Nigerian Veterinary Journal
Vol. 32(2): 2011; 79 - 86
ARTICLE

Handling and Management of Radioactive Materials in Medical and Research Institutions: A Review

*[1] AWASUM, C. A., [1]A. Z. HASSAN, [2]A. S. YILA, [3]SYLVESTER, E., [1]M. LAWAL, M., AZIZAT, M[4] and [3]CHOM, N.D.

[1]Department of Veterinary Surgery and Medicine, [2]Veterinary Teaching Hospital ABU [3]Department of Radiology ABUTH and [4]Department of Biological Science ABU Zaria *Corresponding Author

Summary

Radioactive materials have been used as a source of energy, diagnostic, therapeutic and as research tools. These materials arise from a variety of sources (x-rays, -rays, radio waves, infra-red and visible light) and constitute electromagnetic radiation. Excessive radiations of all types are not safe for plants and animals. However, safe amounts have valid important uses and their half-lives in most cases are long. Since residues still pose danger to environment, the atomic energy commission has sought proper disposal. This paper reviews the handling and management of radiological materials in medical and research institutions.

KEYWORDS: Handling, management, radioactive materials, medical and research institutions.

INTRODUCTION

Most radiation comes from the sun, from outer space and the earth itself. Radiations are physical phenomena in which energy travels through space without the aid of a material medium. Electromagnetic radiation (x and -radiation) has sufficient energy to produce ionization called x-rays if produced by machines or gamma rays if emitted by radioactive elements. Apart from their origin, there is no essential difference between x and -rays. The International Atomic Agency Commission on Radiological Protection has given guidelines on the precautions to be taken for handling, storage and use of radiological materials.

Several problems emanate from the use of radiological substances in diagnosis, therapy and research. In medical research laboratories, radiological materials are used in vivo in humans and animals, but in vitro in diagnosis, biological and biochemical studies.

In general, some hazards are associated with their handling, storage and use due to internal (ingestion, or inhalation or absorption through broken or intact skin) or external (and - radiation emitted by radioactive materials) exposure. Radiation doses absorbed are often difficult to evaluate and depend on physical and chemical factor forms of the materials, mode of entry and the individual's metabolism. An irradiated body with radionuclide continues in decay until total elimination of their energies in body tissues.

Though the and emitting radionuclides are used in medical diagnosis and therapeutics, data on their nature and energy emission, physical half life, exposure rate constant and the Annual Limit on Intake (ALI) for both ingestion and inhalation of soluble materials are unavailable in the 3rd World. There are greater risks from spills and contamination in laboratories where radionuclides are dispensed, chemical operations are performed or radio-pharmaceuticals are prepared. Entrances to these laboratories may not be restricted to staff and students specifically concerned with work therein and who are aware of the precaution to be taken. Other hazards could arise from accidents, fire, explosion and mechanical damage. Often there is need to treat, or rescue and treat, persons that suffer severe exposure to radioactive materials.

Radiation hazards lead to sterility and "chemical toxicity" especially with radiopharmaceuticals (Anon, 1982). Hazardous wastes are generated during the use of these radioactive materials in various applications (medical, research, agricultural, industrial and environmental). Waste generation in good practice can however be minimized (Jasim, 1995).

Sources of Ionizing Radiation

i) X-rays generated from x-ray machines

(cathode ray tube). The familiar use of x-ray in hospitals provides a potential exposure to ionizing radiation.

ii) High energy particle accelerators used in industry to provide energies capable of penetrating steel shells for evaluation of the integrity of welded beams in non-destructive testing. The betraton (6-25 Mev) is used for deep therapy in cancer cases.

iii) Other sources are radioactive materials (radioisotopes or radionuclides). These are naturally occurring or man-made by use of accelerators or nuclear reactors and fall out.

