Author: N.Vo
Date: 5-12-2016

RADIATION SAFETY PROGRAM AND TRAINING MANUAL

For

GENERAL LICENSE – SEALED SOURCES
General License No. G0631-2

Florida Department of Environmental Protection
DEP Laboratories
Chemistry Program

May 2016

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Date: 5-12-2016

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SECTION 1: RADIATION PROTECTION PROGRAM

I. The Department of Environmental Protection Radiation Protection Program

Radioactive material and radiation sources at the Chemistry Laboratory must be used in accordance with rules and regulations contained in the Florida Administrative Code, Chapter 64E-5 Standards for Protection Against Radiation Hazard and under the conditions specified in several radioactive materials licenses issued by the State of Florida Department of Health. The Radiation Safety Officer has developed a radiation safety program in order to assure compliance with the provisions of these documents.

The program is designed to protect the health and safety of the workers and public from potentially harmful effects of radiation through maintaining both external and internal exposures As Low As Reasonably Achievable (ALARA).

The radiation safety manual sets forth the rules and procedures of the safety program. Users must become familiar with regulations in the appropriate sections of the manual. Many of the regulations in the manual are based on the requirements of Chapter 64E-5.

II. Appointing New Radiation Safety Officer

To comply with subsection 64E-5.213(7), F.A.C., the Department of Environmental Protection will send a written letter to the Department of Health within 30 days if there is a change in radiation safety officer position. The letter will also include documentation of the new RSO's qualifications for the position.

III. Radiation Safety Officer

A Radiation Safety Officer has the responsibility to implement the radiation protection program. Such a program would include:

1. Authorization of individuals and work areas for use of radioactive materials or radiation producing equipment;

2. Assuring the safe use of radioactive material and radiation producing equipment;

3. Approval of all purchases of radioactive material;

4. Maintaining an inventory of all radioactive material received;

5. Assuring that all required surveys and records are maintained;

6. Certifying the proper disposal of radioactive waste;
7. Monitoring leak testing of sealed radioactive materials;
8. Surveys of radiation producing equipment;
9. Responding to radiation emergencies;
10. Providing training to workers.

IV. Authorization to Use Radioactive Materials and Radiation Devices

Procurement and Receipt of Radioactive Materials

It is the responsibility of the Chemist Administrator to notify the Radiation Safety Officer when a purchase order number is issued for radioactive material orders. Since purchase order numbers are used in identifying incoming shipments, it is important that the Radiation Safety Officer be informed as soon as possible.

Procurement of Radiation Producing Devices

The purchase of any device which produces ionizing or nonionizing radiation must be approved by the Radiation Safety Officer; therefore, all requisitions to purchase such equipment (gas chromatography EC detector) shall be submitted to the Radiation Safety Officer.

V. Radiation Caution Signs, Notices, and Posters

The Radiation Safety Officer is responsible for posting of proper radiation warning signs in all areas in which ionizing radiation are used.

The following must be posted where radioisotope are used:

Emergency Notification	Notice to Employees
Emergency Procedures	Safety Rules

All radiation labels on empty shipping containers must be removed or defaced prior to disposing of the container in regular trash.

VI. Sealed Source Leak Tests

All Gas Chromatography with ECD shall be leak tested at intervals not to exceed six months. Leak tests shall be done by individuals who are authorized by the license and the test samples are sent to National Leak Test Center, NLTC Industries, Inc., P.O. Box 486, N., Tonawanda, NY 14120.

A licensee shall retain leak test records for 3 years. The record shall contain the manufacturer's the model and serial numbers of each sealed source tested, the identity of each sealed source radionuclide and its estimated activity, the measured activity of each test sample expressed in microcuries, the date of the test and the signature of the radiation safety officer or designee.

If the leak test reveals the presence of 0.005 microcurie or more of removable contamination, the licensee shall:

a. Immediately withdrawn the sealed source from use and repaired or to be disposed of in accordance with these regulations; and

b. File a report with the DOH within 5 days of receiving the leak test results describing the equipment involved, the test results, and the action taken.

VII. Radiation Control Member

Listed below are names of the current and past Radiation Safety Officers:

Nhon Vo	Radiation Safety Officer	850-245-8137
Liang Lin		850-245-8088
Marek Topolski		850-245-8132

VIII. Office of Radiation Control

If there are any changes in the licensee, notification should be addressed to

Department of Health
Office of Radiation Control
Radioactive Materials Program
4052 Bald Cypress Way BIN #C21
Tallahassee, FL 32399-1741
Phone: 850-245-4545

The Department of Health should be notified by mail within 30 working days.

