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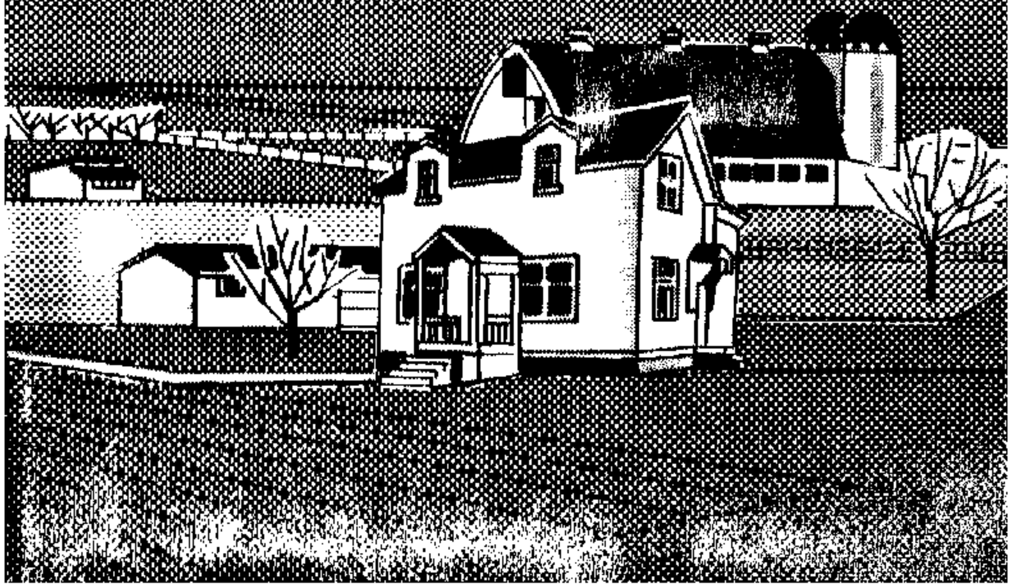
FALLOUT ON THE FARM

BLUEPRINT FOR SURVIVAL NO. 3



CANADA DEPARTMENT OF AGRICULTURE PUBLICATION 1208 1967

POINTS TO REMEMBER

1. Know the facts about fallout and how to protect against it
2. Know your municipal emergency plans.
3. Learn how to reduce the risks you will take in carrying on with the farm after a nuclear explosion.
4. Prepare your shelter area to protect your family.
5. Make sure you have emergency food, feed and water for the family and livestock.
6. Have a battery operated radio.
7. Keep indoors until informed that danger is over.
8. When in doubt, take shelter.

The information in this bulletin will assist you in preparing for an emergency on your farm. Technical words not in common use are defined in the Glossary at the back.

For additional information on personal and family survival, publications on fallout, shelter construction, emergency health and emergency welfare are available from your local and provincial Emergency Measures or Civil Defence organizations. These publications may also be obtained from Post Office Box 10,000 in the capital of your province.

PREFACE

This bulletin has been prepared to provide farmers and agriculturists with information about radioactive fallout. It explains the effect of fallout and suggests how the hazard can be minimized.

It is important that farmers be well-informed on this matter since they will play a vital role in helping Canada to survive in the event of a nuclear war; in fact, continuance of primary food production would depend on their knowing how to safeguard themselves, their families and their crops and livestock.

The Canada Department of Agriculture is responsible in the event of a wartime emergency for food production on farms; control over all food products (except fish and fish products) and inspection as to their freedom from radioactive contaminants; protection of farm families, crops and livestock; and provision of information to farmers on what to do about radioactive fallout. Provincial Departments of Agriculture are co-operating with the Federal Department in organizing and planning to carry out these responsibilities during such an emergency.

