Radiological Emergency Manual for Livestock, Poultry, and Animal Products

prepared for:

UNITED STATES DEPARTMENT OF AGRICULTURE ANIMAL AND PLANT HEALTH INSPECTION SERVICE

by

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QUICK REFERENCE SECTION

A. *It is important to notify the appropriate authorities as soon as possible in order to receive a quick response. The phone numbers of various agencies are included in Appendix B of this document. You should record the agency and phone numbers that are applicable for your state in the following spaces.*

STATE AGENCY	AREA CODE/PHONE NUMBER
REGIONAL FEMA OFFICE	AREA CODE/PHONE NUMBER
OTHER AGENCY	AREA CODE/PHONE NUMBER
OTHER AGENCY	AREA CODE/PHONE NUMBER

B. *The agency that you contact in the event of an emergency will need to know the following information, so be prepared to have this information available.*

Your Name: ______

Location from which you are calling: ______

Your Area Code and Phone Number: ______

Your Address: ______

A description of how to drive to your farm: ______

Types and number of livestock in your care: ______

Where are your livestock now? ______

Your description of current conditions at your farm: ______

Are livestock/poultry foodstuffs protected? yes ____ no ____

Approximately how long will your stored feed last? ______

Where do your animals get their drinking water? ______

C. WHAT TO DO UNTIL HELP ARRIVES:

1. As practical, collect the livestock inside available buildings or corrals, preferably equipped with a cover or roof. (See Chapter III, Section B.)

2. Cover foodstuffs like hay, grain, and corn, to minimize contamination. (See Chapter III, Section C.)

3. Stay inside a shelter to reduce your dose. Make plans to remain indoors for three to four days, except when caring for your animals. (See Chapter II, Section C.)

4. Listen to the radio or television to determine the extent of the incident.

5. Put on a respirator and wear at least one layer of clothing to cover your entire body when you have to be outdoors. (See Chapter III, Section C.)

6. Wash your hands and feet thoroughly to remove contamination before you come inside your shelter from outdoors.

7. Do not wear boots and outer clothing which you have worn outdoors into living areas. (See Chapter III, Section D.)

8. If possible, obtain radiation survey instruments and a fresh supply of replacement batteries. (See Chapter II; Section D.)

9. When advised, begin decontamination procedures. (See Chapter III, Section E.)

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I. INTRODUCTION

Incidents and accidents which involve exposure to radiation have become matters of great public concern. Examples of radiation exposure scenarios might be: accidents at nuclear facilities (such as nuclear power plants, government laboratories, or industrial facilities); detonation of a nuclear weapon (either accidental or from a terrorist incident); transportation accidents; or any other incidents where radioactive materials are released on a local or regional level. This concern has been heightened by media reports which emphasize not only the early effects of large doses of radiation, but also the fears of cancer epidemics occurring among the general public as a result of exposures to even very low levels of radiation. It is in this climate of public fear regarding the effects of radiation that livestock and poultry producers should be aware of the basic facts about radiation, so that they may make rational decisions about their own personal safety, and the protection of the herd or flock in the event of a nuclear incident.

In the United States, farm livestock provide about 40% of our food energy, 67% of our protein, and 75% of the calcium in our diet. They also contribute hides, hair, wool, and many other products for human use. Farm animals are also used as companion and sporting animals. A significant loss of America's livestock or poultry, or reduction in animal products, would impact the entire country.

Over the years, livestock and poultry producers have met and overcome many forms of disaster. Fires, floods, draughts, tornadoes, disease epidemics, and insect pestilence have threatened to devastate herds and flocks. However, a nuclear incident or accident that involves the release of radioactivity into the environment presents an unfamiliar threat which must be met with knowledge, planning, and common sense.

From many years of scientific research, we knowthat farm animals show no measurable effects from being exposed to radiation unless the level is many times greater than natural background radiation. The facts presented in this manual can be of assistance to producers in determining the proper response to a nuclear incident in the unlikely event of such an occurrence.

This manual is intended for the use of those persons directly responsible for the protection of livestock, poultry, and animal products, from any radiation and radioactive materials that may be released in a nuclear incident. While the majority of the material presented in this manual can be applied to radiation protection procedures in the event of global thermonuclear war, there are other factors which must be considered in wartime situations that are beyond the scope of this manual, and will not be addressed here.

This manual can be used as an instruction manual for veterinarians and technical specialists on how to manage livestock, poultry, and animal products during and after a radiological emergency. It can also serve as a training resource for use by technical specialists and others who are undergoing specialized training in radiological emergency management of farm animals. Additionally, it can serve as a reference document for farm managers, animal and animal product producers, and emergency assistance organizations. The management methods for livestock, poultry, and animal products presented in this manual are designed to preserve the maximum number of useful, food-producing animals in a radiologically-contaminated area. However, it is equally important to minimize the health effects to the handlers of animal and animal products. Therefore, basic personnel protection information and techniques will also be presented.

In the event of a radiological contamination incident, emergency assistance will be available from federal, state, and in some cases, local agencies. The Federal Emergency Management Agency (FEMA) has principal responsibility for coordinating assistance in the event of a radiological emergency. Other federal organizations which provide emergency assistance for radiological contamination incidents include the Nuclear Regulatory Commission (NRC), the Department of Energy (DOE), the Department of Defense (DOD), and the Department of Health and Human Services(DHHS). Assistancefrom federal agencies is provided in support of state emergency assistance organizations. The quick reference section of this manual provides you with a place to list the names, phone numbers, and responsibilities of these organizations in your state. A complete listing of emergency assistance organizations and their addresses is given in Appendix B of this manual.

The United States Department of Agriculture (USDA) assists state, local, and Federal agencies in protecting public health and safety. The USDA has instituted a radiological emergency response system which provides assistance from within all levels of its organization. The primary concern of the USDA is the food ingestion pathway. Therefore, a major goal of the USDA response system is protection and control of the food production systems. The Food Safety and Inspection Service of USDA has the principle responsibility for assuring the wholesomeness of meat and meat products, and poultry and poultry products, in the event of a radiological contamination incident. The Animal and Plant Health Inspection Service (APHIS) of USDA provides guidance for the protection of livestock and poultry against hazardous agents. Production and distribution of this manual is only one service provided by USDA in accomplishing its emergency assistance role for nuclear incidents.

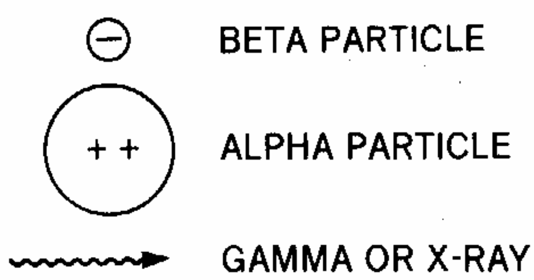
II. BASIC INFORMATION

A. RADIOACTIVITY AND RADIATION

Before presenting information that is specific to management of livestock and poultry in the event of a nuclear emergency, it is important to assist the reader in understanding the underlying principles of radiation protection in order to remove some of the anxieties which many members of the public may have about matters concerning radiation. For those readers that require more detailed information, the Bibliography at the end of this manual contains a listing of additional literature. A glossary of frequently-used words is given in Appendix A. These words are in italics the first time they appear in the text.

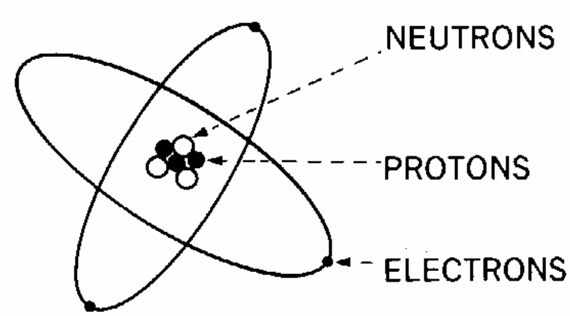
1. Radiation, Radioactivity, and Contamination

In the early 1900s, scientists discovered that certain materials emit three different kinds of energy, which they named alpha, beta, and gamma radiations. This energy can pass through certain thicknesses of air, liquids and solids like tiny bullets, but at speeds many thousands of times faster than the fastest rifle bullet. The energy that is given off by certain materials has come to be called radiation, nuclear radiation, or ionizing radiation. These radiations cannot be seen, heard, felt, smelled, or tasted.



It was later discovered that alpha and beta radiation are really very tiny, electrically-charged particles. Even later,. it was determined that gamma rays are really packets of pure energy, called "photons", that contain neither electrical charge nor matter, and travel at the speed of light. Consequently, gamma radiation is more penetrating than alpha or beta radiation. Visible light and x-rays are also photons, except that photons of visible light have much less energy than the photons of gamma rays or x-rays. Alpha, beta, and gamma radiation originates from the nucleus, or central part, of a radioactive atom, and are therefore called "nuclear radiations".

All matter consists of very tiny particles called atoms. Atoms in turn are made up of even tinier particles called electrons, protons, and neutrons. Electrons and protons are electrically-charged while neutrons, as the name implies, are electrically neutral. Protons have a positive electrical charge and electrons have a negative charge. An atom that contains the same number of electrons and protons is electrically neutral since the positive and negative charges are balanced. The neutrons and protons are arranged in a central cluster called the nucleus. Electrons travel around the nucleus in much the same way that satellites orbit the earth. When two or more atoms combine, they form a molecule. For example, the chemical combination of two hydrogen atoms with one oxygen atom froms a molecule of H2O, or water.



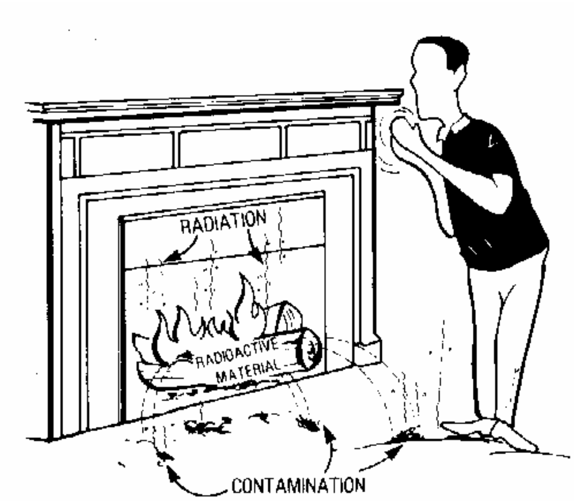
Most atoms are stable and will never emit any radiation, but certain kinds of atoms have a large surplus of energy. These atoms are called "unstable atoms".

Eventually these atoms will emit radiation in the form of particles that have weight, such as beta or alpha particles, or in the form of weightless packets of energy, such as gamma rays. The term radioactivity refers to these unstable atoms which emit radiation.

As we have already discussed, radiation is the energy emitted in the form of particles or packets of energy as some atoms go from an unstable state to a more stable state. Materials that spontaneously emit radiation are known as radioactive materials.

What then is "contamination"? In the simplest terms, contamination is radioactive material in any place where it is not desired. For example, if radioactive material were released during a nuclear incident and deposited on the ground, the ground would be "contaminated".

Perhaps it would be best to illustrate the concepts of radiation, radioactivity, and contamination using something with which we are more familiar. In your mind, picture a fireplace. The heat and light coming from the fire are somewhat like ionizing radiation. The burning logs would be like radioactive material, and embers that fall outside the fireplace are like contamination. You would be "exposed" to the heat and light if you warmed yourself from the "radiation" from the fire, but you would not be "contaminated" unless burning embers ,from the fireplace got on you.

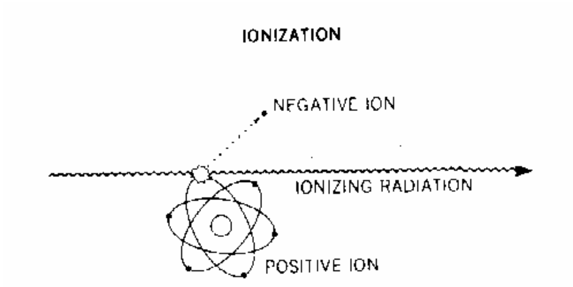


As stated previously, radioactive materials change, or decay into a stable condition by emitting radiations. Some of these materials decay into their stable form faster than others. Those that change fast are very busy producing intense nuclear radiation in a short time period after they are released in a nuclear incident. Those materials that decay more slowly may be responsible for the presence of measurable radiation in the environment for many years after the incident. The halflife of a particular radioactive material is the time it takes for half of the atoms of the material to undergo radioactive decay.

To continue our fireplace analogy, the burning log (radioactive material) emits heat (radiation). But as time goes on, the amount of heat emitted decreases (decays) as the quantity of fuel available for burning decreases. The heat emitted from the log decays until eventually the fire goes out (reaches a stable condition).

2. Radiation Interactions

How does radiation interact with matter? Nuclear radiation differs from heat and other types of radiation, such as microwaves, in that each particle or photon has enough energy to cause ionization within materials. Ionization is the stripping or removal of an electron from an atom. Since the electron has a negative charge, the removal of the electron unbalances the charges and leaves the atoms with a positive charge. The atom and electron, separated, are known as an ion pair. In other words, you are left with a positive ion (the atom) and a negative ion (the electron). As radiation interacts in materials, the result then, is the production of ion pairs in the material. Radiation that has enough energy to cause ionization is known as "ionizing radiation".

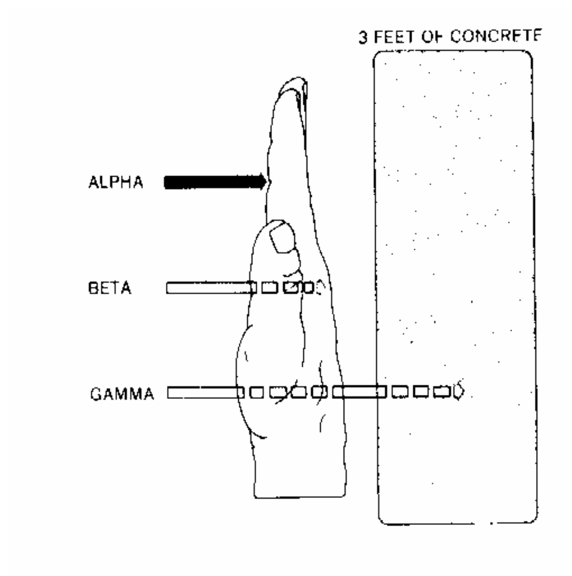


In materials such as water, which makes up the majority of the human body; ionization can lead to breakdown of water molecules and the formation of chemical compounds which may be damaging to living cells. The harmful effects of radiation on the human body, which are described in greater detail in Section B of this chapter, are largely attributable to such chemical reactions.

Alpha radiation consists of positively charged particles which are emitted from naturally-occurring elements such as uranium and radium, as.well as from some manmade elements. Alpha radiation will not penetrate the dead layer, or the surface of the skin,.and can be stopped completely by a sheet of paper. Because of the limited ability of alpha radiation to penetratematter, alpha-emitting materials that are outside of the body are not considered to be harmful. If the alphaemitting material is inside the body, the alpha radiation may cause damage to the tissues inside the lungs or digestive tract. However, during a nuclear emergency, it is unlikely that any humans or livestock can breathe or swallow sufficient alpha-emitting materials to cause early health effects from alpha radiation.

Beta radiation is more penetrating than alpha radiation and can pass through about one-half inch of water or human flesh. A sheet of aluminum less than a tenth of an inch thick can stop most beta radiation. Beta radiation may cause skin burns, or radiation burns, if a sufficient quantity of these particles strike the skin. Although skin burns from radiation look the same as any other burn, you cannot feel radiation-induced burns actually occurring.

Gamma radiation can be very penetrating and can pass through the human body. When a material that emits gamma radiation is taken into the body, the energy of the radiation can escape the body without causing ionization. Therefore, gamma-emitting,materials are primarily a hazard when they are outside of the body. Since gamma radiation is very penetrating, several inches of dense materials such as concrete, steel, lead, or soil must be used as shielding.