IX. Training Requirements for Authorized Users

The Radiation Safety Officer must provide training to all personnel who will be handling radioactive material. Training must include the requirements as specified in Chapter 64E-5, F.A.C. A certificate of completion will be given to the individual after the training. During the training, each employee will sign the training record to indicate the safety manual has been issued out to him or her. To test the students, an open book exam will be given to them at the end of the class. The students will have 30 minutes to complete the exam. Once the exam is completed, the instructor will go over the exam. Each question will be reviewed orally. There is no grade assigned to the exam.

Records of training will be kept during the employment of the individual.

X. Inventory Requirements

The Radiation Safety Officer shall conduct a physical inventory of all sealed sources semiannually unless another interval is specified in the license. Inventory records shall be retained for 3 years. Inventory records shall contain the following:

(a) The model number and serial number of each sealed source;
(b) The identity of each sealed source radionuclide and its estimated activity;
(c) The location of each sealed source;
(d) The date of the inventory;
(c) A signature of the radiation safety officer.

XI Location of the ECDs

Figure 1.0 shows the layout of the third floor lab in Building B. Room B303 is designated as the radiation area. The gas chromatographs and Electron Detectors are kept in this room. Radiation caution signs, notices, and posters are posted at the entrance and inside the room. All doors are secured and locked after hours. Only authorized personnel are allowed to enter this room.

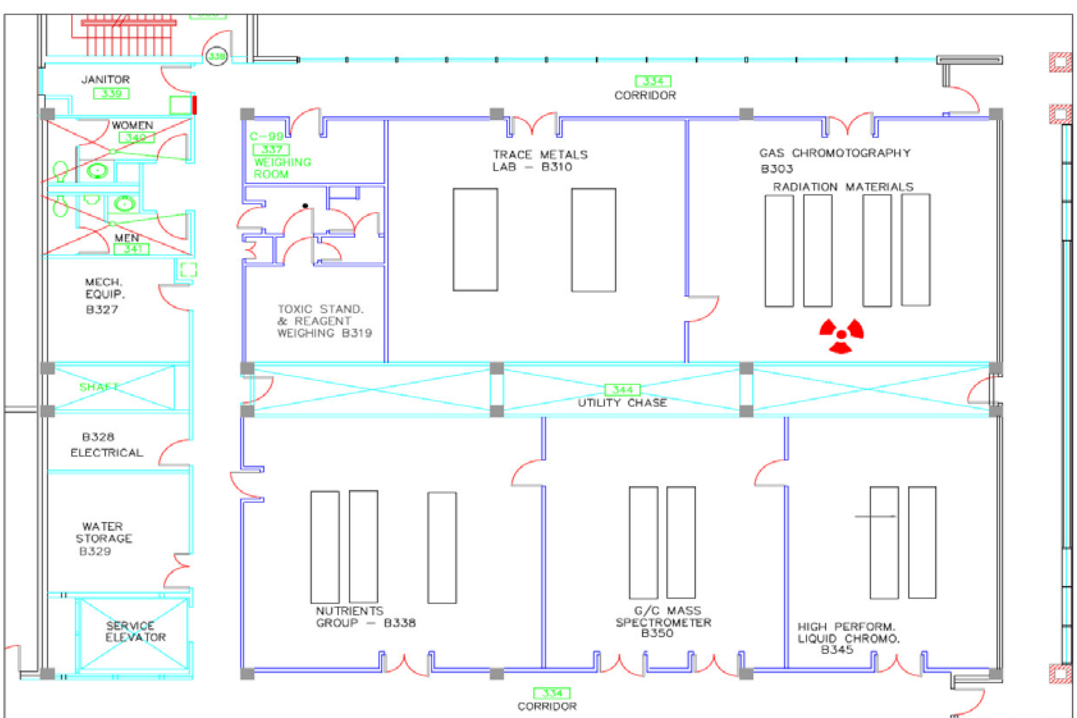

FIGURE 1.0. LAB FLOOR B LAYOUT

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SECTION 2: FUNDAMENTALS OF RADIATION

I. Fundamental of Radioactivity

A. Radioactivity is the property of the nucleus of an atom to spontaneously emit energy in the form of radiation.

B. Radiation is excessive nuclear energy emitted in the form of high energy electromagnetic waves or particles.

C. An element is a pure substance which cannot be broken down chemically or physically into simpler substances.

D. Primary particles forming an atom are:

Particle	**Electrical Charge**	**Mass (relative scale)**
electron	- 1	1/1800 of proton
proton	+ 1	1
neutron	neutral	1

1. The number of protons in the nucleus is called the atomic number and identifies the element.

2. The number of electrons in an atom equals the number of protons; hence an atom is electrically neutral.

3. The number of neutrons in the atom of an element varies.   Atoms of the same element with a different number of neutrons are called isotopes of that element.   The combination of protons and neutrons in the nucleus of an atom is the mass number.

