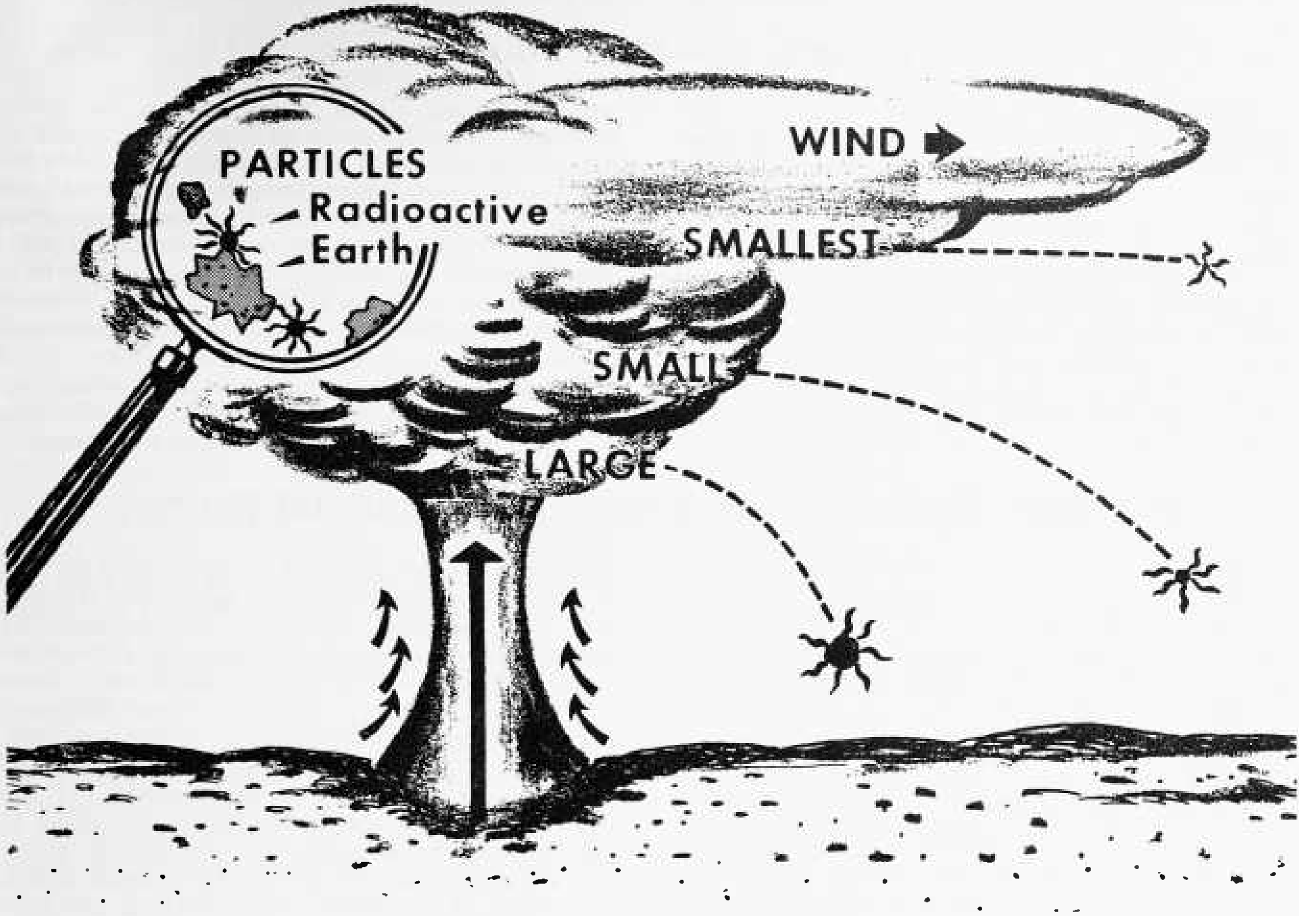

FIGURE 1.—In a nuclear explosion thousands of tons of material are taken up into the fireball. As the fireball cools, radioactive particles formed from the bomb are fused with particles of dirt and debris to form radioactive fallout. Where it falls to earth depends, in part, on the place of origin, on the size of the particles, and on the direction and velocity of the wind.

Radiation is emitted by radioisotopes (fission products, and radioisotopes formed by neutron capture) produced by the explosion of the bomb. It can pass into and through matter. Radiation can change, damage, or destroy living cells through ionization (see glossary) of cell constituents.

Since fallout contains radioactive fission products and other isotopes, it emits nuclear radiation. The fission products condense in and on dust and soil particles. Physically it behaves like dust or soil falling onto exposed surfaces. Sometimes, in areas of heavy fallout, it is visible and to the unaided eye may resemble dust such as that from a cultivated field, as a fine white powder, or tiny glassy beads.

Fallout composition varies with the type of soil or rock at ground zero, but fallout generally takes the form of granular sand, glassy beads, or dust, and is readily distinguished on smooth or polished surfaces, if present in significant amounts. The intensity of radiation from the fallout produced by a given explosion varies roughly with the amount of the fallout.

Radioactivity Not Transferred From Fallout

Radiation from fallout does not cause irradiated matter, living or inanimate, to become radioactive itself. In considering the effect of fallout on agriculture, the radioactive contamination in the fallout itself is the principal concern.

Fallout as a source of radiation can be compared to a lantern as a source of light rays. When the lantern is in a room, it emits light rays that strike various objects. When the lantern is removed, the light rays are gone and the room is dark. In the same way, when it has been possible to remove the fallout, the radiation is gone and the irradiated materials are not radioactive. However, the radiation damage to the living matter may persist, although its effect may not appear until later.

Gamma and Beta Radiation

Gamma rays and beta rays are the two most important types of radiation in fallout. Gamma rays are similar to X-rays. Their danger in fallout is greatest soon after it arrives in an area. The rays can travel long distances (many feet through air and several feet through water) and are difficult to shield against. The intensity of the gamma rays can be reduced only by shielding with a sufficient mass of material between the source of radiation and the subject. In general, the denser the material the lesser is the thickness required for shielding against gamma rays.

Beta "rays" are particles identical with high speed electrons. Beta particles can be easily stopped. Several layers of clothing can aid in protecting against penetration of beta particles. However, if a sufficient quantity of fallout gets on bare skin, beta particles will cause severe burns, and the effects may be even more serious if sufficient fallout is ingested or inhaled by man or livestock. Some of these isotopes continue to emit beta particles for long periods of time—measured in years.

See Appendix A for information concerning special instruments developed for the detection and measurement of various nuclear radiations.

Radiation Hazards From External and Internal Sources

The hazards of ionizing radiation from fallout to living organisms arise generally from two sources: (1) **External** sources and (2) **internal** sources. Both are of concern to agriculture: First, as a potential hazard to farm people and their livestock, including poultry, and second, as a source of danger to the consumers of agricultural food products.

(1) Radiation from **external** sources is a severe problem that would be faced during the first few hours or days following the arrival of the fresh fallout on the surface of the land. The gamma radiation for a time soon after the arrival of early fallout is more hazardous than beta radiation, since it is effective at greater distances from the source and is more difficult to shield against. As radiation intensity declines, the beta radiation from particles in contact with tissue becomes relatively more significant. The effects of the radiation on man and animals can range from nondetectable damage through varying degrees of "radiation sickness" to death. Also, radiation sickness can block the ability of normal body mechanisms to fight or overcome infections.

The amount of radiation that will damage a living body depends upon the number and type of cells affected and the type of tissue or organ affected. If the radiation damages the cell to the extent that its ability to function and reproduce itself is lost, and if enough cells are thus damaged so that it is difficult for surrounding tissues to repair or replace the damaged cells, the injury is severe and in the extreme situation may be fatal.

The human body has recovery processes that are capable of repairing a major portion of the radiation injury, except where the dose is so great that death occurs within a few days or weeks after the onset of exposure. Because of the existence of these recovery processes, individuals are able to survive exposure to larger amounts of radiation when the exposure is distributed over long periods of time. The concept of the equivalent residual dose (ERD), which takes into consideration the recovery processes, is used to allow for differences in biological effects of exposures between those delivered during very short and those delivered during longer periods of time. When exposure occurs over a few days or less, the total accumulated dose and the ERD will be essentially the same. However, when exposure to radiation is spread somewhat evenly over months or years, the total accumulated dose may be as much as five times that of the ERD. The ERD is the controlling factor.

In evaluating the effect of damage from radiation exposure, biologists estimate that 10 percent of the exposure is irreparable and that the body can repair about one-half of the remaining 90 percent in a month. The other 45 percent can be assumed to be repaired after about 3 additional months. Therefore, the ERD at any time is equal to 10 percent of the accumulated dose (the irreparable fraction of injury) plus the fraction of the balance of the accumulated dose that has not yet been repaired. It is assumed that recovery commences about 4 days after the onset of exposure and that each day there is repair of about 2.5 percent of the then remaining reparable damage. This rate of recovery may reduce the **reparable** damage to about zero by the end of 4 months' postexposure.

For example, if a normal healthy adult received a dose of 200 roentgens (see glossary) during the first few days of the month, his ERD early in the month would be approximately 200 roentgens. Of this amount, 10 percent or 20 roentgens would be irreparable and 180 roentgens would be reparable. During 1 month, half of this latter amount, or about 90 roentgens, would be repaired. Therefore, provided additional exposure could be avoided, the individual's ERD at the end of 1 month would be 90 roentgens plus 20 roentgens, or 110 roentgens. In this case an exposure of an additional 90 roentgens, if required during the succeeding month, probably would not incapacitate the individual to an extent requiring medical attention.

All but the most important farm operations should be postponed as long as feasible in order to take full advantage of the decay of the radioactivity.

(2) Radiation from **internal** sources may be a serious and long-lasting problem created chiefly by the consumption of contaminated food and water and the inhalation of contaminated air. It is caused chiefly by the isotopes that produce beta rays which are capable of traveling only short distances in the body, or gamma rays which can travel throughout the body, or both. While inside the body the isotopes continue to emit radiation which damages the surrounding cells. Most food commodities, both plant and animal, can be contaminated with fallout materials and thus can be an internal source of radiation for consumers. Much study is being given to this phase of radiation hazard.

All defense efforts or protective measures against radiation or radioactive fallout are directed at either preventing harmful ionization within living cells or minimizing the radiation exposure and effects of ionization.

The principal protective measure for man and animals against the external hazard is the maximum use of shielding or shelter, allowing time for the decrease of radiation intensities.

Protection against the internal hazard includes all measures to protect food, feed, and water for man and animals from radioactive contamination; **to keep the radioactive materials outside the body.** One radiological defense objective, therefore, is to attempt to prevent contamination where possible or, if this cannot be accomplished, to minimize the amount of contamination of the food supply.

Researchers have developed information on protection against both external and internal radiation hazards of fallout. The remainder of this publication deals with methods of protection for agriculture, farm families, and consumers of agricultural products.

PROTECTION AGAINST EXTERNAL RADIATION FROM FALLOUT

Radioactive fallout would have serious effects upon agriculture and food production and storage in the event of attack with nuclear weapons, but there are practical methods of protection. The four basic elements of protection against external radiation from fallout are distance, time, shielding, and decontamination.

Effect of Distance

Distance is a natural protection against fallout radiation from external sources. As would be expected, the radiation exposure is less the farther away you are from the source of radiation. Thus, fallout on a roof 20 feet over your head will give less radiation exposure than the same amount of fallout on the same roof 5 feet over your head. This is true because the radiation is reduced in intensity as it moves away from the point of origin.

Effect of Time on Intensity of Radiation

The lapse of time after a nuclear explosion is also a natural protection against the external radiation hazard from fallout because of the decay factor of radioactivity. The longer it takes the fallout to reach an area, the greater is the time required for radiation intensity to decrease because of decay.

About 200 different isotopes of nearly 35 elements have been identified among fission products created by nuclear explosions. The radioactivity of each isotope diminishes or "decays" at a specific rate, different for each isotope. Usually the rate of decay is expressed in terms of the "half-life" of the isotope. Some isotopes lose half their radioactivity within seconds after the explosion. Others take days or months or years to lose half their radioactivity. For example, iodine 131 has a half-life of 8 days. Thus, iodine 131 has decayed to half its original activity in 8 days, half the remainder is gone in another 8 days, and so on. After 54 days, only 1 percent of the radioactivity will remain. Strontium 90 has a half-life of 28 years and 1 percent of its radioactivity will remain after 180 years.

The total radiation hazard of newly formed (fresh) fallout decreases rapidly at first because it contains many radioisotopes with short half-lives. The radiation hazard decreases more slowly after the shorter lived elements have lost most of their radioactivity.

In order to estimate the rate of decrease of total radioactivity, an approximate rule may be used.

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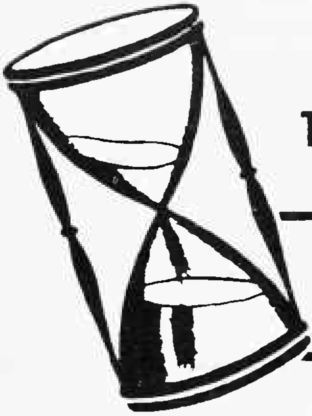
Time - Decay



TIME (hr.)	DECAY	RADIATION INTENSITY
1	—	1,000 r/hr
7	1/10	100 r/hr
7X7 = 49 (2 days)	1/100	10 r/hr
7X7X7 = 343 (2 wks)	1/1,000	1 r/hr

FIGURE 2.—Decay in radioactivity is related to time. For every sevenfold increase in time following a nuclear explosion, the intensity of the resulting radiation decreases. When radiation intensity is 1,000r/hr 1 hour after an explosion, at 7 hours after the explosion the intensity would be approximately 100r/hr, or one-tenth of the original intensity.

According to this rule, for every sevenfold increase in time following an explosion the resulting radiation decreases tenfold. For example, suppose the radiation dose rate in an area is 1,000 roentgens per hour (1,000r/hr) at 1 hour after the explosion. If no more fallout occurs, 7 hours after the explosion the dose rate would be about 100r/hr (a tenfold decrease from 1,000). In 49 hours (7×7) or about 2 days, the rate will be down to 10r/hr. In 343 hours (7×7×7) or about 2 weeks, the rate will be down to 1 roentgen per hour. Approximately 14 weeks would be required for the radiation dose rate to be reduced to 0.1r/hr.

Effect of Shelter and Shielding

Shelter

The most important protection against fallout is shelter. In time of emergency it may not be feasible to evacuate the population because of the lack of information about where and when bombs might explode, and possible sudden and unpredictable shifts in wind direction and velocity which would determine the pattern of the fallout. Therefore, farmers should be prepared to provide shelter for their families and livestock, as well as for their food, feed, and water. For humans the Office of Civil Defense recommends that a shelter be designed to provide a protection factor of at least 100. (It is recognized that shelter for the large herds of range animals may not be possible.)

The interval between the explosion and arrival of fallout may provide the time required to get the family and livestock under shelter and to cover water supplies, food, feed, and other critical items.

A guide for adequate shelter reserve food supply is contained in Home and Garden Bulletin No. 77, "Family Food Stockpile for Survival."

The most critical period of external radiation hazard is during the first 48 hours after a nuclear explosion. In an area where the amount of fallout is great enough to have caused a radiation dose rate of 1,000 to 3,000 roentgens per hour within 1 hour after the detonation, total loss of people and livestock **without shelter** must be assumed. If people and animals can stay within a good underground shelter for the first 2 or 3 days, deaths from radiation can be reduced. The more effective the shelter and the longer it can be maintained, the greater the reduction in death rate and other harmful effects of radiation.

Studies on air intakes for shelters indicate that air ducts with two or more impinging surfaces, that is, baffles, in the ducts will remove about 95 percent of the particles from the incoming air. The opening of the intake, however, should be protected from falling dust and faced downward.

Where forced-air shelter ventilation is employed, the design of the air intake and ducts should conform to that of the Office of Civil Defense regulations.

Radiation Attenuation

Gamma rays are partially absorbed and reduced in intensity (attenuated) as they pass through any material. Therefore, shielding of any type gives some degree of protection. If enough shielding is provided between the individual and the source of radiation, such as fresh fallout, the exposure can be reduced to a negligible level.

Protection from the effects of fallout gamma radiation may be achieved in two ways—barrier shielding and geometry shielding.

In the first method, a barrier is placed between the fallout field and the individual. The heavier the protective barrier, the greater the barrier shielding effect. Examples of barriers in structures are walls, floors, and ceilings.

Geometry shielding is determined by the extent of the fallout field affecting an individual, and his distance from it.

Here is an example of the geometry shielding effect:

If two buildings are of the same height and similar construction, but of different area, the protection from ground contamination would be greater on the first floor in the building with the larger area.

On the other hand, if two buildings are of equal area and similar construction, but differ in height, protection from roof contamination would be greater on the first floor of the higher building.

The combined effects of barrier shielding and geometry shielding result in a shelter "protection factor." This term is used to express the relative reduction in the amount of radiation that would be received by a person in a protected location, compared with the amount he would receive if he were unprotected. Some speak of a material as having a protection factor of 10, while others express the same concept with the decimal fraction 0.10. Both mean that the intensity of radiation behind the shield is about one-tenth the intensity as measured in the open radiation field.

Appendix B relates shelter categories to corresponding protection factors. It is intended to provide (1) a general idea of the relative amounts

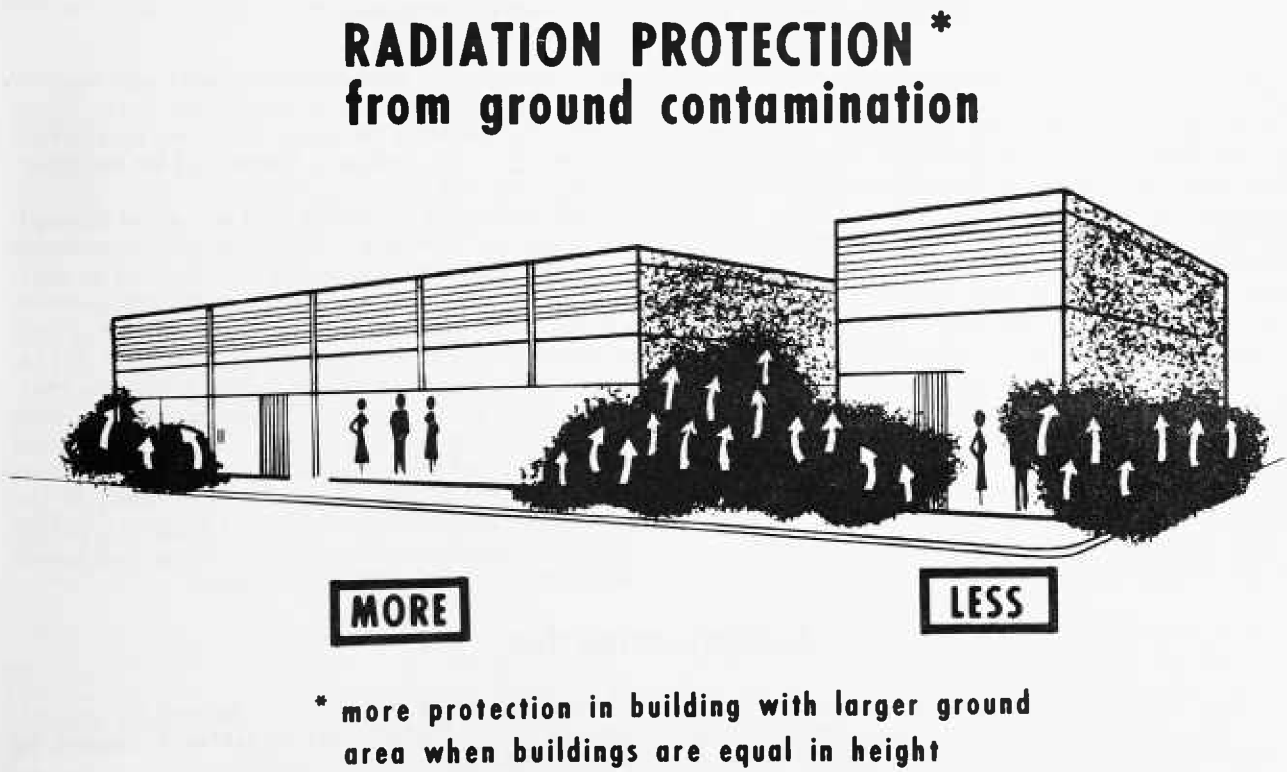


FIGURE 3.—Radiation protection from ground contamination.