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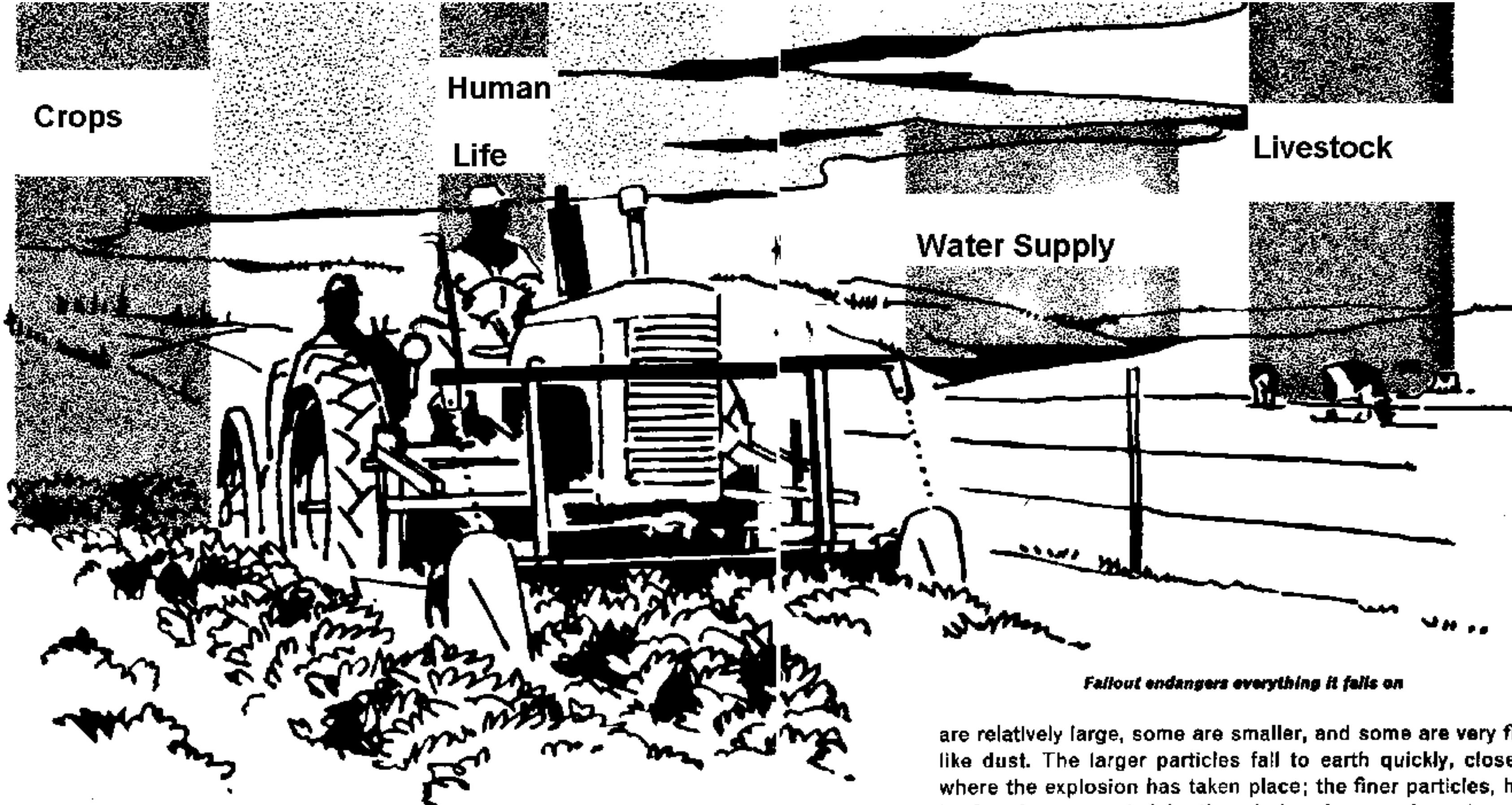


Fallout endangers everything it falls on

FACTS ABOUT FALLOUT

NUCLEAR EXPLOSIONS

A nuclear explosion results in four destructive actions: blast, heat, initial radiation, and residual radiation. The first three are almost instantaneous at the moment of burst but the fourth—residual radiation—produces its effects later and over a vastly wider area.

RADIOACTIVE FALLOUT

When a nuclear explosion takes place on or near the surface of the earth, masses of soil and debris become radioactive and are drawn upwards to form a great cloud very high in the air. These particles give off radiations similar to X-rays. Some

are relatively large, some are smaller, and some are very fine, like dust. The larger particles fall to earth quickly, close to where the explosion has taken place; the finer particles, high in the air, are carried by the wind and come down to earth slowly, giving off their harmful radiations. The name given to all of these particles is FALLOUT.

About 90 percent of the energy of a nuclear explosion is released through blast, heat and initial radiation. The remaining 10 percent of the bomb's energy is released as residual radiation; as time goes on this radiation becomes less dangerous. In considering the effects of fallout on agriculture, its radioactive contaminants are the principal concern.

RADIATION HAZARDS FROM FALLOUT

Living organisms may be exposed to both external and internal hazards of radiation from fallout. Both are of concern to agriculture.

THE EXTERNAL HAZARD

In dangerous concentrations, radioactive fallout in a nuclear war would look and behave much like sand or dirt and could be seen, felt or tasted. The physical senses could be relied upon to determine whether or not a fallout hazard existed. Evaluation of the degree of the hazard would require special instruments. Qualified authorities would broadcast warning instruction and radiation intensities as soon as possible.

The over-riding danger from fallout is external exposure to gamma radiation. Gamma rays are similar to X-rays. They travel many yards through air and several feet through water, and are difficult to shield against. Their intensity can only be reduced by shielding with a sufficient mass of material between the source of radiation and the subject.

Beta radiation is not very penetrating and it is only when the fallout material is allowed to remain on the skin or hair that severe beta burns would result. These are easy to prevent by keeping the skin or hair covered or by brushing off any fallout material that comes in contact.

The effects of gamma radiation on man and animals range from nondetectable damage, through varying degrees of "radiation sickness," to death. Radiation sickness can block the ability of normal body mechanisms to overcome infections, but all living organisms have recovery processes and are capable of repairing some degree of radiation injury.

Plants are more resistant to radioactive rays than animals. To date, the effects of radiation on growing plants has been observed for relatively few species. The severity of the associated heat and blast effects have tended to obscure radiation damage on growing plants. It is considered that the external radiation hazard to edible plant species will be comparatively small.

Seeds of different species vary so greatly in sensitivity to radiation that those of pine or onion, for example, may be completely killed by 1,000 rads (units) of gamma rays, while seeds of alfalfa or flax tolerate more than 100 times this amount. Extremely high doses of radiation destroy the ability of wheat, barley, red clover and millet to develop beyond the germination stage.

THE INTERNAL HAZARD

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. While inside the body, the contaminants continue to emit radiation which damages the surrounding cells. Agricultural products, both animal and plant, can be contaminated with fallout and thus can be an internal source of radiation for consumers.

