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Establishment of a system of Management and Disposal of Radioactive Waste in *Shendi Center of Nuclear Medicine and Oncology*

تأسيس نظام للإدارة والتخلص من النفايات المشعة

بمركز الطب النووي وعلاج الاورام- شندي

Thesis submitted for partial fulfillment of the requirements of M.sc.Degree in Nuclear medicine technology

By

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Chapter one
Introduction

Chapter one

Introduction

1.1. The introduction

Radioactive materials have been found to be very effective when used in a variety of medical applications for diagnostic, therapeutic and research purposes. As a consequence of handling these materials, a wide range of radioactive waste is produced. The amount and types of these wastes varies depending on the scale of the medical application and the radionuclides involved. The waste that is generated during the different applications of radioisotopes in medicine or biological research is considered as biomedical radioactive waste.

Biomedical or medical radioactive waste in many cases will contain an infectious biological component from clinical, anatomical, ancillary or research sources. It may also include spent sealed sources and surplus unsealed sources. Anatomical waste arises from human and non-human sources and may include body parts, tissues, organs and fluids.

Ancillary wastes are materials which may have come into contact with humans or animals and which may be contaminated with radioisotopes and possess other biological, chemical or physical hazards. Wastes from research and education activities may include by-products of radiolabelling experiments.

The overall goal of biomedical radioactive waste management is to minimize the hazards posed by the waste prior to discharge or disposal. This includes consideration of the radioactive, biological, chemical and physical hazards associated with the waste. When planning for the handling of radioisotopes in medical or health care facilities, it is important to design an effective system for the overall management of the biomedical radioactive waste. This includes all steps or

activities involved in the management of radioactive waste from its generation to ultimate presentation for discharge or disposal. (IAEA-TECDOC-1183)
The application of radioactive materials and radiation provides numerous benefits to people and society, and plays a significant role in everyday life. This includes scientific, medical, agricultural and industrial applications. It is natural a consequence of such applications that waste is generated. The radioactive waste needs to be managed in a safe and secure manner. Radioactive waste management involves treatment, conditioning, transportation, storage and disposal of all categories of radioactive wastes, including administrative, operational and safety-related activities. The primary objective is to isolate the radioactive waste from people and the environment for the period the waste remains hazardous.(Ansto, 2011)

In Hospitals, there is a remarkable increasing of using radioactive isotopes for diagnostic and therapeutic applications. The main radioisotopes used in nuclear medicine are technetium-^{99}M (Tc-^{99}M), Iodine-131(I-131), Iodine-125 (^{125}I), Iodine-123(^{123}I), Flourine-18(F-18), Tritium (H-3) and Carbon-14

Radioactive waste should be categorized and segregated on the basis of the available options for treatment, conditioning, storage, and disposal.

The overall goal of radioactive waste management is to minimize the hazards posed by the waste prior to discharge or disposal consideration of the radioactive, biological, chemical and physical hazards, this includes all steps or activities involved in the management of radioactive waste from its generation to ultimate presentation for discharge or disposal, (IAEA-TECDOC-775).

1.2. Problem of the study:

The problem of the study lies in the fact that there is no radioactive waste disposal in systematic ways in the area of the study, to the best of the researcher′s knowledge.

1.3. Objectives:

1.3.1. General objective:

The main objective of this study is to establish a system of management and disposal of radioactive waste in Shendi Center of Nuclear Medicine and Oncology**.**

- **1.3.2. Specific objectives:**
- To design suitable program for radioactive waste management in the center of study.
- To measure the radio activity of different radioactive waste before being disposed of.
- To segregate the waste in separate containers properly labeled to supply information about the physical form, activity and external dose rate.
- To classify the waste according to the types of waste generated in the hospital (Solid waste, Liquid waste and Gaseous waste).
- To ensure safe use of the materials in accordance with the requirements of the national and international regulatory authority.

1.4. Thesis Outline

This thesis is concerned with the Establishment of a system of Management and Disposal of Radioactive Waste in Shendi Center of Nuclear Medicine and Oncology. Accordingly, it is included into the following chapters: Chapter one is the introduction to this thesis. This chapter discusses the objectives and scope of work and introduces necessary background. It also provides an outline of the thesis; Chapter two contains the literature review and theoretical background. This chapter also includes a summary of previous work performed in this field. Chapter three describes the materials and methods. Chapter four reveals and demonstrates the results of this study and Chapter five presents the discussion, conclusion and recommendations of the thesis and gives suggestions for future work.

Chapter Two
Literature Review

Chapter Two

Literature Review

2.1. Theoretical back ground

2.1.1. Characteristics of unsealed radionuclides used in medicine:

Numerous radionuclides are used in both unsealed and sealed forms during different biomedical procedures. A list of the radionuclides used as unsealed sources and their applications can be found in table (2.1) ,Appendix A-1)

2.1.2. Diagnostic radionuclides:

The use of radionuclides for diagnostic purposes has both “in vitro” and “in vivo” applications. In vitro means studies performed on human biological samples outside of the human body while in vivo refers to dynamic function studies within the human body. In vitro applications typically involve KBq activities of aqueous-based radionuclides being utilized to measure levels of drugs or hormones in biomedical samples. By far the greatest diagnostic application of radionuclides in medicine is in vivo investigation of body function using gamma camera imaging. Many in vivo radiopharmaceuticals are prepared by diluting a pharmaceutical with ^{99m}Tc, which is eluted from a ^{99m}Tc generator. Radionuclides are also administered in vivo to act as tracers in monitoring body functions. The usual range of administered doses for technetium radiopharmaceuticals is 40–800 MBq, with lower doses administered for pediatric patients.

Other common diagnostic imaging radionuclides include ^{131}I. This radionuclide is usually administered at activity levels in the range of 40–400 MBq for imaging purposes. Some radionuclides are also used to label human blood components to act as tracers for sites of blood loss or sites of infection. This typically involves removing a blood sample from the patient, radiolabelling the blood and re-injection.

Radioactive gases and aerosols are used for diagnostic purposes during lung ventilation imaging. This involves the use of ^{81m}Kr (up to 6 GBq administrations per patient), ^{133}Xe (up to 400 MBq) and ^{99m}Tc-diethyl tetra penta acetic acid (DTPA) aerosol inhalation (up to 80 MBq inhalation activities). (IAEA-TECDOC-1183-November 2000)

2.1. 3. Therapeutic radionuclides:

Therapeutic applications of radionuclides in medicine utilize a number of unsealed sources in much higher activities than those used for diagnosis. ^{131}I is widely used for treatment of thyrotoxicosis and for ablation of the thyroid tissue or metastases during cancer treatment. Individual patient doses are typically in the range of 200 MBq — 11 GBq. The ^{131}I used for therapeutic purposes may be provided in three physical forms — liquid sodium iodide for dispensing as multiple individual patient doses for oral administration, individual powder filled gelatin capsules for oral administration or sterile sodium iodide solution for injection. Injections are normally only administered where there may be a problem with oral administration.