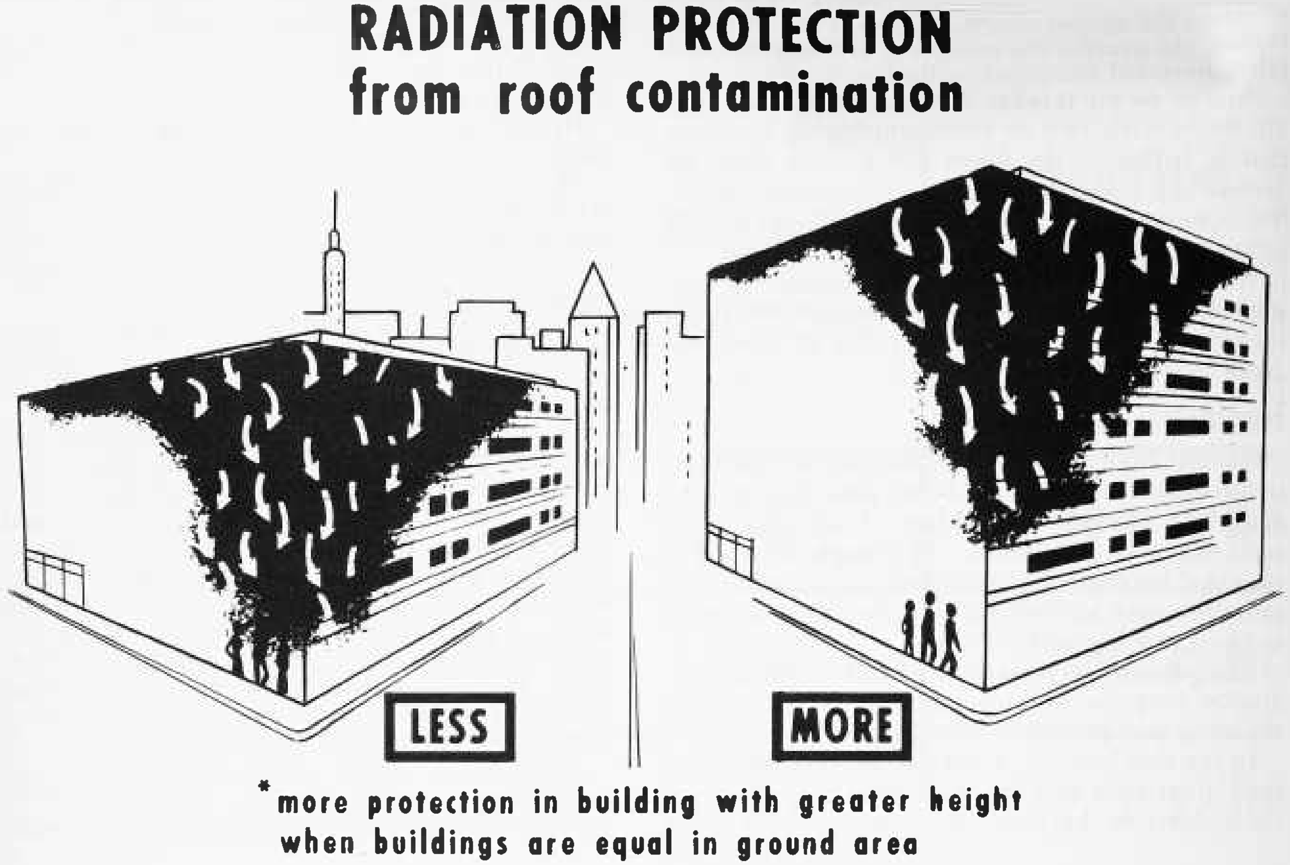


FIGURE 4.—Radiation protection from roof contamination.

of protection offered by common types of buildings and (2) a preliminary estimate of potential shelter areas, the purpose of survey programs. These protection factors may be conservative in many cases, since they are based on isolated structures. For example, if a building is surrounded by taller buildings, the protection factor might be increased sufficiently to raise it to a higher protective category. In any case, on-site examination and practical judgment must be used in assigning a protection factor to any given structure.

If special shelters are not available at the time of a nuclear attack, families should take advantage of available normal indoor and, preferably, basement-type shelter.

Normal shelter reduces radiation in several ways:

(1) The source of radiation — the fallout — is largely outside, on the roof or on the ground and, therefore, not in immediate contact with man or animals, effectively preventing "beta burns";

(2) Radiation is partially absorbed by the roof and walls of an ordinary house and by the intervening air; and

(3) Radiation intensity is diminished through the effect of distance. For example, experience indicates that a person on the first floor of an ordinary frame house in a fallout area receives about one-half the gamma radiation dose received out-of-doors without any protection. If that person were in the basement of the frame house, his radiation dose would be reduced to about one-tenth the value outside the house. An underground shelter covered with a 3-foot layer of earth reduces the radiation to less than one-thousandth of the intensity of that on the outside. Cellars, including tornado and storm cellars, and stone spring houses also provide substantial protection.

Decontamination

Decontamination against radioactive materials is unlike that used against a disease outbreak where a disinfectant, heat, or some other physical means is used to destroy the causative organism of the disease — or in the case of chemical contamination where one chemical is used to neutralize another. **Radioactive materials cannot be destroyed.**

Therefore, since radioactive materials cannot be destroyed, decontamination involves the transport of the source of radiation (fallout). The fallout should be removed from a location where it is a hazard to a place where it can do little or no harm. Thus, there are two procedures, removal and disposal.

Work Schedules in Fallout Areas

Even during an early period following fallout, farm families will be faced with the necessity of doing such farm chores as caring for livestock and making other necessary trips into the open. If supplies of food and water have been protected from contamination and are readily available to the shelter, appropriate schedules of work and time in the shelter can be devised that can save lives and reduce injury to men and animals. Schedules will depend upon the severity of the fallout radiation hazard and the urgency of the task to be performed. **In planning emergency work schedules the guiding principle should be to keep radiation exposures to the lowest practical limit consistent with saving the community, family, and self.**

All but the most important tasks should be postponed as long as feasible to take full advantage of the decay of the radioactivity. Where possible the radiation exposure should be more or less evenly divided among the **adults** available to perform the necessary tasks. Exposure to radiation can increase the probability of genetic defects and may cause other harmful late effects. For these reasons, tasks involving radiation exposure should, where feasible, be performed by adults past the reproductive age.

Civil defense emergency exposure criteria indicate that an acute (short period of time) gamma radiation exposure dose of 200 roentgens is not likely to incapacitate more than a small fraction of the adult population so exposed, and that the body can gradually repair a large fraction of the damage resulting from nonlethal radiation doses. Consequently, a person's total radiation exposure may exceed substantially 200 roentgens without seriously incapacitating him, provided the radiation exposure is so distributed over a long period of time that the unrepaired portion of the injury does not exceed the injury that would result from an acute exposure of 200 roentgens. For convenience, the estimated unrepaired portion of a person's radiation dose is referred to as the Equivalent Residual Dose (ERD).

Table 1 presents an example of a work schedule for areas contaminated with radioactive fallout. Of course, where feasible, the periods out of shelter should be much less, particularly during the first few days when dose rates are high.

TABLE 1.—*Example of* **maximum** *adult work schedule for areas contaminated by radioactive fallout (4-week basis)*

(ERD 100 roentgens; H+1 dose rate 1,000r/hr—equivalent to about 100r/hr at H+7, or 22r/hr at H+24 hours;[1] shelter factor of 100—1% of unsheltered dose)

Time after explosion	Work period (time out of shelter)[2]	Time after explosion	Work period (time out of shelter per day)
	Hour		*Hours*
12 hours (same day or during *first* 24 hours).	½	4th through 7th day	2
		8th through 14th day	3
2d 24 hours	1	15th through 21st day	4
3d 24 hours	1	22d through 28th day	6

[1] Equivalent dose rates for H+7 and H+24 hours are stated in order that those possessing "citizens instruments" be able to measure the degree of fallout contamination in their specific areas and adjust the work periods to suit their situations. See text.

[2] Work periods may be split—part morning and part evening, for instance. It is assumed that most of the work period on the first day would be spent in a barn or similar structure and that on succeeding days at least one-fifth of the work period would be spent in such structures which provide some protection. First 2 weeks—off-duty hours spent in shelter allowing no more than 1 percent of unsheltered radiation to penetrate. Third and fourth weeks—major portion of the worker's off-duty hours spent in shelter but limited fraction of time could be spent in a typical basement or cellar.

For other degrees of contamination the example may be "scaled" to a degree. If the fallout contamination were double that assumed for table 1, humans might work for half the length of the indicated work periods, provided they had shelters with twice the protection. Unless it has been determined that there is no radioactive fallout in the area, all members of the farm family should remain within their shelter during the first 24 hours. Also, if fallout is heavy, say above 1,000 roentgens per hour at 1 hour after detonation, there would be little value in attempting to care for livestock unless they were protected by a shelter at least as good as that provided by a basement.

In the far more extensive areas where contamination is less, scaling of the example presents greater promise. With half the fallout radiation intensity (500 roentgens per hour at H+1 or its equivalent, 50 roentgens per hour at H+7, or 11 roentgens per hour at H+24) livestock could remain healthy with less shelter protection, although some shelter is still required. Given the same human shelter protection assumed for the area when the radiation intensity was 1,000 roentgens per hour at 1 hour after blast, the maximum work scheduled could be doubled, if necessary.

However, the work schedule presented in table 1 is a maximum for radiation exposures approximating those that would incapacitate. The schedule also allows considerable time for performing most of the important duties. Under less severe fallout conditions, one would be wise to stay within the time limits shown, if possible, and correspondingly reduce his personal radiation exposure with its associated hazards.

Handling Livestock

Livestock owners will generally find it impractical to remove animals from fallout areas. Therefore, facilities for the care of the animals in shelter and adequate supplies of uncontaminated feed and water for at least 2 weeks would be needed.

If warning of fallout is received, preparations should be made for the best possible care of animals.

(1) In the expectation of the immediate possibility of radioactive fallout, the following should be observed:

(a) If sufficient time is available, animals should be brought into shelter. Animals should be kept within shelter at least during the first critical period of 24 to 48 hours. A good tight barn would reduce radiation dose by about one-half. The best shelter given

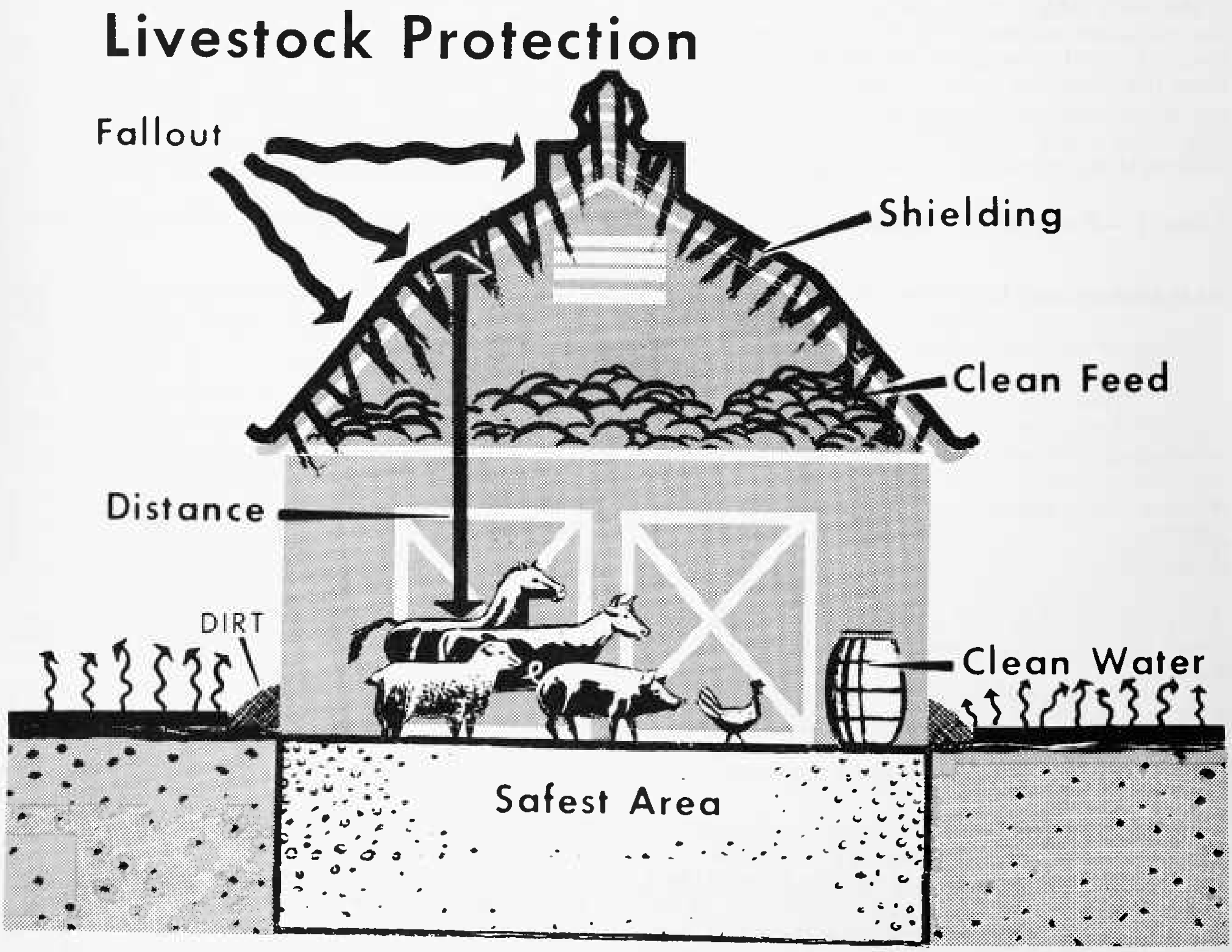


FIGURE 5.—The best protection likely to be available for livestock against radioactive fallout is in the basement of a tight barn with a loft filled with hay.

by a structure normally in use for livestock is a 2-story basement-type barn with a storage loft filled with hay. Proper use of shelter for animals can substantially reduce the number of deaths and injuries from radiation.

(b) Milking cows must be given the most protected place in the barn, not only for the sake of the animals but also for the safety of the milkers. The animals' feed should be reduced to the minimum needed for subsistence.

(c) Provision should be made for a reserve stock of food in the house and feed in the barn for the farmer and his family and for the animals for at least 2 weeks.

(d) If only a limited reserve of feed is stored so that it will not be contaminated, this feed must be reserved for one or only a few milking cows. This milk can then be used by the farmer and his household, primarily for children.

(e) If time allows, already harvested feed lying in the open should be covered with available materials such as tarpaulins. As much as possible of ready-to-harvest crops should be harvested and protected.

(f) Animals that are not placed in a barn or under a roof might, if possible, be placed under trees or where they are covered to some extent.

(g) It is better to keep animals alive on contaminated feed and water than to let them die from starvation.

(h) Take care to protect as big a water reserve as possible. In case of radioactive fallout, it should be remembered that water from sufficiently covered wells not containing surface water must be considered drinkable. During the critical emergency period, in areas contaminated with fallout, the use of water from lakes, creeks, other surface sources, and collected rainwater should be restricted. Use the protected water first.

(2) It may happen that warning will not reach the farmer in time and, therefore, he will not be able to handle his animals in the proper manner as explained in (1). These animals may be directly exposed to fallout. If practical, they should be thoroughly washed off as soon as it is possible for the farmer to stay outside for a limited time. After being washed, the animals should be taken into the barn, or other available shelter. During the washing, the farmer should wear protective clothes, including rubber shoes and gloves. The removal of radioactive fallout from the hide of the animal is difficult and may be ineffective in some cases. However, it will help to reduce the radiation exposure of both the animal and the animal caretaker or milker.

Acute total body radiation exposures of livestock (cattle, sheep, and swine) varying from 500 to 600 roentgens provide a midlethal dose—or the dose level that you could expect to kill 50 percent of the animals within 30 days. Poultry are more resistant, having a midlethal dose of about 900 roentgens. However, tolerance varies among species of animals as well as among animals within the same species.

TABLE 2.—*Percentage of mortality of unsheltered animals after 24-hours' exposure to various radiation doses*

Species	Mortality				
	100%	80%	50%	20%	0
	Exposure dose (roentgens) [1]				
Cattle	650	600	550	450	300
Sheep	700	600	525	450	350
Swine	800	700	600	450	350
Poultry	1, 200	1, 100	900	600	400

[1] Exposure dose in area where livestock and building are located.

All domestic animals have a similar response to **total** body irradiation. Few if any die after exposure to 250 roentgens. And few if any survive an acute dose as high as 1,000 roentgens. Smaller doses or slower dose rates are tolerated better than faster delivered large doses. Some animals like swine have a much faster recovery rate than others like the burro, although there is little difference in response of the species to acute exposure. The body size of the animal has little to do with survival, although the very young or the very old may be more radiosensitive.

Poultry

As indicated in table 2, poultry are among the more radioresistant species of our domesticated animals. Therefore, poultry may represent one of the more dependable sources of fresh foods of animal origin which may be available after a nuclear attack. Furthermore, most of the poultry raised are reared under shelter or are provided with some shelter available for protection from the normal environment. Consequently, compared with other livestock species, poultry should enjoy the greater chance for survival following a nuclear attack, because of the greater availability of immediate shelter for protection from radioactive fallout.

Still another factor to support the above conclusion is that most poultry are raised on commercially prepared or packaged grains or feeds and, moreover, these feeds are necessarily stored under some form of shelter. Therefore, considering the various livestock diets, poultry diets are least likely to be contaminated by radioactive nuclides. Thus, the hazards of direct and indirect (via the diet) fallout contamination are significantly reduced.

Shelter

The value of shelter in preventing death and sickness among animals is greatest in areas exposed to acute radiation doses about equal to the average midlethal dose (550 roentgens). At low radiation intensities, there is little beneficial effect from shelter because no animals would become sick or die whether sheltered or not. At high intensities of outdoor radiation, all animals would die under either condition.

Table 3 indicates the percentage of mortality that might be expected among various species of sheltered and unsheltered animals exposed to different intensities of radiation. This information should be considered as a general guide of expected mortality based on current knowledge, and not as a forecast of exact mortality rates.