X-rays

People have always been exposed to very low levels of ionizing radiation, their existence was not appreciated until November 8th 1895 when Wilhelm Conrad Roentgen, a German Physicists, investigating the properties of electrical charges through cathode ray tubes, discovered a new kind of radiation, which he called, x-rays (Roentgen, 1895). Roentgen accidentally interposed his hand between the tube and a phosphorescent plate and saw a shadow of his bones demonstrating the depths of penetration of these new x-rays on soft tissue. Shortly after, Becqueret discovered that somewhat similar radiations were emitted by uranium ores (Thrall, 1998) and later Professor and Madame Curie isolated the radioactive element of radium (Thrall, 1998). Becqueret 'burnt' himself when carrying some radium in his pocket. Investigating the wounds he discovered some properties of the new radiation as penetrating living tissues and ability to kill them. Applied quickly to medical problems, x-rays were used to examine the internal organs of living patients and the rays from radium used to treat cancer cells in malignant tumors, and angiography was first described in 1896. The discovery of x-rays revolutionized the diagnosis and treatment of diseases in humans and animals. More than 100 years after the discovery, x-rays remained in widespread use for many aspects of medicinal imaging despite its potential biological damage. For his discovery Roentgen was awarded the first Nobel Prize for physics in 1901 (Thrall, 1998).

Emerging problems were those of dermatitis, ulceration, cancer and death of radiologists who exposed themselves during x-ray beam testing. Occurrence of tumor was not foreseen since induction takes over 10-20 years. Insidious hazards that emerged were when Muller, in the late `20s discovered that ionizing radiation could produce gene mutation which is not only detrimental to those exposed but also to their descendants in successive generations (Lawrence, 1979). It became imperative to estimate precisely the risk of exposure to radiation and how best radiation could be used to minimize the harm from unnecessary exposure and to maximize the benefits, when irradiation is necessary. This problem became more urgent with the rapid development of nuclear technology after World War II and the use of radiation in science. This also led to the establishment of stringent regulations to govern and minimize exposure to radiation.

Sound understanding of the biological effects of ionizing radiation and its use in medicine led to a rapid development in the production and use, especially in veterinary radiobiology and radiological protection. Today, veterinary radiobiology is considered diversified including the interactions of radiations with the ecosystems, population, individuals, animals and plant tissues, cells and molecules. Is it possible to study and resolve some of our important problems of animal life by the use of modern technology in radiation at cellular levels rather than in tissues, organs or systems? Unicellular microorganisms and artificial cell cultures derived from tissues of higher organisms including man and animals have been used in radiobiological studies (Lawrence, 1979). How fascinating it is to investigate the ionizing radiation effects on cells and at the same time use the knowledge to find out how cells are constructed and the way they carry out activities in normal life?

Packaging and Transportation of Radioactive Materials

This should meet the requirement by IAEA for packaging types A_1 and A_2 for transportation (Anon, 1976). The use of suitable rooms (areas), separation of materials for storage (stock materials) or waiting disposal is very important. No serious problem should arise from the types and activities of materials used in hospitals and research institutes if proper handling and management is guaranteed especially by giving attention to the following: Reduce hazards associated with storage, total activity within the premises must be minimized. Avoid ordering unnecessary high activity materials to these areas. Materials no longer required or that would become useless if retained (for instance chemical breakdown or bacteriological contamination) should be disposed. Stores should be separated for sealed and unsealed materials. Facilities at storage areas according to Lewis (1994a) and (1994b), outside each store, should indicate a clear warning sign to include the standard radiation symbol and the name of the person responsible for the store. Limit access into the store to specific, authorized staff who are well instructed with precautions and procedures to adopt while in the store. Minimize movement of high activity materials within the premises, store stock materials conveniently close to working area. Situate storage site close to depositing site for easy collection and disposal. Design storage facilities to shield and limit radiation levels in adjacent working areas and control contamination. Provide adequate space in the store for convenient arrangement and segregation of radiation sources with due regards to their easy identification and removal. Provide adequate ventilation and keep the room temperature at levels not to cause freezing of stored liquids. Visit stores infrequently to avoid risk of fire accidents especially where combustible materials are kept in the stores. Seek advice from the fire department for provision of fire doors, automatic detectors and warning systems. Return all stock solutions after use to their storerooms and label all items stored giving details of the materials (chemical form, activity, at a stated date and time and the name of the person responsible for the source), and keep stores in good order. Inspect them periodically. Record keeping for all sources moved in and out. Determine external radiation levels, detect unsuspected contaminations and investigate any discrepancy in the records.