RADIOISOTOPES CAUSING INTERNAL RADIATION

Human beings and animals have always received radiation from natural sources both inside and outside the body. One of the chief internal sources is the radioisotope potassium-40, which is a normal constituent of the element potassium as it exists in nature. Another source is carbon-14, an isotope of carbon. Potassium and carbon are among the most common elements in the food we eat. Uranium, thorium and radium, being present in varying amounts in soil and rocks, are seldom far away. In addition, radiation may be received during localized exposure for dental and medical X-rays and similar treatments, and some is contributed even by the luminous dials of wrist watches and instruments. A final important source is the ceaseless cosmic radiation from outer space. The total amount of radiation received by humans and animals during their lifetime from all natural sources is considerable, but it does not appear to be harmful.

Many isotopes have been identified among fission products of nuclear explosions. The radioactivity of each isotope diminishes or "decays" at a specific rate, different for each isotope. The rate of decay is expressed in terms of "half-life." Some isotopes lose half their radioactivity within seconds after an 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.

Many of the isotopes produced in nuclear explosions are of only minor importance from the viewpoint of internal radiation, because of the small amounts produced, their extremely short half-lives, or the small extent to which they move in the food chain to man and animals. Among the isotopes of significance as internal radiation hazards are iodine-131, iodine-133, strontium-89, strontium-90, barium-140 and caesium-137.

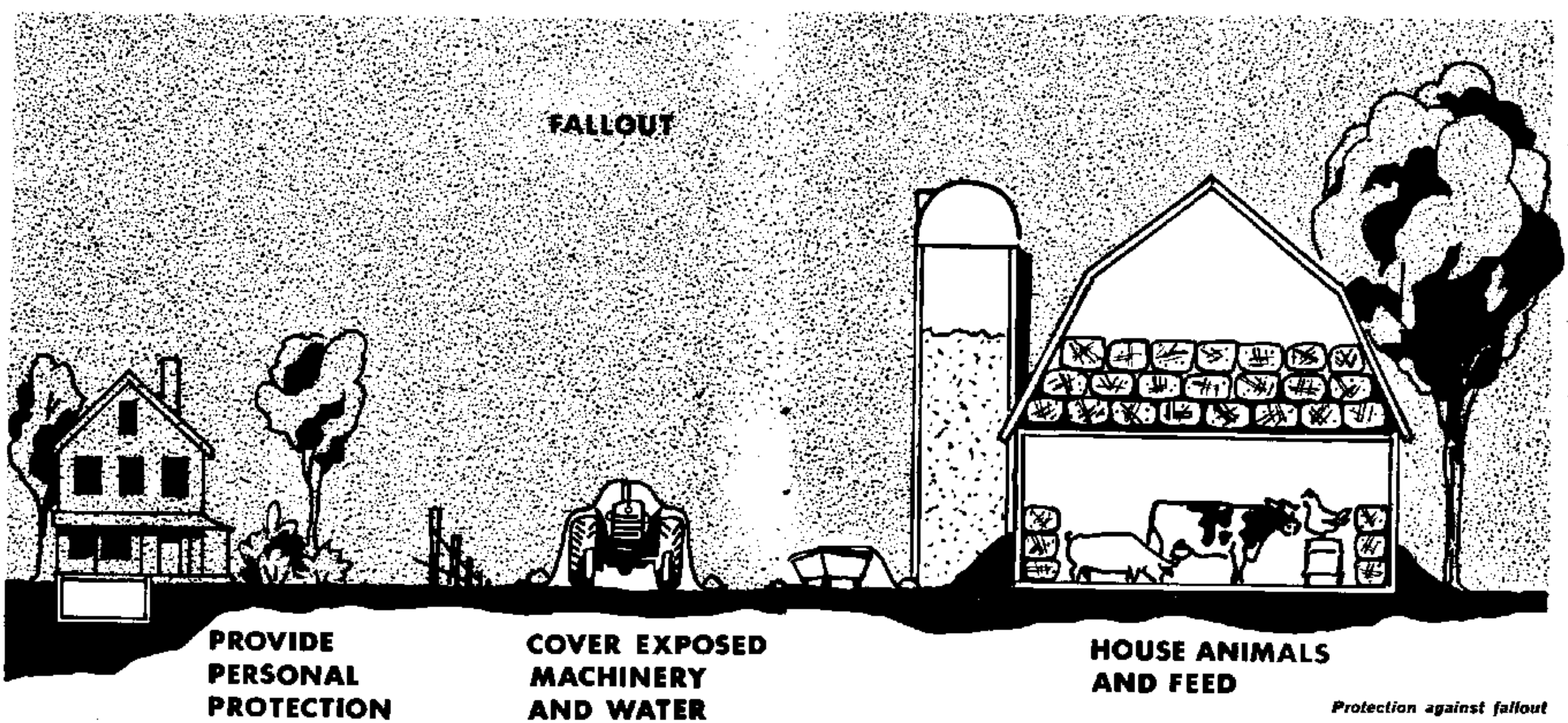
Iodine-131 is the most serious internal hazard during the early period after fallout. Radioactive iodine behaves in the body in the same way as ordinary iodine, and accumulates in the same way in the thyroid gland. It is transferred so rapidly to milk when cows consume contaminated fodder that some iodine-131 may be detected in milk within 30 minutes after ingestion, but its peak levels are not reached for 2 or 3 days. Iodine-131 has a relatively short half-life (8 days), and its removal from pasture by rain also leads to a comparatively rapid reduction in its contamination of milk. The shorter-lived iodine isotope, iodine-133 (half-life 22 hours), is produced in sufficient quantity in nuclear explosions to make a significant contribution to the radiation dose to the thyroid, but only during the first few days after an attack.