Use of other therapeutic unsealed radionuclides usually involves venous injection of a sterile, undiluted solution of the radionuclide, e.g. ^{89}Sr or ^{32}P. Strontium is typically used in therapy for the management of pain associated with bone metastases. Administered doses are usually several hundred MBq. Yttrium-90 is typically injected into the joints of a patient, e.g. knee, as a silicate colloidal solution, with administered activity levels of about 200 MBq per injection.

Some radionuclides used in therapeutic applications are diluted prior to administration. This practice may increase the volume of wastes requiring further management. For example, therapeutic administration of ^{131}I-MIBG (meta-iodo benzyl-guanidine) is usually diluted with sterile isotonic saline and is intravenously administered slowly over a period of up to an hour or more using a pump system.

This results in the generation of additional solid radioactive waste, such as disposable plastics. (IAEA-TECDOC-1183-November 2000).

2.1.4. Research radionuclides:

A wide range of unsealed radionuclides are used for research purposes both in health care biological research centers and pharmaceutical development facilities. Isotopes such as ^{3}H, ^{35}S, ^{32}P and ^{33}P are widely used for DNA sequencing in research. The range of radionuclides used in biomedical research is much wider than the number of radionuclides used for in vitro and in vivo diagnostic/therapeutic purposes. The reason for this is that a large number of new uses of radionuclides are often evaluated for several years in animal studies at pharmaceutical development establishments prior to being approved for use. This is necessary to verify that the product is safe for human administration. Wastes generated as part of drug evaluation research may often be stored frozen for prolonged periods (2–5 years) on the user's premises whilst the drug regulatory organizations evaluate the results of clinical trials. The final approval of the drug for use can involve the sudden requirement for disposal of large volumes of frozen wastes, including animal carcasses, tissues, organs, blood products, urine and faeces and by-products of radiolabelling experiments. The use of radionuclides such as ^{3}H and ^{14}C in GBq quantities for organic synthesis is not uncommon in pharmaceutical research, resulting in low volume, high activity waste for management and disposal. Often the waste generated from biomedical research is more difficult to control due to transient workers on research grants or project work by students.

Since anatomical markers, calibration sources and reference standards may have small dimensions and low activity, special care should be taken to ensure that they are not lost in use, e.g. accidentally discarded with the normal waste or misplaced during medical applications.(IAEA-TECDOC-1183-November 2000)

2.1.5. Characteristics of radioactive sealed sources used in medicine:

2.1.5.1. Diagnostic radionuclides:

Sealed radiation sources may be used for the following diagnostic purposes: bone densitometry, anatomical marking and calibration; and reference standards; Density scanners for bone mineral determination are one example of a diagnostic application of radiation sources in medicine. Typical sources used for these purposes are ^{241}Am, ^{153}Gd or ^{125}I at activity levels of up to several GBq. At the end of their useful life, these spent radiation sources should be sent to a centralized facility for treatment and disposal. Since anatomical markers, calibration sources and reference standards may have small dimensions and low activity, special care should be taken to ensure that they are not lost in use, e.g. accidentally discarded with the normal waste or misplaced during medical applications.(IAEA-TECDOC-1183-November 2000)

2.1.5.2. Therapeutic radionuclides:

A number of different radionuclides are used in the form of sealed sources for clinical treatment during manual brachytherapy, remote after-loading brachytherapy, teletherapy, blood irradiation and other purposes. Since sources of rather high activity may be involved, attention should be paid to proper shielding, storage and security as soon as the sources are taken into use. Sealed sources are used in a wide range of activities for therapeutic purposes. Many are directly implanted during oncology treatments or applied to a patient, e.g. ^{106}Ru eye plaques and implants of ^{192}Ir, ^{137}Cs and ^{198}Au. Larger sealed sources such as ^{60}Co are used in teletherapy heads for beam treatments of malignant conditions. ^{60}Cois also used in gamma knife surgery where approximately 200 sources are focused on a very small portion of the patients head. Although radium sources are no longer used in good medical practice, spent sources may still be stored and require treatment and

disposal. Specific precautionary measures should be applied to their storage because such sources will eventually leak.(IAEA-TECDOC-1183-November 2000).

2. 1.5.3. Research radionuclides:

Sealed radioactive sources may also be used in research and teaching/training establishments. These may involve small sealed calibration sources used for gamma and liquid scintillation counting and ^{63}Ni sources for gas chromatography. Some establishments may also use much higher activity sealed sources in irradiators such as ^{137}Cs or ^{60}Co sources.

The sealed sources used in medicine and medical research can be found in table (2.2) , Appendix A -2), (IAEA-TECDOC-1183-November 2000)

2.1.6. Types of biomedical radioactive waste:

The use of a wide range of radionuclides in medicine and medical research leads to the generation of waste, which requires a comprehensive management system. In many instances, the potential additional hazards, either from the chemical, biological or physical properties is greater than the radiological hazard due to the presence of radionuclide contamination.

2.1.6.1. Liquid waste: Liquid radioactive waste includes contaminated water and effluent, waste arising from chemical processing and decontamination solutions, solvents, blood or body fluids, discarded liquid radiopharmaceuticals, wound or oral discharges, urine, chemotherapy agents, small quantities of contaminated an oils and scintillation fluids. Waste that includes both radioactivity and a hazardous chemical component is usually referred to as a mixed waste.

2.1.6.2. Gaseous waste: Xenon-133 and ^{81m}Kr are used in diagnostic imaging for assessment of regional lung ventilation. Since they are noble gases, they are difficult to treat and are often released to the atmosphere through an exhaust

system. It is essential to ensure that there is no possibility of re entry of the released gases back into the building through open windows or ventilation system.

2.1.6.3. Solid waste: At health care, medical and research facilities, solid waste is generated in the form of paper and plastic, contaminated materials, discarded radiopharmaceutical containers, bandages, contaminated equipment or organs and tissues. Solid waste is typically classified as combustible/non-combustible and compactible/non-compactible waste. It generally contains a relatively low level of radioactivity when compared to liquid wastes. Solid radioactive waste consists mainly of general biomedical waste, which includes protective clothing, plastic sheets and bags, gloves, masks, filters, overshoes, paper wipes, towels, metal and glass, hand tools and discarded equipment.

2.1.6.4 Spent sealed sources: Sealed sources at the end of their useful clinical life are categorized as waste which needs to be properly conditioned and disposed of. Spent sources could be divided into the following categories: Sources with half-life <100 days, with high activity content such as ^{192}Ir (200–1500 MBq); Sources of low activity used for calibration and as standards; Sources with a potential emanation and contamination hazard. Special security and radiological precautions need to be taken for the handling and the storage of spent radium sources and sources known to be leaking ; and Sources with half-life >100 days, with low or high activity.(IAEA-TECDOC-1183-November 2000)

2.1.7. Segregation and packaging of biomedical radioactive waste:

Segregation is required in order to minimize waste hazards and to facilitate subsequent processing of waste. The segregation of waste at the point of origin is more efficient than performing segregation after mixing (IAEA-TECDOC-1183 - November 2000)

2.1.7.1. Waste volume management:

An essential component of an integrated radioactive waste management system is to ensure adequate control of the activity, activity concentration, and the volume of radioactive waste. The waste management plan should consider the wastes produced both as a result of the original waste activity and the secondary wastes generated by the subsequent treatment and conditioning of the original waste. In all instances, this will involve implementation of waste prevention and minimization practices. However, in some countries under certain well defined circumstances it is allowed to dilute the overall radionuclide content of the waste.