3. Quantities and Units

The concept of a given amount of radiation producing a particular effect is no different from that which applies to the medical administration of drugs. Just as one aspirin is unlikely to harm a patient and 100 may kill him, so too will a small amount, or dose, of radiation have no discernible effect, but a large amount will produce serious biological consequences. In addition, it is essential to recognize the importance of the "rate" at which the radiation is delivered. To continue the preceding analogy, 100 aspirins swallowed in one day may kill the patient, but 100 aspirins taken over a period of one year is unlikely to cause any personal harm. The same concept applies to radiation exposure.

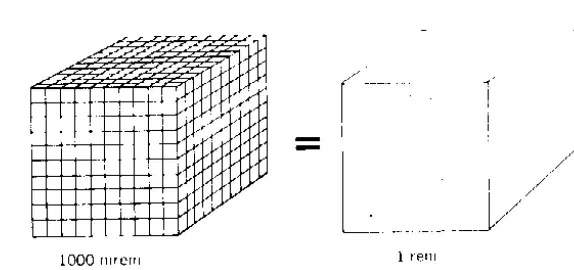
The primary difficulty for the livestock producer in understanding radiation dose lies in the completely unfamiliar units used to measure radiation. It is unfortunate that the common units of weight and volume do not apply. In order to measure radiation exposure or dose, we must make use of the fact that radiation deposits energy and causes ionization within matter.

The unit of absorbed dose is the "gray", or "Gy". In recent years, the units of absorbed dose were changed, so in many publications you will still see that the dose is expressed in rads. One gray is equal to 100 rads. Both units are used to indicate the amount of radiation energy absorbed in biological materials.

Since some types of radiation can cause relatively more damage than others, another unit is needed which will put all ionizing radiations on an equal basis with regard to their potential for causing biological harm. This unit is called the "sievert", or "Sv". Like the gray, the sievert is a new unit and in many publications, the older term, rem is still used. One sievert is equal to 100 rems.

Generally, the rem is considered to be applicable to long-term, low-level radiation doses; while the rad is more applicable to short-term doses. However, to avoid the confusion of mixing units, for the remainder of this report we will use the term "'rem" when referring to any type of radiation dose; whether short- or long-term.

In the field of radiation protection, a radiation dose of even a single rem is considered to be rather large. Doses are more likely to be noted in fractions of a rem, such as the millirem, or mrem, which is one-thousandth of a rem. To put this into some perspective, the general population is exposed to naturally-occurring radiation, over which we have little control, at the rate of about 125 mrem per year.



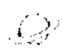
It is important to recognize that humans did not invent radiation. Therefore it is important for the livestock and poultry handler or advisor to realize, and to be able to make quite clear to his employees or clients, that the effects of radiation dose are the same whether radiation is manmade or naturally-occurring. Manmade radiation is no more or no less dangerous than radiation from natural sources. It is the amount of radiation dose received in a given period of time which determines the biological effect. The following section may help to put this into better perspective.

4. Sources of Radiation

Is it true that radiation is basically manmade or artificial? No, not at all. Naturally-occurring radioactivity has been present since the earth was formed. Everyone in the world receives a small dose of radiation at all times from natural radiation sources. This is called "natural background radiation".

Radiation is given off constantly by naturallyoccurring radioactive materials all around us: In the ground, in the walls of buildings, and even in our own bodies. In addition, the earth is bombarded by radiation from the sun and from other sources located in outer space. This radiation is known as cosmic radiation.

The radiation dose that a person receives from natural sources depends on where the person lives. People living at high altitudes receive more cosmic radiation than people living near sea level because there is less air above them to shield them from the radiation from outer space. Also, the soil in some areas contains higher concentrations of naturally-occurring radioactive materials than others. For example, in Denver, Colorado, which has both a high altitude and an abundance of naturally-occurring radioactive materials in the ground, background radiation levels are approximately 200 mrem per year. This is approximately twice the average for the United States.

	SOURCE OF RADIATION	APPROXIMATE ANNUAL DOSE (mrem/year)
	COSMIC RAYS (RADIATION FROM THE SUN AND OUTER SPACE)	30
	BUILDING MATERIALS	[illegible]
	THE HUMAN BODY	[illegible]
	THE EARTH	[illegible]

This figure shows the average yearly radiation dose to individuals in the United States from natural background radiation. The dose applies to most body organs, although some organs such as the lung receive somewhat higher doses.

In some parts of the world, such as certain regions of India and Brazil, there are much higher levels of background radiation. Radiation from radioactive sands in these areas can cause people living there to receive natural radiation doses of 1000 to 3000 mrem per year. (There have not been any observed health effects in these people as a result of these doses.)

People are also exposed to manmade sources of radiation, such as; medical and dental x-rays; radioactive materials injected into the body for medical diagnosis or treatment; fallout from nuclear weapons tests throughout the world; radiation from consumer products (such as color television sets, smoke detectors, some luminous dial wrist watches and clocks, and uranium contained in false teeth); radiation released by nuclear power plants; and occupational dose of people who work with radiation on their jobs. The following table shows the average annual dose from these sources.

	SOURCE	APPROXIMATE ANNUAL DOSE (mrem/year)
	MEDICAL (PRIMARILY FROM DIAGNOSTIC X RAYS)	90
	FALLOUT FROM ATOMIC TESTS	5
	NUCLEAR POWER GENERATION	0.3
	CONSUMER PRODUCTS (SUCH AS COLEMAN LANTERN MANTLES, COLOR TV SETS, BRAZIL NUTS AND SOME SALT SUBSTITUTES)	1

As you can see from this table, people get most of their dose from manmade radiation from medical and dental x-rays. The average annual dose from medical and dental use of radiation is approximately 90 mrem per person. All other manmade sources of radiation combined add less than 10 mrem to the average person's dose. The average manmade radiation dose to an individual in the United States is approximately 100 mrem per year.

Therefore, in round numbers, the average person in the United States receives an annual radiation dose from all sources of about 225 mrem per year. Approximately one-half is from natural background radiation and the other half is from manmade sources. Let us now compare this radiation dose to typical occupational radiation doses.

Radiation sources are used in various occupations, such as medical diagnosis and therapy, industrial radiograpy, and the operation and maintenance of nuclear power plants. There are more than 1.5 million workers in the United States who work with or near radiation in some way, although most of these workers have little contact with the radiation sources and receive very little measurable radiation dose.

The maximum amount of radiation that radiation workers are permitted to receive in their work is 5 rems per year (or 5000 mrem). In practice, the actual doses received are much lower than this. For example, the average occupational dose to workers at a typical radiography company is approximately 400 mrem/year. To put this into perspective, an airline pilot who flies 3000 miles per day at approximately 35,000 feet would also receive a radiation dose from cosmic rays equal to approximately 600 mrem/year.

5. External and Internal Exposure

Radiation reaches human tissues in two ways: From sources outside the body, or from sources that get inside the body from radioactive substances contained in the food or water consumed, or the air breathed. These two categories of radiation exposure are called external exposure and internal exposure, respectively. Both arise from natural, as well as man-made sources.

The most significant sources of external radiation are cosmic rays, beta particles, X-rays, and gamma rays. Penetrating radiations such as gamma rays, deliver relatively uniform doses to all organs. Beta particles are so readily absorbed in tissues that they will irradiate only the skin or lens of the eye. Therefore, they are usually considered to be an insignificant source of external radiation to the general population. However, injuries to skin ancJ:;damage to the lens of the eye can arise at high levels of exposure to beta radiation.

All radioactive materials are considered to be potentially hazardous if they get inside of the body in sufficient quantity. Radioactive materials that are present in food or water may irradiate the gastrointestinal (GI) tract. Similarly, those materials that are contained in air may irradiate the air passages and lungs. But the most important sources of internal irradiation are those radioactive materials that are absorbed from the GI tract and lungs into other tissues. The extent to which absorption occurs depends on the chemical and physical nature of the individual radioactive materials.

The majority of radioactive materials that enter the body for long periods of time after a contamination incident are in foodstuffs. There are, however, some exceptions. After certain types of industrial nuclear accidents, inhalation could be of greater importance. However, this would depend on the physical and chemical form of the material.

B. BIOLOGICAL EFFECTS

The primary cause of all biological effects resulting from radiation exposure is energy released as a result of ionization within cells. It is important, therefore, to describe the general manner in which radiation affects individual cells, since direct injury to a sufficient number of cells will affect tissues within the body. Likewise, if a sufficient quantity of tissue is damaged, organ function may be impaired. Because few organs within the body function independently, impaired function in a single organ will likely affect the function of a number of others, which ultimately impacts the health status of the total body.

The death of a single cell in tissue, by whatever cause, is a normal event. Most tissues, such as skin and bone marrow, have a large reserve of reproducing cells so that death of any cells becomes important only when the number of cells is so large that the loss cannot be replaced. If the new tissue is composed of normal cells, it will function normally. However, if the new tissue comes from defective cells, tissue function may suffer. It is suspected that malignant, or "cancerous", changes in tissue comes from reproduction of defective cells.

Biological effects in humans are usually discussed in terms of "total body" and "partial body" irradiation, with reference to damage to a particular organ. Because of the importance of some organs in the body, damage to them can induce effects in other organs. A number of physical factors are important in determining the extent of biological effects caused by radiation exposure. These are:

Nature or type of radiation— Some types of radiation are more effective in producing damage;
Radiation dose—This is a function of the amount of ionization in tissue;
Time distribution—A dose of radiation which is lethal if given in a short period of time may not be lethal if given over a long period of time;
Dose distribution—This is a function of whether the total body is irradiated or only a specific organ or part of the body.

All of these factors combine to vary the biological effects on different organs for any changes in the radiation exposure conditions. Indeed, even the age of the individual enters the picture, since children are generally more affected by radiation dose than are adults.

Scientists have long known that exposing humans to radiation can have harmful effects. Some of these effects are burns, cancer, genetic defects, and death. Scientists have studied these effects in people who have been exposed to radiation as a result of medical treatment, radiation accidents, or as a result of exposure to radiation from the atomic bombs in Hiroshima and Nagasaki, Japan. Scientists have also studied the effects of radiation on animals that were exposed to radiation as part of experiments. These effects which are observed as a result of radiation dose can be divided into "early" and "late" effects.

1. Early Effects on Humans

Early effects are generally those which appear within a few weeks after receiving the radiation dose. The range of these effects, as well as their duration, depends upon the type of exposure, dose, dose rate, and dose distribution.

For very large total body doses, there are three basic forms of early, or acute damage. If a human receives a radiation dose to the total body above a few thousand rems, it is fatal within minutes to hours after exposure. The same thing happens when someone receives a high radiation dose to the head only. This results in a breakdown of the central nervous system.

For total body doses in the range of 500 to 2000 rems, physical symptoms may appear within minutes to hours. Death often occurs within a week or so. In this dose range, the damage to the lining of the intestinal tract is the most severe. At the lower end of this range, around 500 rem, it is possible for a person to survive the digestive tract damage, only to fall victim to the effects which prevail at lower doses.

For total body doses which are less than 500 rems, the most important effect is damage to the bloodforming organs, such as the bone marrow. The first signs of bone marrow death may appear within a few days, but the total effect may not develop for a few weeks. Severe changes to the bone marrow occurs when the total body dose exceeds 200 rems. In the range above 300 rems, the damage is so severe that death becomes more and more probable.

In general, there are almost no.earlyeffects when the radiation dose to a human is less than 100 rems. Some people may experience mild symptoms mentioned previously in the range of 50 to 100 rems, due to the basic biological differences between individuals. However, below 50 rems, no early effects are expected in any individuals.

As you can see from the above, death occurs in a larger fraction of people as the radiation dose increases. If the dose becomes large enough, everyone that was exposed will die. In the range where survival is possible, the concept of the median lethal dose (LDso) is used. This value represents the short term, total body dose where 50% of the people who have been exposed are expected to die. For humans, the best estimate of the LDso is approximately 300 to 500 rems. Of course, in this dose range, all of them would experience severe symptoms, whether death occurs or not.

2. Late Effects on Humans

It is difficult to study the "late effects" of radiation exposure on humans, since the effects are seen many years after the exposure takes place. Thus, it is difficult to relate the "cause" to the "effect". Since late effects may be caused by many other agents besides radiation, there can be no positive determination of the cause. At best, it can be shown that radiation increases the incidence of certain nonspecific injuries, such as cancer, tissue changes, and altered growth and development.

The study of hereditary effects, or "genetics attempts to discover the traits which can be transmitted from generation to generation in a given species. The genes are what determines inherited traits. Anychange or mutation of a gene can result in an altered trait. These changes can be produced by radiation, as well as other agents. Therefore, the study of radiation-induced mutations is also hampered by the fact that other substances act to produce the same effects.

Since the change might occur anyway, radiation only serves to increase the probability of occurrence of the effect. Increases in the genetic mutation rate are small even for high doses.

Study of the late effects of radiation exposure requires the use of large numbers of subjects, who must be studied over many generations. In the case of humans, this type of study is difficult, since large populations that have been irradiated are seldom available, and the time between generations is so long.

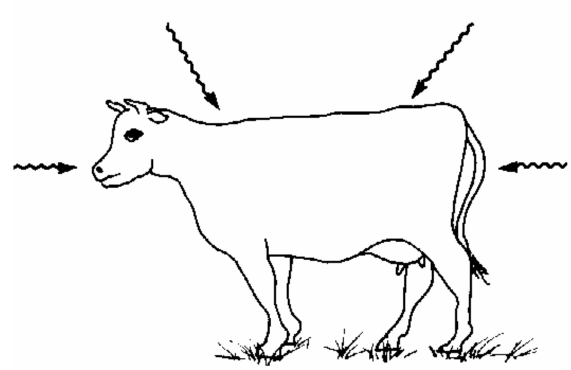
For this reason, much of the present knowledge that we have of the late effects of radiation exposure is based on work with animals. This research has shown that for all doses and dose rates, radiation is known to induce mutations in all species studied. Based on this conclusion, any increased radiation exposure to humans is expected to cause an increase in the rate of effects above the level that occurs spontaneously. Similarly, increased exposure of animals will result in an increased incidence of effects among this species. In fact, the effects on some animal species are similar enough to those in humans to be useful. It is noteworthy that the estimate given above for the median lethal dose for humans of 300 to 500 rems for short term total-body radiation, is applicable to several animal species as well.

3. Early Effects on Animals

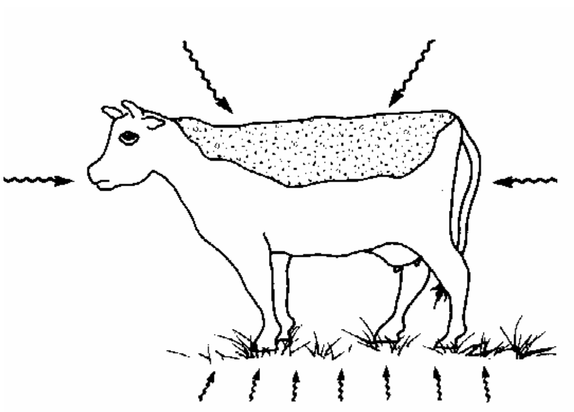
In the event of release of radioactive material as a result of a nuclear incident, the effect on the health and productivity of livestock would depend upon the type of radioactive material released, the amount or magnitude of the release, and the way in which an animal is exposed. The information contained in this section was obtained from a number of pamphlets which have been printed and distributed by the USDA. For greater detail on this topic, the reader is referred to the listing of these pamphlets, contained in the Bibliography of this report.

In general, livestock could be subjected to four possible types of radiation doses as a result of an incident. These are:

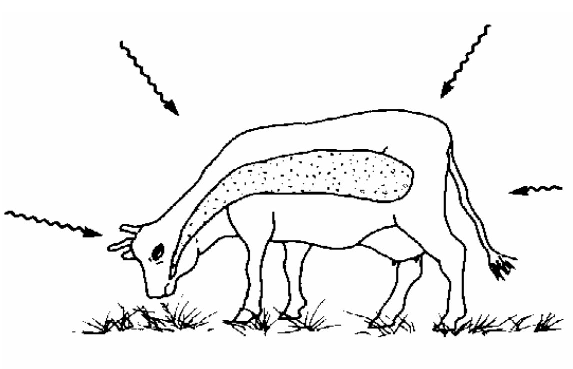
Type I. A dose from gamma rays from radioactive material (contamination) deposited anywhere except directly on the animals or on their food. This type of dose would be received by animals that are kept in barns or other buildings with roofed covers, such as hog and poultry houses during the incident.