4. All the isotopes of all the elements are called nuclides.
   a. Radionuclides are radioactive.
   b. Stable nuclides are not radioactive.

5. There are approximately:

   1,500 nuclides
   285 are stable => 1,215 nuclides are radioactive => 65 radionuclides found in nature
   1,150 are man-made radionuclides

II. Radiation

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A. When the coulomb forces (repulsion forces due to the positive charges of protons) are sufficient to overcome the nuclear forces (which hold the nucleus together), excess energy is emitted from the nucleus in the form of electromagnetic waves or rays and/or high - velocity particles.

B. **Three types of radiation are of major concern:**

1. **Alpha particles**- Particles consisting of two protons and two neutrons bound together with an electrical charge of +2. Identical to helium nuclei.

2. **Beta particles-** Particles with a single electrical charge. When negatively charged, identical to electrons.

3. **Gamma rays**- High energy, short wavelength, electromagnetic radiation. Other types of electromagnetic radiation include visible light, ultraviolet, and radar.

C. After the emission of an alpha or beta particle (but not gamma radiation), the original atom is transferred or transmuted into an atom of a different element called a "daughter". The daughter product may or may not be radioactive.

1. By the process of ionization, radiation interacts with the electrons surrounding the nucleus of the atoms or molecules that comprise the material through which the radiation is traveling.

2. This process creates an ion-pair, positively charged atom or molecule and an electron(s) which is freed from the atom due to the interaction with radiation.

3. After a series of ionizing interactions, each requiring a finite amount of energy from the radiation, the radiation loses its initial energy. In the case of alpha and beta particles, after loss of all velocity.

    a. An alpha particle picks up two electrons and becomes a helium atom.
    b. An electron loses its velocity (kinetic energy) and becomes a free electron.
    c. Gamma radiation is eventually degraded and finally absorbed.

ENERGY OF RADIATION: 1 MeV

Type of radiation	Distance traveled in air	Ion-pairs in 1 cm of air	Shielding required
Alpha	Less than 1 inch	Hundreds of thousands	A sheet of paper
Beta	Inches	Hundreds	1/16 inch of Aluminum foil
Gamma	Hundreds of feet	1-2	2 feet of aluminum foil

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III. Radioactivity Units

The instantaneous number of atoms, N, remaining at a particular instant in time is given by:

$$A = \lambda N$$

where A is the activity, defined as the instantaneous number of atoms decaying per unit time. The activity determines the quantity of radioactive material in a sample. The special unit for activity is called the Curie (ci), and is based on the decay rate of 1 gram of radium:

1 Curie = 3.7×10^{10} disintegration per second (dps)

Because the Curie is a very large quantity, fraction of the Curie are often used:

1 millicurie = (mCi) = 2.22×10^{9} dpm = 10^{-3} Curies
1 microcurie = (uCi) = 2.22×10^{6} dpm = 10^{-6} Curies

Since radioactive material is measured in units of activity, the decay equation now takes the form:

$$A = A_o e^{-\lambda t}$$

Where: A = Activity after some time t
A_o = Original activity of the sample
λ = The radioactive decay constant equal to $0.693/T_{1/2}$

t = Decay time

NOTE: The Becquere (Bq) is the new System International (SI) unit intended to replace the Curie; it is equivalent to 1 disintegration per second (dps).

Definition of some terms used in this manual:

Half-life- the amount of time it takes for 1/2 the original number of atoms of a specific radionuclide to decay is always the same.

Ion Pair - Two atomic particles of opposite charge consisting of an electron and the atom from which it was ejected (resultant positive charge). The term "ionization" is the name of the process by which a neutral atom or molecule acquires a positive

Specific Ionization - The number of ion pairs per unit length of the pathway of the ionizing radiation in a medium; such as, per cm of air or per micron of tissue.

Linear Energy Transfer (LET) - The average energy imparted per unit distance by a charged particle to a medium; such as, tissue. The term "LET" is used when attention is focused on the energy absorbed by the medium.

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Electron Volt (eV)- A unit often used to express the energy of radiation: keV for kilo electron volts; MeV for mega electron volts. The eV is not a unit of electrons or volts; it is a unit of energy and may be interchanged with any other units of energy: 1eV = 1.6 x 10^{-12} ergs.