The objectives of providing shelter for livestock and poultry are to (1) protect livestock from the lethal effects of radiation, thereby conserving an important food resource and (2) protect the feed and water of food-producing animals from radioactive contamination, thereby assisting the production of safe food products for human consumption. After the first critical 24 to 48 hours or when outdoor work periods can be scheduled, livestock can be given short periods of exercise in areas or yards that do not contain contaminated vegetation or water. When it is no longer practical to keep animals off contaminated pastures, supplemental feeding with uncontaminated feed should be provided as far as possible. (See Appendixes B and C for protection factors and suggested livestock shelters.)

Food animals that have received radiation doses that may result in sickness or death may not show any injury within a period of 2 to 10 days after exposure.

Meat from animals exposed to lethal doses of external radiation may be used for human consumption without great hazard from radiation. The greatest danger to human health in this case would come from bacterial invasion of the tissues as a result of radiation sickness. This may occur between the 7th and 12th day after exposure. Briefly, animals can be safely used for food if they show no temperature rise or apparent injury or illness. Temperatures may rise from 101.5° to 108–110° F. when bacterial invasion occurs. Some normally edible organs, such as the liver, would not be safe.

If any animal shows signs of sickness, it should not be slaughtered for food purposes until it is fully recovered and in good health. This may take several weeks or months. Sick animals may be treated according to the symptoms shown.

However, if animals have ingested or inhaled fallout, the butchering process would be complicated by the additional exposure of the workers to fallout on the animal's hides and in the alimentary and respiratory organs. These organs (lungs, trachea, stomach, intestines, esophagus, tongue, and lips) must be removed so as to avoid contam-

Table 3.—*Effect of shelter on the mortality rate of livestock* [1]

Kind of livestock and radiation exposure—unsheltered dose (number of roentgens—1 day)	Mortality rate by nature of shelter			
	No shelter	Tight wooden barn (protection factor of 2)	2-story barn with loft full of hay (protection factor of 5)	Basement-type barn with loft full of hay (protection factor of 10 or more)
	Percent	*Percent*	*Percent*	*Percent*
Cattle				
500	30	0	0	0
1, 000	100	30	0	0
3, 000	100	100	80	0
Hogs				
500	30	0	0	0
1, 000	100	30	0	0
3, 000	100	100	50	0
Sheep				
500	38	0	0	0
1, 000	100	38	0	0
3, 000	100	100	80	0
Poultry				
500	10	0	0	0
1, 000	64	10	0	0
3, 000	100	100	20	0

[1] The reduction of radiation by shelter is described as the "protection factor." For example, if the protection factor of any given structure is 2, then the intensity of outside radiation is reduced by one-half. See appendix B for additional information on protection factors for other types of farm dwellings. In fallout areas, one-half or more of the radiation would be released after the end of the first day.

inating usable parts. In this case, only muscle and muscle fat would be safe for use as food. The hides, organs, and other parts containing fallout must be disposed of by burial.

Irradiation Effects on Animals

General

In general, domestic animals are about as radiosensitive as man. There is no specific therapy for radiation sickness. In presumed cases of serious radiation injury, animals should be placed under observation and treated symptomatically if signs of radiation sickness appear. Animals surviving the first few weeks following a brief exposure may be expected to recover.

Limited studies indicate that unsheltered animals that fail to develop beta burns after having been in the path of a fallout cloud will ordinarily escape serious external radiation injury. Animals that sustain exposure intense enough to produce beta burns but live longer than 3 weeks or a month should recover.

If areas have been subjected to sublethal amounts of fallout, animals may develop signs of radiation sickness. Such animals might be placed on clean, uncontaminated feed and treated symptomatically. Treatment may include the use of antibiotics until they either recover or die from exposure to radiation.

Sexual and Genetic Effects

Sperm or ova production is halted following total body irradiation in the lethal dose range of 300 to 800 roentgens, and is not resumed until several weeks after general recovery. Male animals irradiated within the lethal range, however, maintain some interest in females in estrus up to just a few days before death. These animals may be fertile, as sperm may survive in the testes for a number of days after exposure to radiation. Doses in the lethal range are necessary to produce sterility.

Embryologic Effects

Irradiation of the embryo is particularly hazardous. Doses ordinarily without danger to the female can be of grave consequences to the embryo during early pregnancy. The abnormalities encountered are associated almost entirely with cessation of development of growth of a particular organ or organ system brought about by irradiation.

PROTECTION AGAINST INTERNAL RADIATION FROM FALLOUT

The second phase of radiation hazard from fallout is internal radiation; that is, exposure to the radiation from isotopes that enter the bodies of animals and human beings. These radioactive elements generally enter in food and water.

At first, the principal source of internal radiation is external contamination of edible plants when fresh fallout drops on the affected area. For livestock, this would include primarily forage grasses and legumes. For man, it would include fruits, vegetables, and milk — the last particularly for children. As time passes and the initially contaminated food and feed have been discarded, the principal source of internal radiation for man and animals is indirect — from the radioisotopes in the soil which are absorbed through plant roots into food and feed crops. When meat and dairy animals eat contaminated feed, some radioactive elements are absorbed into their bodies. Thus, man's food supply of both plant and animal products can become contaminated with radioactivity.

Radioisotopes Causing Internal Radiation

Many of the radioactive isotopes created by nuclear explosions are of minor concern, in the hazard of internal radiation, because of (1) the small amounts involved; (2) their extremely short or extremely long half-lives; or (3) the fact that they are not incorporated into the food chain (see glossary) and hence do not seriously affect man and animals.

Among the isotopes that are taken up in the food chain are the following: Barium 140, cerium 144, cesium 137, iodine 131, iodine 133, promethium 147, ruthenium 106, strontium 89, and strontium 90. Of these, the radioactive isotopes of most significance as internal radiation hazards are **barium 140, iodine 131, iodine 133, cesium 137, strontium 89,** and **strontium 90.**

Radioactive iodine, because of its chemical identity to ordinary iodine, accumulates in the thyroid gland when it gets into man or animals. However, iodine 131 has a relatively short half-life of 8 days. Iodine 131 will not be an important long-term fallout hazard, but it is the most hazardous internal emitter during the first 60 days. When considering the dosage to the thyroid derived from radioiodine in the first few days after attack, it is important to consider both

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MOVEMENT OF STRONTIUM 90

On and Into Plants

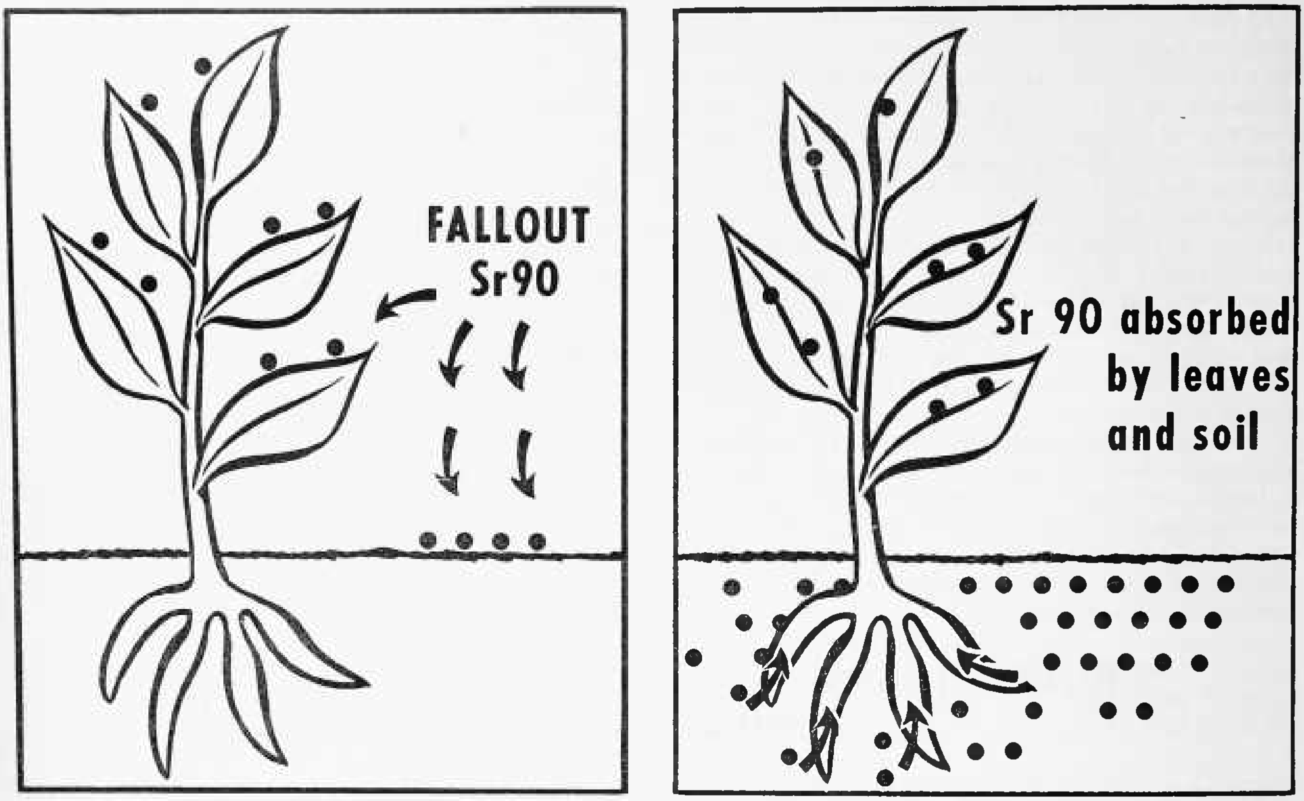


FIGURE 6.—When fallout first arrives, it falls on the surface of the plant and soil. As time passes strontium 90 is absorbed into the plant leaves and into soil where it is available to be taken up by the plant roots along with nutrients.

iodine 133 and iodine 131. Iodine 133 has a half-life of 22 hours but occurs in sufficient quantity to make a significant contribution to the thyroid radiation dosage.

Cesium 137 has a long half-life of 27 years and is chemically similar to the essential nutrient element potassium. When cesium 137 is consumed and absorbed, it is found primarily in muscle tissue and can cause several types of cell damage, including genetic damage. But this radioisotope is not retained long in the body. It continually enters and leaves the system just as does potassium.

Strontium 90, however, with a half-life of 28 years, is of primary importance. Strontium 89 is chemically identical, but it has a half-life of only 53 days. They behave much like calcium in soils, plants, and animals. Nuclear explosions produce large amounts of radioactive strontium. It is taken up in biological systems, in plants, is secreted in milk, and collects in bones, where some of the strontium 90 remains for years. Radioactive isotopes of strontium deposited in the bone probably can produce serious consequences, such as bone cancer. Children are relatively sensitive to radiostrontium, because during their early growth period they require larger quantities of calcium than adults, a greater fraction of the ingested strontium is deposited in their bones, the concentration of strontium is more uniform throughout their skeletons, and because they have longer life expectancies for a slowly developing disease such as bone cancer to occur.

Barium 140 behaves similarly to strontium 89 and strontium 90 in that it is deposited in the bone. However, both the proportion of ingested barium 140 that reaches the skeleton and the half-life (12.8 days) are smaller than for radiostrontium, so that barium 140 contributes less to the bone hazard.

Although the radionuclides mentioned above are of special concern in view of their predominance in the food chain, total fission products in fallout have to be considered in the event of food being contaminated directly with fallout. While only the group described above passes into the blood stream in significant quantities, the entire material irradiates the gastrointestinal tract as it passes through and can cause serious injury. The results of this damage are among those that appear earliest.

Protection of Food, Feed, and Water

The concern in protecting food, feed, and water is to prevent the consumption of contaminated materials that would subject man and animals to **internal** radiation hazards. However, the immediate problem is to protect a sufficient quantity from fresh fallout to provide for survival during the critical period.

The principle of protecting food, feed, and water from external fallout is simple: Prevent the fallout from becoming mixed or incorporated into these materials. They may be irradiated by the fallout, but if the radioactive particles do not come in actual contact with them — or if the fallout is removed — they will not be radioactive and thus will be safe to eat or drink. Methods of prevention would be the same as those for preventing dust from contaminating food or water if the air were heavily dust-laden. Fallout can also be removed in much the same way as dust — by washing, vacuum cleaning, and brushing. Precautions should be taken to avoid inhaling or ingesting the material while removing it.

Food

Radioactive fallout deposited on agricultural land will contaminate food chains with radioisotopes by way of the soil and crops. It may, depending upon the radiation intensity level, prevent farmworkers from handling crops properly. The deliberate overexposure of farmworkers to radiation in order to save contaminated crops that are not essential or might be discarded later is **not** warranted. Depending upon the stage of growth when fallout occurs, salvage of unharvested crops such as grain, fruits, and vegetables would be impaired by crop contamination, external exposure hazard, and unavailability of fuel and machinery.

For example, if fallout is heavy, ripe fruits may be lost because of the personal hazard in harvesting them. Fruits that do not have to be picked immediately and that can be decontaminated by washing and peeling before eating can probably be saved. Orchard trees should be maintained as usual and the fruits monitored for radioactivity.

Consequently, the land contamination problem in heavy fallout zones would be primarily a long-term soil contamination problem. For most crops and soils, about 1 percent of the available strontium 90 in the soil is removed in a single crop. On sandy soils, some crops may remove as much as 5 percent. Even at this higher rate of removal, more than 40 crops would be required to achieve 90-percent decontamination of the soil.

Fallout particles that fall directly on food and forage plants contaminate them by remaining attached to the aboveground parts, or by releasing radioisotopes that are absorbed into the leaves and other plant parts. Rain and wind move these particles from plants to soil, but certain characteristics of the leaves, such as hairiness and roughness, increase the retention while smoothness reduces it.

Strontium 89, strontium 90, and ruthenium 106 absorbed into leaves tend to remain there because they do not move readily into the other parts of the plant from the leaves. On the other hand, cesium 137 and iodine 131 will move readily throughout the plant from the leaf. Accordingly, internal contamination by strontium 89, strontium 90, and ruthenium 106 from leaf absorption is greatest in leaves and is comparatively less in fruits, seeds, and edible roots and tubers. As the season progresses, the fallout contaminants that have accumulated in the leaves, especially strontium 89, strontium 90, and ruthenium 106, may be washed from the leaves to the soil in rain and dew. They may then be absorbed by the roots and distributed throughout the entire plant and thereby increase the total content of contaminants. In arid regions with little rainfall these contaminants are not washed to the soil from the leaves, and any new growth that develops after the fallout will be relatively lower in strontium 89, strontium 90, and ruthenium 106.

Vegetables and fruits harvested from fallout zones in the first month after attack will require decontamination before they can be used for food. First, the exposed parts must be thoroughly washed to remove the fallout particles. Then vegetables or fruits should be peeled, pared, or the outside otherwise removed in such a way that hands or utensils do not contaminate the parts to be eaten. It should be possible to decontaminate almost completely such crops as apples, head lettuce, and cabbage by repeated parings, washing hands, and washing utensils before each paring. Since fresh fallout provides only surface contamination, it should be possible to wash and shell peas and beans or husk sweet corn to remove the contaminated parts. This type of decontamination could be applied to many human food items in the home immediately after harvest, preferably using well water, or other noncontaminated water. Cooking will not destroy radioactivity.

Some food products that have fallout on or mixed in them can be used only after holding the products long enough to allow the radioactivity to decay to a safe level. Storage of the contaminated material for a period ranging from 2 weeks to several months, depending upon the degree of contamination, will reduce the amount of radioactivity present, usually to a negligible level. This is due to the comparatively fast rate of radioactive decay. Obviously, many food products, including most meat that is not canned, could not be stored for the necessary time. Fallout on unpackaged meat presents a salvage problem, since it is extremely difficult to remove the outer surface without carrying contamination onto other parts of the meat. Washing is not an effective method of removing this type of contamination. Meat products contaminated with fresh fallout could be canned and then stored until the radioactivity had decayed sufficiently.

Meat and meat food products in home or commercial storage will be most effectively protected if canned. For uncanned products, a sealed covering of one of the commonly available plastic films, such as polyethylene, will provide adequate protection from contamination by fallout. Even fiberboard and similar tight containers that will exclude dust will be effective. Refrigeration facilities should be maintained as usual to control spoilage.

Feed and Water

Because early radioactive fallout is dustlike in character and results in surface contamination, the simplest method to protect feed and water is to place a cover over them to prevent fallout from coming in direct contact with the materials.

Grain stored in a permanent bin and ensilage in a covered silo are provided with adequate protection against fallout, and the contents can be safely used as soon as the farmer is able to get into the area to use them. The haystack in an open field can be protected with a covering such as a tarpaulin. The fallout will lodge on the tarpaulin, but by carefully removing it, the radioactive fallout will be removed. The hay and the contents of the feed bin and silo would not be radioactive and could be used immediately as safe feed for live-

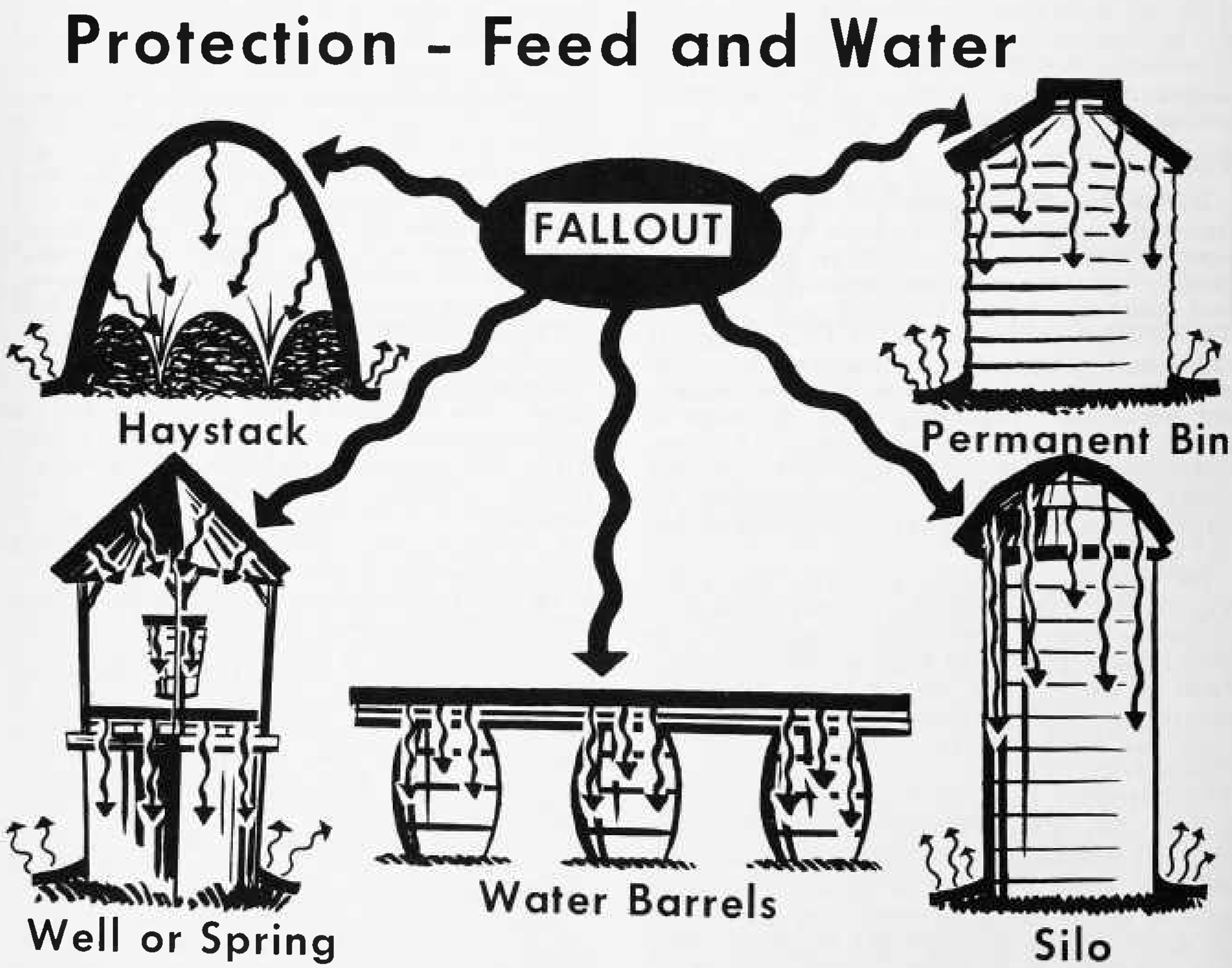


FIGURE 7.—A tarpaulin on a haystack and other covering for feed and water prevent fallout from becoming mixed with the materials and thus prevent contamination. Even though the materials have been irradiated, when the fallout is removed from the covering the feed and water are not radioactive.

stock. Many materials such as uncovered haystacks and piles of farm produce may be safely used as food and feed if the contaminated outer portions are removed.