2.1.7.2. Waste prevention and minimization: When designing experiments or planning patient diagnosis, the need to use radionuclides should always be justified and only the required quantities should be procured. In the case of medical treatments, this is done on the basis of individual benefit/risk evaluation, whereas in research, the existence of an alternative technology and the high costs of radioactive waste management are important considerations. The objective of waste minimization is to reduce the activity and the volume of wastes for storage, treatment and disposal. Consequently the environmental impact will also be reduced, as well as the costs associated with contaminated material management. Waste minimization can be achieved by considering the following fundamental principles:

Keeping the generation of radioactive waste to the minimum practicable, in terms of both its activity and volume, through appropriate design measures, facility operation and decommissioning practices specific for medical facilities; Minimizing the spread of radioactive contamination, which leads to the production of radioactive waste; as far as it is practicable, separating valuable materials from waste and to clear valuable materials for recycling and reuse; and minimizing the amount of radioactive waste once it has been created through optimizing the use of

available treatment technology. The volume of radioactive waste from medical facilities may be reduced by increased use of processes such as compaction, incineration, filtration, and evaporation.(IAEA-TECDOC-1183-November 2000)

Dilution: Dilution can be considered as the release of radionuclides to the environment (gases or liquids) while maintaining proper clearance levels or the addition of nonradioactive waste to decrease specific activity levels.

In many countries, the practice of increasing the volume of radioactive waste prior to disposal to achieve compliance with a maximum specific activity limit per unit volume is either not practiced or specifically prohibited. It is a common practice in some countries for non-biologically hazardous, very low level radioactive waste to be subject to addition of other non-radioactive waste to increase the volume to bring the overall consignment within a specific activity limit.

2.1.8. Principles for collection and segregation of waste:

To minimize waste arising and optimize use of available radioactive waste disposal routes, waste should be accumulated and segregated with due regard to the future steps used in the waste management process. In contrast to other nuclear applications, the use of radionuclides in medicine nearly always involves only one radionuclide being used per procedure. This makes segregation of waste by individual radionuclides possible and practicable to organize.

Collection should be made in containers suitable for the waste, having due regard to its physical, chemical, biological and radioactive properties. Due regard should also be taken of any specific approved packaging requirements of the final disposal route. Waste bags/containers should not be over-filled such that their integrity is compromised. When selecting packaging for biomedical radioactive wastes, it is necessary to consider the different types and properties of the waste generated, and also the future waste treatment method.

Storage for decay is particularly important for medical radioactive wastes, since many of the radionuclides used in medicine are short lived and the activity of the radioactive wastes produced is well defined. Practical experience shows that segregation can be used to deal with the large volumes of medical radioactive wastes that are produced, such that most of the wastes can subsequently be disposed of as inactive refuse. Considerations for segregation should include such criteria as: non-radioactive and radioactive materials; radionuclide and activity content; physical and chemical form; spent sealed sources; and non-radiological hazards (toxic, biological, carcinogenic, infectious, flammable, etc.).

2.1.8.1 .Liquid wastes: liquid biomedical waste should be collected and segregated in accordance with the particular procedures accepted at the establishment, Liquid radioactive wastes that meet clearance levels can be discharged directly to an approved drainage/sewage system such as a municipal sewer. In some circumstances the biological hazard makes the radioactive waste unsuitable for immediate release, hence the necessity for deactivation prior to discharge. The liquid waste may also contain carcinogenic chemical products which may also contain ethidium bromide which may need disposal as chemical waste. If meeting all release criteria, namely radiological, chemical and biological, cannot be assured, biohazardous radioactive waste must not be discharged directly into a drainage/sewerage system. It is necessary to segregate liquid wastes taking the following criteria into account: radionuclide content and activity; Half-life of radionuclides and suitability for decay storage. Organic/aqueous liquids; non-homogeneity of waste (sludges); infectious hazard; chemical hazards; and flammability. Chemically toxic or carcinogenic waste which is incompatible for release to the environment must be collected separately in order to avoid uncontrolled chemical reactions. These wastes should be sent for appropriate waste treatment as required by the regulatory authority.

2.1.8.2 .Solid wastes*:* Collection of solid biomedical radioactive wastes normally involves distribution of a range of suitable containers throughout the working area to receive discarded radioactive materials. These containers should be lined with primary packaging, such as a heavy duty plastic bag. The containers should be brightly colored (e.g. yellow) with the radiation symbol clearly displayed so as to distinguish them from bins for inactive wastes. It is advisable to have a range of types and sizes of containers for segregation of the different types of solid biomedical radioactive wastes at the time and place of production. Due to the biological hazard of these radioactive wastes, lidded containers are advised for their collection. Refuse cans/bins with foot operated lids are particularly recommended. They should be lined with heavy gauge plastic bags which can be sealed and removed. Waste collections must be scheduled so that biohazardous materials do not deteriorate in the refuse bins. Special consideration should always be given to the management of contaminated sharp objects, such as needles and syringes, scalpel blades, blood lancets, glass ampoules, etc. These items commonly referred to as “sharps” are usually suitable for management as dry solid radioactive waste, although very small amounts of liquid might remain inside the needles/syringes. Where treatment is by incineration, which is obligatory in some countries, heavy duty cardboard, waxed cardboard or polyethylene/polypropylene containers, clearly labeled as sharps containers, should be used to collect these wastes. Containers should be no more than three quarters filled before sealing. Where there is no incineration facility available, it may be more appropriate to collect sharps in metal cans of approximately 5 L or 10 L capacity. When filled, the cans can be firmly lidded and transfer to a centralized waste processing facility or to landfill disposal site (when the waste composition allows this option). Regulations for biohazardous waste in some countries, e.g. Belgium, require hermetically sealed polyethylene

drums to be used instead of plastic bags not only for sharps but also for blood contaminated wastes.

Wherever possible, accumulation of damp wastes should be avoided where there is a requirement for long term storage. Significant moisture can lead to undesirable and possibly dangerous chemical and biological reactions whilst the waste is in storage. In such circumstances, damp or wet medical material should be drained, de-watered or dried to the extent possible, consistent with other safety concerns, before it is placed in waste receptacles.

The addition of moisture sorbent such as vermiculite may be advantageous. Refrigerating or freezing carcasses and similar remains is recommended. (IAEA-TECDOC-1183-November 2000).