Gamma and X-ray Photons - Short wavelength (ionizing) electromagnetic radiation. Photons originating in the nucleus are gamma rays and those originating in the extranuclear part of the atom are x-rays.

Naturally occurring radioactivity:

Carbon-14 is also an abundant naturally occurring isotope. It is produced by cosmic rays interacting with nitrogen-14 and is very important in the dating of organic matter.

Many common items contain naturally occurring radioactivity; watch dials, gas lantern wicks, cat litter, glossy paper. The amount of radioactivity is generally very low, but is often detectable with a Geiger-Mueller (G-M) meter.

Much of the air we breathe, especially inside some structures, is ladened with radon-222, a colorless, odorless radioactive gas; which is a naturally occurring daughter product of radium-226 in the uranium decay series. Radon tends to enter structures through cracks and holes in floors and is reportedly responsible for approximately 14,000 lung cancer death per year in the U.S. alone.

IV. Radiation Dosimetry

Standard Units of Radiation Measurement

Roentgen - "R":
1 R = 88 erg/gram in air. This correspond to the production of 2.083 x 10^{9} ion pair/cubic centimeter of air. This term should only be used to express exposure rate measurement in air for gamma and x- rays.

Rad - "Radiation Absorbed Dose"
1 rad = 100 erg/gram absorbed dose. This is defined as energy absorbed in the amount of 100 ergs/gram at the point of interest by any given material by any type of ionizing radiation. *The equivalent SI unit is the Gray; 1 Gy = 100 rads.*

Rem - "Roentgen Equivalent Man"
Rads x Quality Factor (QF) = Dose Equivalent.
The equivalent SI unit is the Sievert (SV); 1 Sv = 100 rems.

The QF corrects for the linear energy transfer (LET) associated with different types of radiation as indicated in the table below:

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RADIATION TYPE	**QF**
Gamma and x-rays	1
Beta and Electrons where E > 0.03 MeV	1
Beta and Electrons where E < 0.03 MeV	1.7
Thermal neutrons	3
Fast neutrons	10
Alpha particles	20

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SECTION 3: BIOLOGICAL EFFECTS OF RADIATION

I. Discovery

The first case of human injury due to radiation was reported in the literature four months after William Roentgen's original paper in 1895 announcing the discovery of x-rays.

In 1899, two Swedish physicians achieved the first radiation cure- the removal of a skin tumor. Human evidence of harmful effects as a result of exposure to radiation in large amounts existed in the 1920's and 30's from exposed to airborne radioactivity underground, persons working in radium industry, and other special occupational groups. As late as the 50's, it was commonplace for show stores to have poorly shielded do-it-yourself x-ray fluoroscopy machines for checking shoe fit.

II. Development of Standards for Radiation Protection

In the early 1920's the permissible limit of exposure to radiation was about 5 rem per month. At this time, genetic effects were not known.

In 1949, the National Committee on Radiation Protection (NCRP) recommended the dose be reduced to 0.3 rem per week. The NCRP did not have any scientific evidence that the original levels were harmful, but desired to be conservative. In 1956, due to large increase in number of radiation workers, the NCRP reduce the exposure limit to 0.1 rem per week or 5 rem per year. This exposure limit remains in effect today.

III. Radiation Chemistry

Radiation-induced injuries begin with molecular damage. Water molecules react as follows:

H_2O -> H + OH

These free radicals are highly reactive and form H_2, H_2O, H_2O_2. The amount that the free radicals will react with solute molecules is determined by the concentration of the solute. If several solutes are available, the free radicals will react depending on the largest size, number and chemical reactivity, in that order.

Direct "hits" on solute molecules may occur, but this is a very small number versus the indirect effects from free radicals. Large molecules in biological systems are often sensitive to radiation induced structural changes; these include degradation and intermolecular and intramolecular cross-linking. Proteins are effected more by direct "hits" -50 to 200 eV of energy will disrupt the weak hydrogen and disulfide bonds.

IV. Cellular Level Radiation Effects

Radiation induced chromosome aberrations occur throughout the mitotic cycle. Many types of aberrations occur, but fortunately as many as 99% of the single breaks rejoin by a process called restitution. Aberrations that occur may be lethal immediately or at some later time.

Aberrations also occur spontaneously and these versus radiation induced aberrations are identical.

Membrane systems of the cells have altered permeability after 3,000-5,000 rads. A decrease in synthesis of DNA and RNA is seen in irradiated cells. While small doses delay RNA production, larger doses depress part of the synthesis. This effect is suggested as a cause of death following moderate radiation exposure. The gradual depletion of enzymes and proteins would lead to "reproductive death".