PROTECTION AGAINST EXTERNAL RADIATION

Practical methods of protection against external radiation from fallout are based on distance, time, shielding and decontamination.

DISTANCE

Distance is a factor of natural protection against radiation from external sources. The farther away you are from the



Protection against fallout

source, the less intense is the radiation. If you could keep 12 feet or so away from the nearest fallout, you would receive only about two-thirds of the radiation. If fallout is on a roof 20 feet over your head, you will get less radiation exposure than you would get from the same amount of fallout on a roof immediately over your head.

TIME

The lapse of time after a nuclear explosion is another natural protection against the external hazard from fallout because its radioactivity decays as time passes. All but the most important farm operations should be postponed as long as feasible in order to take full advantage of this decay.

The total radiation hazard of fallout decreases rapidly at first because many of the isotopes that it contains have short half-lives. In order to estimate the decrease of total radioactivity, an approximate rule may be used. For every sevenfold increase in time (hours) following an explosion, the resulting radiation decreases tenfold. As an example of this decrease:

> If the radiation dose rate in an area is 1,000 roentgens per hour at 1 hour after the explosion, and if no more fallout occurs, the dose rate 7 hours after the explosion would be about 100r/hr (a tenfold decrease from 1,000). In 49 hours (7 x 7) or about 2 days, the rate will be down to 10r/hr. In 343 hours (7 x 7 x 7) or about 2 weeks, the rate will be down to 1 roentgen per hour.

SHIELDING

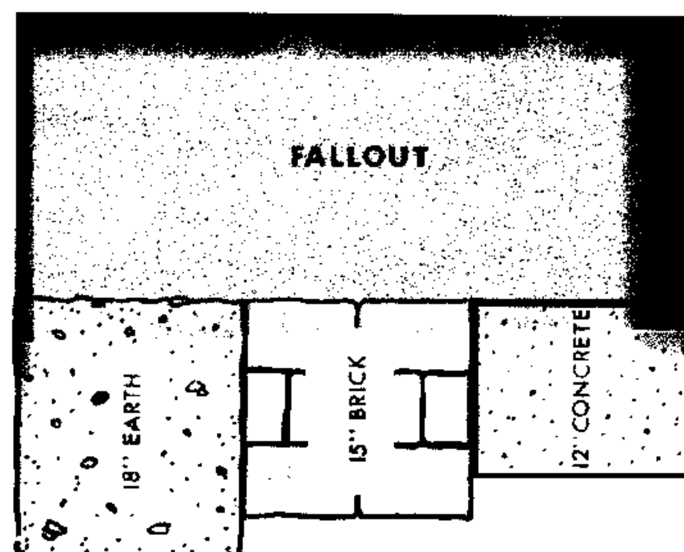
The most important protection against fallout is shielding. The interval between an explosion and arrival of fallout may provide the time required to get your family and livestock under shelter and to cover water, food and feed. Within the limits of their resources farmers should develop plans to provide shelter for their families and for that part of their livestock that could be protected. If people and animals can stay within a good 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 harmful effects of radiation.

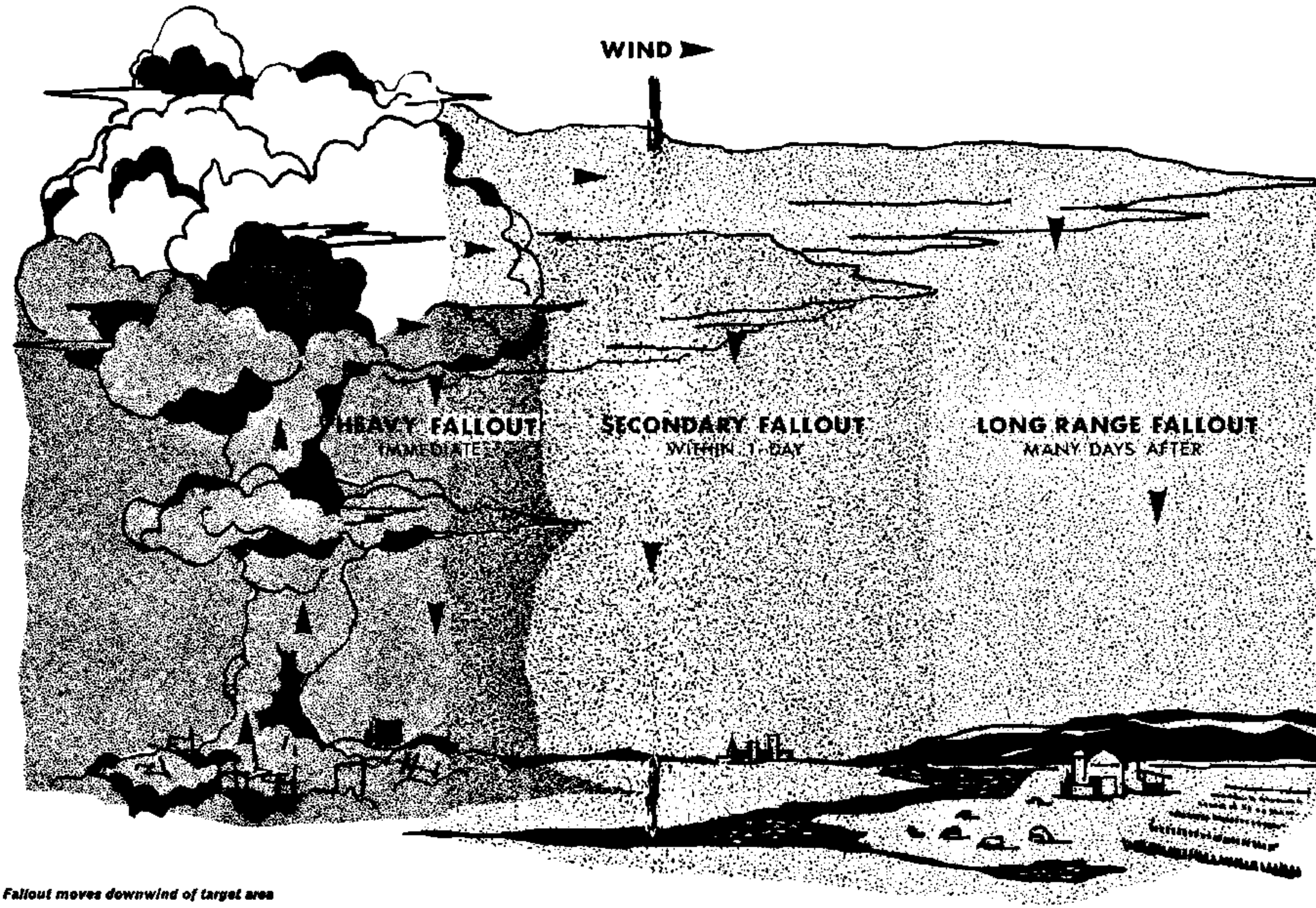
Radiation is partially absorbed and reduced in intensity as it passes through any material. Therefore, shielding of any type gives some degree of protection. If enough shielding is provided between a person and a source of radiation, exposure can be reduced to a permissible level. Radiation is markedly absorbed by heavy materials like brick, concrete and earth. A person shielded by a foot of concrete, or 15 inches of brick, or 18 inches of earth, would receive only one-twentieth of the dose he would get if unprotected.

