Ionizing Radiation

Description

Ionizing Radiation is the name given to a band of energy on the electromagnetic spectrum. X-rays and radioactive substances are examples of ionizing radiation.

In order to understand the difference between ionizing and nonionizing radiation it is necessary to review the structure of an atom.

All matter is made up of molecules which are chains of atoms hooked together in various combinations and shapes. An atom is the smallest unit of an element (like helium, oxygen or carbon) that still has all the properties of that element. Atoms are so small they cannot be seen with even the most powerful microscope.

All atoms are made up of three major subatomic particles: protons, neutrons, and electrons. Protons and neutrons make up the nucleus or center of the atom. Protons have a positive electric charge but neutrons have no electric charge. Electrons circle the nucleus and have a negative charge. In most atoms the negative charges of the electrons exactly balance the positive charges of the protons in the nucleus. If an atom has too many or too few electrons in orbit to balance the protons, the atom is called an ion.

The number of protons in the nucleus of an atom determines which element it is. An atom of helium has two protons and two neutrons. An atom of carbon has six protons and six neutrons. If the atom has too many or too few neutrons for the number of protons, the atom is unstable and is called an isotope. It will give off bursts of energy (radiation) in an attempt to become stable.

These bursts of energy or disintegrations may be in the form of alpha particles (two protons and two neutrons), beta particles (a negatively-charged electron), or gamma rays (an energy wave). If these charged particles or waves interact with another atom, they have enough energy to knock an electron out of its orbit, creating an ion. That is why this type of radiation is called ionizing radiation.

Other forms of energy, like visible light, radiowaves, and infrared light, do not have enough power to knock electrons out of their orbits so they are called non-ionizing radiation.

Amounts of ionizing radiation can be expressed in several different units. A roentgen (R) is an amount of x-rays or gamma radiation which causes a specified amount of ionization among the atoms and molecules in a cubic centimeter of air. Another unit is the rad which applies to all ionizing radiation. It is a measure of the amount of energy absorbed from radiation in a specific volume of material.

A third unit which is more useful and used more commonly is the REM (Roentgen Equivalent Man). Measuring radiation in rems or millirems (one thousandth of a rem) allows direct comparison of the biological effects of different types of radiation. Alpha particles, beta particles, and x-rays or gamma radiation, differ in their ability to cause damage in tissues due to their differences in ionizing and penetrating ability. Alpha particles are 20 times more damaging in tissue as the same amount of x-rays. Measuring radiation in rems takes this difference into account so that one rem of alpha radiation in...
tissues has the same effect as one rem of beta radiation or one rem of x-rays. A rem is a relatively large quantity of radiation so most human exposures are measured in millirems. An easy way to remember the difference between these units is that a roentgen is a measure of how much you are exposed to, the rad is how much you absorb, and the rem is how much damage it does.

All people receive ionizing radiation from naturally occurring sources. Depending on where you live, most people receive an exposure in the range of 100 - 200 millirems per year from cosmic radiation from outer space and from naturally occurring isotopes (excluding radon) in the ground, air, food, and water. Radon is estimated to add another 150 - 200 millirems per year to our background.

Medical and dental uses of x-rays can also contribute to a person's yearly radiation exposure. A typical well conducted chest x-ray involves an exposure of 10 - 30 milliroentgens.

With the use of radioactive isotopes in industry and the increasing use of x-ray sources, ionizing radiation exposures may occur in a wide variety of occupations. The following examples show the diversity of occupations potentially exposed to ionizing radiation.

Aircraft workers Military personnel
Atomic energy plant workers Nurses
Biologists Oil well loggers
Cathode ray tube makers Ore assayers
Ceramic workers Pathologists
Chemists Petroleum refinery workers
Density testers Physicians
Dental assistants Physicists
Dentists Pipeline oil flow testers
Dermatologists Pipeline weld radiographers
Drug makers Plasma torch operators
Drug sterilizers Plastic technicians
Electron microscope makers Prospectors
Electron microscopists Radar tube makers
Electrostatic eliminator operators Radiologists
Embalmers Radium laboratory workers
Fire alarm makers Radium refinery workers
Food preservers Research workers
Food sterilizers Television tube makers
Gas mantle makers Thickness gauge operators
High voltage television repairmen Thorium-aluminum alloy workers
High voltage vacuum tube makers Thorium-magnesium alloy workers
High voltage vacuum tube users Thorium ore producers
Industrial fluoroscope operators Tile glaziers
Industrial radiographers Uranium dye workers
Inspectors using, and workers in Uranium mill workers
proximity to, sealed gamma ray Uranium miners sources
sources (cesium-137, cobalt-60, Veterinarians
and iridium-192) X-ray aides
Klystron tube operators X-ray diffraction apparatus operators
**Health Effects**

The health risks and effects of exposure to ionizing radiation are dependent on the type of radiation (alpha, beta, gamma or x-ray), the energy, the dose rate, the quantity, and the body part exposed.