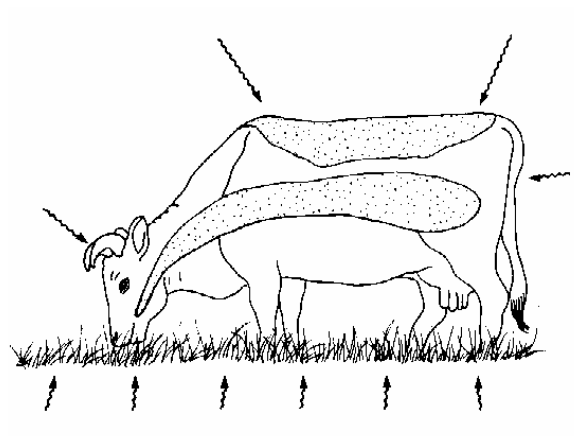
Type II. A combination of dose to the entire body of animals from the gamma radiation from radioactive material (contamination) deposited either on the animal or on the ground, as well as beta irradiation of the skin from material deposited on the animals. This does not include internal dose from eating contaminated feed. Animals held in open corrals, feed lots, or make-shift pens during the incident would be subject to this type of dose. Since many hogs, and most poultry are produced under a roof, this type of dose would not be of significance to many hog or poultry producers.



Type III. A combination of whole-body gamma dose and beta radiation dose to the digestive tract from eating radioactive material. This type of dose would be of special significance for grazing animals which were confined in shelter during and after the radioactive material was deposited on the ground, but which gained access to a contaminated pasture within a relatively short time after the nuclear event.



Type IV. A combination of gamma dose from all sources, beta radiation from radioactive material (contamination) deposited on the skin, and beta radiation from materials eaten by the animals with pasture forage. This type of dose would apply to unconfined grazing animals, or to those held in open corrals while later gaining access to contaminated pasture.



Animals receiving only gamma dose, or a Type I dose would not be of any additional danger to the people handling them. However, because of the presence of radioactive material (contamination) on or in the animals, doses of Types II, III, or IV, could present a possible radiation hazard to persons handling or processing the animals. This hazard could continue for some time after the nuclear incident. The seriousness of the hazard depends upon the total amount of radioactive material that is present, and the time between when it was deposited on the ground and when it came in contact with the animals. The following is a description of what can be expected in the event of a severe radiation dose of each of the four types.

Effects from Type I (External Gamma) Dose: Animals receiving enough Type I radiation dose to cause death, will show well-defined signs. After receiving an LDso dose (300 to 500 rem), cattle will appear normal or slightly listless for the first five to ten days. You might see blood-tinged feces and slight diarrhea, but their appetite would remain good.

Twelve to fourteen days after this severe dose, noticeable stiffness in the joints might develop, especially in the hind legs. There will be a peculiar knuckling of the fetlocks. Diarrhea becomes prominent by about 16 days. Feces become watery and bloody in animals that suffer prolonged radiation sickness. Generalized weakness, especially in the hind legs, depression, thirst, and a slight-to-moderate decrease in appetite are evident.

When near death, severe blood loss occurs through the gut, in the form of black, tar-like feces. Body fluids may accumulate in the legs and under the skin, causing swelling and discoloration. Weight loss would not be severe, but animals could appear to lose their muscle tone or condition in the later stages. As death approaches, some animals will become too weak to stand, and will be forced to breathe through the mouth in deep, rasping breaths.

Doses even higher than the LDso will accelerate the start and increase the severity of respiratory complications. Respiratory distress may be noticeable as early as day 7. Rapid, rasping respiration and heavy, predominately bloody nasal discharge may appear by day 14. Severe diarrhea can develop within 10 days. Although respiratory distress is a common cause of death, sudden unexplained deaths mayoccur in seemingly healthyanimals at around 10 to 15 days after exposure.

Dairy cows may be exposed to radiation while already under the stress of high production. The added stress, combined with the lack of adequate care, could result in a lower LDso for these animals. In other words, 50% deaths may occur at radiation exposures that are lower than 300 to 500 rems. Loss of appetite would be evident in these animals by 8 days. Forage consumption could drop 30% to 50%, and milk production would be drastically reduced.

In contrast to cattle, sheep often show little, if any, visible signs of early radiation effects. In those animals that do, the signs are too diverse to be of much value in predicting survival. Perhaps the most reliable symptom that can be seen after an LDso dose, would be increasingly severe and bloody nasal discharge that occurs 3 to 4 weeks after the dose is received. Deaths would probably begin to occur in the animals at about 3 weeks after exposure as well. Bloody feces and diarrhea would not be a consistent symptom, but could be evident. However, in many cases, signs of impending death would not be evident.

Swine which may die from an LDso dose from external gamma radiation would appear normal until about 10 days after the exposure occurred. At that time, bleeding from the nose and blood-tinged feces may develop gradually. In some, no outward signs may be visible. However, prolonged bleeding from small cuts could occur. High fever may appear as early as 14 days, accompanied by increasing lameness, pronounced weakness in the hind quarters, lack of coordination, and stiff gait. Death is often preceded by difficult, labored breathing, loss of appetite, blood-tinged urine, bloody or blood-tinged feces, and bloody discharge from the mouth and nose. Some weight loss could be evident, but many hogs might not show a lack of appetite until one or two days before death. At higher doses, hogs will often show moderate to severe diarrhea and vomiting in only 5 to 10days, and the survival time decreases to about 14 days.

By 7 to 10 days after an external gamma dose equal to the LDso, horses and mules would appear apathetic but irritable when handled. Severe watering of the eyes and nasal discharge may be evident. Sudden deaths may occur with no other outward signs. Some of the animals might develop encephalitis-like signs, such as pushing against buildings or fences, or a rhythmic jerking of the head. The food and water consumption of these animals may be below normal. After 10 days, the animals will appear to be normal for a short while. Then a second period of apathy will occur at about 14 to 21 days, accompanied by ulceration and bleeding of small wounds on the skin and nose. Severe respiratory congestion will develop. Although diarrhea is not a consistent sign, bloody feces might be evident. Animals exposed to high levels of radiation will die within three to four days, due to effects on the nervous system.

Poultry is the most radiation-resistant type of livestock. In birds receiving external gamma radiation doses equal to the LDso, which is approximately 850 rems, deaths will begin to occur at 20 days. However, much higher doses could cause death even earlier; such as 8 days for a dose of 1600 rems. The LDso for young birds may range from 50% to 75% of that for mature birds. Affected animals would show a noticeable shaking of the head, followed within a few days by extreme depression. They often sit immobile in a sleeping position for hours. As time passes, the comb and wattles develop prominent swelling, and difficult breathing appears. This is accompanied by a serum-like discharge from the beak. Droppings will become green-colored as death approaches. In birds that live for a considerable time, loss of feathers may occur.

If the dose to the animals is known, survival of animals exposed to external gamma radiation can be estimated from the following table.

In an actual nuclear incident, the exact dose that the herd or flock receives may not be known, but average values reported for your area on the radio or television can be used to approximate the dose to your animals. If no estimates are available, you can use the following procedure:

> If no signs of sickness or only slight signs of sickness, appear within 21 days after the incident, 80% to 100% of the animals will survive. If more definite signs of sickness appear on or after day 14, 50% to 75% of the animals will survive. But, if severe signs or sudden unexplained deaths begin to occur on or before 10 days after the incident, less than 5% of the flock or herd will survive.

Effects from Type II (External Gamma/External Beta) Dose: Survival of animals suffering an LDso dose under Type II conditions would be determined mostlyby the level of gamma-ray dose. Radiation damage to the skin from beta particles becomes important to survival only when an exposed animal was on the borderline between eventual death and eventual survival. Thus, although beta radiation of the skin would probably not cause death, severe beta doses in combination with comparatively large gamma doses, could increase the death losses.

By virtue of their thick hides, cattle, horses, and mules are less sensitive to beta radiation injury than sheep and hogs. Contamination tends to be caught in the wool of a sheep, and it is more likely to fall off of an animal with less hair, such as hogs. The visible signs of skin damage will depend upon the amount of beta radiation received. At low doses, signs may not be evident for months, with greying of the hair being the only effect noticeable. Damage from larger doses is characterized in horses by development of scaly, dandruff-like areas occurring about 45 days after exposure. This is followed by healing with smooth, hairless skin. In cattle, moist, sticky areas will appear on the skin at 25 days. Scabs will develop at 50 days and later, the coat will be replaced with white, fuzzy hair from silkyfeeling scar tissue. In sheep, cessation of wool growth will begin at 25 days. This is accompanied by abnormal appearance and slipping of wool. Later, you will see relatively severe skin burns, followed by healing with scar tissue. Full-fleeced sheep will probably experience little skin damage, since the fleece will hold the radioactive particles away from the skin.

At very high levels of exposure to beta radiation, shorn sheep will begin to lose wool in as early as 10 to 15 days. This will be followed by the appearance of oily, sticky, sensitive areas on the skin which will develop into severe burns by 60 days. These areas will heal slowly, leaving hard scar tissue, covered with a hornlike substance. In cattle, signs of skin damage

Estimated Survival of Livestock and Poultry from Short-Term External Gamma Radiation Doses

Cattle Dose (rem)	Survival (%)	Sheep Dose (rem)	Survival (%)	Swine Dose (rem)	Survival (%)	Horses and Mules		Poultry Dose (rem)	Survival (%)
						Dose (rem)	Survival (%)		
0-250	100	0-200	100	0-350	100	0-400	100	0-350	100
300	95	300	80	400	90	500	90	450	90
400	90	400	50	500	70	600	70	550	80
500	50	500	100	660	50	700	50	650	70
600	10	600 or more	0	800	10	800	30	750	60
700 or more	0			850 or more	0	900	10	850	50
						1000 or more	0	950	30
								1150 or more	0

appear 20 to 25 days after exposure as moist, sensitive, sticky areas which are warm or hot to the touch. Loss of hair does not usually occur, but scabs will form in the hair. By 8 weeks, the skin is easily torn or sloughed off, leaving large, ulcerated sores which will heal slowly. If the wounds cover a large enough area, healing may never be complete.

In external gamma /external beta doses, signs of radiation sickness from the gamma radiation would be evident before the effects of the beta radiation appear. However, muscular weakness from the beta radiation, especially in the hind quarters, could be apparent by 25 to 30 days, even though there is insufficient gamma radiation to have caused this effect.

In some nuclear incidents, it is impossible for animals to receive severe external beta doses, while gamma doses would cause no detectable damage. But a good rule of thumb is that the higher the gamma dose, the greater will be the beta dose and subsequent damage to the skin.

The effect of a combination of skin damage from external beta doses and whole-body gamma doses on animal survival is to lower the LD_{50} by 50 rem, or more. This effect would probably be the same in horses, mules, and sheep. In animals under severe production stress or in cold climates, the effect may be even greater.

In an external gamma/external beta dose situation, signs of gamma dose may be used to segregate the animals that will die from those that will live. The effects of skin damage from beta radiation will resolve borderline cases. The survival of exposed animals may be estimated, as described above, if the gamma dose is known or can be approximated. However, you may wish to hedge against the effects of beta radiation by assuming that gamma doses of 150 rem or more are accompanied by severe beta doses. In this case, simply subtract 10% to 20% from the estimated survival shown in the previous table for doses in the LDso range. Under cold climatic conditions, subtract somewhat more.

If no gamma estimate is available, and no or only slight signs appear in the animals by 21 days, generally 80% to 100% of the animals will survive an external gamma/external beta dose. If more definite signs occur on or after 14 days, 40% to 60% will survive. But severe signs or sudden deaths occurring by day 10will indicate that practically none of the animals will survive.

Effects from Type III (External Gamma/Internal) Dose: When radioactive material is eaten 'by animals, the particles settle out in pockets in the digestive tract, creating concentrated irradiation of the lining of the tract. If this occurs, severe and even fatal damage can be expected. Major sites of damage are the rumen and, to a lesser extent, the abomasum (true stomach) of cattle; the abomasum, followed by the rumen of sheep; the cecum (blind gut) and possibly the stomach of horses and mules; and the large intestine of hogs.

Animals receiving external gamma as well as internal exposure could suffer severe effects, even though they do not graze pasture when the danger from gamma ray exposure is highest. For example, suppose a group of beef cattle gained access to contaminated pasture 24 hours after the radioactive material released during the nuclear incident arrived in an area, and the total gamma dose at 24 hours was about 140 rem. Suppose the pastures are in fair to good condition, and about 10% of the radioactive contamination stays on the plants. After the cattle have grazed on this pasture, essentially all of the beta dose would be to the gut of the animals, because little radioactivity would be deposited on their backs while they grazed. Over the next 3 days, the cattle could eat enough radioactive material to kill about half of them, even though their total gamma dose would be only about 180 rem. The beta radiation damage to the gut from consumed radioactivity would be equivalent to about 300 rem of additional gamma dose, which accounts for the difference between 180 rem and the LDso dose of 500 rem. Animals eating to capacity would take in more radioactive materials, resulting in even greater damage. In highly stressed animals, the effects may be enhanced even further.

If the cattle do not start grazing until 48 hours after radioactive materials are deposited in the pasture, about 5% of them might die with a total gamma dose of about 225 rem. If the radioactive materials involved have relatively short half-lives, increasing the timefrom deposit to grazing from 24 to 48 hours in order to permit the radioactive material to decay, will result in a ten-fold decrease in fatalities.

Horses and mules would suffer appreciable damage under similar conditions. Sheep, however, may be more resistant to the early effects of gut damage than cattle. Hogs on pasture, primarily brood sows, are also affected. At higher levels of gamma dose, greater danger from ingestion of radioactive materials exists for all species.

The distinguishing feature of an external gamma/ internal dose is that the animals will go off feed within 7 days. Food consumption will drop to 15% of normal or less. Evidence of high fever wili appear within 10 days. Affected animals will grind their teeth (more prevalent in cattle than in sheep) and many will vomit. They will stand in a peculiar position, with the neck extended and the head down. As their condition becomes progressively worse, watery diarrhea will develop within 10 to 15 days, becoming bloody by 20 days. However, some animals may die before this time. Severe weight loss of 10% to 30% of body weight can be seen in the first 25 to 30 days.

Muscular weakness will be evident and, near death, lethargy will be frequently observed. Neither respiratory complications nor tar-like blood are consistent signs of impending death in an external gamma/internal dose. Death is due to general weakness from tissue destruction, weight loss, and diarrhea. The animals appear to "waste away". In animals that survive for a considerable period of time, areas characteristic of moderate to severe skin damage from beta irradiation mayappearon their muzzles and just above the hooves. Similar signs are found in horses and mules.

Hogs will show loss of appetite and diarrhea within 6 days after an external gamma/internal dose. Diarrhea will become severe and bloody very quickly and weight loss will be evident. Severely affected animals will die rather quickly because of tissue destruction and loss of body fluids.

Even higher gamma doses will accelerate symptoms that are similar to internal beta radiation damage.

Effects from Type IV (External Gamma/External Beta/Internal) Dose: The damage caused by this dose is the most severe. Cattle that are free to graze on contaminated pasture, could ingest enough of the material within 6 to 8 hours of grazing to cause very high mortality, even though the total external gamma dose may be less than the LD5o. The hazard from ingested radioactivity would be greater yet at even higher gamma doses. Beta radiation dose to the skin would contribute only a small part to the overall damage, since the majority of the effects will be due to ingested radioactive material.