2.1.9. Packaging and labeling:

Appropriate packaging and correct usage of such packaging is an essential component of the waste management system for biomedical radioactive waste. Choice of the proper types of materials and package style is necessary to minimize waste volume, provide reliable containment during storage, facilitate handling and simplify subsequent treatments. Packaging considerations for waste to be stored include: the nature of the waste to be stored; the expected time period for storage, with the possibility of extended storage; any further treatment necessary for the packaged wastes; further handling and movement requirements that the packaging must withstand without sustaining damage or deterioration; compliance with any existing national and local safety standards; compliance with any packaging requirements of the organization that will undertake treatment or final disposal of the wastes; ease of closure/sealing of the radioactive waste packages to prevent dispersion/seepage of contents and ease of labeling of the package for purposes of future traceability of origin and identification of the waste contents; ability to contain foul odors and to obscure visually offensive wastes; ability of the packaging

to withstand, without deterioration, the full range of temperature variations likely to be encountered, i.e. ability to withstand freezing without becoming brittle and liable to fracture; Suitability of shape and size of the filled packages to optimize use of the available storage arrangements; and plastic bags for containment of medical radioactive waste should meet certain manufacturing criteria.

In all instances: Plastic bags must be effectively sealed before handling; the maximum weight contained in any bag should be compatible with its holding capacity and any manual handling weight restrictions; Bags are to be handled by the neck only, and under no circumstances are they to be clasped against the body; bags must never be thrown or deliberately dropped during handling operations; check that the seal on any waste storage bag is intact at the end of any movement; check that the appropriate gauge of plastic bag has been used dependent on the waste being collected; bags must never be more than two-thirds filled to permit future safe handling by the neck of a securely sealed bag.

The following requirements should be met when selecting packaging suitable for containment of sharps: packaging should be puncture resistant and leak proof, even if toppled over or dropped; it must be capable of being handled and moved within the working area whilst in use with minimum danger of the contents spilling or falling out; the container should have an aperture which, in normal use, will inhibit removal of the contents, but will ensure that it is possible to place items into the sharps container using one hand, without contaminating the outside of the container; have a firm closure device attached for sealing when the container is no more than three quarters full; be marked with the words "Danger, Contaminated Sharps Only". Destroy by incineration or “to be incinerated; be of dimensions compatible with the clearance measurement system; made of materials which can be incinerated; and have a horizontal line to indicate when the container is 3/4 full, and marked with the words “warning — do not fill above the line”.

The use of plastic bags or single use polyethylene drum containers for medical radioactive waste containment have the advantage that damp wastes will not seep through them and contaminate the floor. A double wrapping with plastic bags is advisable. Very heavy, wet wastes should not be packaged in plastic bags due to the possibility of rupture of the seam of the plastic bag with resultant loss/seepage of contents. When available, single use disposable plastic containers with lids (volume range 10 L–200 L) should be used. These containers once lidded and sealed are especially useful as they are leak free, even if the container becomes accidentally inverted during further handling. Additionally, the containers have the advantage that they are suitable for incineration in furnaces designed for plastics. The fixed geometry of hermetically closed polyethylene containers makes them ideal for easy handling and a useful geometry for calibration and automation of activity measurement. Their shape also makes them suitable for optimized close stacking for short-term storage prior to disposal. Although these containers are unsuitable for sharp objects as they are not puncture resistant, they are of value where large quantities of radioactive waste which is biologically hazardous, offensive in nature or with a potential for fluid leakage requires containment, e.g. blood filled organs or tissues, vials/tubes of scintillation wastes. It is essential that the lid is firmly pressed down when sealing these containers to ensure there will be no fluid seepage. These containers are also advantageous in that they may retain offensive odors during short term storage prior to treatment and/or disposal of the waste. (IAEA-TECDOC-1183-November 2000)

2.1.10. Storage and transportation of biomedical radioactive waste:

2.1.10.1. Consideration for storage waste:

On-site interim storage of biomedical radioactive waste may be necessary for different reasons: Storage for decay; Storage before pretreatment/treatment; and Storage prior to returning to vendor.

Although the safety requirements in the case of temporary storage may be less stringent than for long term storage, nevertheless adequate attention should be paid to the needs of shielding and prevention of leakage as well as to the specific requirements of chemical and biological components of waste (freezing, refrigeration, neutralization, sterilization, etc.).

Each facility should define a policy for storage of biomedical radioactive wastes. The design of the storage facility for unconditioned radioactive waste should reflect governmental guidance and regulation, and include the following features: the storage area should be used solely for the purpose of holding biomedical radioactive wastes, which may or may not be biohazardous. It is not permitted to store any other materials in this area; the storage area should be constructed of rigid building materials; the area should be well illuminated, either by natural or artificial light; installation of electric lighting should provide for protection from spark ignition when volatile organic wastes are unavoidably stored; the storage area should be physically isolated, well away from areas where potentially flammable or explosive materials are located, or where employees or other persons might receive unnecessary exposure; the storage area should be sited away from routes available for public access, but it should be readily accessible for transportation of wastes, especially from vehicular traffic if required; the storage area should be appropriately ventilated; it should be appropriately labeled outside with a radiation symbol and warning of any other chemical or biological hazard; it is recommended

that the name of the person responsible for supervision of the radioactive waste storage area, along with contact daytime and out of hours telephone numbers, should also be displayed; the storage area should be of sufficient size to hold, in a well organized way, all of the radioactive wastes requiring storage, with adequate capacity to deal with contingency arrangements; the storage area should have a system for segregation of the various categories of radioactive packages, i.e. racks, drums or bins for storage of plastic bags of waste; there should be no mixing of wastes destined for different routes of management; storage of food wastes in the vicinity of the radioactive waste store is to be discouraged, as this encourages infestation by insects or rodents; the storage area should have an impervious, well drained flooring, preferably with wash down facilities; washing facilities for employees working at the facility should be provided adjacent to or in close proximity to it; an area for protective equipment and materials for dealing with spills should be provided at or in the facility; appropriate monitoring devices (radiological, chemical and physical) should be provided as needed; inventory/log book of stored waste should be maintained; provision for floor protection should be made in the event of accidental floor contamination; the size and capacity of the storage area should reasonably reflect its expected inventory; and a simple storage room that provides the above features and is located at the waste producing institution may be adequate for small amounts of waste. (IAEA-TECDOC-1183-November 2000)

2.1.10.2. Security:

A radioactive waste storage facility should be well protected against unauthorized human intrusion. It should be constructed, operated and maintained in such a way that unauthorized removal of radioactive wastes is prevented. An adequate locking mechanism should be provided to prevent unauthorized access. It is recommended that physical barriers, including fencing and an intruder alarm system be installed.