DECONTAMINATION

Contamination by fallout is different from contamination by disease organisms or by poisonous chemicals. Disease organisms can be destroyed by sterilization; poisonous chemicals can often be neutralized. But since radioactive fallout cannot be destroyed or neutralized, decontamination involves removing it by washing, vacuuming, brushing or some other method. Fallout should be removed from any location where it is a hazard and placed where it can do little or no harm.

Intensity of radiation is reduced to 1/20 by different thicknesses of heavy materials





Fallout moves downwind of target area

PROTECTION AGAINST INTERNAL RADIATION

Radioisotopes inside the body may damage the cells with which they come in contact. When fresh fallout drops on an area the principal source of internal radiation for man and animals is likely to be surface contamination on food, feed and water. After some time radioisotopes in the soil may be absorbed into crops through their roots, and may be injurious to humans who eat food prepared from crops so contaminated or derived from animals that have eaten the contaminated feed.

Protection against the internal hazard includes all measures to prevent or reduce inhalation or ingestion of fallout. Since significant amounts of fallout might be breathed in, respirators, dust masks or masks made of finely woven cloth should be worn during the first few days of fallout and later on during dusty periods or when working with contaminated crops or livestock. Surface contamination on food should be removed by washing or by discarding outside parts. Hands and face should be washed well immediately after working with contaminated materials.

FARMING UNDER FALLOUT CONDITIONS

SOIL

Agricultural land should not be subjected to drastic remedial measures such as decontamination unless it has been seriously contaminated with strontium-90. Neither special remedial measures nor modifications of normal practice should be introduced until responsible authorities have determined the seriousness of the contamination. If it became necessary to reduce the soil radioactivity, decontamination or drastic modification of usual practice would be required, and would possibly be followed by other measures at successive links in the food chain. Some methods have already been investigated and others are being studied.

Decontamination of soils is necessary only for the removal of strontium-90. Other biologically significant fission products

have such short half-lives or are taken up from soils by plants in such small amounts that decontamination is not necessary. The degree to which any area would be decontaminated would depend upon the need for more cropland, and the availability of manpower, equipment and fuel. The costly methods of soil decontamination now known would be used only in limited areas, and only if absolutely necessary.