For other grazing livestock species with a severe external gamma/external beta/internal dose, the outcome will be about the same. In general, the signs of internal damage will become more severe and will appear fairly early. Many animals will die within 20 days, even before diarrhea becomes distinctly bloody. Weight loss will be very severe in animals surviving for longer periods. Muscular weakness and prostration will be signs of impending death. In animals that survive 30 to 50 days, areas of skin damage due to beta irradiation might appear on the back, around the muzzle, and above the hoofs.

Survival from external gamma/external beta/internal doses could be influenced by the retention of radioactive materials on pasture and the quality of the pasture. For a given percentage of radioactive materials retained on pasture plants, survival will be greater on higher quality pastures than those of poor quality. This is because less total feed, thus less radioactivity, will be eaten. Likewise, survival will be higherfor animals grazing on a pasture that has retained less of the radioactive material on surfaces of the foodstuffs than it will be for animals grazing on pastures with high retention of the materials.

4. Late Effects in Animals

Generally, surviving livestock will show the same signs of early radiation effects described above, only they will be less severe than in those animalsthatdie. If the quantity of radioactivity released in a nuclear incident is quite low, it is likelythat livestock and poultrywill show no early signs at all. The most significant late effect of radiation dose on livestock and poultry is the impact on meat, milk and egg production. The following is a listing of late effects on production for doses that are less than the LD_{50}.

Type I (External Gamma Dose): For all practical purposes, recovery, as judged by the absence of signs of sickness, will have occurred in surviving animals by 60 to 120 days after exposure. After that time, only slight, if any, damaging effects on meat and egg production would be evident. Animals on feed would gain weight normally, and the performance of brood cows, mares, and ewes would be normal. Pullets surviving doses near the LD5o may show decreased production for at least 2 weeks following recovery, but this drop is rarely seen in hens. Dairy cows recovering from appreciable doses in early or mid-lactation will probably showdecreased productivity for the rest of the lactation period. Cows with the highest initial production will show the greatest eventual decrease in production. Cows exposed during the dry period will show decreased production in the first part of the next lactation.

Type 11 (External Gamma/External Beta Dose): Animals surviving a Type II radiation dose will show decreased productivity following severe external beta doses, even after recovering from the effects of the gamma dose. In cold climates the impaired ability of animals to regulate heat loss due to skin damage, could cause severe problems for at least 2 years after the dose occurs.

Wintering beef cattle and sheep could lose considerable weight, and calves and lambs could be lighter at weaning due to lowered milk production. Many sheep that may appear to have recovered from the early effects of the gamma dose, may die unexpectedly 4 to 7 weeks later as a result of respiratory failure. Dairy cows will show significant milk production decreases. High-producing animals may go dry completely. Cattle and lambs on feed will show daily weight gains that are only about three-fourths of normal. However, in cold weather, weight gains may be only one-fourth of normal, or less. Growing-finishing hogs may be less affected.

The skin sores created by beta radiation from external gamma/external beta dose would increase susceptibility to certain diseases and pests, such as flies and external parasites. Severe cases of skin damage may never heal completely, but much healing will occur with time. As time passes, breeding stock appear to adjust to the damage and 'life-time production may eventually return to normal. However, some high-producing dairy cows may never fully adjust to the damage they receive. They may appear normal in late lactation or during the dry period, but the stress of calving and high production could make the radiation injury even more evident.

Type III (External Gamma/Internal Dose): The late effects of a Type III dose depend on the amount of internal beta and external gamma radiation dose received. But, in general, animals that survive will regain their appetites within a few weeks. In sheep, this will occur within 15 to 20days. In cattle, feed intake will not begin to increase until day 25. As the feed intake increases, diarrhea will abate and normal-appearing feces will return. Weight gains in sheep and lambs on pasture will rise to near normal levels by 7 to 8 months.

Cattle on stored feed would weigh only three-fourths of normal at eight months after an External Gamma/Internal dose. Cattle and horse breeding stock may show greater initial weight loss and a slower return toward normal weight. This is because they usually consume diets of lower quality than animals being fed for slaughter. Ewes may not be so seriously affected. During this period, calves, lambs, and colts could show decreased weight gains, and some may die due to inadequate milk.

Some brood cows on pasture may show the same signs as grazing animals. However, if it is possible to continue feeding them concentrates, the effects will be minor. Dairy cows in late lactation and dry cows will probably show the same pattern as brood cows. Surviving high-producing cows, or cows in early lactation, that do not receive large amounts of concentrates, would show a severe drop in production. Relatively few will return to acceptable production when the feed intake is increased.

Over a period of years, performance of brood cows, sows, and mares, as judged by growth of offspring, may improve slowly, finally achieving a level that is slightly below normal. Although individual ewes may perform at this level, the production of flocks could be decreased due to the deaths of many apparently healthy ewes during times of stress. Dairy cattle may appear to have recovered during the dry period, but milk production in later lactations could average well below normal.

Type IV (External Gamma/External Beta/Internal Dose): Survivors of a Type IV. Dose will show severely decreased production for a year or so. The decrease could be more severe for sheep than for cattle, and many sheep may later die. Lambs fattening on pasture will weigh only one-half to three-fourths of normal weight. Ewes may regain only part of their original weight and condition losses. As a result, lambs will probably be considerably lighter than normal at weaning. Some lambs may even die from starvation.

Performance of brood cows, mares, and some sows will be affected similarly. Milk production will be drastically reduced, or it may ceaseentirely. Pasture-fattened cattle might weigh about two-thirds of their normal weight at 8 months after an external gamma/external beta/internal dose. In areas with very cold weather, weight gains could be less than one-fourth of normal during the winter. Milking dairy cows will probably go dry after this type of dose. Later lactation performances will average one-half to two-thirds of normal performance. Animals exposed during the dry period will produce little milk the following lactation. In time, performance of herds and flocks will probably increase toward normal.

Contrary to widely-held opinion, livestock surviving fallout radiation doses will not be permanently sterilized. Since only gamma radiation can penetrate the body to any extent, it is the only type of radiation which can have a direct effect on the reproductive organs. A radiation dose to reproductive organs large enough to cause permanent sterility would be lethal if the same dose were delivered to the whole body.

In males surviving doses or 200 rems or more of gamma radiation, there could be a temporary drop in sperm production beginning around 6 to 9 weeks after exposure. However, this condition will eventually recover. At doses in the LD5o range, bulls, rams, and stallions might show a lack of sperm production for a variable period, beginning about 12 weeks after exposure. Recovery toward normal occurs slowly, with sperm production averaging about three-fourths of normal within two years of exposure. However, these levels are adequate for normal fertility. Unless the animals become ill, they will not show a decrease in willingness to serve females in heat. Boars will show a somewhat faster return to normal, with sperm production returning to normal at about 26 weeks. Male poultry will probably not show decreased production of sperm at doses in the LDso range, but the survival of fertilized eggs may be reduced.

Like males, female livestock will not be sterilized by gamma doses in the LDso range. The ovary is even better protected and thus more resistant to the effects of radiation than the testis. An exception appears to be the hen, where LD5o doses cause degeneration of developing follicles, decreasing reproductive efficiency.

Doses of 200 rems or more over a short period in early pregnancy, (i.e., 33 to 34 days in cattle, 23 to 27 days in sheep, and 19 to 21 days in hogs)couldcause deformed offspring. Most of these would be unable to breed. In those that do, performance would be nearly normal. The incubating egg appears to be quite resistant to radiation damage.

Draft and pleasure animals, such as horses and mules, which survive gamma ray doses in the LD5o range, could show decreased work performance while sickness is apparent. Thereafter, little effect will be seen. Doses from gamma and external beta radiation could be followed by instances of decreased ability to work within a few weeks, due to muscular weakness. As the effects of radiation on body weight and conditions become apparent, work efficiency could drop within 8 to 10 months after exposure. These effects will be more noticeable in cold weather.

Large areas of skin damage could make it impossible to harness or saddle work animals. As these areas heal and body weight returns normal, work performance will increase. Animals who receive gamma, internal beta, and possibly external beta radiation doses could show decreased work performance within a short time, due to body weight losses, and tissue destruction and repair. Performance over the first year could be well-below normal. As the damage heals and weight is regained, strength will increase to near normal levels.

There is a common belief that irradiated animals will produce offspring with genetic abnormalities. This may be technically correct, however there is little or no evidence to support the contention that transmission of undesirable traits, as a result of radiation-induced changes in the germ cells of livestock, will be a problem after a nuclear incident. It is important to note that radioactive materials incorporated in parents are not transferred to offspring in the reproductive process. Only the effects can appear in later generations.

The longevity of farm animals is directly related to their productivity. The more productive animals will stay in the herd the longest. To the extent that radiation doses affect productivity of livestock, they affect actual lifespan. It is probable that doses involving combinations of external and internal beta radiation would have the greatest effect on lifespan, because performance may never return to what it was before the incident. On the other hand, the need to increase herd or flock numbers could decrease culling rates and lessen the importance of performance in the selection process. Culling on the basis of health and disease will probably increase in later years, since survivors will show a slightly increased incidence of other health complications in later life.

C. RADIATION PROTECTION PRINCIPLES

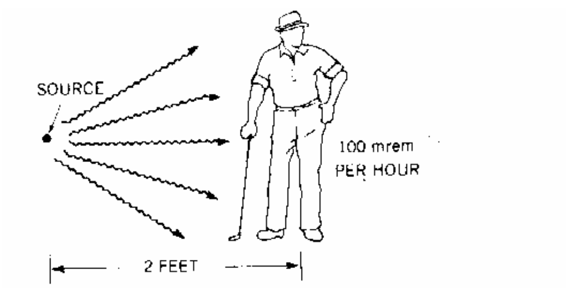
The goal in any program of radiation protection is to reduce exposure, whether internal or external, to a minimum. If it is impossible or impractical to remove the source of radiation, as may be the case in a nuclear incident involving the release of radioactive material, other means must be considered in order to protect humans and livestock from the effects of both external and internal radiation exposure. Basic protection principles for each of these exposure modes are described as follows:

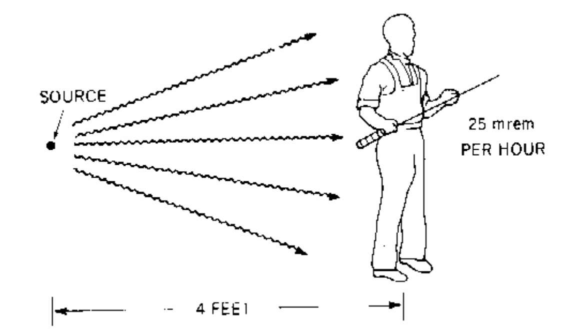
1. Exposure from Radioactive Materials Outside the Body

There are three factors which determine the level of external dose one receives in a given radiation field. These are:

1. Time (duration) of exposure
2. Distance from the source of radiation
3. Amount of "shielding" present

The time factor simply means that the longer someone remains in a radiation field, the greater will be the external dose. At times, especially during emergencies, work must be performed in a high radiation field. In this case, the work procedure should be carefully planned beforehand in a safe area so that a minimum amount of time is used to perform the work in a high radiation area. If the time required for one person to complete the job would result in an excessive radiation dose, then a "team" of workers should be employed. This would result in a small dose to several people instead of a large dose to one individual.





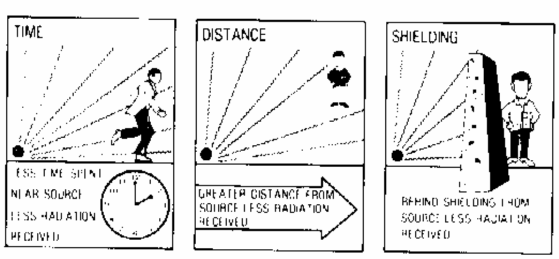
The intensity of a radiation field decreases as you increase your distance from the source of radiation. For example, if you are standing two feet away from a very small radiation source and your dose rate is 100 mrem per hour, and you move back to four feet from the source, then your dose rate drops to only 25 mrem per hour. In the case of a large radiation source, like a contaminated field or barn, the dose does not drop off quite as rapidly as it does in the case of a small radiation source. Nevertheless, the farther away from a radiation source you are, the lower will be the dose rate to you.

In many cases the job to be performed, such as cleaning (*decontaminating*) farm equipment, calls for the worker to be near the radiation source. This limits how much distance you can put between yourself and the source. We can reduce the radiation hazard further, in this case, by placing a suitable "shielding" material, or combination of materials, between the radiation source and worker.

A *shield* is a material of some thickness which will stop or effectively reduce radiation doses to lower levels. The effectiveness of a shield depends mainly upon the type of radiation (i.e., alpha, beta, or gamma), the energy of the radiation, and the type of shielding material. In choosing a shielding material, our first consideration is always protection of people and animals. However, other factors may influence our choice of material, such as: Is it available? Is it too heavy to move to where it is needed? How much space do we have for the shield? Does it have proper structural strength?

A material such as aluminum, glass, or thick sheets of plastic, is used to block the beta radiation. Gamma radiation does not lose energy continuously in material, as do alpha or beta particles. As a result, gamma radiation is much more penetrating than alpha or beta radiation. Materials of higher density, such as lead, iron, steel, or concrete are used for gamma radiation shielding.

All of these "time-distance-shielding" factors can be used individually, or in combination, to minimize external radiation doses. Which of these are the best methods for protection of livestock in the event of release of radioactive materials, and how can they best be used? This information will be presented in detail in Chapter III.



2. Exposure from Radioactive Materials Taken Into the Body

If it is possible for radioactive materials to enter the body, the following measures can be taken to reduce or prevent internal radiation dose: Confining the source, preventing or minimizing intake, reducing uptake, and increasing the excretion of the material.

Confinement of the source means that the material is kept in a container, building, or isolated area. In some instances, it may not be possible to completely isolate or contain the radioactive material. In that case, internal dose can be minimized or prevented by isolating the body from the radioactive material. Protective clothing and "respirators" are used for this purpose. Examples of protective clothing are rain suits, plastic jump suits, or coveralls. Other ways that can be used to prevent or minimize the intake of radioactive materials into the body are washing the face and hands before eating, staying inside of specially-designed shelters, or, in the case of animals, limiting their access to feed and water that is contaminated with radioactive material. Specific methods for controlling internal radiation exposure are contained in Chapter III.

D. RADIATION DETECTION AND MEASUREMENT

1. Principles of Detection

How do we measure nuclear radiation? We cannot weigh it or collect it in a box, just as we cannot weigh or collect sunshine in a box. However, we can measure it indirectly by measuring the effects that it causes. Unlike that portion of sunshine that we can see, invisible nuclear radiation produces an electrical effect, called ionization, in the materials through which it passes. To review some of the concepts presented in Section A of this chapter, ionization means that two ions, or electrically charged particles, have been created when an electron is ripped off an atom due to the passage of the nuclear radiation. The electron has a negative electrical charge, and the atom that remains behind has a positive electrical charge. A radiation measuring device responds to charged particles, or ions, that are created inside its *detector*.

It is possible to collect the charged particles (ions) that result from ionization, if they are free to move in a gas. If a gas is located between two metal plates, each with an electrical charge - one positive and one negative - it is possible to collect the electrons and the positively charged atoms. The charged particles move to the metal plates because opposite electrical charges attract each other.

Electrical current is generated when charged particles, such as electrons, move. If we measure the electrical current, we can determine how many charged particles are moving in the gas. From the measured current, we can determine the quantity of radiation it took to produce these particles. This is the basic principle of the operation of a radiation "survey meter".

A radiation survey meter is a portable, hand-held instrument that is used to detect radiation. By reading the meter dial, you can determine the radiation rate at that moment and location. A survey meter generally consists of a cylindrical tube filled with a gas. The tube is generally located inside of the survey meter case, but can also be located outside of the case, connected by an electrical cable.

2. Types of Detectors

Gas-filled tubes are used in two types of survey meters: the ionization chamber (or "ion chamber") survey meter, and the "Geiger-Mueller" (or "G-M") survey meter. Both ionization chamber instruments and G-M survey meters are accurate enough to measure the intensity of most gamma radiation encountered in nuclear incidents. In general, G-M survey meters are used more often because they are rugged, and quite sensitive to small amounts of radiation.