Should intrusion occur, security arrangements should ensure that any unauthorized removal of waste would be promptly discovered and effective measures initiated to recover the missing material. (IAEA-TECDOC-1183-November 2000)

2.1.10.3. Protection from fire

The careful selection of non-flammable construction materials when building the radioactive waste storage facility will greatly reduce this hazard. The radioactive waste storage facility should not be used to hold any highly flammable or highly reactive materials. Their advice should be sought regarding provision of firefighting equipment in the vicinity of the radioactive waste store. Potentially flammable wastes requiring storage, i.e. organic scintillation fluids in vials, should
be adequately sealed in heavy-gauge plastic bags, and stored in metal drums with lids. (IAEA-TECDOC-1183-November 2000)

2.1.10.4. Protection from temperature extremes:

Extreme heat can cause biomedical waste to putrefy greatly increasing infectious hazards, possible bursting of container and obnoxious odors. Extreme cold is not as critical as extreme heat; however, liquid aqueous waste should be protected from frost to avoid the breaking of aqueous liquid containers. Temperature control is necessary in a waste storage facility where temperature extremes are known to occur. (IAEA-TECDOC-1183-November 2000)

2.1.10.5. Storage for decay:

Decay storage, traditionally practiced by small and medium size establishments, has now spread to larger establishments, Practical experience shows that decay storage is suitable for wastes contaminated by radionuclides with a half-life of less than or equal to about l00 days.

Particularly where large volumes of biomedical radioactive wastes are produced, it may be more convenient to partition the short term decay storage facility to provide

areas for storage of wastes according to their half-life . Wastes with a half-life of greater than 100 days can be accumulated in the decay storage area until sufficient volume and/or activity is collected for transportation to a centralized waste processing facility for treatment, conditioning and disposal.

A decay storage period of ten half-lives will reduce the initial radioactivity to less than one thousandth of its original radioactivity, which in many cases means below the clearance levels for release, depending on the local regulatory requirements, Certain categories of biohazardous radioactive waste which have been subjected to pretreatment, so that they are no longer a biological hazard, can be disposed of at clearance levels. Waste contaminated with hazardous chemicals must be excluded from disposal as municipal refuse and should be routed to a suitable processing/disposal facility. (IAEA-TECDOC-1183-November 2000)

2.1.10.6. Storage of waste before treatment:

It is usual practice for all health care institutions to have a facility for on-site interim storage of radioactive waste. In nearly all hospitals, the waste from nuclear medicine diagnostic procedures is dealt with “in house” rather than at a centralized facility. Interim storage is usually in a room with segregated storage areas for the waste of different half-lives.

Where waste is managed on-site at a medical facility with incineration capabilities, most waste will be promptly routed for incineration.

In circumstances where generated solid waste has a half-life of greater than 100 days this waste could be collected and stored before transportation to a centralized waste processing facility for further treatment. Choice of the proper types of materials and package style is necessary to minimize waste volume, provide reliable containment during interim storage, facilitate handling and simplify subsequent treatments. (IAEA-TECDOC-1183 -November 2000)

2.1.10.7. Storage before returning to vendor:

It is normal practice in many countries for technetium generators to be supplied in reusable Type A packages. The generator is usually decayed for about six weeks before being repackaged and labeled, using labels provided by the vendor, and returned via the transport system at the time of delivery of a new generator.

Interim storage capacity should be available for spent sealed radiation sources prior to their return to the original supplier. It is essential to liaise with the supplier to ascertain the conditions for return of spent sealed sources. Measurement of the remaining level of radionuclide activity and an appropriate integrity test to prove that the source is not leaking will be required. (IAEA-TECDOC-1183-November 2000)

2.1.11. Transportation:

Transportation of biomedical radioactive waste is normally required when removing waste to a central facility for further treatment (conditioning) and disposal, to a disposal facility or landfill disposal site and to return to vendor.

Prior to transportation, specific requirements for biomedical radioactive waste should be taken into account. Transportation of liquid biomedical radioactive waste must be in appropriately designed containers.

Documentation accompanying biomedical radioactive waste to be transferred should contain sufficient information for its recipient to handle the wastes safely and in accordance with requirements of any applicable regulations. As a minimum, the activity, isotope composition, chemical composition, biomedical content, volume, weight, dangerous properties of transported material, date of transport and responsible person should be recorded. The regulatory authority may require copies of all transfer documents, or require that they be available from the shipper and/or receiver for inspection.

The documents should also include details of contingency arrangements to be followed in the event of an accident/incident during transport.

Documentation accompanying biomedical radioactive waste should be readily available for inspection during transport; and should be handed over by the driver to an appropriate person at the centralized facility for checking, prior to the radioactive consignment being unloaded.(IAEA-TECDOC-1183-November 2000)

2.1.12. Treatment of biomedical radioactive waste:

Collection, handling, segregation and packaging of biohazardous radioactive waste utilize essentially the same practices that are normally associated with good radioactive waste management. However, the practices used for radioactive waste management are not usually sufficient to control any biohazardous waste component. The Universal Precautions used in healthcare facilities should be considered together with contamination control and radiation protection procedures used in the nuclear industry.

Biohazardous radioactive waste cannot always be treated using the same methods as non-radioactive biomedical waste. Autoclaving is not a suitable method to destroy a microbiological hazard when the waste is contaminated with radionuclides. (IAEA-TECDOC-1183-November 2000)

2.1.13. Radioactivity survey:

An essential part of any radioactive waste programme is the measurement of the radioactivity associated with a waste package (i.e. plastic bag, drum or other container). The measurement, often called a survey, is an integral part of the waste pretreatment, i.e. when it is first collected, and should be repeated whenever the waste packages are handled or moved into storage. This serves to protect workers

handling the package, helps prevent accidental spread of contamination, and provides an independent check of the record keeping system.

In surveying a waste package, independent measurements are usually made to determine: Dose rate, mSv/h, or activity in Bq, both of which are measured at a specified distance from the container; The radioactivity concentration of the waste and/or isotopic content (Bq/g or Bq/L); Any radioactive contamination of the outside surfaces of the package.

Measuring the radioactivity from within the waste itself is important for handling the package and verifying records. The initial activity measurement provides information on the level of radioactivity present in order to determine further treatment requirements. A second measurement is required where waste is to be released at clearance levels. Gamma radiation with energies above 100 keV is easily detected allowing rapid and reliable measurements. Waste containing low energy gamma emitters or the high energy beta emitters can be quantified using commercially available instruments and appropriate conversion factors to correct the measured activity for losses due to absorption and geometry. Portable commercial instruments with sensitive detectors adapted to the radiation characteristics of the waste are useful but do not always allow the estimation of residual activity in numerous waste configurations.

A survey for transferable surface contamination is especially important before the package is handled or moved. This is best accomplished by physically wiping the container with a semi-porous material such as filter paper or a cotton swab. If possible, it is best to wipe over the entire surface.

The unexpected presence of radioactive contamination on a waste package often indicates that the package itself has been breached or physically damaged.

Example of a flow chart for managing medical radioactive waste can be found in fig (2.1),Appendix -B), (IAEA-TECDOC-1183 -November 2000).

2.2. Previous studies:

Packer, (2001) report the discharge of activity for 174 patients (202 treatments) undergoing treatment of thyroid carcinoma with radioactive iodine. The result was approximately 55% of administered activity was excreted in the first 24 h and that 85% of administered activity was discharged to the sewer over a typical inpatient stay of 5 days. There was no significant difference in levels of discharge between those patients undergoing inaugural ablation therapy and those having further treatments with radioactive iodine.