Transportation

According to Tsyplenkov (1994) transportation of these materials whether within or outside the establishment should comply with the national and international regulations and should meet the IAEA recommendations not listed. Preparation for transportation should be by the person responsible for radiological protection. These materials must remain unopened in their transport containers until delivery and authorized person who is aware of the nature and activity of the material should supervise and take necessary precaution in case of damage. The containers for transportation should be constructed to avoid spillage, provide adequate shielding effect, permanently retain marks indicating maximum activity of the materials and an external label to indicate its chemical form and activity at a given time, and date as well as proper address for delivery. This label should be removed or detached from the container after removal of contents to avoid confusion. Automatic (pneumatic) systems of transport must not be used to avoid obvious accidents in transit. Sealed sources must be tested for leakage for which if activity of more than 0.05 Ci is indicated, the source shall be considered "leaking" (Tysplenkov, 1994). Any material (swab) used in wiping radioactive materials must be monitored for contamination. Leaking sources should be immersed in a liquid, which does not attack the container; the liquid should be checked for radioactivity. If the source is immersed in a liquid under reduced pressure, leakage may be detected by emission of a stream of bubbles from the source.

Disposal of Radiological Materials

The generation of radiological waste is inevitable by hospitals and research centres that use these materials. These materials must be managed in such a way that their activity decays to a negligible level not sufficient to cause exposure to persons since these wastes constitute a hazard not only to its users but also to the public.

The factors influencing the methods of disposal of these wastes vary with countries and in accordance with the regulations or codes of practice in each country as well as the responsibility of the authority in administration of the establishment. The two principal ways to deal with these materials are: Storage of waste under controlled conditions until it has decayed to permissible levels for disposal. Disposal of radioactive materials in the environment so that natural processes transfer them back to man only in amounts that, in combinations with other sources of radiation the resulting radiation doses, are considered safe. It is important to note that chemical works requiring these materials do not create difficult problems regarding wastes because the activity and types used are known and most often have short-half-lives (< 1 month). Therefore immediate disposal is permissible or short period storage will further reduce activity to levels at which disposal poses no problem (NCRPM, 1968).

A system of collection, transfer to storage and subsequent disposal sites with foot-operated lids are most suitable. These containers must be clearly and distinctly labeled. Technically competent personnel must recommend the conditions for handling and disposal of waste under accident conditions. If as a consequence of accidents, these materials are released to the environment, the relevant authorities must be informed immediately according to regulations. Disposal of liquid waste suspensions and solutions, biological wastes (excreta, macerated materials, blood and urine from individuals receiving radionuclides can ordinarily be released through normal drains and toilets, and also solvents from scintillation counting containing ^{14}C and ^{3}H because they do not posses radiation protection problem, more so their activity does not exceed 2 Ci/Kg. Tritium concentration of 1 mCi/kg has negligible radiation hazard (Tysplenkov, 1994). The principal part of a solution (organic substances = toluene, ethanol, dioxin) should not be disposed of through the sewage system but in approved manner by local authorities. Substances of high activity, spills of radiopharmaceuticals should be stored under adequate radiation protection condition to allow for radioactive decay or sent to special disposal organization.

Disposal of Solid Wastes

Solid wastes usually consist of used generators, contaminated syringes, glassware, laboratory clothing, cleaning materials, bench covers and precipitated radiopharmaceuticals. Materials to be re-used should be stored in labeled containers until the contamination has decayed to acceptable levels. Low-level solids can be disposed of with ordinary refuse. Note that accurate monitoring of waste is generally not practicable. However, in hospitals and research institutes, it is possible to identify the materials and maximum activity in the solid waste. Materials of non-immediate disposal should be segregated into appropriate containers and clearly marked with details and short-lived materials can be stored for decay to permissible levels for disposal with ordinary refuse. To reduce long-term storage of long-lived materials, disposal may be arranged by: -

- Controlled incineration and special burials on municipal refuse dumps
- Delivery to special disposal organizations and
- Decay.

Radioactive Animals and By-Products

Contaminated carcasses constitute a special problem. Subject to local regulations, these may be disposed of by: -

- Incineration and burial under approved conditions, maceration and subsequent disposal as liquid waste to the sewage and preservation and storage for decay and transfer to a special organization or as above long-lived materials.

These carcasses must be kept securely so that they are not used for human consumption or become accessible to predators.

Air-Borne Radioactive Waste

Gaseous radioactive wastes can be routinely discharged to the environment if adequate assessment of the local conditions is not made to determine the permissible amounts. Areas concerned where such wastes are generated should be made to have stacks or equipped ventilation systems with filters when large activities of these materials are discarded to the atmosphere.