Unfortunately, most people do not have manychoices in the purchase of an off-the-shelf survey meter suitable for measuring radiation from a nuclear incident. Although inexpensive "dose-rate meters" or dosimeters have been under development for the past 20 years, they are not yet in widespread production for public use. The average cost of a typical G-M survey meter is about $600.

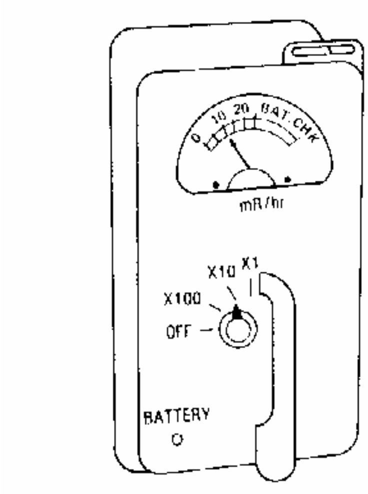
It is possible to construct a very simple survey meter, called the "Kearny Fallout Meter", or "KFM". This simple electrostatic instrument is made with common, inexpensive materials found in millions of homes, requires no radioactive material to check the instrument for accuracy, and needs no battery to operate. Detailed instructions that have helped untrained people to make and use KFMs are contained in the document entitled Nuclear War Survival Skills, shown in the Reference and Bibliography sections of this report.

In the unlikely event that an animal handler must go out and buy all of the materials necessary or construction of a KFM and its "dry bucket", it would cost less than $20.00. However, this sum will actually buy most of the materials for several KFMs.

Previous experience has shown that it takes the average individual approximately six hours to construct a KFM. Also, during the confusion that maybe associated with a nuclear incident, supplies to construct the device may not be readily available. Fortunately, for most local nuclear incidents, commercially-produced survey meters will be available from the state, federal, and private agencies that respond to calls for assistance. The following describes the method of operation of typical survey meters used by these agencies.

3. Use of Portable Survey Instruments

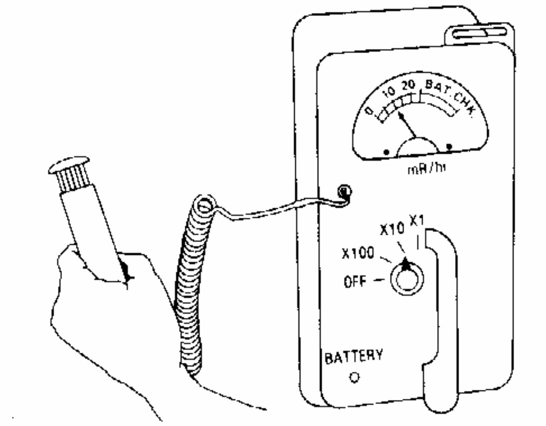
The following figure shows a typical G-M survey meter. The scale on the dial reads in ""mR per hour". The needle is pointing to "10". To tell the correct dose rate, look at the position of the "range switch". In this case, the range switch is set at "x10". This means the dial reading is multiplied by 10. The dose rate, then, is 100 mR/hour, which is equivalent to 100 mrem per hour.



Note the *"battery check"* button on the face of the survey meter. Pushing this button tells you whether the batteries are good or not. If the button is pushed, the needle should fall within the "BATT CHECK" bar on the survey meter dial. If the needle falls to the left of the "BATT CHECK" bar, the batteries should be replaced before the survey meter is used. Otherwise, the meter will not operate properly.

The following figure shows a G-M survey meter with an externally-mounted detector and four ranges. Internally-mounted tubes are preferable to externally-mounted tubes because the externally-mounted detector is more easily damaged. The electrical connections on the detector cable sometimes fail to make contact, or an electrical "short" may result because of the presence of dirt or moisture.

As you work with a survey instrument, you will also notice the rate at which the survey meter needle moves as you approach a source of radiation. The speed of the needle movement is a good way for you to judge how fast the dose rate is changing. You will also learn roughly where the needle should settle and howquickly it should settle there. The "approximate dose rate" is often used rather than a precise value, because the position of the survey meter relative to the radiation source will be a little bit different every time you make a survey.



Do not attempt to make radiation measurements unless the survey meter is operating properly. This is one of the most important rules in radiation protection. Since the most common cause of survey meter failure is weak batteries, the condition of the batteries should be checked before each use. After the survey has been completed, and if the survey meter will not be needed for some time, switch it off. This will prolong the life of the batteries.

Fresh batteries typically last for about 100 to 200 hours of operation, but newly-purchased batteries may not always be fresh and may give considerably shorter life. If there is a short circuit in the instrument, possibly caused by dirt, moisture, or damage, or if you accidentally leave the instrument turned on for several days, the batteries can become discharged sooner than you expect.

Next, check the meter's response to radiation. Place the survey meter very near any radiation source, such as a' Colemanlm Lantern Mantle. From previous measurements of this radiation source, you should know what meter reading to expect. If the meter does not respond as expected, check the batteries for correct voltage.

If the meter gives the expected dose rate, move the survey meter away from the radiation source. The meter needle should fall. With a little experience you will be able to tell if the needle is falling at the expected rate.

Although your survey meter is operating properly when you start your radiation survey, it can malfunction during the course of the survey. Here are two ways you can check to see if your meter is still functional:

You can use shielding. If you put the meter behind some shielding material, such as 6 inches of concrete, or 1 inch of steel, does the reading drop? Does it drop by the expected amount? (With practice, you can make this determination easily.)

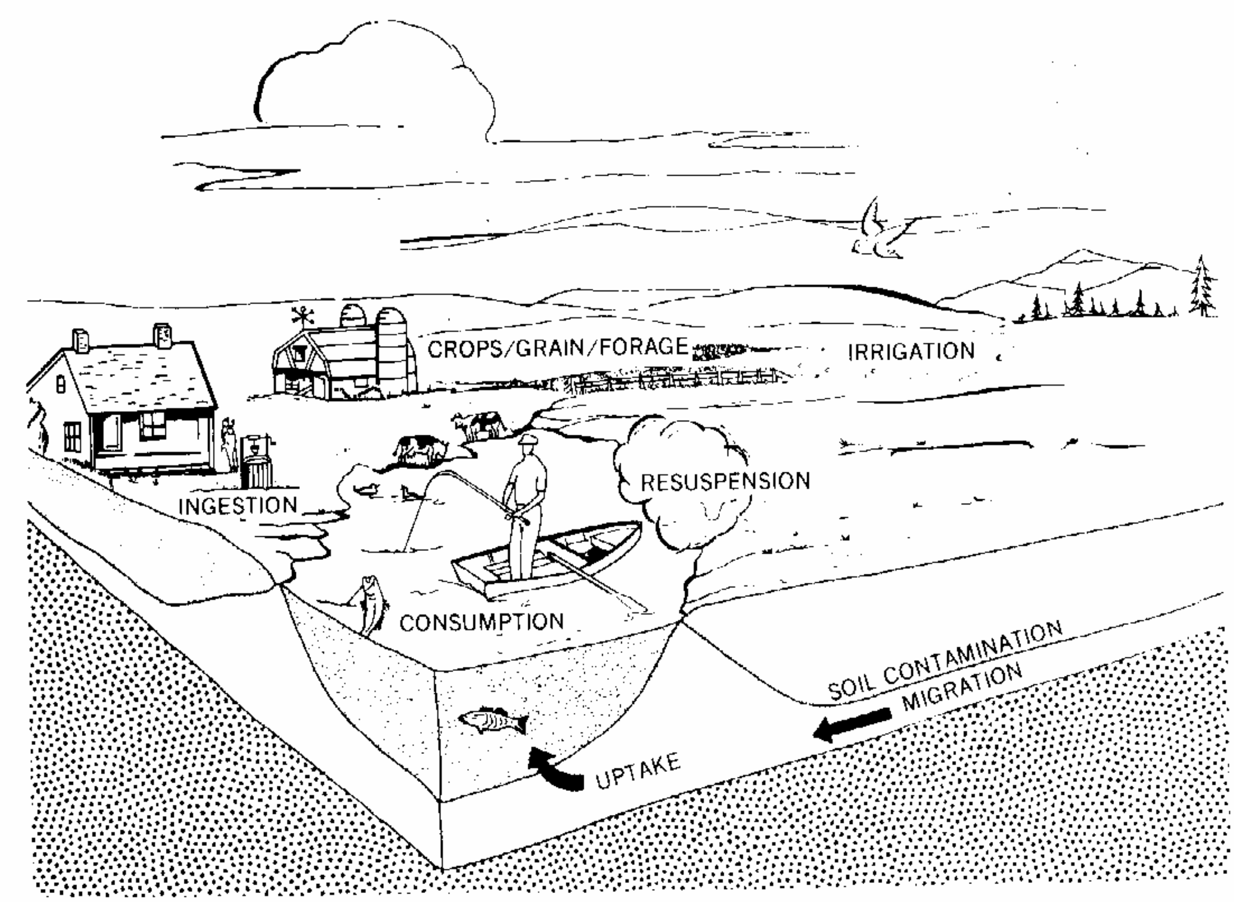
You can use distance. Make a measurement of your radiation source with the survey meter. Move the source away from the survey meter. If the reading drops, the meter is responding properly.

Manufacturers of survey meters have succeeded in making them quite rugged, but they can still be broken by rough handling. Wires inside the case can come loose, the G-M tube can break, the battery connections can come off, and the meter mechanism itself can break. You should handle your survey meter gently. You should never throw it into a truck or use it as a hammer. Water entering the case, or areas of very high humidity, will cause the survey meter to fail due to a short circuit or battery failure. Salt or other chemicals can corrode the electronic circuits and cause the survey meter to fail. Survey meter cases are generally made to be watertight, but a bent or cracked case may not keep water out. Damaged cases should be repaired or replaced.

III. INFORMATION AND INSTRUCTIONS CONCERNING RADIOACTIVE CONTAMINATION INCIDENTS

A. EXPOSURE AND CONTAMINATION IN THE EVENT OF RELEASE OF RADIOACTIVITY

Radioactive materials can be released into the environment in a number of different ways, such as by accidents at nuclear facilities, detonation of a nuclear weapon, and transportation accidents. When these materials are released from containers or buildings they can be spread through the air and water like any other material such as chemicals, smoke, dust, or gases. Radioactive gases and small particles can be spread by the wind over great distances. As they are carried from the location of the accident, their concentration in air decreases. For this reason, the greatest concentrations of radioactive materials are usually found near the accident location. These airborne radioactive materials can present both an internal radiation hazard and an external radiation hazard to people and animals. The following figure shows the pathways by which the radiations from these airborne radioactive materials reach humans and livestock.



These pathways can be grouped into the following general categories:

Dose from airborne radioactive releases. This type of dose could occur within a short period following an incident as a result of inhalation of radioactive materials or from external whole body dose from submersion in a radioactive cloud. Radioactive materials which fall directly onto animals and people can present a seriousexternal radiation hazard.

Dose from radioactive materials deposited in water. Surface water can be contaminated directly with radioactive materials. Fallout can occur onto streams, lakes, and other surface water. One important way that surface water becomes contaminated is when rain falls onto surfaces covered with radioactive materials. The materials are then carried along with the water and can settle in pools. Internal contamination occurs when animals or humans drink the water. Dose from radioactive materials deposited on the ground. Soil and vegetation can become contaminated when radioactive. materials settle on them. The contaminated soil may be spread to other areas by the wind or by animal or human movement. The vegetation may be eaten by animals or humans to cause internal contamination. Exposure pathways for internal dose may include inhalation (dust resuspended in air by mechanical disturbances such as walking, driving, plowing, or wind), and ingestion (through the food chain). The contaminated soil also serves as a source of external dose if sufficient radioactive materials are present. Both types of dose, internal and external, should be considered when trying to control and limit the total radiation dose.

Dose through food. This dose will be from ingestion of contaminated foodstuffs and water. It may commence shortly after the passage of airborn radioactive materials and may continue for a long or short period of time depending on the type and amount of radioactive material involved.

The relative significance of internal and external doses to both man and animals can vary greatly depending not only on the nature of the food production system, but also on the composition and physical form of the radioactive material that is deposited. Radiation doses received through the food chain may be either short-term or long-term, depending on the characteristics and half-lives of the radioactive materials involved. Control of this pathway of exposure can be achieved by: control of access to contaminated animal feeds; decontamination of certain foodstuffs; diversion and storage of food to permit radioactive decay of short half-life radioactive materials; and destruction of contaminated foods.

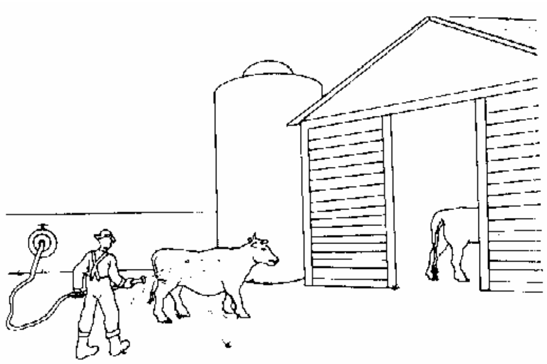
Doses from radioactive materials that are deposited on the ground might also be either short-term or longterm, depending on the radioactive materials involved. Control of the external exposure pathway can be achieved by evacuation and controlling access to the contaminated area. Since ground contamination will ultimately result in an increase in background levels in the area, the area may be abandoned for an extended period of time. If this is the case, decontamination may then be the only action which will permit free access to, and utilization of contaminated areas within a short time. Restorative actions would be reentry, decontamination, and then occupying the area.

The remainder of this Chapter contains a number of methods that can be employed for controlling internal and external doses in the event of a nuclear incident. However, the reader is advised to maintain contact with appropriate authorities for the duration of the incident in order to receive assistance and instructions that are specific for the incident in your area.

B. EXTERNAL EXPOSURE CONTROL

The basic principles of time, distance, shielding are simple and relatively easy to apply to protection of livestock and persons. The object is to reduce the total radiation dose received. One of the most important concepts to remember for incidents that involve the release of manmade radionuclides with short half-lives, is that after the radioactive materials are deposited on the ground, the actual level of radiation decreases with time. Therefore, for these types of incidents, you may wish to take as many early protective actions as you can, and then remain in your shelter for a period of about three to four days. The following is a discussion of the best methods for control of external radiation dose of livestock and poultry in the event of a release of radioactive materials, and how they can best be used.

Protection against beta radiation can be achieved by preventing direct contact of the radioactive materials. If animals are confined under an overhead cover or roof, which reduces the amount of radioactive material deposited on the animal's hide, skin damage from beta radiation would be reduced, thus more animals would survive. If animals have been grazing in a contaminated field, wash the animals before they enter the holding area to remove large quantities of radioactive contamination. Skin burns can be minimized with prompt de-contamination but not reduced completely. Preventing contact with the radioactive materials is an extremely effective method for decreasing beta radiation damage, particularly to grazing animals.



Protecting against gamma radiation is a much more difficult problem. Again, the task is to decrease the amount of radiation reaching the animals. This can be achieved by increasing the distance between the radioactive materials and the animals. Radiation is emitted from radioactive particles in all directions. If a radioactive particle is very close to an animal's skin, as much as 50% of the radiation could strike the animal. If the particle is 20 feet away, less than 1% of the radiation can strike the animal. One way to increase the distance between the source and the animals would be to move the animals from contaminated pasture or areas, to uncontaminated or less contaminated areas.