Packer also mentioned in the same study by representing that the decay tank systems are often the best option for the management of larger volumes of higher activity effluents that are unsuitable for direct discharge.

Ravichandran,(2017) mentioned that disposal with permission from the regulatory authority and appropriate monitoring is known as a controlled disposal. Solid wastes (Diagnostic): Syringes, sharps, gloves kept in yellow plastic containers, allowed minimum 2 months decay, monitored by GM survey instrument and released. They bear dates written on them. They go for incineration. I^{131} Therapy Isotope is received in capsule form, and directly administered to patients orally. Half-life of 131I is 8.05d, and therefore about 8–10 half lives will reduce the waste activity burden. 131I therapeutic Solid wastes) all are monitored, and sent to ‘Decay (about 2–3 months), individual bags are re-monitored to ascertain residual radioactivity. If they reach background count rates, they are released. Waste release with BIN number, informed to regulatory authority for records. The urine toilet releases are collected for about 2 months, kept closed for achieving a delay time of 2 months before releasing into the sewage treatment plant (STP) of the hospital.

(Shoukat et al, 2010) represented that an important objective in radioactive waste management is to ensure that the radiation exposure to an individual (Public, Radiation worker, Patient) and the environment does not exceed the prescribed safe limits. Disposal of Radioactive waste in public domain is undertaken in accordance with the Atomic Energy (Safe disposal of radioactive waste) rules of 1987 promulgated by the Indian Central Government Atomic Energy Act 1962. Any prospective plan of a hospital that intends using radioisotopes for diagnostic and therapeutic procedures needs to have sufficient infrastructural and manpower resources to keep its ambient radiation levels within specified safe limits. Regular monitoring of hospital area and radiation workers is mandatory to assess the quality of radiation safety. Records should be maintained to identify the quality and quantity of radioactive waste generated and the mode of its disposal. Radiation Safety officer plays a key role in the waste disposal operations.

Chapter Three
Materials and Methods

Chapter Three

Materials and Methods

3.1 Materials:

- Survey meters: (X5C plus calibrated on 1/3/2017) used to detect and quantify the radiations at the place of radioactive waste storage and at the time of disposal. is portable radiation detection and measurement instruments, used to measure ionizing radiation fields and the direct exposure hazard to a person. The radiation dose rate is normally read in microsieverts per hour (µSv/h).
- Storage containers labelled with a radiation trefoil and a unique identification code.
- Safety box containing sharps such as syringes.
- A room for interim storage of radioactive waste.
- Records.
- Lead shielded containers.

3.2 Methods:

3.2.1 Methods of data collection:

The data were collected from data sheet, textbooks, websites, personal contact..etc.

3.2.2. Methods of data analysis

The data were analyzed using SPSS program of personal computer version (AL2017 Ab) .This Descriptive study was done At Shendi Center of Nuclear

Medicine and Oncology which is providing diagnostic and therapeutic facilities in nuclear medicine

3.2.3.Techniques:

The protocols of management radioactive waste under the guidelines of the International Atomic Energy Agency (IAEA), and regulatory. The Radioactive waste at is comprised of used materials contaminated with TC^{99m}, I^{131}.

The strategies guidelines are to store waste of I^{131} andTC^{99m} to complete its decay process and bring its activity to background level which is not harmful for humans and environment.

3.2.3.1. Tc^{99m} radioactive waste: the generators will have to be kept at least 3 to 6 months, preferably in their lead containers but removed from the laboratory to a storage room the time needed for decay will be determined by the longer-lived radionuclide impurities (e.g., Zn-65, Cs-134, Sb-124, Zr-95, Nb-95, and Nb-92) in the column rather than by the Mo-99.

After 3 to 6 months of decay-in-storage, the generators can be dismantled.

Dismantle the oldest generators first, keep a radiation detection survey meter "on" at the work area and Hold each individual column in contact with the radiation detection survey meter in a low background (< 0.5 µSv/hr) area If the survey meter reading could not be distinguished from background, the column could then be firmly lidded and transfer to a centralized waste processing facility. Log the date the generator was brought to storage for decay, disposal date and dose rate at contact of bare column for waste disposal records. There are different kinds of the radioactive waste produced related to using generator; to manage these waste firstly segregate wastes at the point of origin using of suitable containers (strong bins), each container should be lined with heavy gauge plastic bag Segregation includes

separation of sharp materials, glass bottles and rest of solid waste like gloves, tissue papers .etc. Sharps waste should be collected in special containers (puncture-resistant and leak proof) labeled with the radiation symbol. Proper shielding should be provided for the containers to keep the radiation level within limits i.e., 10 µSv/h. secondly: Radioactive waste should be stored in containers that prevent dispersion, behind lead shielding.

Solid waste containing radionuclides with relatively short half-lives (e.g. <100 days) should be segregated at source to facilitate decay storage and disposal.

Solid wastes can be collected in simple containers lined inside with a durable plastic bag (about 0.5 mm thickness). Sharp wastes should be collected separately and stored in rigid, puncture-resistant containers (preferably metal) which have been clearly labelled "sharps". Liquid waste collected in suitable containers,(high-density polyethylene (HD-PE) .And stored in glass or chemically compatible metal containers (e.g. stainless steel) ;marked to indicate the maximum filling level; labelled with a radiation trefoil and permanently marked with a unique identification number. Waste packages inspected on a regular basis (at least weekly) to ensure that they are intact and still present in the store. The optimum decay storage period of the waste evaluated prior to storage (A decay storage period of ten half-lives will reduce the activity of the waste by a factor of approximately 1000). The storage rooms with Entrances suitable both for personnel and radioactive waste packages, doors – secured by a lock and access should be restricted to authorized persons; include adequate ventilation and a fire protection system.(be good lighting and at least passive ventilation)

; An impermeable, hard-standing floor with good drainage; it easy to clean and disinfect. And protected from the sun. Waste transported within the hospital by wheeled trolleys, containers, or carts that are not used for any other purpose.

3.2.3.2. Iodine-131: used in the form of capsule is the only radioisotope presently used for therapy (thyrotoxicosis, ablation of the thyroid tissue and metastases during cancer treatment) in Shendi center. Patients admitted for thyroid ablation treatment typically remain in the hospital for a period of between 3 and 7 days following iodine administration to allow radioactivity to decay to levels that will not pose a radiological hazard to the families of patients and/or members of the public with whom they may come into contact. The radioactive waste also include the solid and liquid waste; the solid waste which consist protective clothing, plastic sheets and bags, gloves, masks, overshoes, paper wipes, towels, metal and glass, hand tools and the generated solid wastes from the isolation wards patient clothes, food, bed sheets put it in containers and lined with primary packaging, such as a heavy duty plastic bag. (Yellow and black bags) are labeled with patients' numbers and sent to a temporary storage trolley, designed and fabricated locally for this purpose.