Water stored outside—such as in stock water troughs—should be covered with any material that would normally keep out dust. Larger farm ponds and lakes would be difficult if not impossible to protect. As time passes the problem of contamination of ponds and lakes may not be a major problem. The dilution of the radioactive fallout in the water and its adsorption by clay on the sides and bottoms of the pond or lake will be effective in reducing the hazard below that of the surrounding land. The mere boiling of water contaminated with radioactive particles will not make it safe but distillation does remove nearly all of the radioactive material.

Water from covered sources, such as springs and wells, would be essentially free from contamination even in heavy fallout areas and could be used for man and animals with confidence.

Radioactive Iodine and Radioactive Strontium in Food

The study of radioactivity in milk has been more widespread than in other foods for several reasons. Milk provides a vital part of the Nation's diet, particularly for young children, invalids, and older people for whom substitutions in diet are difficult. Because of the normal system of production and distribution of milk in this country, it is one of the easiest foods to obtain for testing at central points and, therefore, more testing of milk has been done. Milk is produced throughout the year in all sections of the country so that samples are always available.

Several radioisotopes ingested by dairy animals can be secreted in milk to an appreciable degree. Among them are iodine 131, strontium 89, strontium 90, barium 140, and cesium 137. The most important of them are usually considered to be iodine 131, strontium 89, and strontium 90. The effects of others are believed to be less important.

Radioactive Iodine

For a period of days following a heavy deposition of fresh fallout, iodine 131 may be a major radioactive contaminant of vegetation, including food crops such as fresh vegetables and fruits. After ingestion by animals, iodine is rapidly absorbed from the gastrointestinal tract, collected in the thyroid gland, and secreted in milk and eggs.

In the event of a nuclear attack, radioiodine would be the most critical single factor in the contamination of milk during the first few weeks after an explosion. The hazard would decrease relatively rapidly (see table 4) because of radioactive decay, but the short-time problem would be serious in some areas.

A large fraction of the radioiodine ingested by human beings, ranging from about 20 percent for adults to 50 percent for children, is deposited in the thyroid gland. In addition, children are relatively more sensitive to radiation of the thyroid than are adults. It has been estimated that the ingestion of 5 microcuries (see glossary) of radioiodine would result in a dose of 200 rads (see glossary) to the infant's thyroid. The infant thyroid weighs about 1.5 grams, whereas the adult thyroid weighs about 20 grams. For several reasons, therefore, a greater amount of radioiodine is required to damage the adult's than the infant's or child's thyroid.

TABLE 4.—*A general guide to the periods of time before contaminated milk should be consumed* [1]

Roentgens per hour at H+1	Time before consumption by—		
	Infants under 2 years	Children 2–16 years	Adults over 16 years
	Weeks	*Weeks*	*Weeks*
10	0	0	0
30	1	0	0
100	3	1	0
300	5	3	0

[1] Estimates based on radioiodine contamination and the rate of its radioactive decay. To be used only if adequate alternative sources of milk are available and if specific local information is lacking.

Table 4 is a suggested guide that would result in a milk contributing not over 200 rads to the child's thyroid or 1,000 rads to that of the adult. Table 4 is intended as an approximate temporary guide to the usability of fresh milk during the first part of the critical postattack emergency period. If alternative uncontaminated sources of milk in various forms are unavailable or inadequate for subsistence, the guide should be ignored to the extent necessary for the maintenance of life and general health. As alternative assessment of the food situation and analytical measurements on milk become available with the passage of time, the general guide should be supplanted by specific knowledge of a local situation.

Since milk is an essential food for infants and other young children, and the weight of milk consumed by them is high in relation to their body weights, the contamination of milk with radioiodine during the first weeks after nuclear attack would be primarily a problem of thyroid injury to young children.

Studies indicate that sheep whose thyroids have been exposed to radiation doses ranging from 50,000 to 70,000 rads do exhibit serious pathological and physiological disfunctioning. Observations on cattle show that they require at least twice the radiation dose of sheep for thyroid changes.

The hazard discussed here is created by dairy animals grazing on vegetation contaminated with radioiodine from fallout and thus producing contaminated milk. Available information indicates that from 5 to 10 percent of the daily intake of iodine 131 is secreted in milk of dairy cows. On the basis of current knowledge, suggestions have been developed for reducing the hazards of radioiodine in milk in the event of a nuclear attack.

Milk produced from pastures that received fallout equivalent to a radiation level of 30 roentgens per hour or higher 1 hour after a nuclear bomb explosion should not be used immediately for consumption by infants. For example, several days after a nuclear explosion, civil defense authorities measure the radiation level in a given area. From this measurement, the equivalent radiation level at H+1 can be calculated. If this is as high as 30 roentgens per hour, then milk produced by cows **grazing** in that area should not be used as fluid milk by infants for 2 weeks after the explosion, unless specific radioiodine measurements show the milk to be safe or other sources of usable milk are lacking. Table 4 indicates the time before acceptance at other levels of radiation.

It would be best to have a means of expeditiously determining the iodine content of milk; for example, a special monitoring instrument (milk counter probe for radioiodine). Until such equipment is developed and available, table 4 can be used as a guide.

Stockpiles of storable milk or milk products for children are needed. Some areas, affected by fallout but not by the bomb blast, may not be producing safe fresh milk for 2 months if the above standards are met. Therefore, families with children should keep an ample supply of powdered milk, whole or skim, or canned milk on hand to help provide necessary nutrients during this period. This supply should be rotated into current use and the reserve replenished regularly.

Reducing Iodine 131 Contamination of Food and Dairy Products

On the premise that radioactivity from iodine 131 has largely disappeared from materials after a 2 months' period, the dairy farmer can confine lactating animals to the barn before the appearance of fallout in the area and provide forage and feed that had been harvested before the detonation or stored for 2 months after exposure to fallout. Freshly contaminated forage can be fed to nonlactating stock. Concentrated mixtures prepared on the farm should be prepared from grains harvested before the fallout or that have been stored for 2 months or longer. Ensilage that has been stored for at least 2 months could also be a safe feed for dairy animals.

Confining dairy animals to reasonable dust-tight buildings and providing them with clean, noncontaminated feed and water will aid greatly in minimizing the contamination of the dairy products produced.

If, despite all precautions, fluid milk supplies should become contaminated, a number of steps could be taken to avoid danger to consumers. Since the half-life of iodine 131 is only 8 days, its decay is moderately rapid and delayed marketing is a key to safe usage of contaminated milk and dairy products.

If the contamination of milk supplies with iodine 131 were fairly localized, milk from other areas with little or no contamination could be diverted to contaminated areas for immediate consumption, and the contaminated milk processed and stored for later consumption. If contamination were widespread, this might be impractical and consumption of fresh fluid milk would have to be deferred until radioactivity was reduced to safe levels.

For high rates of contamination, storage for 1 to 2 months might be necessary before iodine 131 was reduced to safe levels. Freezing of packaged milk in paper cartons for storage before delivery would be one way of handling the problem. The frozen product would be thawed before delivery to the consumer and the consumer would have no responsibility for keeping track of storage time. During the period when fresh milk supplies were not available, reconstituted dry milk or canned milk could be safely used.

Any of these marketing modifications would be difficult. Nevertheless, they could become necessary.

There should be no destruction or disposal of milk contaminated with iodine 131, since it can be processed into products such as butter, cheese, powdered milk, and canned milk, and stored for a period of time to allow the decay to take place. If processing facilities are not available locally or are not adequate to handle all the milk involved, the contaminated milk can be fed to pigs or calves.

Infants and persons with special dietary needs should get safe milk supplies where limited. During the first weeks after the explosion, adults and children who can get an adequate diet from other foods should leave the restricted safe milk supply for infants and others for whom it is a mainstay in the diet. Mothers should breast-feed their babies during this period insofar as is consistent with medical advice.

Milk produced from existing vegetation in areas of higher radiation levels can be converted into storable dairy products or animal feed. In areas for which the relevant radiation level at H+1 was from 30 to 300 roentgens per hour, dairy cattle may have to continue to graze contaminated pastures. The milk production can be converted into such products as dried milk, canned milk, cheese, butter, and ice cream. These products should be stored until the radioiodine has decayed to a safe level as indicated by table 4. The milk might also be fed to calves or pigs, and the meat thus produced would be safe for human consumption.

Radioactive Strontium

After the first 60 days, the principal hazard of radioactive contamination in milk arises from strontium 89 and strontium 90. The strontium 89, however, will have virtually disappeared by 1 year after its formation. Just as other radioactive isotopes of fallout, strontium 90 falls on the surface of plants and can be consumed with foods and forage. Some of it is deposited directly on the soil or washed into it, remaining indefinitely — for all practical purposes — in the top several inches.

The return to earth of strontium 90 in worldwide fallout from large nuclear detonations is rather slow. Rainfall is the principal mechanism that brings stratospheric strontium 90 to the ground from the air.

Strontium 90 movement into plants has an important association with plant physiology and soil conditions. There are two general routes of entrance for strontium 90 into plants. The first is direct contact with the parts of the plant occurring above the soil. As time passes, following the deposition of fallout, the second route — entrance into the plant roots through the soil — becomes relatively more significant.

Strontium 90 enters plants by three means other than from the soil through the root system. These avenues are floral, foliar, and stem base or root mat.

The floral route is fairly common in plants. Cereal grains are good examples. Rain bearing strontium 90 collects in the upturned flower of the plant. At least a part of this contamination is retained by the developing kernels.

Strontium 90 may also gain entrance into the plant by foliar absorption, that is, through the leaves. There is, however, little movement of strontium 90 from the leaf to other parts of the plant. Consequently, the oldest leaves of a continuously exposed plant have the heaviest internal concentration. With cabbage or head lettuce, removal of the older outer leaves removes most of the contamination from this source. Grazing animals, however, usually consume these parts of grass if the pasture is used at its optimal capacity.

Another route for the entrance of strontium 90 into a plant occurs in permanent pastures composed of perennial grasses having a root mat, by absorption into living roots and stem bases in the mat.

As a rough approximation for sloping land, about 90 percent of the strontium 90 that falls on the soil will remain where it falls. Studies indicate that soil material eroded by surface runoff is about 10 times as high in strontium 90 as the remaining soil. Small areas at the base of slopes may accumulate this material. Areas subject to accumulation should be monitored frequently, especially if used for food crops.

Radioactive Strontium in Food

Strontium is similar to calcium in behavior and is closely associated with it in soil and food and bones. Strontium in the soil is taken up by plants along with calcium.

Fortunately, the metabolic processes of both animals and humans act to reduce substantially the amount of strontium that is deposited in the bones of man relative to that of calcium, as compared to the amount that was originally present in the vegetation and in the soil on which it grew. This protective mechanism is measured by the term "discrimination factor" and refers to the natural preference that the body has for calcium over strontium. Relatively more calcium than strontium is carried along as these elements move together through the food chain from the soil to the plant and then through the body to the bone. In milk the discrimination process operates twice. The biological system of the cow screens out over 90 percent of the strontium in her diet, and the biological system of man screens out still more of the strontium consumed in milk. The same is true, but to a lesser extent, in the production of meat and eggs.

About 70 to 80 percent of the calcium in the average diet in this country comes from milk and cheese. But calcium from these sources carries only about 40 percent of the soil-derived strontium associated with our food.

Meat and eggs contribute only about 5 percent of the calcium and 5 percent of the soil-derived strontium in the diet. Plant foods — grains, vegetables, and fruits — furnish about 15 percent of the calcium in the diet but, because they are consumed directly, they would furnish about 55 percent of the total soil-derived strontium.

Because of the discrimination factor within the human body, the ratio of strontium to calcium retained in the bone is only about one-fourth to one-half (the latter value is especially applicable to children) as great as the ratio of these two elements in the diet. For example, if the ratio in the human diet is 16 micromicrocuries of strontium 90 to 1 gram of calcium, then the ratio in the bone will be about 4 micromicrocuries of strontium 90 per gram of calcium.

Milk should continue to be the outstanding source of calcium in the diet, because the calcium it supplies has had much of the strontium present in the vegetation screened out by the biological system of the cow.

It should be remembered that milk is an essential source of calcium for the bones and teeth of growing infants and children. Any widespread disruption of the production and distribution of this nutritionally essential commodity could create

SOURCES OF CALCIUM AND STRONTIUM 90
From Food

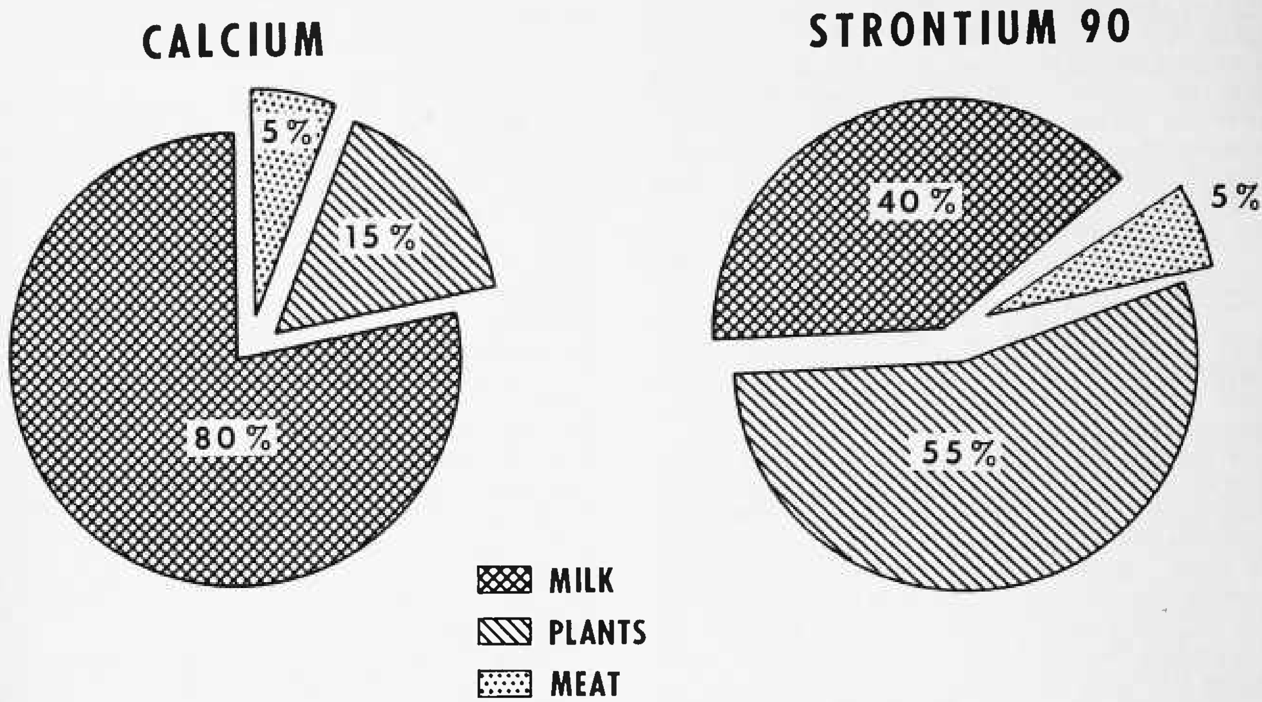


FIGURE 8.—Sources of the calcium and strontium 90 that are contained in human bones are principally milk, plants, and meat. The discrimination factor is demonstrated by the large percentage of calcium derived from milk while the relatively small amount of strontium 90 is being accumulated.

individual and public health hazards far more immediate and serious than might be created by the amounts of radioactive exposure involved at *low* levels of strontium 90 contamination.

Additionally, reduction of milk consumption by children, without competent medical supervision, could not only result in nutritional imbalance but might actually increase strontium 90 exposure, since milk has a lower strontium-to-calcium ratio than other foods.

Also, results of research on animals indicate that a body well nourished with respect to calcium does not retain so much strontium as a body that is deficient in calcium.

In a contaminated environment, rations for dairy cattle can influence the strontium 90 content of milk. For example, a diet of grass hay, corn, and inorganic calcium would provide less strontium for the animal than a diet of legumes, such as clover, lespedeza, or alfalfa, which are good sources of calcium but which would also contribute a greater amount of strontium.

Research studies clearly show that the level of strontium 90 contamination of milk will depend upon the amounts of strontium 90 and calcium in the ration. There would seem to be little gain in simply adding mineral calcium to an otherwise adequate diet. First, any dietary modification would have to be carried out continuously over a reasonably long time period to permit adaptation of the animal. Secondly, it would be difficult to get a dairy cow to eat more than 200 to 300 grams of calcium per day and higher levels might be inadvisable from the standpoint of the health of the animal. Thus, if animals were normally consuming about 80 grams of calcium per day, a reduction factor of 2 to 3 is the most that could be expected by increasing the calcium intake on a usual diet.

A ration consisting of 8 pounds of alfalfa hay, 12 pounds of timothy hay, and 12 pounds of grain would supply a dairy cow with about 80 grams of calcium; mineral supplementation to 160 grams daily would be expected to give a reduction factor of about 2. On the other hand, a ration of 20 pounds of timothy hay and 12 pounds of grain would supply about 40 grams of calcium per day, and supplementation to 160 grams would provide a reduction factor of about 4. The two reduction factors are comparable only if the total strontium 90 is equal in both rations.

In the event that it is necessary to shift from legume hays to the feeding of grass hays to dairy cattle and to supplement their calcium intake, it is recommended that the grass hays be liberally fertilized with nitrogen fertilizer in order to get acceptable yields and that the hays be harvested at the stage when they will be most palatable and digestible and contain the greatest yield of usable nutrients per acre.

To help assure the availability of a safe milk supply following a nuclear disaster, cooperative research between the U.S. Department of Agriculture (Agricultural Research Service), the U.S. Department of Health, Education, and Welfare (Public Health Service), and the U.S. Atomic Energy Commission is resulting in the development of a procedure for removing radiostrontium from milk. The procedure is similar to that used in many homes to take the hardness out of water and to that used in some dairy plants for many years to prepare low-sodium milk.

This procedure will provide a means for removing strontium 90 from milk that can be placed in the dairy plant on a standby basis to be available in case of an emergency.

Studies indicate that the procedure can remove up to 90 percent of the strontium 90 in milk, and that neither the mineral content nor the flavor is appreciably altered.