In 1906, two French radiobiologists recognized that different types of cells differ in their radiosensitivity. They stated cells are radiosensitive if:

1) Their mitotic rate is high,
2) They have a long mitotic future, and
3) They are a primitive type cell.

The damage produced by low doses of radiation can be repaired by cells. This is demonstrated by determining whether a dose divided into two or more fractions is as effective in killing cells as a single dose. Experiments show the cells receiving fractionated doses have higher survival rates, with repair starting immediately after irradiation.

V. Radiation Effects on Organs Systems of Mammals

Various tissues of mammals differ in their response to radiation.

1. Blood is radiosensitive. The cellular elements in blood will respond within hours after an exposure and they will recover within weeks if the dose was not excessive. Lymphocytes, however, decrease in number in the 5-20 rad dose range and are, therefore, used as an internal dosimeter.

2. The digestive tissue systems vary in their radiosensitivity.
   a) Oral mucosa is divided and becomes ulcerated.
   b) The pharynx and esophagus are radioresistant.
   c) The stomach epithelium cells change within 30 minutes. The stomach may recover in five days histologogically, but ulceration and hemorrhaging may occur for weeks.
   d) The small intestine is very radiosensitive-within 30 minutes epithelial cells start to change. Recovery is rapid (within a week) unless a large dose is received, which would result in death within 3-5 days.
   e) The large intestine is radioresistant, but is prone to ulceration.

3. The vascular system contributes indirectly to many changes in other tissues, as capillary occlusion may block the blood supply; however, the heart, arteries and vein are radioresistant.

4. Deposition in bone is of concern when radionuclides that are "bone seekers" are ingested; e.g., plutonium, strontium, radium. These isotopes will lodge in bone marrow resulting in high doses. In growing bones it can result in a shortening of the bone.

5. The germinal layer of the skin is radiosensitive; a dose of 35 rads will cause a decrease in cell division. Erythema is due to dilation of capillaries that supply the skin, which are not drained due to collapse of small veins.

6. The nervous system of adult mammals is very radioresistant.

7. Male reproductive organs are radioresistant though the sperm is radiosensitive. Maturation depletion will occur, but fertility will return in about a month. Female reproductive organs are also radioresistant. However, the ovaries are radiosensitive, with infertility resulting from moderate doses and lasting as long as three years. Sterility in males and females occurs after high doses.

8. The endocrine system is radioresistant; the thyroid gland may be damaged by radioiodine if a high dose occurs.

VI. Radiation Syndromes in Adult Mammals

Acute radiation syndrome takes place within 30 days after a high exposure. The $LD_{50(30)}$ value is used for expressing lethality (lethal dose to 50% of the exposed organisms with 30 days). Some examples of $LD_{50\ (30)}$ values are:

1) Dog, 350 rads
2) Man, 400 rads
3) Rat, 750 rads
4) Goldfish, 2,300 rads
5) Drosophila flies, > 64,000 rads (Invertebrates are more radioresistant than vertebrates).

There are four recognized radiation syndromes, which are named in regard to the clinical symptoms that arise from each range of radiation doses:

1) The Molecular death syndrome results from doses of 100,000 rads or more. Death is immediate, associated with the inactivation of critical molecules (DNA, RNA, proteins).\
2) The Central Nervous syndrome results from doses of 10,000-100,000 rads. Death occurs one to two days after exposure, associated with incoordination, respiratory failure, and intermittent stupor.
3) The Gastrointestinal syndrome results from doses between 900-10,000 rads. Death occurs from three to five days after exposure, associated with morphological changes in the GI tract (holes in the intestines, blood loss).
4) The Hematopoietic syndrome results from doses between 300-900 rads. If death occurs, it is generally 10 to 15 dyas after exposure, resulting from changes in the blood cells.

5) Whole body doses of 50 rads or more produces symptoms of radiation sickness. The symptoms include: headache, dizziness, nausea, diarrhea, insomnia, and decrease in white blood cells and platelets. Treatment is generally given after clinical conditions exist; such as, large doses of antibiotics after an infection is contracted.

VII. Mechanism of Radiation-Induced Cancer

Radiation in sufficient quantities causes increases in the absolute incidence of cancer and causes it to appear sooner. There is usually a five to 30 year latent period between the exposure and the clinical appearance of a tumor.