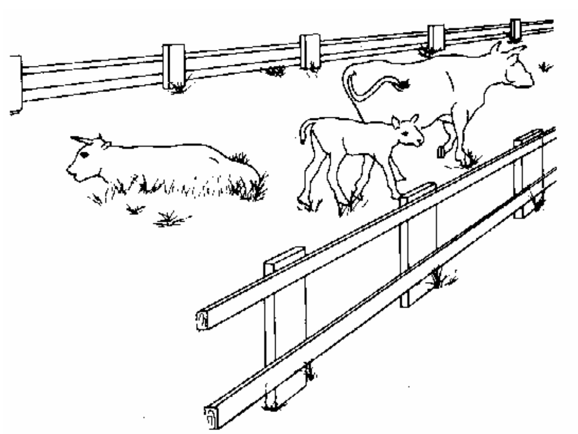
You can also decrease the amount of radiation reaching the animals by placing more dense material between the animals and the radioactive material. The more material that gamma radiation must pass through and the greater its density, or weight per unit of volume, the greater the chance that the gamma radiation will be deflected or absorbed before reaching the animals. In other words, higher density materials make better radiation shields. For example, if 10 inches of earth were placed around the sides of a shelter, the radiation dose of confined animals would only be about 12% of those animals that remained outside of the shelter. To achieve the same protection as 10 inches of earth, 7.5 feet of baled hay would be required. About 7 inches of poured concrete would achieve the same effect. Stacked lumber or other building materials are also effective shields. Stated differently, about 3 and one-half inches of earth will reduce the radiation intensity to 50% of its initial value, as will 27 inches of baled hay, 10 inches of wood, and 2.2 inches of concrete.

Any farm structure will offer some protection from gamma radiation, and confining animals under cover will prevent beta dose as well. Also, crowding animals together in any structure provides some shielding for each other. The following table shows the protection offered by various types of farm structures:

PROTECTION FACTOR	TYPE OF SHELTER
10-20	Large barns, concrete or masonry
2.5-5	Large frame barns
2-3	Conventional frame barns
2	Conventional hoghouse (part concrete block)
2.5-5	Full masonry or concrete block hoghouse
1.5	Pole barns, sotck confined under roof
5	Masonry poultry houses
10-20	Trench silo with light covering of plastic
20-25	Roadway underpasses

You can see from this table that barns of conventional size and construction can reduce the radiation dose to one half of the outside dose level. Even pole barns provide some protection. Notice there is good protection offered by underpasses and trench silos.

Animals confined in open pens would shield each other to some extent, reducing gamma dose, however they would still be subject to fallout on their backs. Another advantage of corralling livestock in open pens is that the danger from ingested radioactive materials would be decreased or averted since the livestock would have little opportunity to graze.



In some areas of the country, no buildings may be available for shelter or it may be impractical or impossible to move livestock long distances to shelter. In other areas, available shelters may be full or time may be too short to get animals to the shelter. In these situations, natural shelters can be used to good advantage. Forests and woodlots could offer shielding from gamma rays that is equal to that of pole sheds, especially in the summer. Confining animals to these areas would also reduce deposition of radioactive material on the skin.

For a few animals without shelter, tying plastic sheets around them, and removing the sheets after the fallout passes, may reduce skin damage from beta radiation. Penning animals would keep them from grazing contaminated pastures when the danger was greatest.

Steep-sided canyons, draws, or ravines make excellent natural shelters: The steeper the sides, the better the shelter. These areas could offer protection similar to uncovered trench silos, and at the same time reducing the hazard of permitting animals to graze on contaminated pastures.

Consideration must be given to the relative ease of confining animals in prospective natural shelters. Areas unfamiliar to animals should be considered cautiously since animals being hastily moved might balk or stampede during attempts to confine them.

It would be desirable to make sure that the animals stay confined for at least four days, but this may not always be possible. This time interval would allow radioactive materials on the pasture to decay to levels which would cause less internal dose to the grazing livestock.

C. INTERNAL EXPOSURE CONTROL

A common route by which radioactive contamination enters the body is by inhalation, or breathing radioactive particulates into the lungs. The dose received while caring for contaminated livestock can be minimized by wearing a "respirator", capable of filtering the radioactive particulates before they enter the respiratory system. High efficiency cartridges are commercially available, and approved for the effective removal of radioactive materials, but probably would not be available immediately following an incident. Certain household items are also effective for removing particulates and aerosols. The following table lists some of these materials and their effectiveness.

The major problem with the use of household items instead of a commercially-available respirator is that it is not always possible to achieve a good seal with the face. If there is not a good seal, radioactive contamination is not filtered properly by the respirator because of leaks from the sides. It is as important to maintain a good seal as it isto select the correct filtering material. A material should be selected to hold the filter in place and should be form-fitting, snug, and capable of letting air through to prevent suffocation. Some examples are: nylon netting (female hosiery), stocking-type ski masks, and bandannas.

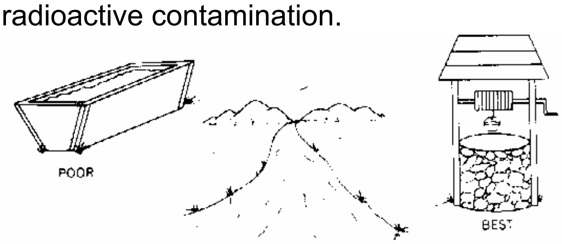
Since it will not always be possible to completely isolate yourself from the radioactive materials while caring for your animals, the amount of material that is actually retained in the bodycan be reduced by reducing the body's ability to absorb the materials. Also, methods can be used to increase the rate of elimination of the radioactive materials from the body. In both cases, these measures will decrease the amount of time that the radioactive material is retained in the body, and thus will reduce the internal radiation dose. Specialized methods for reducing absorption and increasing the rate of elimination of radioactive materials from humans and in animals are usually performed under medical direction.

Now let us look at methods of reducing intake of radioactive materials in animals. It is important to remember that when considering shelter for livestock, you should not forget the basic needs of the animals. Poor ventilation or lack of water will kill animals more quickly than radiation exposure.

RESPIRATORY PROTECTION PROVIDED BY COMMON HOUSEHOLD AND PERSONAL ITEMS

ITEM	NUMBER OF THICKNESSES	PROTECTION FACTOR
MAN'S COTTON HANDKERCHIEF	16	17
TOILET PAPER	3	11
MAN'S COTTON HANDKERCHIEF	8	10
BATH TOWEL	2	7
BATH TOWEL (WET)	1	3.5
COTTON SHIRT (WET)	1	3
COTTON SHIRT	2	3
RAYON SLIP	1	2
COTTON DRESS MATERIAL	1	1.9
MAN'S COTTON HANDKERCHIEF	1	1.4

Since producers may not be able to ensure an adequate air supply in prospective shelters, those with seriously restricted air flow should not be used unless absolutely necessary. Some water supplies may become contaminated. However, animals should not be denied water for fear of them consuming radioactivity in it. Luckily, water from most sources would not be contaminated enough to pose an appreciable danger. Water from wells and covered tanks immediately after an incident will likely contain no radioactivity. Moving river water will be of a poorer quality, while standing water in shallow ponds and open holding tanks will have higher levels of radioactive contamination.



Feeding animals confined in shelters is, of course, necessary. Self-feeding hay racks and concentrate feeders could help reduce the radiation dose to the people who must care for the animals. If these are not available, it would be a good idea to let the animals go without feed for the first few days after the incident. This decision should rest with the individual producer, but most animals would not be permanently damaged by a fast of four or five days, as long as water is available. In areas of heavy deposition of radioactive materials, people who are outdoors feeding their livestock during the first week or so after the incident could receive high radiation doses.

If possible, uncontaminated feed should be used. Dairy cattle should have priority for uncontaminated feed. This will cut down on any "radioactive iodine" secreted into milk when normal milking routines resume after the incident. The concern, in this case, is for people drinking milk contaminated with radioactive iodine. Radioactive iodine can cause severe damage to the thyroid if taken in large quantities.

Stored feed that has been exposed to radioactive materials can be fed to the animals after carefully removing the contaminated outer portions of the feed pile. To reduce the possibilityof radioiodine contamination in milk, allow the retained radioactivity on the contaminated portion of the feed to decay at least 40 days if possible, before feeding it to the animals. For other types of radioactive materials, feed may need to be stored for even longer periods before use.

If adequate watering facilities are not available in the shelters, do not feed the livestock. Eating will make animals, especially ruminants, thirsty. Fasted animals will consume less water than fed animals; a point which could help alleviate borderline water supply situations. For the first few days, feed is not nearly as important as water and fresh air for animal survival.

Since milk cows may not receive normal care for the first few days after the nuclear incident, efforts should be made to decrease the stress on them. Lack of feed will decrease milk secretion in most dairy cows, but to help avoid udder distention and perhaps decrease the incidence of mastitis, it would be helpful to turn calves and young stock in with milk cows.

D. CONTAMINATION CONTROL

The principal cause of both internal and external radiation doses to people and animals in a nuclear incident that involves the release of radioactive materials, is radioactive contamination of surfaces, air, water, and food. The best method for keeping internal and external doses to a minimum, is to prepare and follow contamination control plans and procedures. The basic goal isto keep radioactive contamination completely away from people and animals. However, in practice, this is difficult at best. Therefore, the plans and procedures shown below are intended to keep contamination levels as low as possible.

1. Available Instrumentation

Since people cannot feel, smell, taste, hear or seethe radiation from a nuclear incident, control of contamination can be verified only with the use of radiation survey instruments. In most cases, radiation levels can vary greatly over short distances, and radiation levels that are broadcast over radio and television, may not be typical of your property. Therefore, in order to determine the radiation levels at any location, a functional survey meter is an important part of contamination control. If you do not have access to radiation survey instruments, the following procedures, when properly implemented, can help to prevent the spread of radioactive contamination.

2. Containment

Areas (zones) which permit some method of controlling entry and exit, and provide some protection from airborne radioactive materials can be chosen as "clean" zones to house animals and/or feed. If possible, animals that were already in these clean zones at the time of the nuclear incident should be left in these zones. Any animals, people, food, water, or other supplies and equipment coming in from outside the clean zone must be decontaminated to remove any loose sources of radioactive material that may be on them. All "clean" animals, people, or materials must be kept within the protected clean zone. If permitted to leave, they must be decontaminated again before reentering the clean zone. Decontamii,ation methods are described in the following section.

E. DECONTAMINATION

Farmland could become severely contaminated as a result of accidents in transporting radioactive materials, mishaps at reactor facilities, or radioactive fallout from the atmosphere. Such incidents are expected to be rare. Nevertheless, it might be necessary to remove the contamination from the land in order to reduce the radiation hazard in the area or to prevent the radioactive material from entering the food or water of humans and livestock. This is called decontamination. Because effective decontamination requires considerable effort, it is important to choose suitable equipment and to use it properly. Each type of contamination incident presents different problems. Therefore, no single decontamination method would be best for all occasions, and various means of decontamination should be considered. However, the following are some suggested methods that can be used in the absence of specific instructions from the appropriate authorities.

1. Animal Care Facilities

The effectiveness of any land decontamination method is dependent on the thoroughness with which they are carried out. If possible, decontamination should be accomplished before rainfall washes the radioactivity into low-lying areas where it is more difficult to remove. Large-scale scraping operations requiring heavy earthmoving equipment can be used to scrape off the top layer (several inches) of contaminated soil and move it to suitable temporary storage areas. Scraping operations can utilize motorized graders, motorized scrapers and bulldozers.

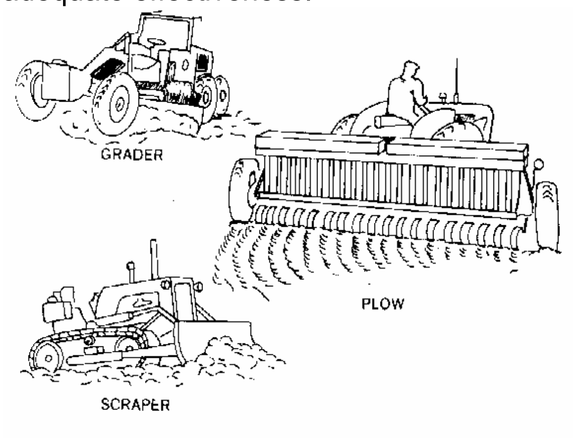
Motorized scraping is the surface removal method. designed to make shallow picking up the radioactive material into a hopper for disposal. The decontamination efficiency of motorized scrapers depends on the nature of the surface soil. They are extremely effective on large flat areas that have been sodded or tilled. Decontamination can be accomplished by a motorized scraper with a 12-foot blade at the rate of approximately two acres in three hours. Application of a concrete or asphalt coating over the deposited radioactivity is ineffective and only makes later pickup of radioactivity more difficult.

The motorized grader is designed for grading operations, such as for spreading soil or for light stripping. A motorized grader can be used effectively on any long narrow area. The scraped up earth is placed in a windrow for removal or burial.

Both grader and scraper can be utilized in combination to increase efficiency. In this combination method, the grader grades off the surface of the soil into windrows and the scraper picks it up and carries it to a temporary storage area. A bulldozes can be useful in
most effective and efficient Motorized scrapers are cuts into the soil surface, scraping small contaminated areas, burying material, digging sumps, and in back-filling disposal areas. It can also be used as a prime mover to assist motorized scrapers in their scraping operations.

Where scraping procedures cannot be used because of rocky ground or permanent obstructions, an earth fill can be placed over contaminated land areas. The purpose of filling is to cover the contaminated area with uncontaminated soil in order to provide shielding. Motorized scrapers, bulldozers, graders and large dump trucks are necessary for filling operations over large areas.

Plowing is a rapid means of reducing dose rates by using clean earth as shielding when the contaminated soil is turned under, with a layer of uncontaminated soil placed on the surface. The depth of plowing should be at least 8 to 10 inches to achieve adequate effectiveness.



Since it is not feasible to operate large earthmoving equipment in confined areas or around buildings, small garden tractors, or front end loaders equipped with a small scraper can be used for scraping or plowing. Hand labor with shovels and wheelbarrows may be necessary to remove radioactive material from some smaller areas.

Cold weather decontamination methods will, in general, utilize the same procedures described previously. The presence of snow or ice can complicate decontamination efforts because of decreased mobility of equipment and personnel. Radioactive particles may be clearly visible on or within a snowfall, or on ice. This is useful for guiding the decontamination activities. The removal of a layer of snow or ice containing fallout particles can be accomplished with readily-available snow removal equipment. Motorized street sweepers can be used on dry pavement, traffic-packed snow, level frozen soil, or ice covered areas. Snow plowing can be utilized to windrow contaminated snow into piles, before loading into dump trucks for removal to temporary storage areas. Firehosing is possible and can be used on paved areas and exteriors of structures at below freezing temperatures. Firehosing under these conditions should only be used when proper drainage is provided in order to prevent unnecessary contamination of strategic water supplies.

The major constraints on the usefulness of area decontamination are the time required to accomplish the work, and the effectiveness of the selected decontamination procedures. The effectiveness depends only on the procedure itself and the surfaces to be worked on. The time required toaccomplish the work must take into consideration the radiation dose constraints to the decontamination crews; the availability of manpower, equipment and supplies; the size of area; the type of surfaces; and the rate that the particular decontamination method can be applied.

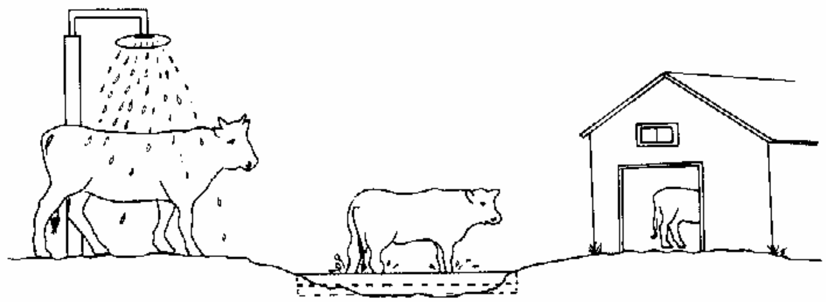
It is important to note that most of the decontamination activities listed above have the potential for spreading the radioactive material, re-suspending it in the air, and creating additional exposure hazards to the workers. Therefore, decontamination efforts should be performed correctly while adequately protecting workers.

2. Animals

External decontamination of livestock and poultry must be performed as early as possible. Since the most likely source of contamination is from airborne radioactive materials, contamination will usually be concentrated on the backs and feet of animals. Contamination can be removed by washing the animals with uncontaminated or, if necessary, slightly contaminated water. A water spray can be used to efficiently decontaminate most animals. The feet are the last parts of the animal to be decontaminated before the animal enters the "clean zone", or the decontaminated animal care facilities. This can be done by having the animals walk through a water trough at the entrance to the clean zone. If possible, animals should be checked for contamination with a radiation survey meter before they enter the clean zone.