Croplands Contaminated by Fallout

A nuclear attack on this country could contaminate huge areas of crop and rangelands with radioactive fallout. This contamination presents a twofold problem: (1) the external exposure of agricultural workers who attempt to enter heavily contaminated areas — or to leave protective shelter in such areas — to carry out farm duties; and (2) the continued production of food without excessive internal radiation hazard to the population, because succeeding crops grown on this soil would take up some of the contamination.

The first hazard, external exposure, can be at least partially combatted by observing maximum work periods and denial times for outdoor activity as suggested in table 1. In combatting the second hazard, research workers are conducting studies on methods of using contaminated soil for agricultural purposes or for decontaminating it.

Use of Contaminated Land

One of the first decisions to be made by agricultural leaders is how to use land contaminated with fallout in order to continue to produce, indefinitely, a diet that permits the survival of the people without exposing them to unacceptable internal radiation hazards. Table 5 has been devised to serve as a guide for such decisions. Land contamination levels (acid-soluble strontium 90 is assumed to be the long-term available strontium 90) for each food group are based on the expected strontium 90 content of the foods. Land contamination levels for denial of the use of the land for the various food groups may be raised or lowered as more information becomes available. Under no circumstances should land be cultivated if the farmer or rancher thereby will expose himself to unacceptable levels of external radiation.

With the present average diet, Americans are presumed to derive about two-fifths of their strontium 90 from dairy products, one-twentieth from meat and eggs, and the remainder from plant foods, including fruits, vegetables, and cereal products. If uncontaminated milk and dairy products are used, other foods from plant and animal sources can be accepted from land with 50 percent more contamination (as indicated in table 5) without exceeding the recommended limit for strontium 90 in the total diet. If dairy products and food from plant sources could be obtained free of contamination, meat, eggs, and poultry could be accepted from land with much higher levels of contamination.

TABLE 5.—*Guide for land usage, based on soil contamination levels of acid-soluble strontium 90 above which production of foods should be limited, by available calcium level of the soil* [1]

Product of land	Contamination level per square mile on soil with—		
	Low Ca (2,000 lbs. /A.)	Medium Ca (6,000 lbs./A.)	High Ca (20,000 lbs./A.)
	Curies	*Curies*	*Curies*
All foods in the diet, if they all come from a contaminated area	3	10	30
All foods other than dairy products, if they come from a contaminated area, and dairy products are free from contamination	5	15	50
Meat, eggs, and poultry, if all other foods are free from contamination	60	200	600

[1] This guide is based on a daily intake of 2,000 micromicrocuries of strontium 90.

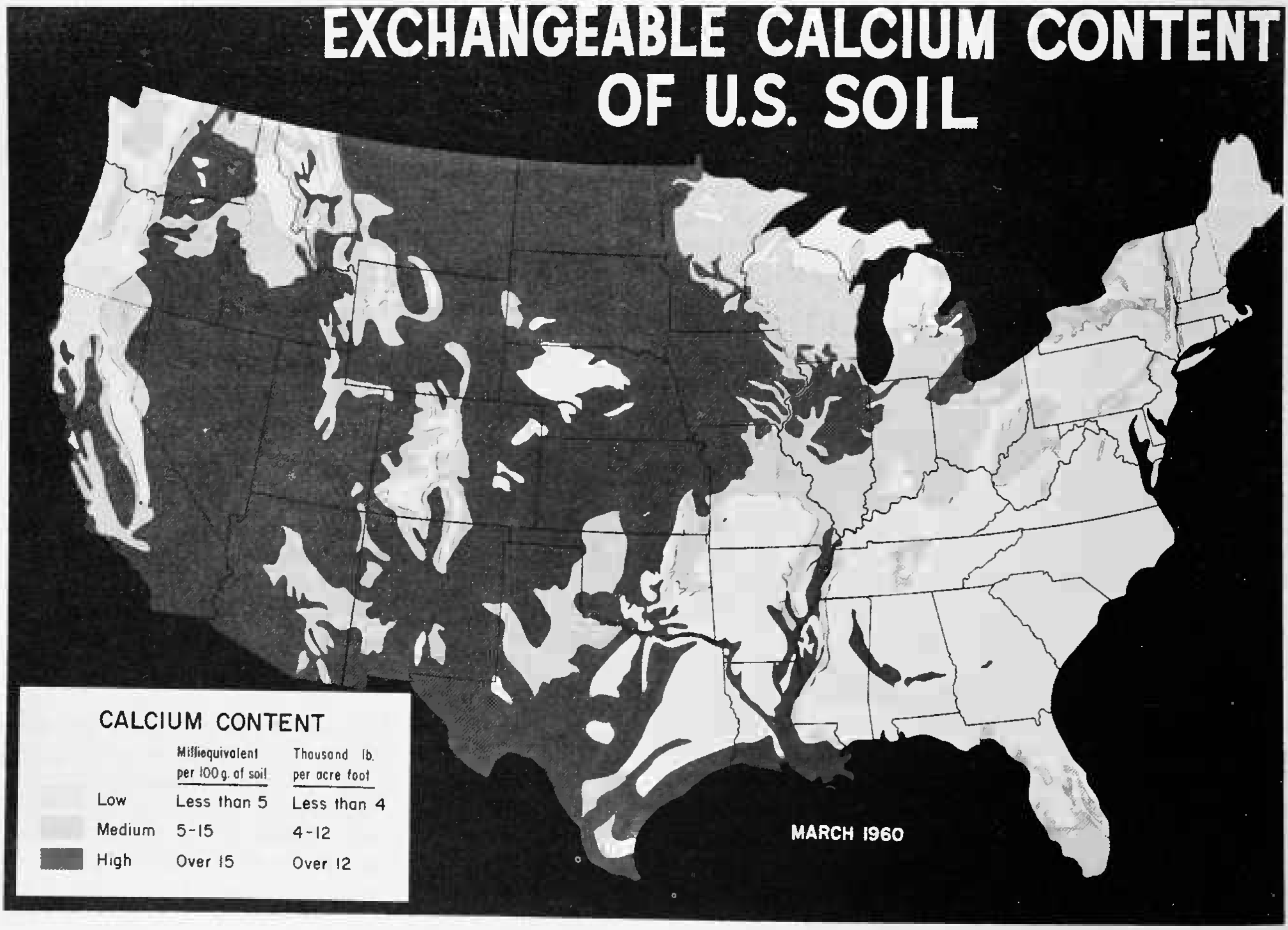
The amount of contamination of crops with strontium 90 depends markedly on the available calcium content of the soil. For simplification of the table, soils have been grouped as being low, medium, or high in calcium content of the root zone, which is considered to be about 1 foot for most soils and crops. A sandy loam soil of pH about 5 may contain 2,000 pounds or less of available calcium per acre. An average loam soil of pH about 6 may contain 6,000 pounds of available calcium per acre and would be considered medium. A silt loam or silty clay loam of pH about 7 may contain 20,000 pounds or more of available calcium per acre and would be considered high. The available calcium contents of most agricultural soils of the country are well known from soil test data. (See map of the exchangeable calcium content of U.S. soil.)

A delay of several months or longer might elapse before strontium 90 analyses could be made on many contaminated soils. Therefore, it is recommended that temporary land use be based on the standardized gamma radiation intensity at H+1. On low-, medium-, and high-calcium soils, the recommended intensities, above which crop production should be limited, are 100, 300, and 1,000 roentgens per hour, respectively. The purpose of the temporary limitations is to minimize in a practical manner the cultivation of land that should be decontaminated before plowing.

The denial of land use, on the basis of strontium 90 analyses, is suggested for an indefinite period unless modified by other measures. For example, decontamination of the soil by such methods as surface soil removal and deep plowing would increase the suitability of the land for agricultural production.

Contaminated land may be diverted to other uses if the radiation level is too high for the original type of production. The diversion may mean changing the species of crop grown on the land. The quantity of strontium 90 absorbed could be reduced by growing crops with low concentrations of strontium and calcium in their edible tissues. Potatoes, which contain about 10 milligrams of calcium per 100 calories, are a particularly suitable crop in contrast to leafy vegetables, which may contain from 100 to 1,000 milligrams of calcium per 100 calories. Corn would be another low-calcium crop to consider. Sugar and oil crops would also be suitable low-calcium crops for substitution on land too heavily contaminated to produce other foods. In general, crops producing high-calcium foods should be grown on the less contaminated land. However, since plants are a source of calcium, the calcium content of diets containing only low-calcium crops would be low. Unless alternative sources of dietary calcium were provided, a change to low-calcium crops would have obvious limitations.

Land formerly used for dairying can be diverted



to the production of beef or other meat. The strontium retained by animals grazing contaminated pastures or eating contaminated hay goes mostly into the bones or milk and not into the meat. Consequently, the meat produced on contaminated land, within the limits set in table 5, could be boned and used for food.

Byproducts of crops produced on contaminated land, such as beet pulp, and cottonseed, linseed, and soybean oil meals, should be used as animal feeds only in accordance with the levels of contamination set in table 5. Milk produced on contaminated pastures could be used as feed for meat production.

Another diversion might be to take the land out of food production and use it for the production of cotton fiber, flax, castorbeans, timber, or other nonedible commodities. If the land is very heavily contaminated, it might have to be taken out of agricultural production for an indefinite period or decontaminated.

Reducing Strontium 90 Uptake With Soil Amendments

The addition of lime, gypsum, fertilizers, or organic matter in practical amounts usually reduces the uptake of strontium 90 by less than 50 percent. Combinations of soil amendments and tillage practices may reduce the uptake more than would any single amendment. The best use of soil amendments for maximum crop production is often the same as their best use for reducing strontium 90 uptake.

The plant's need for the calcium of lime or gypsum leads to the absorption of the chemically similar element strontium. In soils low in exchangeable calcium, more strontium 90 will be taken up by the plant. By liming acid soils, more calcium is made available to the plant and less strontium 90 will be absorbed. It is useful on highly acid soils on which liming would be normally beneficial for other reasons. Gypsum would be most useful on soils containing large quantities of exchangeable sodium, which would normally need gypsum regardless of the strontium 90 hazard. However, usually at best, the application of lime can reduce the strontium uptake to only about one-half of that from untreated soil.

For most soils and crops, it is recommended that lime not be applied in excess of the amount of calcium needed for maximum crop growth.

In the production of small cereal grains, the addition of **more** calcium than is needed for optimal growth may be helpful in reducing the strontium hazard, without reducing the quality or quantity of the crop.

The application of lime to the surfaces of established pastures increases the calcium content of the vegetation. An application rate of 2 tons of lime per acre, for example, has lowered the ratio of strontium to calcium in grass pastures by two-thirds.

Farmers should use the amount of lime recommended by their county agents or State officials to bring the soil approximately to pH 6.5. The limestone should be finely ground so that it will react quickly with the soil. On plowed land, it should be mixed thoroughly and as deeply into the soil as possible. A surface application on pastures growing in acid soil will also reduce the strontium 90 content of forage, but it may not be possible to use as much lime on pastures as in plowed soil.

Best results from liming are possible on infertile or highly acid soils of the type found in the humid eastern half of the United States. This is because acid soils are low in available calcium, and lime, a calcium compound, makes this essential nutrient available to plants. In low-calcium soils, the plant's need for the calcium leads to absorption of the similar element, strontium. Thus, liming would have no appreciable effect on strontium intake in good agricultural soils containing plenty of available calcium.

No one season is best for applying lime but, in areas where the winter weather is cold enough to harden the ground, farmers often prefer to apply lime when the ground will support heavy spreader equipment easily.

Potassium fertilization of soils of relatively low available potassium content at the rate of several hundred pounds per acre can also reduce the uptake of strontium 90. However, the calcium uptake by the plants is also reduced by this practice. Crop residues and manure applied at the rate of 20 tons per acre have reduced the uptake of strontium 90 by one-third.

Croplands Contaminated by Irrigation Water

Irrigation waters will not add much strontium 90 to agricultural land compared with direct fallout on the cultivated soil or on crops themselves. Strontium 90 and other fallout isotopes are considerably diluted in surface waters of any appreciable depth. Most of the radioactive contaminants, including strontium 90, are readily adsorbed by the soil of the banks and bottoms of lakes and streams. They are subsequently adsorbed further by irrigation canal linings and ditch banks. Any strontium remaining in the water is subject to adsorption at the surface of the cultivated soil with which the water first comes into contact, and thereby is added to the surface accumulation originating from direct fallout.

Direct contamination of crops by sprinkler irrigation with contaminated water pumped from lakes, streams, or ponds would be a greater hazard, particularly from the contamination of leafy

EFFECT OF LIMING ACID SOIL
On Uptake of Strontium 90

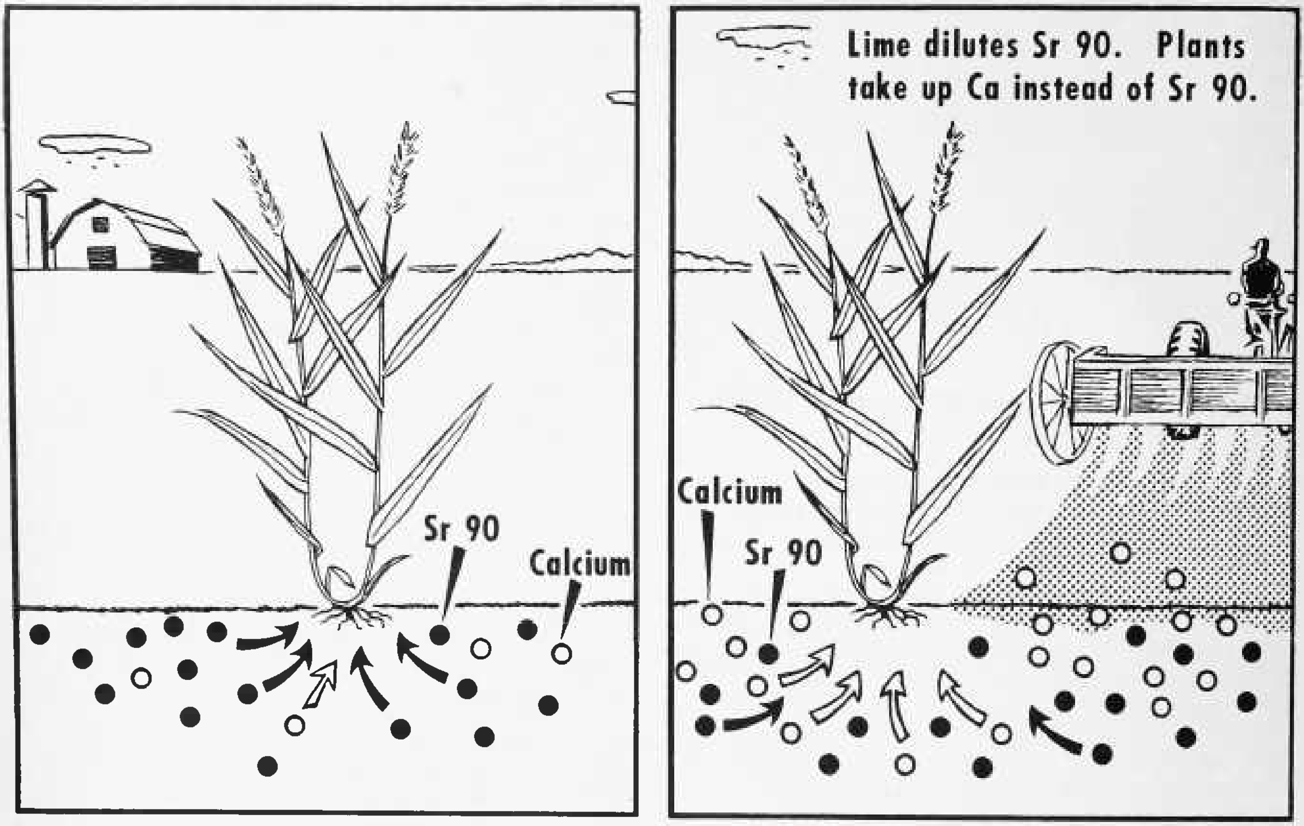


FIGURE 9.—Addition of lime to contaminated acid soil dilutes the strontium 90 present and favors the uptake of calcium instead of strontium 90 by plants.

vegetables. Irrigation water used for such crops, applied with a sprinkler system, should be as low in radioactive contamination as acceptable drinking water.

Reclaiming Contaminated Land

Agricultural land should not be subjected to drastic remedial measures such as decontamination until after it has been seriously contaminated with strontium 90.

Neither special remedial measures nor unusual modifications of normal practices should be introduced, however, until responsible authorities have declared that a state of emergency exists, making some kind of decontamination measures advantageous or necessary.

For instance, it might become necessary to reduce the radioactivity in small highly contaminated areas, or in large areas generally blanketed by radioactive contamination. These situations would require decontamination measures, drastic modifications of usual practices, or a sequence of smaller remedial factors at various successive links in the food chain.

Decisions concerning the application of drastic measures or of sequences of measures probably never will be made easily. They must be based on balancing medical assessments of probable damage from radiation against the cost, along with the resulting reduction in available food supplies, and the economic and social dislocations.

The usefulness of a particular remedial measure depends primarily on how well is does the job it's supposed to do. Various possible methods already have been experimentally investigated. Others remain to be studied.

Field experiments have shown that when fallout is deposited on land where standing crops are growing, no more than one-third of the deposit can generally be removed from the land by harvesting the aboveground portion of the plants by mowing.

Decontamination of soils is necessary primarily for the removal of strontium 90. Other biologically significant fisson products either are taken up from soils by plants in much smaller amounts or have such short lives that decontamination is not necessary. In zones of heavy strontium 90 deposition, stringent decontamination measures will be necessary in order to reduce the strontium 90 content of the soil to a level acceptable for the production of vegetables and milk. (These products absorb a greater percentage of the available strontium 90 than do others.)

For the production of other crops, or in zones of lighter strontium 90 deposition, it may be sufficient to use less effective practices which reduce the uptake of strontium 90 to a lesser degree. Obviously, heavily contaminated lands should be placed in cultivation only when their use is absolutely necessary. In fact, the degree to which any land is decontaminated must depend upon the availability of manpower, fuel, and equipment, and most important, upon the need for more cropland. The costly methods of decontamination now known would be used only in limited areas of intensively used croplands.

Decontamination by Removal of Ground Cover and Crops

Decontamination by the removal of ground cover is effective when the existing cover is thick enough. Tests and experiments revealed that removal of heavy contaminated mulches, 5 tons per acre, removed from 50 to 80 percent of the radioactivity even following irrigation. Removal of lighter mulches, 2 tons per acre, removed from 30 to 50 percent. The cutting, rolling, and removal of sod contaminated with fallout resulted in a reduction of radioactivity by over 90 percent.

Standing crops usually provide less complete ground cover, especially when young, and their harvest may remove only a small fraction of the fallout. Contaminated crops could be disposed of by harvesting and baling to reduce their bulk. The bales must be stored where they will not contaminate other foods. The workers should wear respirators to avoid breathing the dust created by these operations. Clothing should be kept as clean as possible. Thorough washing of the hands and face is necessary before eating.

Soil in greenhouses closed at the time of fallout deposition would provide a limited source of uncontaminated soil.

Decontamination by Removal of Surface Soil

The removal of surface soil is one of the most effective methods of decontamination, but it would be expensive, in many areas may not be applicable and, with the procedures developed at this time, not suitable for large areas. It might be useful if small clean areas are needed to produce food for survival of people.