Solids, liquids and gaseous materials produced during the manufacture or use of radioactive substances have been often disposed in water (Purdom, 1971) constituting water pollutant substances such as strontium, radium etc have been found in large bodies of water which constitute threats to aquatic life and man. Large volumes of water have also been used to cool laboratory operations in electric power, petroleum refining, petrochemical processing etc. These volumes have often been discharged into lakes, streams, and coastal waters

Some Common Radiological Materials Used in Hospitals and Research Institutes

According to Anon, (1982), some commonly used radiological materials include:

a) Tritium (^{3}H) - Short-range -particle emission radioisotope. Has low toxicity. Difficult to monitor especially air-borne. Constitute no external hazard to the body but biological hazard when ingested. Used as thymine drugs combined to DNA to form complexes culminating in a genetic hazard.
b) Carbon (^{14}C) – Commonly used isotope, which selectively concentrate in cellular DNA. Has toxicity levels approximate to tritium (^{3}H).
c) Phosphorous (^{32}P) - This isotope concentrates on the surface structure of the bone and irritates the bone marrow. Great care is needed here when used.
d) Sulphur (^{35}S) - This isotope can be firmly bound to protein molecules within the body since certain amino acids contain sulphur. Great care is needed here as with ^{32}P.
e) Strontium – One of the most toxic elements of low atomic number as it easily replaces related elements in bones.
f) Calcium (^{45}Ca) – A non-volatile isotope of low atomic number. It selectively concentrates in ash and could result to serious dust hazard.
g) Iodine (^{125}I and ^{131}I) – The thyroid gland has a high ability to absorb iodine selectively from the blood stream. It is extremely volatile. Precaution against inhalation is needed.
h) All -particle emitters have a high toxicity, difficult to monitor so great care must be taken to prevent inhalation.

General Hazards

The effect of radiation lies on the public health significance of any source of radiation especially associated with the biological damage to cells due to ionization regardless of the type of radiation causing the damage. The effects are categorized as; Somatic damage that occurs to the individual within his life span; these effects may be acute or chronic depending directly on the radiation dose received over a period of time. Such effects may manifest as an increase in cancer or cataract formation or shortening of life span (Wider, Shaw and Thrall, 1996). Others have been severe erythema, epilation resulting from prolonged exposure to x- radiation. Systemic injuries include damage to the blood forming organs, production of malignancies and possible reduction in fertility. The biological effect of radiation is related to damage done to living cells due either to internal radiation or external hazards (Internal radiation hazard result from breathing of particulate radioactive debris from fallout of nuclear weapon explosions; nuclear reactors or ingestion of contaminated food with radioactive fallout or materials absorbed through skin (intact, cuts, abrasions) to blood stream where they are carried and lodged in areas where they cause damage. The external radiation hazard involves exposure to photon energy radiation. This exposure depends on distance between the radioactive material and the handler, adequacy of shielding and time of exposure.

Genetic effect results in gene mutation of reproductive cells (the biological "blue print"). Any mutation is harmful because the inheritance mechanism is very sensitive to radiation of any biological system in the human body (Glass, 1957). Effects are cumulative over years. Genetic damage produces undesirable deviation from the normal in offspring of irradiated parents. The mutants or undesirable offsprings are characterized by decreased longevity, increased susceptibility to disease, decreased fertility and usually recessive or masked effects so that first generation offfsprings do not bear the full brunt of the genetic damage. These effects have been seen in humans exposed to nuclear explosions (e.g. the Hiroshima and Nagasaki incidents). The National Council on Radiation Protection (NCRP), (1987) recommends that from conception to the age of 30 years, man should not receive more than 10 rem (Purdom, 1971). Do this hold time for those handling these materials especially in 3rd World countries?

ACCIDENTS

The uses of x-rays have not been without some incidents affecting man. Most of our knowledge of radiation effects comes from nuclear weapons in the atmosphere and bomb explosions over Hiroshima and Nagasaki, which concluded the World War II. Another was at the Windscale reactor, United Kingdom Atomic Energy Authority in October 1975 (Purdom, 1971) in which an air-cooled, graphite moderated natural uranium reactor was consumed in combustion. This accident occurred because of inadequate check on the temperature of the core releasing energy due to insufficient instrumentation. Many other accidents have happened.

Evaluation of Hazard

Hazards from direct external radiation do not pose a serious problem. Where high levels (millicuries) of -rays emitters are utilized, it is not considered a serious case (e.g. 10 MCi of ^{24}Na will deliver a dose of about 204 milliroentgen/-hour/at 1 ft distance) (Anon, 1995). Possibilities of ingestion of or emitting traces are high especially when handling compounds with long turnover time in the human body. Acute clinical signs are noticed if materials are aerosol or dry powder.