Carcinogenesis is a multistep process in which two of more intracellular events are required to transform a normal cell into a cancer cell. It is now widely accepted that carcinogenic process, and, in most cases, promotion is required to complete the process. Radiation may produce carcinogenic changes by the following mechanism of introduction:

1) Mutations, including structural alterations of genes or chromosomes,
2) Changes in gene expression without mutations,
3) Oncognic virus, which in turn, may cause neoplasia (formation of a tumor).

Some generalizations about the process of carcinogenesis:

1) The effects of radiation and chemical carcinogens, which induce cancer are dose dependent and irreversible.
2) The carcinogenic process is dependent on cell proliferation.
3) The changes that initiate carcinogenesis in a cell are passed on to daughter cells.
4) The subsequent events in carcinogenesis can be profoundly influenced by various noncarcinogenic factors.
5) Tumors tend to become increasingly malignant with time.

Cinogenesis is a two stage process. A dose of chemical carcinogen that is too small to cause a detectable increase in tumors will induce many tumors if it was followed by repeated doses of a promoting agent- an agent which did not cause tumors when administered alone.

VIII. Human Evidence for Radiation Carcinogenesis

A. Radium Dial Painters. Luminous numeral on watches and clocks were painted by hand with fine sable brushes, dipped first in the radium-containing paint and then often tipped on the lips or tongue. Young girls commonly were employed in this occupation. Years later, studies of these individuals who had ingested radium paint have disclosed an increased incidence of bone sarcomas.

B. Radiologists and Dentists. Some early medical and dental users of x-rays, largely unaware of the hazards involved, accumulated considerable doses of radiation. As early as the year 1910, there were reports of cancer death deaths among physician.

C. Uranium Miners. Early in this century, certain large mines in Europe were worked for pitchblende, a uranium ore. Lung cancer was highly prevalent among the miners as a result of the inhalation of large quantities of airborne radioactive materials.

D. Atomic Bomb Survivors. One of the strongest supports for the concept that radiation is a leukemogenic agent in man comes from the epidemiologic studies of the survivors of the atomic bombing of Hiroshima and Nagasaki. Survivors exposed to radiation above an estimated dose of approximately 100 rem showed a significant increase in the incidence of leukemia.

IX. Sequential Pattern of Biological Effects

The sequence of events following radiation exposure may be classified as follows:

A. Latent Period

Following the initial radiation event, and before the first detectable effect occurs, there is a time lag referred to as the latent period.

B. Effects on Cells and Tissues

During or immediately following the latent period, certain discrete effects can be observed.

One of the phenomena that is seen most frequently in growing tissues exposed to radiation is the cessation of mitosis, or cell division. This may be temporary or permanent, depending upon the radiation dosage. Other effects include breaking or clumping of chromosomes, formation of giant cells and/ or other abnormal mitosis.

C. Recovery Period

Following exposure to radiation, recovery can take place to a certain extent. This is particularly apparent in the case of the short-term effects, i.e., those appearing within a matter of days or week after exposure. However, there may be a residual damage from which no recovery occurs, and it is this irreparable injury which can give rise to later long-term effects.

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SECTION 4: RADIATION PROTECTION

The three basic methods used to reduce the external radiation hazard are time, distance, and shielding.

A. **Time**

The amount of radiation an individual accumulates will depend on how long the individual stays in the radiation field:

Dose = Dose Rate x Time
mRem = mRem/hr x hr

Therefore, to limit a persons dose, one can restrict the time spent in the area. How long a person can stay in an area without exceeding a prescribed limit is called the "stay time" and is calculated from the simple relationship:

$$\text{Stay Time} = \frac{\text{Limit (mRem)}}{\text{Dose Rate (mRem / hr)}}$$

B. **Distance**

The amount of radiation an individual receives will also depend on how close the person is to the source.

The Inverse Square Law - Point sources of x-gamma radiation follow the inverse square law, which states that the intensity of the radiation decreses in proportion to the inverse of the distance squared.

$$\mathrm{I}\ \alpha \frac{1}{\mathrm{Zd}}$$

Example: The exposure rate one foot from a source is 500 mR/hr. What would the exposure rate three feet from the source be

Given the formula $I_1d_1^2 = I_2d_2^2$,

where I_1 = 500 mR/hr

d_1 = 1 foot
d_2 = 3 feet
$I_2 = I_1d_1^2/d_2^2$ = 55.6 mR/hr

C. **Shielding**

When reducing the time or increasing the distance may not be possible, on can choose shielding material to reduce the external radiation hazard. The proper material to use depends on the type of radiation and its energy.