The effectiveness of decontaminating surface soil by scraping varies from being partially successful for rough land to being highly successful for smooth land. Rough, freshly plowed surfaces are difficult to decontaminate. Scraping off 2 inches of soil with a road grader may remove more than 99 percent of the fallout from smooth soil, but only 60 percent from rough soil. The latter value is too low to justify the effort and expense. Rough soil surfaces may be decontaminated more completely by scraping off more soil or by repeating the scraping operation. Just as in harvesting, precautions against breathing dust and for cleanliness will be necessary.

The safe disposal of contaminated surface soil after removal is a serious problem. For the large volumes of soil involved, the only practical places for disposal appear to be pits in the center of small fields or regularly spaced ditches across fields. The pits or ditches would have to be protected from erosion and should not be used for crop production.

Other Methods of Decontaminating Soil

Several other methods of decontaminating soils appear to be even less practical on a field scale. Among them are leaching and cropping soils to remove strontium 90. Leaching would require extremely large amounts of water and calcium salts or acids. In addition to removing strontium 90, plant nutrients would be leached out of the root zone and would have to be replaced. Cropping, even with those crops known to take up large amounts of calcium and strontium, would require more than 40 successive crops to achieve 90 percent decontamination.

Reclaiming Soil by Deep Plowing

Decontamination by deep plowing would be aimed at placing the contaminated surface soil 18 inches or more below the surface — or below the root zone of the plants that are to be grown. In shallow-rooted crops, such as grasses and many vegetables, deep plowing might reduce the uptake of strontium 90 to about one-half of that under normal cultivation. It will be most effective when the freshly exposed surface soil has a high supply of calcium either naturally or by the addition of lime or gypsum. However, before the method is used, the situation in the area, the need for the crops which may be grown, and the possible alternatives should be carefully evaluated. Once strontium 90 has been plowed under, not only by deep plowing but also by normal tillage, future removal is virtually impossible. Further, the productivity of some soils may have been drastically reduced by the deep plowing.

Effects of Radiation on Plants and Seeds

The effects of radiation on plants and seeds differ widely, depending upon age, moisture content, state of metabolism, and for neutron irradiation, chemical content. These factors may cause a ten- to twenty-fold difference in radiation sensitivity in different kinds of seeds.

Small seeded legumes appear to be very resistant to radiation, while rice, tomato, and cotton are moderately resistant. Rye and barley are moderately sensitive, while peanuts, soybeans, and cowpeas are especially sensitive to injury from gamma rays.

Sensitivity of seeds of different species varies so greatly that seeds of pine or onions, for example, may be completely killed by 1,000 rads of gamma rays, while seeds of alfalfa or flax tolerate more than 100 times this amount.

Total destruction of the ability of wheat, barley, red clover, and millet to develop beyond the germination stage results from extremely high doses of radiation of seeds. Post-germination development of wheat and barley will begin to be noticeably affected at a dose of about 5,000 rads and will cease after a dose ten times that amount. Red clover begins to lose its post-germination development ability at about 15,000 rads, and it ceases altogether at 100,000 rads.

Radioactivity stored in leaves and stems is many times greater than that found in seeds. For example, in wheat grown on artificially contaminated soil, the leaves showed 11,422 disintegrations from strontium 90 per second per gram, compared with 638 in the grain. And most of this was in the bran. In corn, the difference was even more striking. About 4,683 counts were observed in the leaves and only 18 in the grain. The same story held true for cesium 137.

The high radioactivity found in the leaves compared with that in the seeds is in keeping with the high calcium or ash content in the leaves compared with that in the seeds.

SUMMARY OF EFFECTS OF FALLOUT ON AGRICULTURE

An evaluation indicates that the total effect of radioactive fallout on American agriculture in case of nuclear attack would be serious. A series of nuclear explosions across the Nation would create hazards of severe radiation injury to farm people and their livestock. Radioactive contamination of food, feed, and water would increase the hazard. Residual contamination in the soil would continue the problem over a long period of time.

On the other hand, research is providing the basic knowledge and specific means which can help to lessen the seriousness of these widespread effects. Knowing the radiation level in his area, the farmer can take several protective and remedial measures.

Shelter

The most vitally important measure for the protection of farm families in time of emergency is to seek shelter quickly and stay there as long as recommended for the radiation intensity in the area, making short trips for only the essential jobs or supplies. The interval between a warning of possible attack or the explosion and arrival of fallout may provide the time to get the family and livestock under cover. By taking advantage of the protection provided by shelter, many families and their livestock could escape injury or death.

Food, Feed, and Water

By protecting a sufficient quantity of food, feed, and water from fresh fallout contamination, farm families can prevent early internal radiation damage when the intensity is at high levels.

Maximum Work Times

Farmers who observe the maximum work times suggested for alternating shelter and outdoors work periods can gradually assume duties and yet still take advantage of recommended protection against radiation injury.

Food Decontamination

Some of the food that has been contaminated can be made safe for consumption by following suggested methods for decontamination or by allowing time for sufficient decay of radioactivity. Such food could be used for farm families or the community, or salvaged for market.

Reclaiming the Soil

Some severely contaminated farmland could be maintained in production by diverting it to its safest use, or by decontamination through the method best suited to the conditions.

These, then, are some of the safeguards available now against fallout damage. Research on radioactive fallout is being continued. New knowledge is expected to lead to improved methods of protecting American agriculture against hazards of fallout in time of emergency.

GLOSSARY

(Definition of terms as they are used in this publication.)

ACCUMULATED DOSE: The total radiation dose resulting from repeated or prolonged exposure.

ACUTE EXPOSURE: Radiation exposure of short duration.

ADSORPTION: The adhesion of one substance to the surface of another.

AIR BURST: The explosion of a nuclear weapon at such a height that the expanding fireball does not touch the earth's surface.

ATMOSPHERE: The entire envelope of air surrounding the earth.

ATOM: The smallest particle of an element that still retains the characteristics of that element.

ATTENUATION (RADIATION): The absorption and reduction of radiation intensity as it passes through any material.

BACKGROUND RADIATION: Nuclear radiation arising from within the body and from the surroundings to which individuals are always exposed in normal living. The main sources of natural background radiation are potassium 40 in the body, potassium 40, thorium, uranium, and radium present in rocks and soils, and cosmic rays.

BETA "RAY" (OR PARTICLE): A minute, high speed particle with a negative charge and originating in the nucleus of certain radioactive elements. Physically the beta particle is identical with an electron moving at high velocity.

BLAST: The effect in air of the liberation of a large amount of energy in a short interval of time within a limited space. The liberation of this energy is accompanied by a great increase in temperature creating extremely hot gases from the products of an explosion. These gases move outward rapidly, pushing away the surrounding air with great force, and cause the destructive effects of an explosion.

BRIEF EXPOSURE: Exposure within the first 96 hours.

CELL: The fundamental unit of structure and function in plant and animal organisms.

CONTAMINATION (RADIOACTIVE FALLOUT): The deposit of radioactive material on the surface of land, structures, objects, human beings, animals, plants—entire areas—following a nuclear explosion. Plants may also be further contaminated by absorbing radioactive material from contaminated soil or water; and animal products through the animal's consumption of contaminated feed and water.

COSMIC RAY: Any of the rays of extremely high energy and penetrating power produced, it is believed, by electric action in interstellar space (beyond the earth's atmosphere). They bombard the earth from all directions.

CURIE: A unit for measuring radioactivity, equal to that produced by a gram of radium. (Microcurie is one-millionth of a curie, and a micromicrocurie or picocurie is one-millionth of a millionth of a curie.)

DECAY (RADIOACTIVE): The decrease in activity of any radioactive material with the passage of time. See—HALF-LIFE.

DENIAL TIME: The period of time persons would be prohibited from entering a contaminated area or leaving shelter in such an area because of radiation intensity. Also, the period of time croplands would be prohibited from use for designated agricultural products because of radioactive contamination, or milk prohibited from human consumption because of radioiodine content.

DISCRIMINATION: The natural discrimination against one chemical element in favor of another by the biological systems of plants, animals, and man. An example is the discrimination against strontium in favor of calcium.

DOSE: A (total or accumulated) quantity of ionizing (or nuclear) radiation. The term dose is often used in the sense of the **exposure dose,** expressed in roentgens, which is the measure of the total amount of ionization that the quantity of radiation could produce in air. This should be distinguished from the **absorbed dose,** given in reps or rads, which represents the energy absorbed from the radiation per gram of specified body tissue. Further, the **biological dose,** in rems, is a measure of the biological effectiveness of the radiation exposure. See RAD, ROENTGEN.

DOSE RATE: The amount of dose of ionizing radiation to which an individual is exposed per unit of time (hour, day, week, or month). It is usually expressed as the number of roentgens per hour. The dose rate is also commonly used to indicate the level of radiation intensity in a contaminated area.

ELECTRON: A very small particle of matter carrying a negative charge. Electrons are present in all atoms surrounding the nucleus. In a neutral atom their number is equal to the number of positive charges (or protons) in the particular nucleus.

ELEMENT: One of the distinct, basic varieties of matter which, individually or in combination, have unique chemical characteristics. Ninety-two naturally occurring elements have been identified in nature and about 10 others have been produced as a result of nuclear reactions.

EQUIVALENT RESIDUAL DOSE: The accumulated exposure dose of gamma radiation corrected for such recovery as has occurred at any particular time.

FALLOUT: Dustlike particles of radioactive matter created by a nuclear explosion. The term is also used to describe the process of the fall back to earth of the contaminated particles from the bomb cloud.

FIREBALL: The luminous sphere of hot gases which forms a fraction of a second after a nuclear explosion and immediately starts to expand and cool.

FISSION (NUCLEAR FISSION): The process in which the nucleus of an atom of a heavy element; for example, uranium, splits into (generally) two nuclei of lighter elements, with the release of large amounts of energy.

FISSION PRODUCTS: A general term for the complex mixture of radioactive substances produced as a result of nuclear fission. (The mixture contains over 200 different isotopes of over 35 elements.)

FOOD CHAIN: The route of nutrients from the soil through plants and animals, and through the biological system of man as human nutrition.

GAMMA RAYS: Electromagnetic radiation of high energy emitted by the nucleus of an atom. These rays accompany many nuclear reactions including nuclear fission. Physically, gamma rays are identical with X-rays. The only essential difference is that X-rays do not originate in the nucleus of an atom.

GEIGER COUNTER: An instrument for measuring radiation rate. As usually constructed it is a highly sensitive instrument with a very short range of measurement that would be useful only for monitoring low levels of intensity such as for food, water, and personnel.

GENETICS: The branch of biology dealing with heredity and variations from one generation to another.

HALF-LIFE: Time required for a radioactive substance to lose 50 percent of its radioactivity. Decrease of radioactivity is usually referred to as decay.

INITIAL RADIATION: Nuclear radiation emitted from the fireball and atomic cloud during the first minute after a nuclear explosion.

INTENSITY (RADIATION): The term is used loosely to express exposure dose rate of radiation at a given location. For example, the intensity of radiation at the location could be expressed in the number of roentgens per hour measured by an appropriate instrument at that point.

ION: An electrically charged atom or molecule, either positive or negative.

IONIZATION: The process by which a neutral atom or molecule matter receives an electrical charge, either positive or negative.

IONIZING RADIATION: Radiation capable of producing ions either directly or indirectly as it passes through matter. Passage of ionized radiation through living cells causes biological damage.

IRRADIATION: Exposure to radiation.

ISOTOPES: Forms of the same element which usually have identical chemical properties but which differ in their atomic masses (because they have a different number of neutrons in their respective nuclei). They may be stable (nonradioactive) or they may be radioactive.

KILOTON NUCLEAR BOMB: A nuclear bomb which produces the same amount of energy as 1,000 tons of TNT.

MAXIMUM PERMISSIBLE EXPOSURE: As applied to postattack emergency operations, the total amount of ionizing radiation exposure which it is believed a normal person may receive without the harmful effects outweighing potential benefits.

MEGATON NUCLEAR BOMB: A nuclear bomb which produces the same amount of energy as 1,000,000 tons or 1,000 kilotons of TNT.

MIDLETHAL DOSE (MEDIAN LETHAL DOSE, OR MLD): The amount of ionizing radiation over the entire body which is expected would be fatal to 50 percent of a large group of a given species of living creatures or organisms within 30 days. It is commonly (although not universally) accepted that 450 roentgens is the midlethal dose for human beings.

MOLECULE: The smallest group of atoms that can exist isolated from other like groups, as in a gas or in a solution. The molecule of a compound contains more than one kind of atom. The molecule of an element consists of one or more like atoms.

NEUTRON: A neutral particle of matter (with no electrical charge) present in all atomic nuclei except those of ordinary hydrogen. Neutrons are required to initiate the fission process, and large numbers of neutrons are produced in nuclear explosions. The short path and life of neutrons from a detonation limit their damage to initial radiation at the time of the explosion, and they do not contribute to residual fallout radiation hazard. Neutrons present little hazard ouside the area of heavy blast damage.

NUCLEAR RADIATION: Radiation emitted from atomic nuclei in various nuclear processes. The types of radiation discussed in this publication are beta rays and gamma rays. (Other radiations important in the results of nuclear explosions are alpha rays and neutrons.) All these nuclear radiations are, or result in ionizing radiations, but the reverse is not true. For example, X-rays are ionizing radiations, but they are not nuclear radiations because they do not originate in the nucleus of an atom. See—IONIZING RADIATION.

NUCLEAR WEAPON (OR BOMB): A general name given to any weapon in which the explosion results from the energy released by reactions involving the nuclei of atoms. Thus, both atomic bombs and hydrogen bombs are in fact nuclear weapons, and the term is used to include both types in this publication.

NUCLEUS (OR ATOMIC NUCLEUS): The core of an atom that carries most of the mass and the total positive electrical charge. All atomic nuclei (except ordinary hydrogen) contain both protons and neutrons (positively charged and neutral particles). The electrons (negatively charged particles) of an atom are outside the nucleus.

PROTECTION FACTOR: The relative reduction in the amount of radiation that would be received by a person in a protected location, compared with the amount he would receive if he were unprotected.

PROTON: A particle of matter carrying a positive charge. It is identical physically with the nucleus of the ordinary hydrogen atom. All atomic nuclei contain one or more protons.

RAD: A unit for measuring an absorbed dose of radiation.

RADIATION: See—NUCLEAR RADIATION.

RADIATION SICKNESS: A disease resulting from excessive exposure of the entire (or a large part) of the body to ionizing radiation. Some early symptoms are nausea, vomiting, and diarrhea, which may be followed by loss of hair, hemorrhage, inflammation of the mouth and throat, and general loss of energy. In severe cases, where the radiation exposure has been relatively large, death may occur within 2 to 4 weeks. Those who survive 6 weeks after the receipt of a single dose of radiation may generally be expected to recover.

RADIOACTIVITY: The spontaneous disintegration or nuclear change of certain atoms in which energy is released. The process is accompanied by the emission of one or more types of radiation, such as beta and gamma rays.

RADIOIODINE (RADIOACTIVE IODINE): Iodine in which the nuclei of the atoms emit radiations.

RADIOISOTOPE: See—ISOTOPES.

RADIOSTRONTIUM (RADIOACTIVE STRONTIUM): Strontium in which the nuclei of the atoms emit radiations.

RESIDUAL RADIATION: Nuclear radiation, chiefly beta and gamma rays, which persists longer than 1 minute following a nuclear explosion. The radiation is emitted mainly by the fission products and other bomb residues in the fallout.

ROENTGEN: A unit for measuring a radiation exposure dose.

SHELTER (FALLOUT): A specially constructed refuge, or the use of normal buildings or materials primarily for the purpose of protecting people, livestock, or other living organisms from the gamma radiation resulting from fallout.

SHIELDING: Any material or obstruction which absorbs radiation and thus helps to protect people and livestock from the effects of radioactive fallout. A considerable thickness of material of high density may be needed.

STRATOSPHERE: The part of the earth's atmosphere extending from the troposphere (approximately 7 miles above the earth) to altitudes as great as 45 to 50 miles. (See—TROPOSPHERE.)

SURFACE BURST: The explosion of a nuclear weapon at the surface of the earth, or at a height above the surface close enough for the fireball to touch the land or water. The effect of fallout is most serious following a surface burst.

TROPOSPHERE: The lower part of the earth's atmosphere, characterized by formation of clouds and precipitation. Typical upper limits of the troposphere are about 6 miles in the polar regions and 9 to 12 miles near the equator. (See—STRATOSPHERE.)

UNDERGROUND BURST: The explosion of a nuclear weapon with its center beneath the surface of the ground.

UNDERWATER BURST: The explosion of a nuclear weapon with its center beneath the surface of the water.

APPENDIX A

Measurement of Fallout Radiation

Monitoring is essential to determine the degree of contamination of personnel, objects, facilities, food and water, as well as to determine where in the general environment decontamination is required and the effectiveness of decontamination measures. Monitoring services and information must be available to farmers and agricultural officials to help them determine their ability to conduct essential farm activities.

In agreement with national defense plans, programs, and operations of the Department of Defense, under Executive Order No. 10952, the Department of Agriculture is responsible for developing plans for a national program, directing Federal activities, and furnishing technical guidance to State and local authorities concerning protective measures, treatment, and handling of the following, any of which have been exposed to or affected by radiation:

(1) Livestock, including poultry.
(2) Agricultural commodities on farms or ranches.
(3) Agricultural lands.
(4) Forest lands.
(5) Water for agricultural purposes.
(6) Meat and meat products, poultry and poultry products in establishments under the continuous inspection of the U.S. Department of Agriculture.
(7) Agricultural commodities and products owned by the Commodity Credit Corporation or by the Secretary.

The intensity of gamma radiation from fallout at any given time and location is expressed in terms of a unit of measurement called a "roentgen." It is an accepted unit for measuring radiation in air, just as a calorie for heat or a kilowatt hour for electricity. The roentgen is used in two different connotations: (1) Total **accumulated** radiation exposure is expressed merely as so many roentgens, and (2) the **rate** of radiation exposure given off by fallout or any other nuclear radiation source is expressed as roentgens per unit of time (per hour, minute, or second.)

The human senses do not detect ionizing radiation. Special instruments have been developed for the detection and measurement of various nuclear radiations.

These devices can be divided into rate meters and dosimeters:

Rate meters are used to measure **radiation rates** in an area. They are basically reconnaissance instruments to measure the radiation dose rates across an area or near items that might be contaminated. Such measurements are essential as a basis for evaluating potential occupancy of areas, utilization of. materials, or need for decontamination. They might be used in three ways:

(a) For field station monitoring; scheduled measuring and reporting of dose rates at a predetermined point outside a sheltered location.

(b) For aerial surveys to enable general estimation of radiation levels over a wide area.

(c) For detailed monitoring of areas, facilities, objects, and materials after radioactive decay has reduced dose rates to a level permitting extended field activity.

The Office of Civil Defense, Department of Defense, has developed monitoring instruments or rate meters to be used for survey purposes in the event of emergency operations. Examples of instruments having the widest application are:

(a) The low-range beta-gamma survey meter (CD V–700) is a Geiger counter type. It is a highly sensitive instrument and is suitable for emergency monitoring of food, water, and personnel. It has a measurement range from 0 to 50 milliroentgens per hour. (A milliroentgen is one-thousandth of a roentgen.) Such a short range of measurement would be of little use in an area with significant contamination, since a relatively low level of radioactivity would drive the indicator needle off the scale unless the Geiger tube and sample were exposed in an adequate shield.