Radiation damage to biological system occurs in two ways: physiological or histological. High radiation doses are required to elicit the latter type, however.

Disposal of radioactive wastes resulting from hospitals or research institutes such as excretas, carcasses or large volumes of solutions must be given serious attention. Possible methods of disposal will depend on the specific radioisotopes present, its concentration, activity and the nature of the waste. Disposal must conform to the code of Federal regulations, which differ with countries.

Radiation Monitoring

i) Prior to mid 1960s, the average practitioner worked occasionally with low output x-ray unit, which was portable. When practitioners became better educated in the use of radiological equipment, most hospitals and research institutes upgraded their departments with radiation generating materials. The result of this is greater potential for personnel exposure. For instance, of all the healing arts that use x-rays for diagnostic purposes, the veterinary science is unique, owing to the more frequent need for their patients to be restrained and for personnel to be close to the patient while exposures are made. In such departments and elsewhere, radiation detectors are used frequently to monitor radiation exposure to occupationally exposed persons. When properly calibrated, film badges, pocket ionization chambers, and thermoluminescent dosimeters (TLDs) yield adequate approximations of the dose from x-rays striking the body surface in the region of the monitor (Douglas, 1963). Personnel exposure results from exposure to the primary beam, from secondary radiations (scatter) generated by interaction of the primary beam with objects in its path and from leakage radiations from the x-ray tube housing (Douglas, 1963).

These monitors function as follows: -

ii) Film badges consist of photographic films that contain silver halides crystals embedded in a gelatinous emulsion and worn around the breast in females and groin in males. The film is enclosed in a light-tight envelope and placed in a holder that incorporates several metallic filters. The filters permit differentiation between different types of and energies of radiation that contributes to exposure. Ionization radiation converts the silver halide in the film to metallic silver and increasing exposure produces increased darkening of the film when it is processed. The optical density of the film is compared with the optical density of control films, which have received known exposures. The badges are personalized and processed every six months to determine the level of exposure.

iii) Pocket dosimeters are pen-like small ionization chambers that fit conveniently into a pocket. It consists of an ion chamber and an electrometer. Before use, the chamber is charged, and subsequent incident radiation discharges from the chamber at a rate proportional to the exposure and the exposure received can be read directly and instantly from the chamber. This apparatus is useful for short-term measurements of exposure and by persons who risk measurable exposure in short intervals of time such as radionuclide handlers and brachytherapists.

iv) TLDs are “chips” of thermoluminescent phosphor (e.g. Lithium Fluoride [LiF]). The energy of incident radiation excites the phosphor crystals, and some electrons absorb sufficient energy to 'jump' to the conduction bands where they are trapped. The record of cumulative exposure is stored until the TLD is “read”. To read the exposure, the chips are heated and the trapped electrons return to their valence bands, excess energy is released as light. The light is proportional to the exposure recorded and is used to provide record of exposure. TLDs are almost tissue equivalent and have a linear dose response in the diagnostic exposure range. They are not affected by environmental influences (except extreme heat) and are reusable. The energy stored as trapped electrons remain unaltered stored for years after radiation. The TLD dosimetry is a superior method of personnel dosimetry but photographic dosimetry is still considered adequate for routine personnel monitoring especially in veterinary practice.

Radiation Protection

The object of diagnostic radiology is to obtain, maximum diagnostic information with minimum exposure of the patient, radiology personnel and the public. The United State Nuclear Regulatory Commission (NRC) established a guideline for radiation protection. It indicates that the annual occupational radiation dose to adults be limited to a maximum of 5rem per year. According to NRC report No. 93 (1987), in an individual worker's lifetime effective dose should not exceed age in years x 1rem and no occupational exposure should be permitted until age 18 years. Therefore an individual's lifetime effective dose equivalent in rems should not exceed the value of his or her age in years which the effective dose in any one-year should not exceed 5rem. For the general public, radiation exposure excluding medical use should not exceed 0.1rem. In pregnancy, monthly limit to the embryo or foetus should not exceed 0.05rem.