Alpha and Beta Radiation
Alpha particles are easily shielded. A thin piece of paper or several cm of air is usually sufficient to stop them. Thus, alpha particles present no external radiation hazard. Beta particles are more penetrating than alpha particles. Beta shields are usually made of aluminum, brass, plastic, or other materials of low atomic number to reduce the production of bremsstrahlung radiation.

X-Ray and Gamma Radiation
Lead is a common shielding material for x-ray and gamma radiation

External Exposure Limits

The maximum permissible exposure given on the following page are specified by Federal regulations as set forth in the Code of Federal Regulations, Title X, Part 20, "Standards for Protection Against Ionizing Radiation," and by the Florida Department of Health, "Control of Radiation Hazard Regulations", Chapter 64E-5 (as amended July, 1997). Since any radiation exposure is undesirable, it is important that all exposures be kept as low as possible.

A. Maximum Permissible Occupational or Restricted Area Exposure:

1.Whole body; head and trunk;
active blood forming organs;
lens of eyes; or gonads.. 1.250 Rems per calender quarter

2.Hands and formearms;
feet and ankles .... 18.750 Rems per calendar quarter

3.Skin of whole body .... 7.500 Rems per calendar quarter

B. Maximum Permissible Non-Occupational or Unrestricted Area Exposure and Maximum Permissible exposure to Minors and Women Who Have Declared Pregnancy.

1.Whole body; head and trunk:
active blood forming organs;
lens of eyes; or gonads .... 0.125 Rems per calendar quarter

2.Hands and forearms; feet and ankles	1.875 Rem per calendar quarter
3.Skin of whole body	0.750 Rems per calendar quarter

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SECTION 5: RADIATION INSTRUMENT

I. Portable Survey Instrument

The major principle for sensing and measuring radiation in survey instruments is based on the ionizations radiation produces when interacting in a gas filled detector. The detector converts radiation into electrical signal through the use of an electrical field. The signal, either a current or a probe, is then used to register the presence or amount of radiation. There are various types of radiation detectors. The three types of radiation detectors are discussed below.

A. Ionization Chambers

Ionization chamber type instruments are designed to measure exposure rates of ionizing radiations in units of mR/hr or R/hr. The detector is usually cylindrical, filled with air and fixed to the display instrument. When radiation interacts with the air in the detector, ion pairs are created and collected generating a small current.

B. Geiger Counter

The most common type of portable radiation survey instrument is the Geiger Counter, also known as a Geiger-Muller (G-M) Counter. The G-M counter's detector consists of a tube filled with a mixture of "Q-gas", containing 98% helium and 1.3% butane. This tube can usually be removed from the display instrument to survey an area. Instead of measuring the average current produced over many interactions, as in Ion Chambers, the output is recorded for each individual interaction in the detector. Thus, a single ionizing event causes the G-M tube to produce a "pulse" or "count". Because all pauses from the tube are the same size regardless of the number of original ion pairs that initiated the process, the G-M counter cannot distinguish between radiation types or energies. This is why most G-M counters are calibrated in "counts per minute" (cpm). However, G-M counters can be used to measure exposure rates in mR/hr or R/hr as long as the energy of the x- or gamma radiation is known and the instrument is calibrated for this particular fixed energy. At best , for a given x- or gamma ray energy, the count rate will respond linearly with the intensity of the radiation field. However, in most applications, the radioactive source will have x- or gamma rays of various energies which can result in erroneous and unreliable readings. Therefore, G-M counters are primarily used to detect the presence of rasdioactive material.

C. Liquid Scintillation Counter

The liquid scintillation counter is the ultimate beta detector. When the sample to be counted is mixed with scintillation fluid, the beta energy is converted into pulse of ultraviolet light that is detected by a pair of photomultiplier tubes. It can efficiently detect even the lowest energy beta emitters; tritium up to 50% and all other beta emitters near 100%.

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II. Use of Radiation Survey Instruments

Choose the instrument depending on the type of radiation. Generally, Geiger Counters are more sensitive than Ion Chambers at monitoring low levels in the laboratory, therefor an Ion Chamber is the proper instrument to use. Outlined below are basic instructions on the proper use of portable radiation survey instruments.

a. Read the instrument's operating manual.

b. Check the batteries.

c. Check the operability of the detector. Pass the detector over a radioactive check source to verify that the detector responds to radiation.

d. Determine the instrument's response time. By passing the detector at varying speeds over a check source, you can determine how long it takes for the detector to respond to the radiation.

e. Determine the operating background. Note the instrument's response in an area free of contamination or radiation levels. This is normally due to natural sources of radiation called "background".

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SECTION 6. TRANSPORTATION OF RADIOACTIVE MATERIALS.