CULTURAL PRACTICES

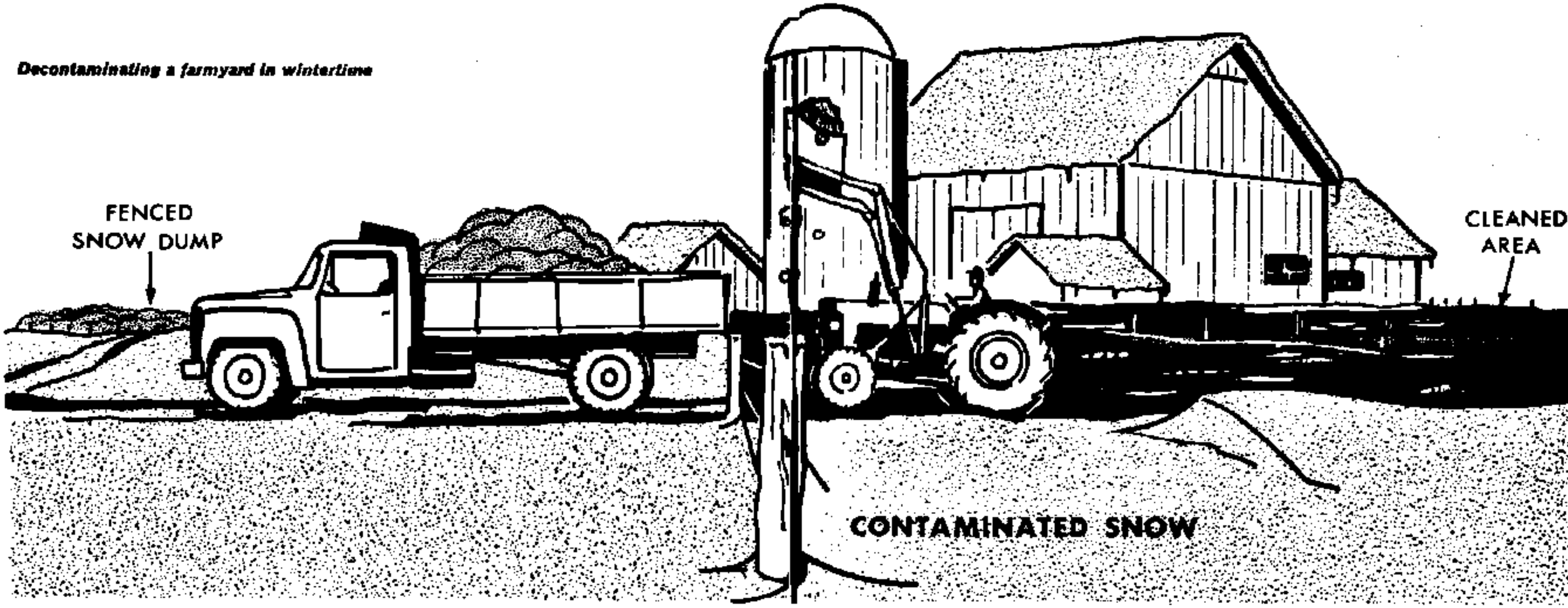
Although removal of surface soil is one of the most effective methods of decontamination, it would be very expensive, but might be essential if small clean areas were needed to produce food for survival. Scraping off 2 inches of soil with a road grader may remove more than 99 percent of the fallout from smooth soil, but only 60 percent from rough soil. The latter may be decontaminated by repeating the scraping operation.

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 could not be used for crop production.

Decontamination by deep plowing would be aimed at placing the contaminated surface soil 18 inches or more below the surface where it would be below most of the roots of plants that would be grown. After deep plowing, shallow-rooted crops such as grasses and many vegetables might take up 50 percent less strontium-90. But once strontium-90 has been plowed under, either by deep plowing or by normal tillage, future removal of it is virtually impossible. Further, as the productivity of many soils would be drastically reduced by deep plowing, the need for the crops that could be grown and the possible alternatives would have to be carefully evaluated.

Decontamination by the removal of ground cover is effective when the existing cover is thick enough. For example, removal of contaminated heavy straw mulches (5 tons per acre) removes from 50 to 80 percent of the radioactivity even following rainfall or irrigation. Removal of contaminated lighter straw mulches (2 tons per acre) removes from 30 to 50 percent. The removal of sod contaminated with fallout can reduce radioactivity by over 90 percent. Standing crops usually provide less complete ground cover, especially when young, and harvesting them

Decontaminating a farmyard in wintertime



may remove only a small fraction of the fallout. 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. Contaminated crops should be harvested, baled and stored where they will present the least possible hazard to humans and animals.

FERTILIZERS

In low-calcium soils the need for calcium by plants leads to absorption of the chemically similar element strontium. Liming of acid soils reduces the uptake of strontium by making more calcium available to the plants: but liming soils that contain plenty of available calcium would have no appreciable effect on strontium uptake. For most soils and crops, lime should not be applied in excess of the amount needed for maximum crop growth. Farmers should use the amount of lime recommended to bring the soil to pH 6.5. Limestone should be finely ground so that it will react quickly with the soil. On plowed land it should be mixed thoroughly into the soil.

The addition of lime, gypsum, fertilizers or organic matter usually reduces the uptake of strontium-90 by less than 50 percent, but liming the surface of established grass pasture at the rate of 2 tons per acre has lowered strontium uptake by

two-thirds. Gypsum would be most useful on soils containing large quantities of sodium which would normally need gypsum regardless of the strontium-90 hazard. Potassium fertilization of soils low in potassium will help to reduce the uptake of strontium-90, but calcium uptake by plants is somewhat 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.

CROPS

Radioactive fallout could contaminate large areas of crop and pasture. In most areas this would not damage seeds or young plants, nor would it affect growth, but the crops might not be fit for consumption when harvested.

Fallout that settles on plants contaminates them as long as it adheres to the above-ground parts, or if its radioisotopes are absorbed into the leaves or other plant parts. Rain and wind may remove fallout from plants to the soil. Certain characteristics of the leaves, fruits or seeds, such as hairiness and roughness, increase the retention; smoothness reduces it. Even badly contaminated crops might sometimes be saved for food. Salvage of unharvested crops would depend on the amount of fallout or the stage of growth when it occurred.

Contaminated cereal crops would be partly decontaminated in the threshing process; even if only slightly contaminated, cereal crops would be made safer by threshing. Mature root crops would not be likely to absorb fallout but should be thoroughly washed before use. Grain, potatoes and root crops stored in weather-proof buildings before fallout would be safe to eat. Hay or straw stacked before fallout would be safe to use if the outside layers or bales were removed. Crops contaminated by fallout should be kept on the farm until their use has been approved.