Alpha particles, due to their relatively large size and mass, do not travel very far in air (a few centimeters) and cannot pass through skin or even a sheet of paper. Alpha radiation is only hazardous if inhaled or ingested. It is the most damaging to tissue, however if it is inhaled or ingested. Beta particles are more penetrating than alpha; a thin sheet of aluminum will stop beta radiation, but beta radiation is not as damaging to tissue.

X-rays (and gamma) are the most penetrating and least damaging to tissue. Their penetrating capability makes them useful for medical diagnoses.

Some body parts are more sensitive to damage from ionizing radiation than other body parts. The reproductive and blood-forming organs and the eyes are the most sensitive while the extremities such as arms, hands, and feet are less sensitive.

The quantity of ionizing radiation to which a person is exposed is the greatest factor in the risk and severity of a radiation-related injury. Information on the health effects of a single large dose of ionizing radiation is readily available from studies of the casualties and survivors of the atomic explosions in Hiroshima and Nagasaki, from studies of people exposed to radioactive fallout from the early atom bomb testing and from accidents involving ionizing radiation.

Table 1 briefly outlines the health effects of a single acute dose of whole body radiation.

<table>
<thead>
<tr>
<th>Dose</th>
<th>Acute Effects</th>
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<tbody>
<tr>
<td>less than 25 rems</td>
<td>No detectable effect</td>
</tr>
<tr>
<td>25 - 50 rems</td>
<td>Drop in white blood cell count, no serious injury</td>
</tr>
<tr>
<td>50 - 100 rems</td>
<td>Possible injury and sickness; no disability</td>
</tr>
<tr>
<td>100 - 200 rems</td>
<td>Acute radiation sickness (nausea, vomiting, diarrhea, weakness, shock, skin sores, hair loss); possible disability</td>
</tr>
<tr>
<td>200 - 400 rems</td>
<td>Acute radiation sickness; disability certain, possible death without treatment</td>
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</tbody>
</table>
Occupational exposure to ionizing radiation is usually limited to a small area of the body such as the hands resulting in reddening of the skin or dermatitis. Whole body radiation and acute radiation sickness occurs very rarely in occupational settings.

The health effects of long term exposure to low levels of ionizing radiation are less easily studied and documented. The concern about possible health effects, cancer and genetic effects in particular, from low level radiation stems from the known health effects of high doses of radiation and the assumption that the degree of risk is directly related to the degree of exposure. It is assumed (not proven) for safety sake, that any exposure to radiation above natural background levels contributes to small increases in the risk of developing cancer. Reducing exposure to the lowest level possible will, therefore, reduce the risk to the lowest level possible.

**Emergency Procedures**

The following emergency procedures were developed for medical facilities but can be generally applied to any workplace where radioactive substances are used.

A. Spills

Accidental spillage of radioactive material is rare, but cannot be prevented absolutely, and may occur in any laboratory, in any hall or passageway traversed by messengers transporting such material.

Except for a major accident to a shipping container or a serious spill in the hot laboratory, the amount of radioactive material involved in a spill will usually be small and the radiation from it will not constitute a serious hazard. The real danger is the spread of the contamination on shoes or other contaminated garments. The following is a general outline of the procedure to be followed in the event of a spill.

1. Confine the spill immediately by dropping paper towels or other absorbent material onto it.
2. Put on waterproof gloves.
3. Check shoes for visible signs of contamination. If it appears possible that they are contaminated, remove shoes when leaving the contaminated region.
4. If fans, ventilators, or air conditioners are operating in the area, they should be shut off. Preferably this should be done by someone not involved in the spill and therefore not likely to spread contamination.
5. Mark off or isolate in some way the entire suspect area and police it to be sure that no one walks through it.
6. **CALL THE RADIATION PROTECTION SUPERVISOR.** If the number is not posted in a convenient place, and you do not know it, call the telephone operator, report an emergency and ask the operator to find the supervisor.
7. In general, inexperienced personnel should not attempt to clean up a spill. It is better to wait a little while for the supervisor than to risk spreading the contamination by erroneous procedures. If the spilled material is covered and bystanders are kept a few feet away, there is little or no danger.
from the radiation.