(b) A medium-range gamma survey meter (CD V–710)[3] would be most widely useful for general radiological monitoring following attack. The measurement range is from 0 to 50 roentgens per hour. The instrument is designed for ground survey where the radiation levels would be expected to change relatively slowly. Until a special instrument is available, it will be used for aerial survey.

(c) A high-range beta-gamma survey meter (CD V–720) would be required in areas where

[3] In future procurement of instruments by the Office of Civil Defense, the CD V–710 survey meter will be replaced by a CD V–715, Radiological Survey Meter, gamma only, 0–0.5, 0–5, 0–50, 0–500 roentgens per hour.

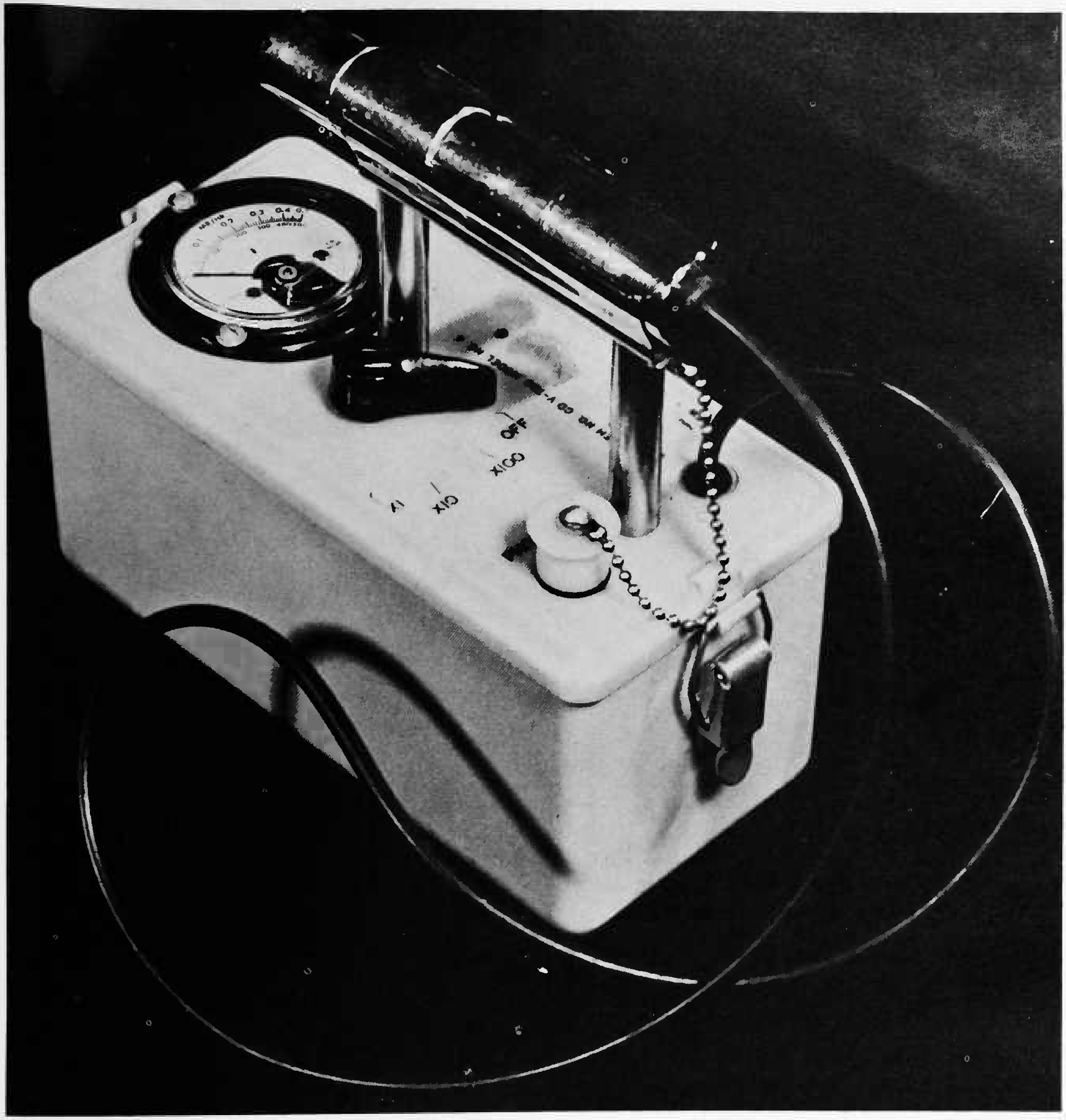


FIGURE 10.—A Geiger counter is a monitoring device used to detect and measure radioactivity. Its range of measurement is very small, but in time of emergency it would be useful for monitoring food, water, and personnel.

contamination levels are extremely high and for making high level beta radiation measurements. This instrument has a measurement range from 0 to 500 roentgens per hour.

Dosimeters are used to measure **accumulated dose** of radiation in an area or the accumulated exposure of people and livestock. Self-indicating dosimeters have been developed. Two examples are:

(a) CD V–730, with a measurement range from 0 to 20 roentgens.

(b) CD V–740,[4] with a measurement range from 0 to 100 roentgens.

As part of the Nation's preparedness program, the Federal Government is assisting the States and their political subdivisions to develop systems for

[4] In future procurement of instruments by the Office of Civil Defense, the CD V–740 dosimeter will be replaced by a CD V–742, Radiological Dosimeter, self-reading, gamma only, 0–200 roentgens.

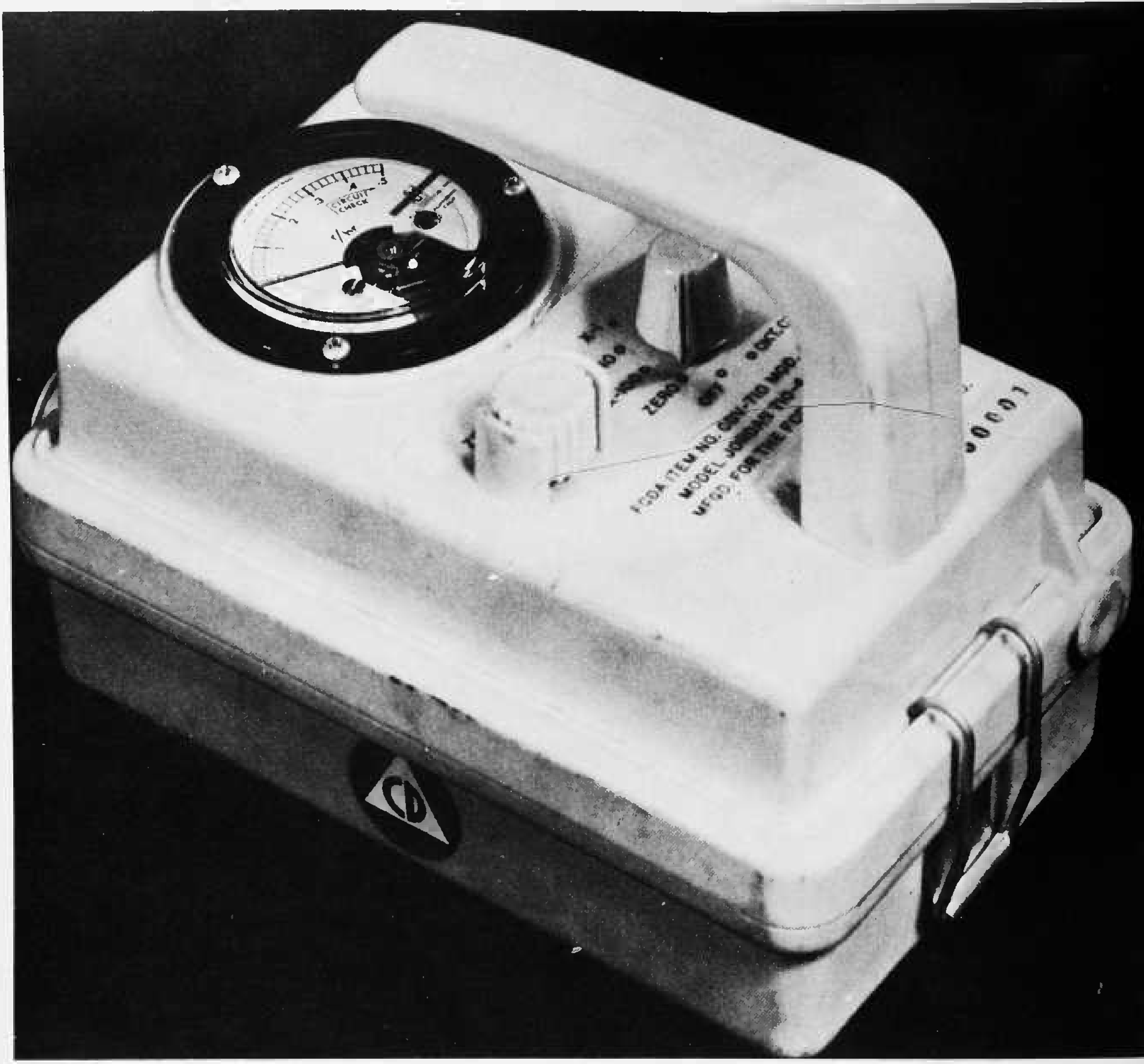


Figure 11.—A medium-range gamma survey meter (above) would be generally used to determine the intensity of radioactivity at ground level following an attack.

postattack radiological monitoring and reporting. Kits of instruments are made available to the States when monitors are trained and qualified for emergency operations from sheltered locations. Financial assistance is also given for the procurement of some types of communications equipment for civil defense purposes.

Information resulting from plotting, analysis, and evaluation of reported radiological data will be used as a basis for the control of radiation exposure during emergency operations, and for warning and instruction of the public.

In the event of a nuclear attack, States and local civil defense organizations would be responsible for scheduled periodic radiological monitoring and reporting. As information on intensity and location of radiation becomes available, it will be broadcast on radio stations.

Details of local, State, and national radiological defense systems are beyond the scope of this report and are described in the Office of Civil Defense publications listed under "Publications and Films," page 140.

As a supplement to organized Federal, State, and local monitoring systems, every home and community shelter should have an instrument to measure radiation dose rate—a ratemeter. In the event of a nuclear attack, such an instrument would provide information that will help the user determine the degree of fallout danger he faces, and help him make logical decisions for greater

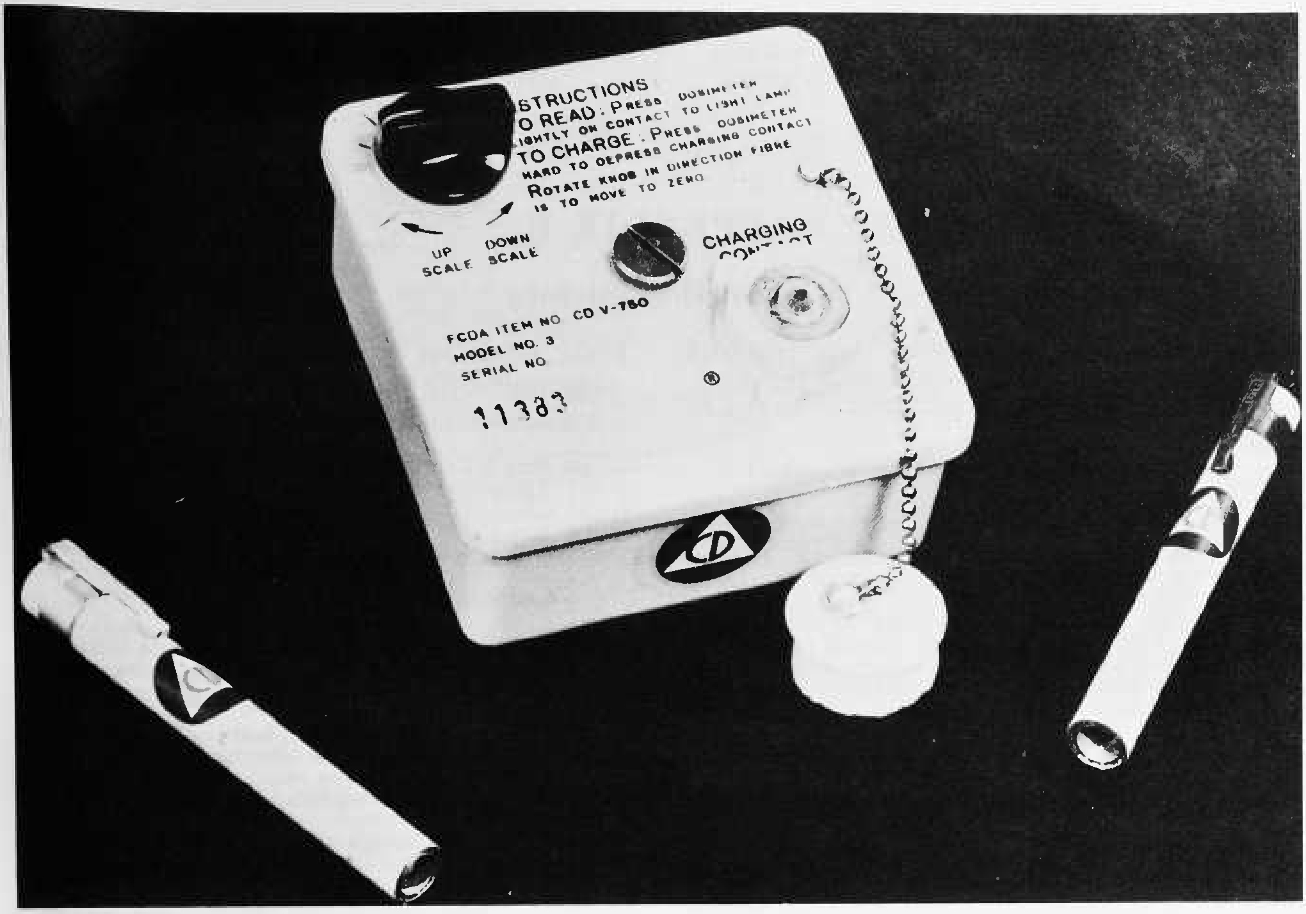


FIGURE 12.—A dosimeter measures the accumulated dosage of radioactivity.

safety. For example, a citizen's radiation instrument should help the user determine when to take shelter, when to leave the shelter, and how long it would be advisable to remain in an unprotected area. The instrument also should be of value in locating that portion of the home or protective structure that offers the best protection from fallout.

In addition to a ratemeter, a dosimeter would be useful for keeping track of accumulated radiation exposure over a long period. A reasonable range for a citizen dosimeter is from 0 to 600 roentgens.

Instruments having all of the essential and most of the desirable characteristics described are commercially available. Other instruments, designed on the basis of these characteristics, are being developed.

APPENDIX B

Protection Factors

TABLE 6.—*Description of shelter categories with associated protection and attenuation factors* [1]

Shelter category	Protection factor [1]	Common examples [2]
A	1,000 or greater (better than 0.001).	OCD underground shelters. Subbasement of multistory buildings. Underground installations (mines, tunnels, etc.).
B	250 to 1,000 (0.004 to 0.001).	OCD basement fallout shelters (heavy masonry residences). Basements (without exposed walls) of multistory buildings. Central areas of upper floors (excluding top 3 floors) of high-rise buildings [3] with heavy floors and exterior walls.
C	50 to 250 (0.02 to 0.004).	OCD basement fallout shelters (frame and brick veneer residences). Central areas of basements (with partially exposed walls) of multistory buildings. Central areas of upper floors (excluding top floor) of multistory buildings with heavy floors and exterior walls.
D	10 to 50 (0.1 to 0.02).	Basements (without exposed walls) of small 1- or 2-story buildings. Central areas of upper floors (excluding top floor) of multistory buildings with light floors and exterior walls.
E	2 to 10 (0.5 to 0.1).	Basements (partially exposed) of small 1- or 2-story buildings. Central areas on ground floors in 1- or 2-story buildings with heavy masonry walls.
F	2 or less (0.5 or poorer).	Aboveground areas of light residential structures.

[1] This term expresses the relative reduction in the amount of radiation that would be received by a person in a protected location, compared with the amount he would receive if he were unprotected. The reciprocal of the protection factor is called the attenuation factor.

[2] These examples refer to isolated structures.

[3] For the purposes of this example, "high-rise" buildings are those greater than about 10 stories; multistory buildings are those from 3 up to about 10 stories.

Source: Adapted from Appendix 2, Annex 10, National Shelter Plan NP 10–2, OCDM, May 1960.

TABLE 7.—*Types of buildings that will provide approximately the stated attenuation for loose-housed livestock and poultry* [1]

Item	Attenuation factor	Types of buildings
1	0.0125	a. Large barn (50′ × 80′ minimum); full bank on 3 sides; heavy solid concrete or stone wall on fourth side; few doors and windows; 6 feet baled hay [2] above basement.
2	.025	a. Large barn; half bank; solid concrete or stone foundation; few doors; windows above animals' backs; over 12 feet baled hay above.
3	.05	a. Large barn; half bank, cinder block foundation; windows above cattle; 12 feet baled hay. b. Large barn; gambrel roof; two-story on cinder blocks; no windows and few doors; full of baled hay (gambrel roofs retain less fallout than do gable roofs). c. As in 1a, empty of hay.
4	.075	a. As in 2a, empty of hay. b. Full cinder block ground floor; 25 feet baled hay.
5	.1	a. Large barn; full masonry ground floor; no windows; empty. b. Large barn; one-half bank; cinder-block foundation; 12 feet baled hay.
6	.2	a. Large barn; full frame; no foundation above floor; 25 feet baled hay. b. Hog house; solid concrete walls, no windows; metal roof. c. Poultry house; first floor only of large multistory masonry construction; windows 3 feet above floor.
7	.3	a. Medium-sized frame barns; no foundation above floor; 25 feet baled hay. b. Very large frame barns; two-story; 2-foot foundations; few windows; empty of hay. c. Full cinder-block barns if empty; cinder-block hog barns with metal roof. d. Large frame barn; one-half bank on cinder block; empty of hay.
8	.4	a. Very large, all frame, two-story barn; empty of hay.

See footnotes at end of table.

TABLE 7.—*Types of buildings that will provide approximately the stated attenuation for loose-housed livestock and poultry*—Continued

TABLE 7.—*Types of buildings that will provide approximately the stated attenuation for loose-housed livestock and poultry*—Continued

Item	Attenuation factor	Types of buildings
8	.4	b. Very large quonset-type barn; full of confined stock.
		c. Larger sheep sheds, hog houses, and very large one-floor poultry houses; limited openings; full of confined stock.
9	.5	a. Medium-sized barns with haylofts; frame; few windows; low foundations; empty.
		b. Barns in items 7 and 8 with asphalt or flatter roofs with high fallout retention.
		c. Cinder block or tile low poultry houses and hog houses, if asphalt roof or other retentive types.
		d. Larger one-floor poultry houses with limited openings.
		e. Midfloors of multistory poultry houses, including large frame barns converted to poultry houses.
		f. Any farm building giving shelter equivalent to first floor of a two-story frame dwelling with normal windows.
10	.6	a. Very large "pole sheds," open on low side; animals confined under roof.
		b. Large poultry houses; one floor; numerous openings that can be covered with canvas.
		c. Smaller poultry houses with few windows.
11	.7	a. Smaller poultry houses with considerable openings.
		b. Sheds on side of larger buildings, considerable openings; stock confined.
		c. Top floor of barn converted to multiple-floor poultry house.
12	.8	a. Smaller sheds with large side open; animals confined.
		b. Smaller poultry houses and shelters; many openings.
13	.9	a. Open sheds; animals free to run in shed or adjacent small lot only.
14	1.0	a. No significant shelter-free running or grazing animals. These values assume loose housing of animals or poultry; animals confined in stalls near doors and low windows would have far less protection than would those in the most protected areas in the building.