Contaminated land may be diverted to other crops if the radiation level is too high for those usually grown. The quantity of strontium-90 absorbed could be reduced by growing crops with lower calcium requirements. For example, as potatoes contain only about 10 milligrams of calcium per 100 calories, they are more suitable than leafy vegetables, which may contain from 100 to 1,000 milligrams of calcium per 100 calories. Corn, sugarbeets and oil crops may be suitable for substitution on land too heavily contaminated to produce other foods. Their by-products, such as beet pulp, linseed and soybean oil meals, should be used as animal feeds only after certification by the proper authorities. In general, the less contaminated land should be used for crops that have a high calcium need; very heavily contaminated land might have to be taken out of food production and used for the production of non-edible commodities.

WATER

To protect water from radioactive fallout may not be difficult. The simplest method may be to place a cover over it. Well water could be considered drinkable if the well was carefully covered and sealed to prevent the entry of contaminated dust or surface run-off. Water stored outside in stock-watering troughs should be covered with any material that will keep out dust. By protecting adequate reserves of water, farm families can prevent internal radiation damage from fallout when the intensity of its radiation is at high levels. During the emergency period after fresh fallout, the use of surface water or collected rainwater should be restricted. The protected water should be used first.

Ponds or dugouts would be difficult, if not impossible, to protect. But contaminated ponds and lakes may cease to be a problem, as the hazard is gradually reduced by the dilution of the radioactive fallout in the water and its adsorption by clay on the sides and bottom of the pond or lake.

LIVESTOCK

The relatively large particles of early fallout are not readily ingested or inhaled. Their main hazard to animals would be external whole-body irradiation. But as the distance from detonation increases the character of fallout changes and the hazard would be chiefly that of internal irradiation due to ingestion of fine radioactive particles.

The various effects of ingestion of fission products on food-producing animals are largely determined by the degree of absorption, as well as by their distribution and localization within the body. When the amount of consumed fission products is great enough and the retention long enough, isotopes widely distributed throughout the body can produce an injury resembling whole-body irradiation. Caesium-137 is fairly uniformly distributed, while iodine-131 is concentrated principally in the thyroid gland. As strontium-90 is concentrated in the bone crystal its damage would be restricted chiefly to the bones. This damage is not likely to be encountered in animals intended for meat purposes but may be seen in those usually maintained for a substantial period of time, such as breeding stock and dairy cows.

Tolerance to whole-body irradiation varies among species of animals as well as among animals of the same species. Domestic animals are about as radio-sensitive as man; they can tolerate continued exposure to radiation at a low rate better than brief exposure to radiation at a high rate. For swine, the midlethal dose is 600 roentgens in a 24-hour period; but if they do not receive more than 50 roentgens per day, the midlethal dose may be fourteen times as great. In other animals, this effect may not be so great but still is substantial.

Animals, both male and female, observed for a number of years have not become permanently sterile after experimental exposure to midlethal or higher radiation doses. The effects produced on fertility by fallout radiation will probably not be serious in farm animals.

SHELTER

At low radiation intensities no animals would die or become sick even if unsheltered. The objective of providing shelter for livestock and poultry is to reduce the number of deaths and injuries from midlethal radiation. Under good shelter many animals could be saved even if radiation intensity was fairly high outside.

Preparations should be made so that, if there is time to attend to livestock after warning of fallout is received, they can be given the best possible care. A good tight barn would reduce the radiation dose by about one-half. The best shelter is a 2-storey basement-type barn with its loft filled with hay. Milking cows should 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.

If sufficient warning time is available livestock for which there is no proper shelter should, if possible, be placed in a fenced, wooded area, under trees where they are covered to some extent. Any animals that have been exposed to fallout should be washed or wet-brushed (not dry-brushed) as soon as it is safe for the farmer to stay outside for a limited time. Detergents can be used to advantage.

FEEDING

Feed should be reduced to the minimum needed for subsistence. If no shelter is available, or when feed reserves are low, grazing on contaminated pastures may be necessary but should, if possible, be supplemented by small amounts of uncontaminated feed in order to reduce the daily dose from ingested radioactive material. It is better to give livestock contaminated feed and water than to let them die from starvation, but in extreme cases and for short periods of time farmers may have to withhold all feed and water. If only a limited amount of feed can be protected from fallout, it should be reserved for one or two milking cows. This milk can then be safely used by the farmer and his household.

LIVESTOCK PRODUCTS

It is highly unlikely that food such as meat and eggs, derived within a few days from exposed but surviving animals, will contain enough radioactivity to result in immediate harm to the consumer. Children should not consume milk from these

animals as the iodine-131 level is likely to be dangerously high.

Poultry are more resistant to radiation than mammals and may serve as a particularly useful source of protein. Hens quickly eliminate ingested fission products such as radiostrontium and radiobarium by way of the egg shells. Their usual housing gives them moderate protection; their feed is generally stored and hence unexposed; they are easily transported; they can be slaughtered and dressed by consumers; and they do not require refrigeration since they can be kept alive until they are needed and can be consumed immediately after slaughter.