8. If any of the spilled material has splashed onto a person or clothing, immediate steps should be taken to remove it. Laboratory coats or outer garments should be taken off and left in the contaminated area. Hands or other skin areas should be washed thoroughly with soap. If it is certain that shoes or feet are not contaminated, it is permissible to walk to a washing facility, which subsequently, however, must be treated as a contaminated area until cleared by the Radiation Protection Supervisor. If there is doubt about contamination of the feet, a washbowl and soap should be brought to the suspect area for cleaning them.

9. The Radiation Protection Supervisor should bring decontamination materials and a survey meter, and the clean-up operation will proceed under the supervision of the RPS.

10. If the RPS is not immediately available, or clean-up must proceed without him or her, one person should do the work. This person should put on waterproof gloves, shoe covers and a surgical face mask if it is available. He will then take up the spilled material with absorbent paper, which must be handled with forceps or tongs, and deposit it immediately in a waterproof container. After as much as possible has been removed in this way, the surface should be washed with damp, not wet, rags held in forceps, always working toward the center of the contaminated area rather than away from it.

11. A survey meter should have been obtained from the office of the Radiation Protection Supervisor, and careful monitoring carried out during this procedure, on area and personnel. The meter should preferably be operated by someone who is not involved in the spill, so that the instrument is not likely to be contaminated.

12. Reduction of counting rate to five times background, over an area of 1 or 2 square feet or to ten times background over a few square inches is usually satisfactory, especially for short-lived nuclides. Eventually, the Radiation Protection Supervisor should check the area and give it clearance.

13. When the operation is finished, gloves and other protective garments should be carefully checked for residual contamination. If any is found, the garments should be left with the other contaminated material for ultimate clearance or disposal by the RPS.

B. Loss of a Sealed Source

The following is a general outline of the procedure to be followed in the event of loss of a sealed source:

1. Call the Radiation Protection Supervisor.
2. If all sources are supposed to have been removed from the patient, he or she should be checked with a survey meter to make sure that none has inadvertently been left behind.
3. Try to make sure that all bandages, linen, and bedding have been kept in the patient's room. If this is not the case, try to stop them on the way to the laundry or the incinerator.
4. Check all this material, a little at a time. Then check the room, to be sure the source is not on the floor or furniture.
5. Check the drain tap of any accessible plumbing facility.
6. Check the incinerator.
7. Check all barrels of ashes or garbage. The more active the source, the easier it should be to find it.
C. A Ruptured or Broken Sealed Source
   1. Shut off all fans and ventilators.
   2. Drop damp towels on the suspect material; throw nothing away.
   3. Call the Radiation Protection Supervisor. The RPS will remove the questionable material and check the area for contamination.
   4. If possible, evacuate the room. If not, keep all personnel several feet from the suspect material until the RPS arrives.

D. A Major Calamity: Fire, Earthquake, A Massive Spill
   1. Call the Radiation Protection Supervisor.
   2. Prevent access to suspect areas, or removal of anything from them. Shut off ventilating system; close drains if possible.
   3. Do not try to do anything until the RPS arrives. The RPS must be given complete charge.
   4. If for any reason the RPS cannot take charge, call the Radiological Physicist with the Alaska Department of Health and Social Services in Juneau. (907) 465-3019.

Medical Treatment
Medical treatment of a person who has been accidentally over exposed to ionizing radiation will depend on the dose. Exposures less than 25 rems generally do not require treatment. The treatment will also depend on whether the source of the radiation is outside the body such as from x-ray equipment or a gamma emitter, or from inside the body such as when a radioactive dust is inhaled or ingested.

When the source of radiation is outside the body, and treatment is considered necessary, it is started after the entire radiation dose has been received. The dose cannot be lessened, therefore the objective of the treatment is to lessen the acute effects of radiation sickness, prevent secondary infections and provide transfusions to supplement weakened and damaged blood cells.

When the source of the radiation (the emitter) has been inhaled or swallowed, radiation exposure will continue and the goal of treatment is to reduce the quantity of the emitter in the body. This may be accomplished by speeding up the excretion of the emitter by chelation therapy. A chelating agent is a chemical which binds with Radioactive heavy metals enabling the body to excrete them faster. Chelation therapy is effective for internal emitters which are soluble in body fluids. Insoluble emitting substances which have been inhaled can be removed to some extent by bronchopulmonary lavage, a procedure which rinses out the lung's air sacs and airways.