Techniques for performing internal decontamination of animals are very limited. The basic concept is to clean out the bowels of the animals by giving them uncontam-inated food and water in as large quantities as possible and then removing the urine and manure from the clean zone as quickly as possible. However, this may not be feasible if there is a limited supply of uncontaminated food and water available.

Other internal decontamination techniques should be performed under the supervision of your veterinarian. Additionally, care must be taken that any internal decontamination technique does not cause subsequent animal products such as meat or eggs to become unsafe for human consumption.



3. Water and Foods

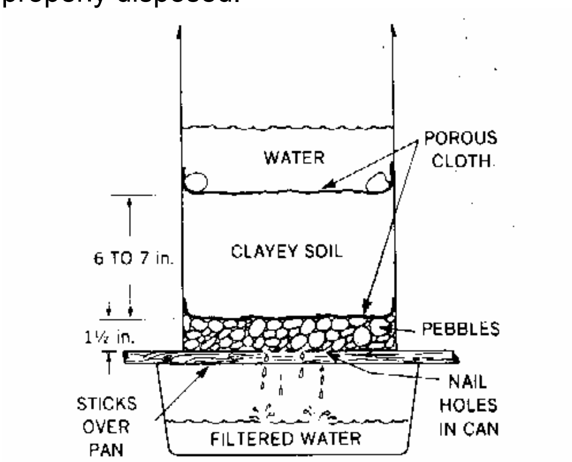
Once the immediate needs of people and livestock are met and recovery is under way, or if the incident is relatively minor, it will then be important to begin de-contamination of food and water supplies. The less severe the incident, the earlier food and water decontamination could be performed. This task would be of primary importance in a single, local incident, or when the contamination is limited to a small area. In a larger scale nuclear incident, changes in the diet of people and animals, as directed by the proper authorities, would depend on the nature and scope of the initial incident. In some cases, these changes, which are designed to reduce the intake of radioactivity, might be of limited value if mass devastation has occurred. If this is the case, more pressing needs, such as survival, health, and nutrition, would have a much higher priority during the recovery cycle than food decontamination.

In any case, clean water supplies should be identified and protected immediately upon notification of a nuclear incident or accident. Closed tanks of water and well water are the safest sources of clean water and should be protected from radioactive contamination. Decontamination of other water supplies should be performed if clean water supplies are exhausted.

Radioactive contamination of water may be due to undissolved particles or dissolved materials. There are two basic methods of decontaminating water: settling and filtering. Settling is one of the easiest ways to remove undissolved particles from water. Although large particles will settle in a few hours, smaller particles may take several days to settle.

If uncontaminated, pulverized clay soil is added to a container of water at a clay-to-water ratio of one tofour, stirred thoroughly, and allowed to settle for at least six hours. The settling clay particles will carry most of the suspended particles to the bottom. The decontaminated water can then be carefully siphoned or dipped from the container without disturbing the clay. The clay that has settled to the bottom should not be reused, but should be properly disposed of.

Filtering water through a homemade earthen filter removes most of the particles and dissolved radioactive materials. This type of filter is shown in the following figure. For a filter of this size, contaminated water should be poured into the filter at a rate of about three to five quarts per hour. Earthen filters which can filter water at higher rates can be constructed on a larger scale, using a clean metal drum and proportional quantities of filter components. Filters should be cleaned and components replaced after approximately eight to ten hours of continuous use. Replaced components should be treated as radioactive waste, and properly disposed.



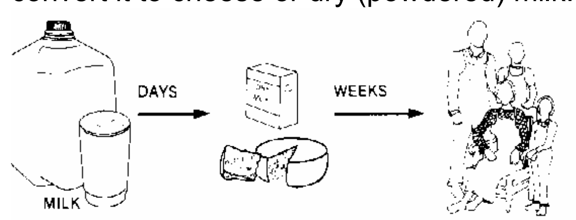
Settling, filtering, and a combination of the two are the easiest and most efficient methods for decontaminating water. These methods should provide sufficient temporary water supplies for the animal handling facility. It is recommended that clean, stored water be used primarily for human consumption and decontaminated water be used for animal consumption. If decontaminated water must be used for human consumption, it should first be disinfected by boiling or by chlorination.

However, boiling will not remove the radioactive materials from the water.

Canned and safely stored foods are not expected to be contaminated with radioactive materials. Care should be taken to ensure that such uncontaminated food supplies do not become contaminated during preparation for consumption. Foods that are known or suspected of being contaminated with radioactive materials should be decontaminated as carefully and completely as possible. Where possible, foods should be washed, and the washing water should be stored for decontamination and future use. Foods suspected of being contaminated which have an outer layer or skin should be peeled and the peelings treated as radioactive waste.

Decontamination of animal food, such as grain, is difficult. However, it is important to segregate clean food (stored under cover, or packaged in sacks or barrels) from contaminated food (stored outside, unprotected). Care must be taken to decontaminate any containers and to remove the grain from containers without contaminating the contents. If the only food available was stored outside without protective covering during the incident, carefully remove the top layers or outer portions of feed piles, and put it aside. Cover the remainder of the food in order to protect it from further contamination. Food that is determined to be contaminated should also be covered, and stored for a sufficient period of time to permit the radioactive materials with short half-lives to decay. At that time, such food should be checked for contamination before being given to livestock and poultry.

There are two approaches to removal of radionuclides from fluid milk. The first is reduction of the concentration of radioactive iodine at the point of production on the dairy farm by modification of farm practices. The second approach is the treatment of milk at a processing plant before the milk reaches the consumer. A survey of the current literature indicates that there are several methods for removing radioactive materials from milk, with some commercial success. However, it appears that hold-up for radioactive decay is the best and most economical approach for radioactive material with short half-lives. Since four to six weeks is required for decay of most of the radioactive iodine in milk, it may be important to store the milk, or convert it to cheese or dry (powdered) milk.



4. Equipment and Supplies

In general, "hand scrubbing" of equipment and supplies plays a major role in a decontamination program. The actual method employed can vary from a simple wipe with a dry or damp cloth, to a scouring action with an abrasive pad, possibly using cleaning chemicals. The chemicals which should be used will depend upon the amount of decontamination required and the type of contamination deposited on the surface. In all methods of decontamination of equipment and supplies, care must be taken to prevent spread of the contamination.

If the radioactive contamination is loosely-held on the surface, a simple wipe of the surface of the equipment with a damp cloth may remove most of the contamination. If the radioactivity is incorporated into the surface film, a more aggressive method may have to be employed. This may require the use of chemical cleaning agents, in conjunction with abrasive scrubbing. Cleaning agents are typical household cleaning products such as powdered laundry detergent. Abrasive pads of emery cloth or steel wool can be used for the scrubbing.

If the contamination is associated with an oil layer on the equipment, the surface of the equipment must be first wiped with cloths wetted by acetone, isopropyl alcohol, or some other organic solvent. These solvents will remove the oil layer, along with any associated radioactivity. The removal of the oil will then expose the contaminated surface film for further decontamination by conventional techniques, described above.

In some cases, hand scrubbing under dry conditions can create an airborne contamination problem. Two methods suggested for coping with the airborne problem include wearing respirators, or performing the cleaning under water. Decontamination performed under water will also shield a portion of the radiation from the person, thus reducing the radiation dose associated with the decontamination process.

F. CRITERIA FOR USE/DISPOSAL

Any radioactive contamination of food for human consumption can deliver an internal radiation dose to persons who eat that food. Therefore, federal, state, and local agencies will determine acceptable limits of contamination of food and water, based upon the type and extent of the contamination incident.

Animals and animal products which have been contaminated or which come from areas where a contamination incident has occurred must be properly monitored before they are released for human consumption. Unless directed otherwise, all such monitoring will be performed by federal, state, or local agencies prior to use of these products. Based upon their surveys, animals and animal products will be properly packed, marked, or labeled to indicate that a potential radiation hazard exits. If possible, the approximate level of radioactive contamination of these items should also be indicated. Proper identification of animals and animal products is necessary in order to prevent their unplanned use or consumption; to keep contaminated materials confined and separated from uncontaminated materials; and to alert the proper authorities so that monitoring, analysis, and protective measures can be initiated.

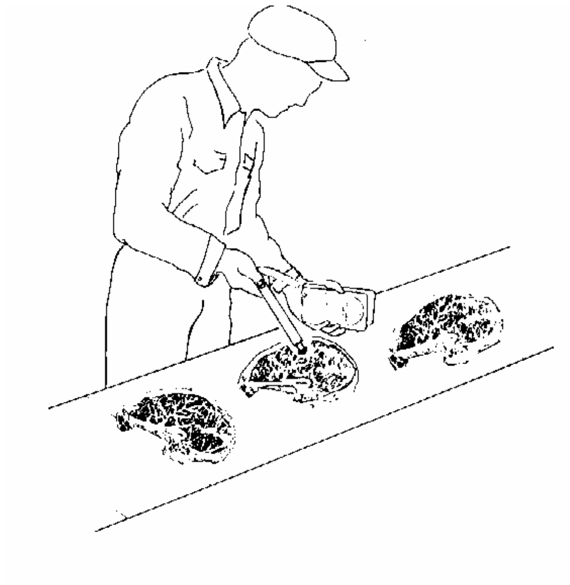
Care must also be taken in shipping and storing uncontaminated animals and animal products to prevent their subsequent contamination. Performing proper radiation surveys of animals and animal products and selecting transport routes through low contamination areas is the principle responsibility of the federal and state authorities. In preparation, you can provide clean and protected storage areas for uncontaminated animals and animal products prior to shipment.

To assist emergency response personnel, it is important for you to maintain accurate and up-to-date records. Examples

of important records to keep include: radiation survey information; types and amounts of food and water consumed; animal health data; meat, milk and egg production; slaughter records; and shipment records.

G. USE OF CONTAMINATED LIVESTOCK, POULTRY, AND ANIMAL PRODUCTS

To be salvageable for human food, animals that have received significant radiation dose must be presented for slaughter, passed, and processed before the signs of radiation damage become apparent. However, PANIC SLAUGHTER



MUST BE AVOIDED. The need to save animals that may survive the radiation dose is more important than the need to salvage doomed ones. The time required to rebuild livestock populations in the event of a serious nuclear incident will be dependent upon the number of survivors.

It is impossible at the time of shipment to know which animals will die and which will survive. With all other things being equal, animals which have survived other severe stresses could probably survive the stress of radiation dose better than others. The most logical procedure would be to save the most productive part of the herd or flock. However, animals exposed while under severe stress conditions could show decreased tolerance to radiation. The decision is up to the producer, but panic slaughter should be avoided.

Gamma radiation would not affect the meat of exposed animals. Also, little if any fallout from the hide or digestive tract will reach the meat, except if contaminated in the slaughtering process. However, there is a possibility that bacterial contamination of meat, from organisms normally present in the gut, could occur in exposed animals. Meat should be thoroughly cooked to destroy bacteria and their by-products. Meat prepared in this manner would be safe, in most cases, for human consumption.

Attempts at salvage of livestock should be governed by gamma radiation levels in the area, the potential radiation dose that personnel would receive, and the availability of transportation, slaughtering, and storage facilities. Individual producers should consider these factors in deciding when, and if, livestock must be moved to slaughter.

In areas where the radiation dose is not high enough to sicken animals, their meat would be safe to eat. In high dose areas however, animals that have eaten or drunk contaminated food or water will have concentrated radioactivity in their internal organs. The thyroid gland, kidneys, and liver of these animals should not be eaten.

If an animal appears to be sick, it should not be eaten. That animal might be suffering from a sickening or fatal radiation dose and might have developed a bacterial infection as a result of this dose. Meat contaminated with the toxins produced by certain kinds of bacteria could cause severe illness or death if eaten by humans, even if thoroughly cooked.

Under crisis conditions, all meat should be cooked until it is extremely well done. In other words, it should be cooked long past the time when it loses the last of its pink color. To be sure that the center of each piece of meat is raised to boiling temperature, the meat should be cut into pieces that are less than 1/s inch thick before cooking. This precaution also reduces cooking time and saves fuel.

H. STORAGE AND DISPOSAL OF CONTAMINATED MATERIALS

An important aspect of decontamination is the ultimate disposal of radioactive materials. The decontamination methods described in the previous section of this manual are designed to remove radioactivityfrom areas requiring decontamination to areas of less importance. In most instances, onsite burial of contaminated materials is recommended. Sumps to contain runoff from wet decontamination methods can be back-filled after evaporation and/or seepage of the water into the subsoil. Wet decontamination of paved areas and built-up areas will result in radioactivity being washed into storm drains which eventually lead to larger bodies of water such as streams, rivers, or, in coastal areas, the ocean. Heavily contaminated soil removed from land areas can be transported to other areas for burial in excavated pits and covered with uncontaminated soil, much the same way as sanitary land fills are operated.

The current regulations that were designed to ensure the safe disposal of radioactivity into the environment generally fall into three categories:

Disposal operations should be initiated only after prior authorization by a competent authority and strictly in accordance with the conditions stipulated.

Special rules have been designed to ensure that the health and safety of both workers and the public shall not be endangered as a result of any radioactive waste disposal operations.

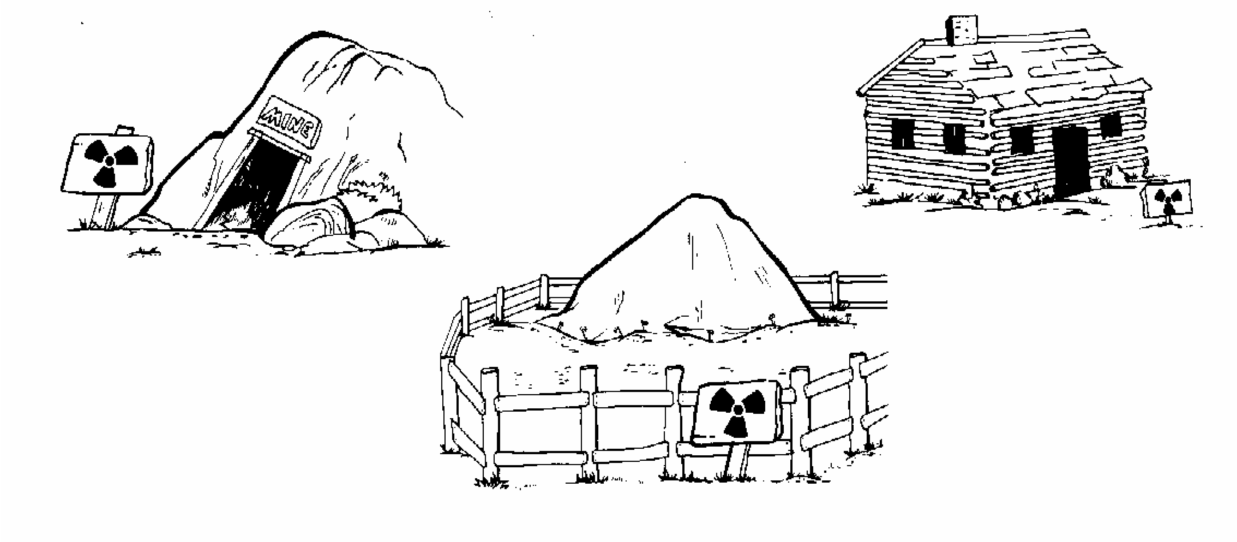
There is a requirement for taking regular periodic radiation measurements or surveys, the maintenance of records, the inspection of premises and other administration of the regulatory norms established.

Although these are goals for radioactive waste disposal, it may not be possible to strictly abide by these recommendations, especially in the event of a large scale contamination incident.

Long-term disposal sites for contaminated materials must be approved by state and federal agencies. The Federal Emergency Management Agency will coordinate the long-term remediation efforts, and will provide you with instructions on the amount, type, form, and packaging of contaminated materials acceptable at each designated site. However, while awaiting this direction, the following practices will be useful for temporary storage of contaminated materials so that radiation doses to humans and livestock are kept as low as possible.