Contaminated sharp objects, such as needles and syringes, scalpel blades, blood lancets, glass ampoules, etc; managed as dry solid radioactive waste, although very small amounts of liquid might remain inside the needles/syringes. Where treatment is by incineration,

Full details of each radioactive waste package recorded on the Radioactive Waste Register when the waste packages are accepted into the Radioactive Waste Store. The strategy of „delay and decay" has been suggested as the preferred management option for medical waste excreted from patients. The storage facility with adequate ventilation provided secure closure to prevent unauthorized access to the sources. The excreta and urine of those patients admitted in a high dose isolation ward after getting flushed passes the PVC pipes through the shortest route possible into customized storage tanks, called delay tanks for storage before dispersal into the sewerage system, The delay tank is located in an area where there is minimal

movement of public and The tank is leak proof, corrosion free with smooth surface from inside; and remain free of leakage for the entire lifetime by using stainless steel and concrete. Decay tank systems are designed as two tanks in series, the decay tank system operates in such a way that one tank might be filling while the contents of the other are decaying. The Tanks are fed by pipes direct from dedicated toilets within ablation suites, the capacity of tank is 1000 liters, sufficient to hold liquid waste arising from 2 to 4 weeks of ablation treatment (depending upon water use by each patient) Once the tank is full, the effluent is held as long as possible prior to the next ablation treatment, at which time it will be emptied through a valve system to the main hospital foul drain system.

3.2.4. Area and duration of Study:

The study was conducted at Shendi Center of Nuclear Medicine and Oncology, during the period from September to November 2017.

3.2.5.Data collection variables: ($T_{1/2}$ = the half life of the isotope) , (E= the energy of the isotope), (keV= kilo electron volte), (nsv = nanosevert) ,(µci =micro curri)

3.3. Inclusion criteria

Radioactive waste from (Tc^{99m} and I^{131}) at Shendi Center of Nuclear Medicine and Oncology.

3.4. Exclusion criteria

Radioactive waste from sealed gaseous sources and other radioactive sources.

3.5. Ethical approval:

- There was official written permission from the administration of Shendi Center of Nuclear Medicine and Oncology to take the data.

Chapter four

Results

Chapter four

Results:

Table (4.1) shows the used system for radioactive waste management and disposal in the center:

materials	Physical properties	Methods of administration	The administer	Type of radioactive waste	management	disposal
Tc^{99m}	T1/2 :6hours E :140,5 keV emission: gamma rays	Intravenous injection	Nurse	M99/Tc99mgenerator	Segregation Storage.	Storage and There is no disposal
				Solid waste(vials ,gloves and absorbed papers) and sharp material needles	Delay and decay	
I^{131}	T1/2:8.02 d E:364kev emission: beta /gamma	orally	Medical physicist	Solid waste (paper and plastic, contaminated materials.	Segregation Storage	There is no disposal for solid waste.
				liquids effluent, urine	Decay tank.	Decay tank system.

Table (4.2) shows the established (proposed) system for management and disposal of the radioactive waste in the center:

Materials	Physical properties	Methods of administration	The administer	Type of radioactive waste	management	disposal
Tc^{99m}	T1/2 :6hours E :140,5 keV emission: gamma rays	Intravenous injection	Well trained Nurse	Mo99/Tc99mgenerator	Dismantled and transport to centralized	centralized waste processing facility
				Solid waste(vials ,gloves and absorbed papers) and sharp material needles	minimization Segregation labelled Storage. Delay and decay	Surveyed the packages before and after Incineration
I^{131}	T1/8.02 d E:364kev emission: beta /gamma	orally	Well trained Medical physicist	Solid waste (paper and plastic, contaminated materials.	minimization Segregation labelled Storage	Surveyed the packages before and after Incineration
				Liquids effluent, urine.	Decay tanks.	Decay tank system.

Table (4.3) shows the Surveyed activity of the radioactive generators and the Date of Storage

Type	Initial activity	Date of Storage	Activity during storage period nsv/h	Method of disposal
MO99/TC99m	15 GBq	12/3/2016	42	Storage
MO99/TC99m	15 GBq	20/6/2016	48	Storage
MO99/TC99m	15 GBq	4/9/2016	41	Storage
MO99/TC99m	15 GBq	28/12/2016	39	Storage
MO99/TC99m	30 GBq	16/3/2017	65	Storage
MO99/TC99m	30 GBq	17/5/2017	63	Storage
MO99/TC99m	30 GBq	1/8/2017	39	Storage

Table (4.4) shows the Surveyed activity of the radioactive waste from Tc99m radiopharmaceuticals and Date of Storage:

Isotope	Activity of the gloves/nsv/h	Activity of the vials nsv/h	Activity of the syringes /nsv/h	Date of Storage
TC99m	45	70	37	12/3/2016
TC99m	63	31	24	20/6/2016
TC99m	35	67	43	4/9/2016
TC99m	46	49	76	28/12/2016
TC99m	29	52	58	16/3/2017
TC99m	53	46	61	17/5/2017
TC99m	64	57	48	1/8/2017

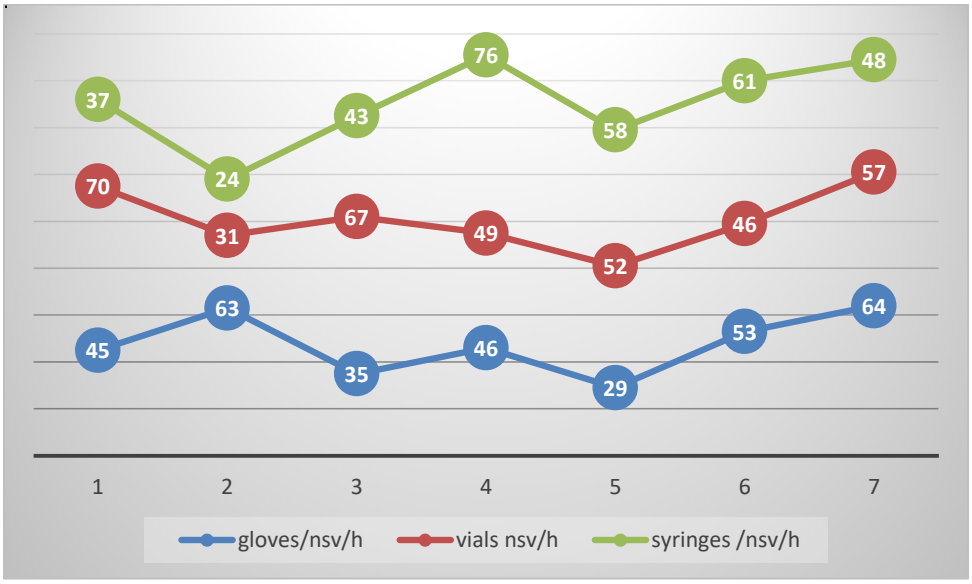

Fig 4.1 shows the Surveyed activity of the radioactive waste from Tc^{99m} radiopharmaceuticals and Date of Storage

Table (4.5) shows the Surveyed activity of the radioactive waste from I131 (per storage periods):