Personnel monitoring is therefore used to check the adequacy of the radiation safety program, disclose improper radiation protection practices and detect potentially serious radiation exposure situations. Radiation safety risks for diagnostic radiation should aim at removing personnel from the room who are not involved in the procedure, never permit an under 18 year old or pregnant woman in the room during examination, rotate personnel who assist with radiographic examination, to minimize exposure to any person. Use sandbags, sponges, tapes, or other restraining devices for positioning the non human patient rather than manual restraint, use anaesthesia or tranquillization for patients restraint when possible, never permit any part of the body to be in the primary beam whether protected by gloves or aprons, never hold an x-ray tube, x-ray machine, or cassette in the hand. Always wear protective aprons when assisting in restraint or positioning individuals, wear protective gloves if hands are placed near primary beams. Use protective goggles for heavy workload; this will provide 0.25 mm Pb equivalent protection and offer protection to the lens of the eye. Use thyroid shields around the neck. Use collimator of the x-ray machines and faster film screens combinations that are compatible with obtaining diagnostic radiographs. All personnel should wear film badges outside the lead apron, plan the procedure carefully and double check machine settings.

PROSPECTS IN RADIOLOGY

The use of radiological materials is continuously on the increase over time with the greatest areas of use being in medicine and research. So the need for radiological protection and health programs must grow with this expanded use. The expansion of the regulation of sources of radiation including electronic product tubes, television receivers etc is of great importance. As the machine producing sources of radiation as research tools for medical practice, institutional and industrial use continue to expand, there is no doubt that our main source of energy in the future will be the use of nuclear power. The use of nuclear fuel for power will stabilize and reduce the cost of power but may increase the hazards to the physical, biological and chemical environment. Therefore, the need for understanding and control of ionizing and nonionizing radiation and its effects on man must continue to grow.

The consideration of radiation effects on man and equipment has become more critical as a result of space flight and its associated hazards which add to those of hospitals and research personnel. Therefore the need to expand continued surveillance in radiation protection especially with ionizing radiation is important for the extensive need to use these materials to better the life of mankind.

REFERENCES

ANON (1982): Radiology safe. Ahmadu Bello University 8

ANON (1976): The handling, storage, uses and disposal of unsealed radio nuclide in hospitals and Medical Research establishments. Annals of the International Commission on Radiation Protection. vol. 25,

DOUGLAS, S.W. (1963): Principles of veterinary radiography. The Williams and Wilkans Company, Baltimore.

GLASS, B. (1957): Genetic basis for limitation of radiation exposure. Amer. J. Roentgenol. **78:** 955-960.

JASIM, U.A. (1995): Waste management of spent radiation sources and other forms of solid radioactive waste.

LAWRENCE, C.N. (1979): The discovery of ionizing radiations and the beginning of radiobiology in Cellular Radiology.

LEWIS, H. (1994): Safety Analysis Report for treatment and storage facilities, radioactive waste management techniques. Hot Laboratory and wastes management center. Inslias Cairo Egypt.

LEWIS, H. (1994): Safety Assessment of disposal facilities, radioactive waste management techniques. Hot Laboratory and wastes management center. Inslias Cairo Egypt.

National Council on Radiation Protection and Measurements (1968): "Medical X-Ray and Gamma-Ray Protection for Energies Up to 10MeV". N.C.R.P.M., 4201 Connecticut Avenue, N.W., Washington D.C.

NCRP. Report No. 93 – Ionizing radiation exposure of the population of the United States. Bethesda, MD, National Council on Radiation Protection and Measurements, 1987.

PURDOM, P.N. (1971): Incidence in Environmental Health. Drexel University. Academic Press N.Y.

Radioactive Waste management technique waste package acceptance requirement. Inslias Cairo Egypt 1994.

Radioactive Waste Management Techniques, Transport of Radioactive Wastes, Hot Laboratories and Waste management center. Egypt June 1994.

ROENTGEN, W.C. (1895): On a new kind of rays. Vet. Rachol and Ultrasound **36**:371.

THRALL, D.E. (1998): Principles of Interpretation: Radiation physics, Radiation Protection, and Dark room Theory in Textbook of Veterinary Diagnostic Radiology 3rd Ed.

TSYPLENKOV, V. (1994): Central waste processing and storage facilities. Radioactive Waste management technique. Hot Laboratory and wastes management center. Inslias Cairo Egypt.

WIDMER, W.R., SHAW, S.M. AND THRAU, D.E. (1996): Effects of low-level exposure to ionization radiation: Current concepts and concerns for Veterinary Workers Vet. Rachol and Ultrasound **37**:227.