Safety Procedures and Control Measures
The specific aspects, equipment, and procedures of a workplace radiation safety program will depend on the nature of the source, the type of radiation emitted, and the circumstances of its use. only general concepts of protection and control can be covered in a data sheet of this scope. The National Council on Radiation Protection and Measurements (NCRP) offers recommendations for specific uses of radiation emitting substances and equipment. A list of publications available from NCRP and an order form are attached to this data sheet.

Restricted Access: Only authorized trained personnel, should be allowed in work areas where radiation
emitting substances or equipment are used. Signs and warning notices using the standard radiation symbol must be posted.

Shielding: The selection of materials and designs for shielding will depend on the type of radiation, the use factor of the equipment, occupancy times, and workload.

Ventilation: Operations that routinely produce airborne contamination should utilize engineered containment and ventilation systems to prevent airborne releases. Appropriate respirators may be used but only when effective engineering controls are not feasible.

Radiation Monitoring: Radiation survey equipment appropriate for the type of radiation to be measured must be maintained and used to evaluate exposure conditions for employees. Working areas must be monitored at a frequency which will ensure safe working conditions. Individuals working in most industrial settings and many medical facilities must wear appropriate radiation monitoring devices to measure actual occupational exposures. Records of results for area and personal monitoring must be maintained.

Licensing and Registration: All by-product radioactive material and special nuclear material must be licensed by the Nuclear Regulatory Commission, and conditions of that license met by the user. Radioactive materials not under the jurisdiction of the Nuclear Regulatory commission and all x-ray sources must be registered with the Alaska Department of Health and Social Services. Use must meet requirements of the Alaska Radiation Protection Regulations, DH & SS, in addition to the Occupational Health and Environmental Control regulations of the Department of Labor. The NRC and the state may conduct inspections of licensees and registrants to ensure compliance.

Consultation: The Radiological Physicist with the Alaska Department of Health and Social Services is available for consultation on all radiation safety matters involving both ionizing and non-ionizing radiation sources. Write to Radiological Physicist, Alaska Department of Health and Social Services, PO Box H, Juneau, AK 99811-0613, or call (907) 465-3019.

Personal Protective Equipment

Respirators used for protection against airborne contamination should be approved by the National Institute of Occupational Safety and Health (NIOSH). If air-purifying respirators are used if only high efficiency (HEPA) cartridges approved for dusts, fumes, mists, and radionuclides or radon daughters (progeny) may be used. A good respirator program must include consideration of respirator type, fit, maintenance, testing, and training.

Protective clothing must be provided if the potential for skin or clothing contamination exists. Selection must be based on the nature of the contaminant (liquid or dry material) and the type of radiation emitted. Appropriate methods of laundering or disposal are also required. Contaminated clothing must not be taken home.

Permissible Exposure Limit

The Occupational Health and Environmental Control regulations of the Alaska Administrative Code (8AAC) in 04.0105(b) state:

(b) Exposure of individuals to radiation in restricted areas.
(1) Except as provided in 04.0105(b)(2), no employer shall possess, use, or transfer sources of ionizing radiation in such a manner as to cause any individual in a restricted area to receive in any period of one calendar quarter from sources in the employer's possession or control a dose in excess of the limits specified in Table 1-18.

| Table 1-18 |
|-----|-----|
| **Rems per calendar quarter** |   |
| **Whole body: Head and trunk; active bloodforming organs; lens of eyes; or gonads** | 1 1/4 |
| **Hands and forearms; feet and ankles** | 18 3/4 |
| **Skin of whole body** | 7 1/2 |

(2) An employer may permit an individual in a restricted area to receive doses to the whole body greater that those permitted under 4.0105(b)(1) so long as:

(A) During any calendar quarter the dose to the whole body hall not exceed three rems; and

(B) The dose to the whole body, when added to the accumulated occupational dose to the whole body, shall not exceed five (N-18) rems, where "IN" equals the individual's age in years at his last birthday; and

(C) The employer maintains adequate past and current exposure records which show that the addition of such a dose will not cause the individual to exceed the amount authorized in 04.0105(b)(1).

As used in 04.0105(b), "Dose to the whole body" shall be deemed to include any dose to the whole body, gonad, active bloodforming organs, head and trunk, or lens of the eye.

(3) No employer shall permit any employee who is under 18 years of age to receive in any period of one calendar quarter a dose in excess of ten percent of the limits specified in Table 1-18.

These regulations (OHEC 04.0105) also cover definitions, exposure to airborne radioactive material, precautionary measures and personal monitoring, caution signs, labels and symbols, evacuation warnings, instruction of personnel, waste disposal, notification of incidents, reports of overexposure, records and disclosure.

**References**