Contaminated materials must be properly stored and disposed in order to keep radiation doses as low as possible and to prevent the spread of contamination. Contaminated materials could include such things as animal carcasses, feed, protective clothing, and equipment. It will be necessary to package and provide temporary storage for these materials before they are shipped to an approved disposal area. When it is practical to do so, contaminated materials should be wrapped or sealed in plastic and labeled as to the contents and approximate radiation level.

The most important point in storing and disposing of contaminated materials is to keep it as far away from humans, surviving animals, drinking water sources, and food stuffs as possible. The best approach would be much like above-ground storage of silage. After a strategic site is located, plastic sheeting is placed on the surface of the ground before the contaminated materials are brought there. Plastic should be placed over the top of the pile as well, in order to prevent run-off into surrounding areas or water supplies. It is also important, for long-term clean-up of the landscape, that records be maintained on where radioactive materials have been disposed. This is particularly important if mines or caves are used to temporarily store contaminated materials.



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APPENDIX A: GLOSSARY

absorbed dose: a technical term meaning the radiation dose or amount of radiation that has been absorbed by a substance, such as the human body. Absorbed dose is measured in units of rads or grays.

activity: A measure of the strength of a radioactive source, or the number of disintegrations that occurs in a radioactive source in a given period of time. Activity is measured in units of curies.

acute radiation exposure: Exposure to a large dose of radiation in a short period of time.

acute radiation syndrome: The medical term for radiation sickness.

alpha particle: A small, electrically-charged particle of ionizing radiation given off by some radioactive materials. Alpha particles have a short range and cannot penetrate the outer dead layer of human skin. But, if radioactive materials emitting alpha particles are inhaled or swallowed, theycan be dangerous.

atom: The basic component of all matter. An atom consists of a central charged nucleus (made up of neutrons and protons) and electrons that surround the nucleus. attenuation: The reduction in the amount of radiation energy as it passes through any material, such as shielding.

background radiation (natural): Radiation that is emitted from naturally occurring radioactive materials in the air, earth, and from cosmic rays that bombard the earth from outer space.

battery check: A check to see that the batteries of a radiation survey meter are strong enough to allow operation of the survey meter. Generally, a "battery-check button" is pushed and a needle moves to show if the batteries are strong enough.

beta particle: An electrically charged particle of radiation emitted by many radioactive materials. A beta particle is a fast-moving electron, sometimes moving close to the speed of light. Beta particles can be stopped by an inch of wood or a thin sheet of aluminum.

cancer: A disease in which rapidly multiplying cells grow in the body, interfering with its natural functions. Exposure to ionizing radiation may increase the probability that a person will get cancer.

chromosome: All the genetic material or genes contained in a living cell. Chromosomes control the reproduction of cells and the characteristics of the cells produced from the original cell. (See gene)

contamination, radioactive: The presence of radioactive material where it is not supposed to be.

cosmic radiation: Ionizing radiation that comes from outer space. (See background radiation).

curie: A basic unit to describe the intensity (strength) of radioactivity in a material. A curie is a measure of the rate at which a radioactive material decays, or emits particles.

decay, radioactive: The breaking up or disintegration of atoms that have excess energy. Radiation is emitted in the process.

decontamination: The removal of radioactive contamination from surfaces.

delayed effects: Those effects caused by radiation that do not become evident until years after exposure to radiation. The possible delayed effects of radiation are cancer in the exposed persons and genetic defects in their offspring.

detector, gas-filled: A radiation detector filled with gas. It detects ions formed by radiation.
detector, radiation: The part of a radiation survey meter that is sensitive to radiation.
disintegration: The breaking up an unstable atom. Radiation is emitted in the process. (See decay, radioactive, and curie).

DNA: Deoxyribonucleic acid. The long spiral molecules found in all living cells that control cell functioning and reproduction. Radiation injury is the result of damage of these molecules.

dose: Dose is the amount of radiation absorbed by an object. Dose can be expressed in units of rems, or rads.

dose rate: A measure of how fast a radiation dose is being received. It is a dose per unit of time. For example, "The dose rate is 10 millirems per hour."

dosimeter: A device used to determine the radiation dose that a person has received.

electron: A very light particle that rotates around the nucleus of an atom and carries a negative electric charge. Electricity is the flow of electrons.

element: A basic type of matter. Each element has distinct chemical properties. There are 92 elements that are found in nature, for example, hydrogen, oxygen, lead, uranium, carbon, tungsten, and iron.

exposure: Being exposed to radiation. People can be exposed to radiation, or film can receive an exposure to radiation. Exposure is also a technical term meaning the amount of ionization in air caused by x-rays or gamma rays.

fallout, radioactive: Radioactive debris from the explosion of nuclear weapons that falls out of the atmosphere onto the earth.

gas-filled detector: See detector, gas-filled negative electrical charge: An electrical charge that is attracted to positive electrical charges. Electricity is the movement of negative electrical charges.

geiger counter (Geiger-Mueller counter, G-M counter): An instrument used to detect radiation and to measure radiation dose.

gene: A part of a living cell that controls the reproduction of atom, the nucleus consists of neutrons and protons tightly the cell and determines the characteristics that the repro- locked together. In a living cell, the nucleus contains the genes duced cells will have (see chromosome). - or genetic material of the cell.
genetic defect: A defect in a living organism caused by a deficiency in the genes of the original reproductive cells from which the organism was conceived. Genetic defects are passed on to the descendants of the person with the defect.

half-life: The time it takes for half the atoms in a radioactive sample to decay. Half-lives of different radioactive materials vary from a fraction of a second to billions of years.

health physicist: A trained specialist working in radiation protection.

internal contamination: Radioactive contamination within a person's body caused by radioactive material that has been inhaled or swallowed.

ion: An atom that has gained or lost one or more electrons or an electron that is not attached to an atom. Ions have an electrical charge.

ion pair: A positively charged ion and an electron. The production of ion pairs is the method by which ionizing radiation gives up its energy.

ionization: The process of creating ions by adding electrons to, or removing electrons from, atoms or molecules.

ionization chamber: An instrument similar to a Geiger counter that is used to detect and measure radiation.

ionizing radiation: See radiation, ionizing.

manmade radiation: Radiation produced by manmade (not natural) sources, such as x-ray machines and nuclear power plants.

median lethal dose: The radiation dose that would result in the death of 50% of the people exposed to that dose. This dose is approximately 450 rems delivered to the entire human body within a few hours or a few days.

millirem (mrem): A commonly used unit of radiation dose, abbreviated mrem. A millirem is equal to one-thousandth of a rem, or 1/1000 of a rem.

molecule: The smallest unit of a chemical compound. A water molecule consists of two hydrogen atoms combined with one oxygen atom.

mutation: In a cell, a change in the genes or genetic material of the cell. (see genetic defect).

natural background radiation: See **background radiation, natural**

natural radioactivity: The radioactivity from naturally occurring elements that are radioactive, for example, radium, carbon-14, uranium, thorium, and potassium-40.

Negative electical charge: An electrical charge that is attracted to positive electrical charges. Electricity is the movement of negative electrical charges.

nucleus: The inner core of an atom or a living cell. In an atom, the nucleaus consists of neutrons and protons tightly locked together. In a living cell, the nucleus contains the genes or genetic material of the cell.

Penetrating radiation: See **radiation, penetrating.**

Positive electrical charge: An electrical charge that is attracted to electrons or other negative electrical charges.

Rad: A unit of radiation dose. The rad is used to tell how much energy per unit mass is deposited by radiation. For gamma rays and x-rays, one rad is equal to one **rem.**

Radiation: A very broad term that refers to vibrating waves or clouds of pure energy or very fast-moving atomic particles (such as electrons, beta particles, alpha particles). Radiation made of pure energy includes gamma rays, x-rays, and radio waves.

Radiation burns: Burns in flesh caused by ionizing radiation. The burns are not caused by heat but by chemical breakdowns in the nucleus of a living cell. Howegver, radiation burns are medically similar to heat burns in effect and in treatment.

Radiation dose: See **dose**

Radiation dose limits: A limit on the radiation dose that a person may receive, as established by a government regulatory agency.

Radiation, ionizing: Any radiation that has enough energy to break apart chemical bonds and cause atoms to form ions (charged particles)

Radiation, penetrating: Radiation that can penetrate matter deeply, such as gamma rays. Visible light is radiation, but it is not penetrating. Microwave radiation can penetrate many materials but is not usually included as a type of penetrating radiation.

Radiation sickness: Sickness, possibly fatal, resulting from a large exposure to radiation (hundreds of rems) in a short time (within several days). See **acute radiation syndrome**

Radiation survey: See **survey, radiation.**

Radioactive: An adjective describing materials that emit radiation when unstable atoms break up.

radioactive decay: See decay, radioactive.

radioactive material: A material containing unstable or radioactive atoms that break up or decay and emit radiation in the process.

radioactive waste: Waste that contains radioactive material. It must be disposed of in a safe manner according to government regulations.

radioactivity: The emission of radiation from an unstable atom.

rate, dose: A measure of the speed at which dose accumulates. That is, 1 mrem per hour. Similar to the speed of an automobile in miles per hour, which is a mileage rate.

rem: A unit of radiation dose. A rem is equal to 1000 millirem (mrem).

shielding (or shielding material): Material that can be placed around a radiation source for the purpose of reducing radiation levels.

source: This term can refer to any source of radiation.

source, radioactive: Any source of radiation where the radiation is produced by the decay of radioactive materials rather than electrically as in x-ray machines.

survey meter, radiation: A portable instrument that measures radiation dose rate (radiation intensity).

survey, radiation: As used in the manual, a radiation survey is a measurement of the levels of radiation taken by using a radiation survey meter.

syndrome, acute radiation: The medical term for radiation sickness.

x-ray: Radiation similar to light, but more energetic and therefore more penetrating. X-rays can cause damage to living things. They are usually produced by bombarding a metallic target with electrons.

APPENDIX B: EMERGENCY ASSISTANCE ORGANIZATIONS STATE RADIOLOGICAL CONTROL AGENCIES

Twenty-five state governments (indicated by an asterisk) have signed agreements with the U. S. Nuclear Regulatory Commission and have assumed control over radiations in their respective states. These individual states have established regulations governing licensing and control of radiation in their jurisdiction.

ALABAMA
State Department of Public Health Division of Radiological Health State Office Building Montgomery, Alabama 36014 (205) 269-7634

ALASKA
Department of Environmental Conservation
Division of Water and Air Quality Control
Pouch 0
Juneau, Alaska 99801 (907) 586-6721

ARIZONA
Arizona Atomic Energy Commission 1601 West Jefferson Street Phoenix, Arizona 85007 (602) 271-4845
(203) 566-5134

ARKANSAS
Department of Health
Division of Radiological Health
4815 West Markham Street
Little Rock, Arkansas 72201
(501) 661-2301

CALIFORNIA
Department of health
Radiological Health Section
714 P Street
Sacramento, California 95814
(916) 322-2073

COLORADO
Department of Health
Division of Occupational and Radiological Heatlh
4210 East 11th Avenue
Denver, Colorado 80220
(303) 388-6111

CONNECTICUT
Deparment of Environmental Protection
State Office Building
Hartford, Connecticut 06115
(203) 566-5134

DELAWARE
Division of Public Health Office of Radiation Safety Jesse S. Cooper Memorial Bldg. Capitol Square Dover, Delaware 19901 (302) 678-4731

DISTRICT OF COLUMBIA Bureau of Institutional Hygiene and Radiological Health Department of Environmental Services
D.C. General Hospital, Box 97
Washington, D.C. 20003 (202) 629-3343

FLORIDA
Department of Health and Rehabilitative Services Radiological and Occupational Health Section
P. 0. Box 210 Jacksonville, Florida 32201
(217) 525-2342

GEORGIA
Department of Human Resources
Radiological Health Unit
State Office Buidling
47 Trinity Avenue
Atlanta, Georgia 30334
(404) 894-5795

HAWAII
Department of Health
Noise and Radiation Branch
P.O. Box 3378
Honolulu, Hawaii 96801
(808) 548-3075

IDAHO
Department of Health and Welfare
Radiation Control Section
Statehouse
Boise, Idaho 83720
(208) 384-2390

ILLINOIS
Department of Public Health
Division of Radiological Health
535 West jefferson Street
Springfield, Illinois 62762
(217) 525-2342

INDIANA
Indiana State Board of Health
Division of Radiological Health 1330 West Michigan Street Indianapolis, Indiana 46206 (317) 633-6340

IOWA
Department of Environmental Quality
Hazardous Substances Section P. 0. Box 3326
Des Moines, Iowa 50316 (515) 265-8134

KANSAS*
Department of Health and Environment
Forbes Air Force Base Building 740
Topeka, Kansas 66620 (913) 296-3821

KENTUCKY
Department for Human Resources
Radiological Heatlh Program
Capitol Annex
Frankfort, Kentucky 40601
(301) 383-2747

LOUISIANA
Division of Radiation Control
Louisiana Board of Nuclear Energy
P.O. Bix 4403, Capital Station
Baton Rouge, Louisiana 70804
(504) 389-5963

MAINE
Department of Health and Welfare
State House
Augusta, Maine 04330
(207) 289-3826

MARYLAND
Department of health and Mental Hygiene
Division of Radiation Control
State Office Building
301 West Preston Street
Baltimore, Maryland 21201
(301) 383-2747

MASSACHUSETTS
Massachusetts Department of Public Health
80 Boylston Street, Room 940
Boston, Massachusetts 02116 (617) 727-5418

MICHIGAN
Department of Public Health
Radiation Division
3500 North Logan Street Lansing, Michigan 48914 (517) 373-1410

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2511 Industrial Drive
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Departemtn of Health and Environmental Sciences
Radiological and Occupational Health program
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Helena, Montana 59601
(406) 449-3454

NEBRASKA
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NEVADA*
State Department of Health and Welfare
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201 South Fall Street Carson City, Nevada 89701 (702) 882-7870

NEW HAMPSHIRE
Division of Public Health Services
Radiation Control Agency Hazen Drive
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(603) 271-2281

NEW JERSEY
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Bureau of Radiation Protection
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(609) 292-5586

NEW MEXICO *
Environmental Improvement Agency
Radiological Health Unit
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Santa Fe, New Mexico 87501
(505) 827-2573

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New York State
Department of Health
Bureau of Radiological Health
845 Central Avenue
Albany, New York 12206
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Division of Industrial Hygiene
State Department of Labor
80 Centre Street
New York, New York 10013

New York City Department of Health
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new York, New York 10013
(212) 566-7150

NORTH CAROLINA
Department of Human Resources
Radiation Protection Branch
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Raleigh, North Carolina 27605
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NORTH DAKOTA *
State Department of Health
Radiological Health Program
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Bismarck, North Dakota 58501
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OHIO
Department of Health
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OKLAHOMA
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Occupational and Radiological Health Service
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Radiation Control Service
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Department of Environmental Resources
Pennsylvania Bureau of Radiological Health
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South Carolina Department of Health and Environmental Control
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SOUTH DAKOTA
State Department of Health
Sanitation and Safety Program
State Capitol
Pierre, South Dakota 57501
(605) 224-3141

TENNESSEE*
Department of Public Health
Division of Occupational and Radiological Health
727 Cordell Hull Building Nashville, Tennessee 37219
(615) 741-3161

TEXAS *
State Department of Health Division of Occupational Health and Radiation Control
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Austin, Texas 78756
(512) 454-3781

UTAH
State Division of Health
Radiation and Occupational Health Section
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Salt Lake City, Utah 84113
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Department of Health
Division of Occupational Health
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VIRGIN ISLANDS
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Division of Environmental Health
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Department of Social and Health Services
Radiation Control Unit
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WEST VIRGINIA
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Department of health and Social Services
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FEMA Region VI
Federal Regional Center,
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FEMA Region VII
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Kansas City, Missouri 64106
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Can be reached at
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APPENDIX C: BIBLIOGRAPHY

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