Regulations of the Department of Transportation and International Air Transport Association specify the packaging standards and labeling requirements for shipment of radioactive materials. Per 49CFR173.422 and Section 6.2.1.5 of the International Air Transport Association regulations, 63Ni ECDs made by Varian, Agilent Technologies, and Perkin Elmer are exempted from most packaging, marking, and labeling requirements. Also, no shipper's declaration is required if the following conditions are met:

1. The materials must be packaged in a strong, tight package such that there will be no leakage of radioactive material under conditions normally incident to transportation.
2. Before offering the package for transportation be sure that all seams and flaps are taped closed so that are no openings and insure the markings as follows:

   " This package conforms to the conditions and limitations specified in 49 CFR 173.422 for excepted radioactive material instruments and articles UN 2910"

3. The outside of the inner container must be labeled "RADIOACTIVE MATERIAL"
4. The radiation level of 4 inches from any point on the external surface of any unpacked instrument or article does not exceed 10 millirem per hour.
5. The radiation level at any point on the external surface of the shipping package does not exceed 0.5 millirem per hour.
6. There must be no significant removable radioactive contamination on the exterior surface of the package.

No measurements need to be made to comply with step 4, 5, and 6 above. To comply with all of the above conditions, it is recommended that the ECD and installation tool be returned in the same inner container (ECD case) in which there were received, with an outer container made of rigid packaging material (e.g., corrugated cardboard).

The dimensions of the container must not be less than 4x4 inches. The ECD case, which is labeled as specified in condition 3 above should be securely and tightly packaged in the outer container. Shock absorbing material should be used between the ECD case and the outer container. If the original ECD case is no available, be sure to label the new inner container.

Author: N.Vo
Date: 5-12-2016

SECTION 7: LICENSING AND REGULATORY MATTERS

The U.S. Nuclear Regulatory Commission (NRC) has been given the authority by Congress to relinquish certain regulatory responsibilities via a formal agreement with the states that have an existing radiation control program. Currently there are 29 "agreement states." Florida became an agreement state in 1964. The Florida Department of Health (DOH) is the regulatory agency that issues licenses for the use of radioactive materials in this state.

Each agreement state must promulgate a set of regulations that are compatible with title 10 of the Code of Federal Regulations (10 CFR) under which the NRC operates.

Florida's "Control of Radiation Hazard Regulations", Chapter 64E-5, Florida Administrative Code (FAC), embodies the rules and regulations governing almost all sources of radiation in this state.

DOH issues and inspects the activities conducted under our radioactive materials licenses. A DOH inspection team periodically visits DEP/Chemistry Section to review every phase of the radiation-related activities conducted under our license.

DOH inspectors check for compliance with the following five criteria:

1. Specific conditions written into the license;
2. Written statements made by the licensee in the license application process;
3. "Generally accepted good health physics practices";
4. Recommendations made by DOH that the licensee has agreed to do:
5. And, of course, the rules in chapter 64E-5, FAC.

FDEP/ Chemistry Section's Licenses with DOH

GENERAL LICENSE

Most of our activities are conducted under a general license. The rules require the general license to have a comprehensive radiation safety program, including a Radiation Safety Officer. Individual users of radioactive materials are listed on a general license

Author: N.Vo
Date: 5-12-2016

SECTION 8: GENERAL PRECAUTIONS FOR RADIOACTIVE WORK

1. Always keep radioactive and nonradioactive work separately.

2. Always work over spill tray and in a ventilated hood.

3. Always wear protective clothing, safety glasses and gloves when handling radioactivity.

4. Always wash hands and monitor yourself before leaving a radioactive work area.

5. Always work carefully and monitor the work area regularly with both swipes and survey meter to avoid ruining experiments by accidental contamination.

6. Always label containers of radioactive material clearly, indicating nuclide, total activity, compound, specific activity, date and the level of radiation at the surface of the container.

7. Never eat, drink, smoke or apply cosmetics in an area where unsealed radioactivity is handled.

8. Never work with cuts or breaks in the skin unprotected, particularly on the hands or forearms.

9. Never pipette radioactive solutions by mouth.

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IN THE EVENT OF ACCIDENT, MALFUNCTION, DAMAGE OR THEFT INVOLVING Electron Capture Detector PLEASE NOTIFY

RADIATION SAFETY OFFICER
Nhon T. Vo 850-245-8137 or 850-510-6821

Department of Health, Office of Radiation Control
850-245-4545

IN THE EVENT OF ACCIDENT:

1. SEAL OFF CONTAMINATED AREA.
2. KEEP PEOPLE OUT.