[1] Based on calculations and guides provided by Neil FitzSimons, Office of Civil Defense, Department of Defense.

[2] As shielding material, 6 feet of hay are equivalent to 1 foot of water or about 7 inches of earth.

APPENDIX C

40 Cow Dairy Barn and Family Fallout Shelter

Protection for highly valued livestock should be considered along with the fallout shelter for the rural family. In many respects, fallout protection requires structural characteristics opposite of those found in efficient farm buildings. This plan is a compromise between a relatively high degree of protection for livestock, and a reasonably efficient dairy operation under normal conditions.

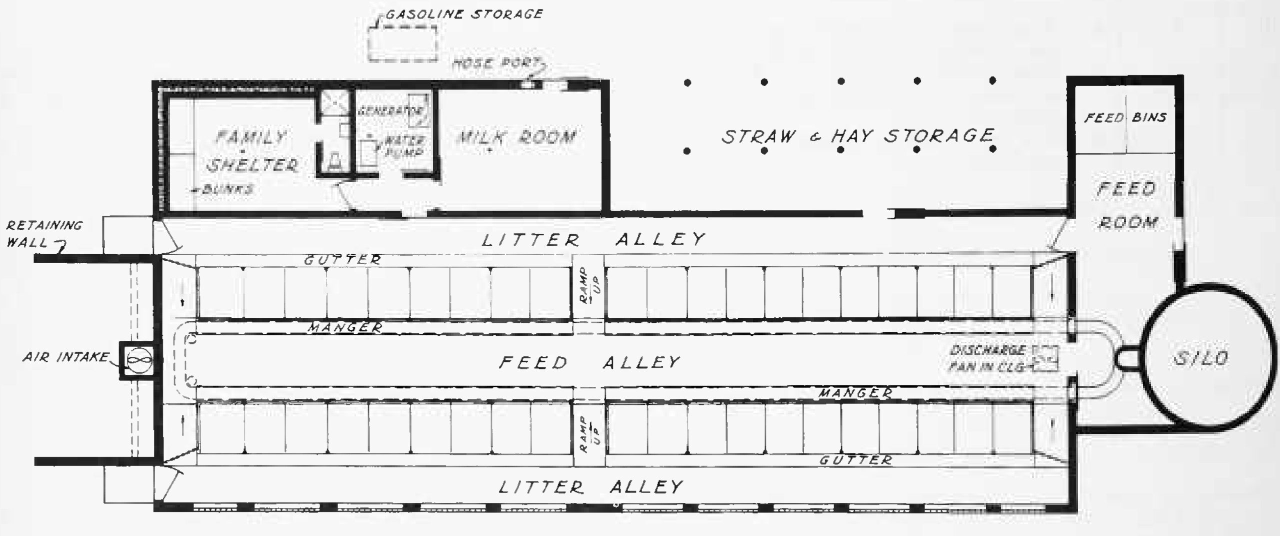
All exterior walls should be at least 12 inches thick and of a dense material such as poured concrete, stone, concrete block or brick with cores filled with mortar or earth, or pressure treated wood with space between filled with sand. Family shelter exterior walls should conform to standards of the Office of Civil Defense, Department of Defense.

The main features of the plan are:

(1) The family shelter is built-in. This gives construction economy over a separate family shelter, and allows the dairy operator to continue work during a fallout emergency without exposure to outside radiation levels.

(2) A thick layer of earth is placed overhead as a shield against fallout on the roof.

(3) Mechanical feeding reduces operator time outside the family shelter, and all stored feed is manually accessible inside the barn.



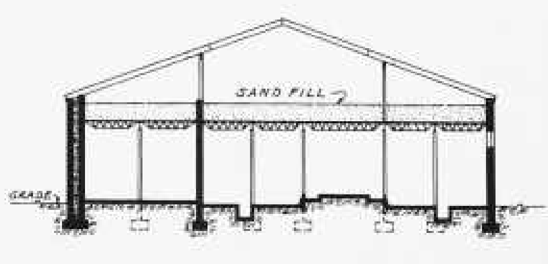


FIGURE 13.—40 cow dairy barn and family fallout shelter.

(4) Other livestock could be temporarily housed, fed, and watered inside.

(5) Stored hay and straw are placed for shielding effect. Outside doors are to be temporarily shielded with water-soaked bales.

(6) The ventilating air is filtered and flow rate is adjustable. Air to the family shelter can be supplied by direct duct or by leakage from the barn.

(7) An auxiliary generator assures electric power, although it is anticipated that many areas will not lose commercial power.

(8) The water supply pump is inside the barn. Tanks not shown on the plan, are covered and vented several feet above ground to exclude settling fallout.

A rough estimate of protection from radioactive fallout is given by the weight of all materials between the fallout and the shielded space. Below ground construction and earth banks increase the protection of a concrete wall several times. If stored forage is relied upon for shielding, a thickness of several feet should be maintained. Ordinary glass windows and wood doors have very little shielding value, and must be blocked with more material. A minimum area of glass block serves as windows in the plan, and local milk sanitarians should be consulted for lighting requirements.

Shielding values of the structure are evaluated according to "Fallout Shelter Surveys: Guide for Architects and Engineers," National Plan Appendix Series, NP–10–2. The percentage of outside radiation entering the structure increases greatly if essential construction features are omitted.

	Percentage of outside radiation	
Construction	*Barn*	*Family shelter*
As shown on plan	0. 9	0. 3
Doors not shielded with wet hay bales	3. 0	. 3
Overhead sand replaced by baled hay	10. 7	3. 7
Glass block replaced by ordinary windows	1. 3	. 4

TRENCH-TYPE SHELTER ARRANGEMENTS

(A, B, C, D) Roofs for Trench-Type Fallout Shelters

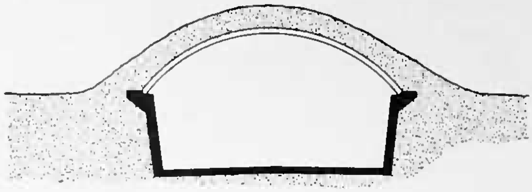
Trench silos can be converted to fallout shelters by adding an overhead earth shield and a baffled entrance. The long, narrow shape facilitates bridging to support overhead shielding and minimizes radiation penetration through openings. A 2-foot thickness of earth overhead and entrances as shown on the sketches, give a radiation reduction factor of 0.0023. This is a protection factor of over 400. It is worthwhile to note that a 1-foot thickness of earth will admit 13 times as much radiation as a 2-foot thickness.

(E, F) Fallout Protection in Buildings

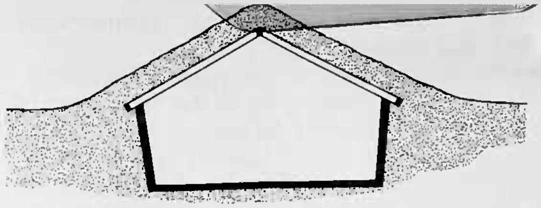
A building constructed as in the sketches would provide a reduction factor of about 0.025. Necessary conditions for obtaining this protection include walls banked with earth to sill level, protected stock kept below sill level, and tightly closed doors. Further improvement in shelter value can be accomplished by reducing or eliminating windows and doors and by full earth banks around outside walls.

With 2 feet of earth overhead, very little radiation would penetrate the roof. With only 1 foot of earth, fallout on the roof would be the main source of radiation inside and flushing would be necessary to obtain the stated reduction factor. A flushing system must provide for rapid runoff away from the building to avoid pile-up of fallout around the walls.

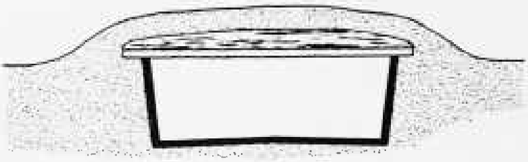
A hay mow with 10 feet of baled hay will give overhead shielding about equal to 1 foot of earth. Also, the steep gambrel roof will retain less fallout. Hay mows and other feed storage spaces should be tightly weathersealed to prevent contamination.



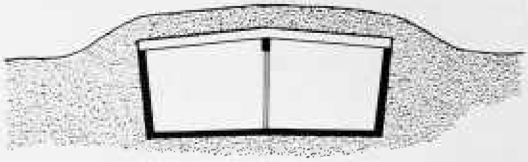
A. ARCHED
Commercial Metal Components



B. PITCHED
Three-Hinged Arch or Trussed Rafters



C. FLAT
Lags, Wire Mesh and Straw



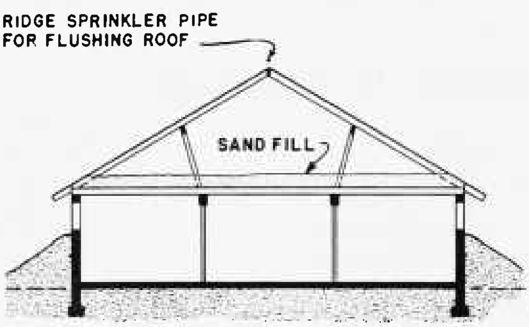
D. FLAT
Posts, Beams and Joists

ROOFS FOR TRENCH-TYPE FALLOUT SHELTERS

CROSS SECTIONS SHOWN ON TYPICAL CONCRETE-LINED SILOS

A 2-Foot Layer of Earth Will Provide a Protection Factor of About 400 and Will Weigh from 200 to 250 Lbs. Per Square Foot of Roof Area.

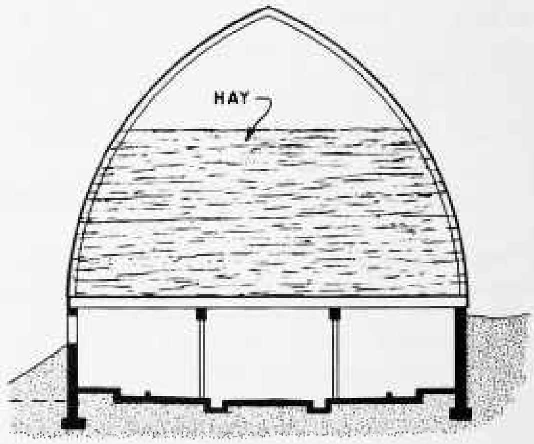
It is Important that the Roof Structure be Carefully Designed to Safely Support all Live and Dead Loads.



E. ONE-STORY BUILDING

The Depth of the Sand or Earth Fill Will be Limited by the Strength of the Ceiling Structure.

Supply Generous Quantities of Water for Decontaminating. Drain Contaminated Water Away for the Lots.



F. BANK-TYPE DAIRY BARN

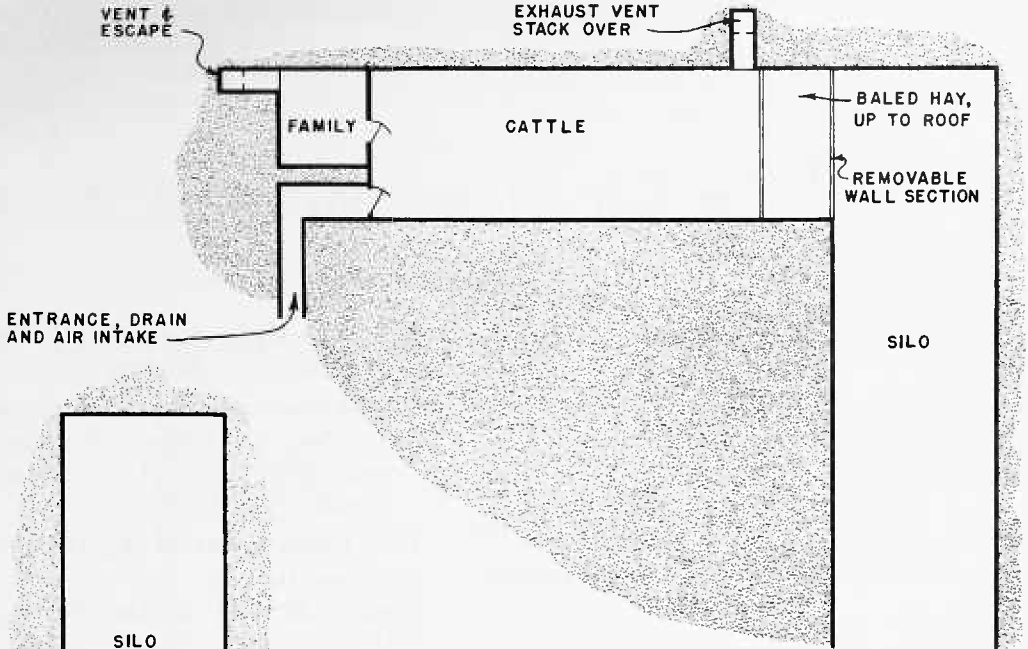
A 15 Foot Depth of Tightly Baled Hay Will Provide Shielding About Equal to a 2-Foot Layer of Earth, but the Depth Should be Reduced if Necessary to Avoid Over-loading the Mow Floor.

FALLOUT PROTECTION IN BUILDINGS

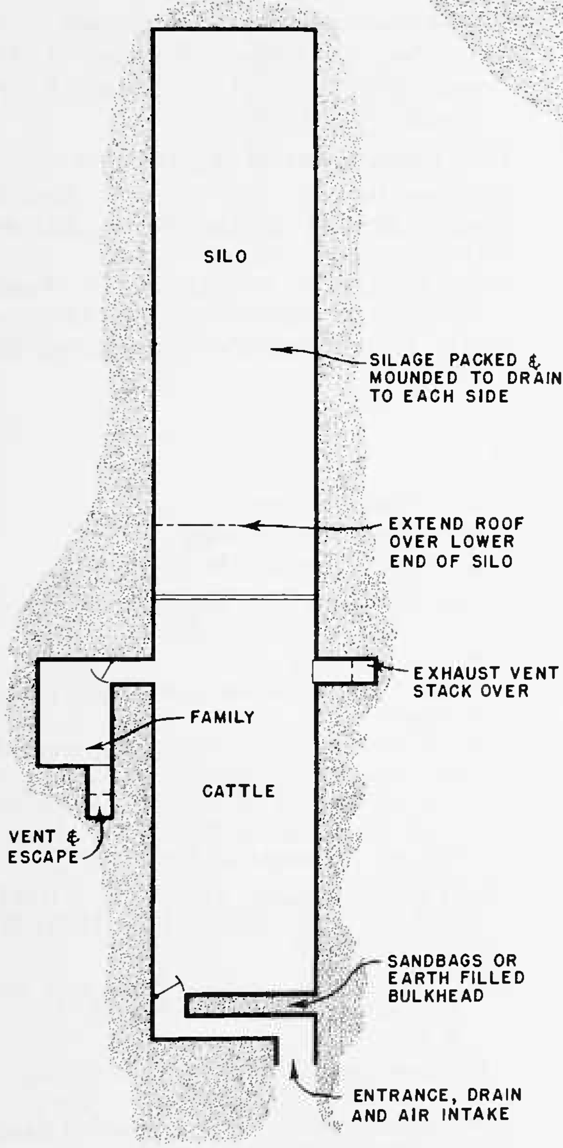
Bank Earth up to Sill Height on all Exposed Walls and Protect Against Erosion.

Windows and Doors May be Closed With Concrete Blocks or Sandbags.

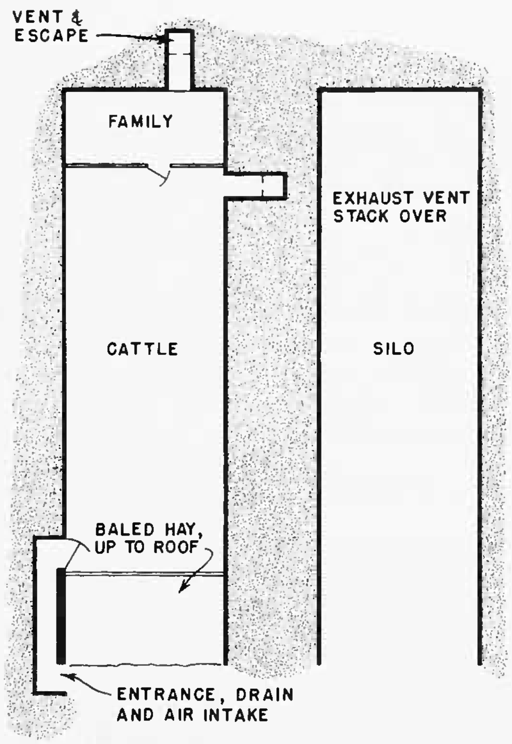
In New Construction, Openings Should be Kept to a Minimum, Window Sills Should be High and the Mow Floor or Ceiling Structure Must be Designed to Support the Heavy Load of Shielding Material. A Concrete Mow Floor Increases Shielding.



L-SHAPED



IN-LINE



PARALLEL

Silos to be Sealed with Plastic Sheeting and Covered with Sawdust or other Suitable Ballast. All other Areas to be Roofed and Covered with Two Feet of Earth, Sodded or otherwise Protected from Erosion.

TRENCH-TYPE SHELTER ARRANGEMENTS

PUBLICATIONS AND FILMS

Publications

Office of Civil Defense, Department of Defense

BULLETINS:

- Permissible Emergency Levels of Radioactivity in Water and Food (September 1955).
- Emergency Measurements of Radioactivity in Food and Water (December 1952).
- Radiation Physics and Bomb Phenomenology (Rev. June 1959).
- Radiological Defense Planning and Operational Guide.
- Fallout Protection.
- Family Shelter Designs.

Office of Emergency Planning

NP–10–1—Fallout Shelter Surveys, Guide for Executives.

NP–10–2—Fallout Shelter Surveys, Guide for Architects and Engineers.

U.S. Atomic Energy Commission

The Effects of Nuclear Weapons. U.S. Department of Defense and U.S. Atomic Energy Commission (April 1962).

U.S. Department of Agriculture

Farmers' Bulletin 2107—Defense Against Radioactive Fallout on the Farm (Revised April 1961).

Home and Garden Bulletin No. 77—Family Food Stockpile for Survival (August 1961).

USDA Radiological Training Manual (Rev. July 1961).

Films

U.S. Department of Agriculture

Fallout and Agriculture. Color; time: 23 min. Released 1960. (Prints available from the Motion Picture Service, Office of Information, U.S. Department of Agriculture, Washington 25, D.C., and Film Service Libraries of all State Colleges of Agriculture.)

Office of Civil Defense, Department of Defense

The following films are CURRENT and may be obtained from your nearest U.S. Army Central Film and Equipment Exchange:

Civil Defense in Schools
Crisis
Emergency Hospital
Fallout
House in the Middle, The (6½ min.)
House in the Middle, The (12 min.)
Invisible Enemy, The
Lifeline of the Nation
No Time To Lose
Operation Cue (Short, silent version)
Operation Cue (Long, silent version)
Operation Cue—Revised (Color, sound)
Radiological Defense
Rehearsal for Disaster
Ten for Survival:
- #1—Enter the Nuclear Age
- #2—Knowledge Is Survival
- #3—Biography of a Disaster #1
- #4—Biography of a Disaster #2
- #5—Fact and Fable
- #7—The Unseen Enemy
- #8—Radiation and the Body

The following films are current, but are to be used for TRAINING ONLY:

Mission Fallout
Nerve Gas Casualties and Their Treatment
Trapped

A new catalog is now being prepared which will contain detailed information on content, type, and prices of all current OCD films. When this publication is available, its release will be announced through an Information Bulletin.

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