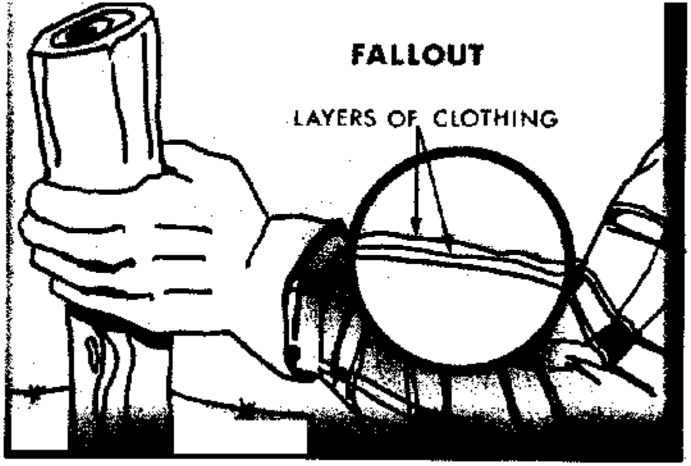
Food that is unacceptable by peacetime standards may have to be used to provide the energy for essential work, since starvation and nonperformance of duties may pose a far more serious threat than the radiation injury to consumers. If livestock that have been exposed are well and can be handled without undue radiation hazard, they can be used for food. External exposure actually contaminates only the outside of an animal. Ingested contaminants are largely eliminated in the faeces and urine, and most of what remains in the animal's body is in the viscera and bones.

PERSONAL PROTECTION

During the first phase of fallout, when little may be known of its intensity and nature, it will be wise for husbandmen to keep their personal exposure to the minimum consistent with the survival of their communities and families. Allowable daily maximum outside work periods will depend on the dose rate in the area and will be broadcast by local authorities. The head, neck, hands, wrists and ankles should be protected by wearing a hat, a muffler and gloves, and by tying overalls at the wrists and ankles. Outside clothing should fit closely and be brushed thoroughly before removing.

If it were safe to be outside for unlimited periods it would be safe to prepare the ground for crops, to sow seeds or set out plants, or to harvest crops. But if advised to stay indoors most of the day, farmers should wait a week or ten days before commencing work on the land or harvesting fruits and vegetables.

Persons handling or slaughtering exposed animals might be in danger of inhaling contamination from dusty hides and of



Clothing helps to protect against beta rays

external exposure from fallout on hides or in discarded organs. The degree of danger will depend upon the precautions taken by the handler and the protection that can be afforded him.

Contaminated hides and viscera should be placed where their radiations will not endanger the processor. When normal processing can be resumed, the washing of contaminated animals and the safe disposal of hides, viscera and bones will greatly decrease the danger. Plants handling contaminated livestock will have to provide special protection for their workers.

GLOSSARY

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

ACUTE EXPOSURE: Severe radiation exposure of short duration.

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

BACKGROUND RADIATION: Ionizing radiation exposure 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 cosmic rays.

BIOLOGICAL HALF-LIFE: The time required for the body to eliminate one half of an administered dose of any substance by regular processes of elimination.

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 causing the destructive effects of an explosion.

CONTAMINATION (RADIOACTIVE): The deposit of radioactive material on the surface of soil, crops, water, structures, humans and livestock following a nuclear explosion. Food may be further contaminated by radioactive material absorbed from contaminated soil or water.

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

DOSE: A quantity (total or accumulated) of ionizing radiation. The term dose is often used in the sense of 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 rads, which represents the energy absorbed from the radiation per gram of specified body tissue.

DOSE RATE: The amount 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.

EXTERNAL RADIATION: Radiation from a source external to the body.

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

FISSION (NUCLEAR): The process in which the nucleus of an atom splits into 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 fresh mixture contains about 200 different isotopes of over 40 elements.)

FOOD CHAIN: The pathway followed by nutritive substances originating from soil, water or air through plants and animals to reach man by means of food.

GAMMA RADIATION: Electromagnetic radiation of high energy with great power of penetration emitted by the nucleus of an atom. This radiation accompanies many nuclear reactions including nuclear fission. Physically, gamma radiation is identical with X-rays of high energy. The only essential difference is that X-rays do not originate in the nucleus of an atom.

HALF-LIFE: Time required for a radioactive substance to lose 50 percent of its radioactivity by 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 the exposure dose rate of radiation at a given location. *See:* **DOSE RATE.**

INTERNAL RADIATION: Nuclear radiation in the body resulting from swallowing or inhaling fallout particles.

IRRADIATION: Exposure to radiation.

ISOTOPES: Forms of the same element which 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 (non-radioactive) or they may be radioactive.

MAXIMUM PERMISSIBLE EXPOSURE: The total amount of ionizing radiation exposure which it is believed a normal person may receive without unduly harmful effects.

MIDLETHAL DOSE (MEDIAN LETHAL DOSE, OR LD/50): The amount of total body radiation which would probably be fatal to 50 percent of living organisms of a given species.

NUCLEAR RADIATION: Radiation emitted from atomic nuclei—alpha rays, beta rays, gamma rays and neutrons. All nuclear radiations are ionizing radiations, but the converse 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.

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 nuclear weapons, and the term is used to include both types in this report.

PERMISSIBLE LEVEL: *See:* **MAXIMUM PERMISSIBLE EXPOSURE.**

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

RADIATION SICKNESS: A disease resulting from excessive exposure of the whole (or a large part) of the body to ionizing radiation.

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.

RADIOISOTOPE: A radioactive isotope. *See:* **ISOTOPE.**

RESIDUAL RADIATION: Nuclear radiation, chiefly beta and gamma rays, which persists for some time following a nuclear explosion.

ROENTGEN: A unit for measuring a radiation exposure dose. *See:* **DOSE.**

SHELTER: A specially constructed refuge, or the use of normal buildings or materials for the purpose of protecting people, livestock, food, feed or water from fallout.

SHIELDING: Any material or obstruction which, by absorbing radiation, helps to protect people and livestock.