Isotope	Dose administered to patient /waiting period	Activity of the Patient clothes/µci After 5days	Activity of the pt clothes /nsv surveyed after 3months	Activity of the Solid waste/ µci after 5dayes	Activity of the solid waste/nsv Surveyed After 3monthes
I^{131}	100mci/5dayes	10.7	0.05	1.1	0.06
I^{131}	100mci/5dayes	8.6	0.09	1.3	0.13
I^{131}	100mci/5dayes	6.5	0.07	0.7	0.07
I^{131}	100mci/5dayes	1.5	0.05	2.7	0.04
I^{131}	100mci/5dayes	85	0.03	4.7	0.01
I^{131}	100mci/5dayes	40	0.17	4.9	0.05
I^{131}	100mci/5dayes	4.7	0.08	5.2	0.09
I^{131}	100mci/5dayes	2.1	0.08	4.5	0.09
I^{131}	100mci/5dayes	8.0	0.11	3.9	0.17
I^{131}	100mci/5dayes	3.1	0.09	8.0	0.22
I^{131}	100mci/5dayes	4.3	0.14	1.71	0.02
I^{131}	100mci/5dayes	1.59	0.06	1.47	0.08
I^{131}	100mci/5dayes	5.2	0.08	1.64	0.07
I^{131}	100mci/5dayes	2.2	0.10	2.5	0.12
I^{131}	100mci/5dayes	10.5	0.014	2.8	0.08
I^{131}	100mci/5dayes	98	0.16	13.6	0.09
I^{131}	100mci/5dayes	15.7	0.18	0.86	0.06
I^{131}	100mci/5dayes	3.3	0.09	0.03	0.25
I^{131}	100mci/5dayes	0.24	0.07	0.08	0.11
I^{131}	100mci/5dayes	6.7	0.05	0.10	1.63

Chapter Five

Discussion, Conclusion and Recommendations

Chapter Five

Discussion, Conclusion and Recommendations

5.1. Discussion:

Management of radioactive waste plays important role in nuclear medicine department, and the objective of radioactive waste management is to deal with radioactive waste in a manner that protects human health and the environment now and in the future to be discharged to the environment or whether it is to be disposed of in a landfill or a specially built facility. More complicated classification by activity level and half-life gives the opportunity for specific guidance to be given on disposal of materials.

Table (4.1) shows the used system for radioactive waste management and disposal in Shendi center using I^{131} and Tc^{99m}. Radioactive waste consist of Mo^{99}/Tc^{99m} generators, vials, gloves, syringes and solid waste from iodine (paper and plastic, contaminated materials) managed by Segregation and Storage for decay in the storage room for a long time without discharge , the previous study of Ravichandran,(2017) mentioned that disposal with permission from the regulatory authority and appropriate monitoring is known as a controlled disposal. Solid wastes (Diagnostic): Syringes, sharps, gloves, allowed minimum 2 months decay,

and monitored by GM survey instrument before being sent for incineration. I^{131} therapeutic Solid wastes were monitored, and sent to 'Decay Waste Box' kept in the hospital, (about 2–3 months). Individual bags are re-monitored to ascertain residual radioactivity. If they reach background count rates, they are released. The toilet containing therapeutic iodine waste are closed for about 2 months, for achieving a delay time of 2 months before releasing into the sewage treatment plant (STP) of the hospital.

Table (4.2) shows the established system for management and disposal of radioactive waste in Shendi center (segregation, labelled, storage and survey the packages with a controlled disposal for the radioactive waste by incineration the waste and survey the waste before and after the incineration . by application the methods which mentioned by (Ravichandran, 2017), and the IAEA requirements .

Table (4.3) shows the Surveyed activity of the radioactive generators and the Date of Storage, The surveyed activity during storage period (nsv/h). The only method for management and disposal the generators in the center is storage for decay in storage room for a long time. This is not the guidelines of the International Atomic Energy Agency (IAEA), and regulatory. The method is by storage the generators for 3-6 months, then dismantled and detected by survey meter in a low background (< 0.5 µSv/hr) area .If the survey meter reading could not be distinguished from background the column transfer to a centralized waste processing facility .

Table (4.4) and Fig (4.1) show Tc^{99m}, radiopharmaceuticals waste and the date of storage. Surveyed activity of the gloves syringes and vials was measured in nsv/h, because the half life of Tc^{99m} is short (6 hours) and the storage period was a long time.

Table (4.5) shows the I^{131} Radioactive waste (patient clothes and solid waste), the activity measured after patient waiting period of five days in µci, and surveyed

activity after three months in nsv because the half live of I^{131} is 8 days and storage period reach the ten half lives .

The measurements of radioactive waste from Tc^{99m} , I^{131} after 10 half lives considered background according to the guidelines of the IAEA and regulatory.

The system in the center storage the waste for many years without disposal plan and guidelines.

The previous studies (Ravichandran, 2017) ensures that the discharge into the environment after 2 months for Tc^{99m} radioactive waste, and after 3 months for I^{131}radioactive waste ,and the controlled disposal by incineration system environmentally acceptable ,this is all applied in the established (proposed) system for management and disposal in the Center .

5.2. Conclusion:

This study was done at Shendi Center of Nuclear Medicine and Oncology during the period from (from September to November 2017) ,using two radio nuclides waste namelyTC^{99m} and I^{131}.The general objective of the study was to establish of a system management and disposal of radioactive waste .

The main results included some problems in management and disposal of the radioactive waste in the center, that there was no radioactive waste disposal in systematic ways and the system for management and disposal of the radioactive waste didn't follow the guidelines and regulations of the International Atomic Energy Agency (IAEA).The record system of waste disposal wasn't available.

The study proposed some recommendations which could be useful in the nuclear medicine field .future studies could give reliable results.

5.3. Recommendations:

Waste segregation should take place in any nuclear medicine workplace and the activity should be measured.

The best management of radioactive waste should always be adopted including the storage for 10 half lives before being discharged.

The disposal by incineration of the radioactive waste is recommended and should be in accordance with the IAEA requirements and Standards.

The ordinary toilets used by patients who have taken radioactive materials should be checked regularly for radioactive contamination by the Radiation Officer.

Proper records in the form of logbook must be maintained.

Details of diagnostic and therapeutic radioisotopes procured and administered should be recorded.

The records must also include the details of radioactive waste generated with the activity levels and the levels at the time of their disposal.

Radioactive waste should be classified, segregated and disposed of according to the material and degree of contamination.

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Appendix A-1

Table (2.1) shows radionuclides used in medicine and biological research in unsealed form:

Radionuclide	Half-life	Principle application	Typical quantity per application	Waste characteristics
^{3}H	12.3 a	Radiolabelling Clinical measurement Biological research Organic synthesis	Up to 50 GBq	Solvents, solid liquid
^{13}N	10 m	Positron emission tomography	Up to 2 GBq	Solid, liquid
^{11}C	20.4 m	Positron emission tomography	Up to 2 GBq	Solid, liquid
^{14}C	5730 a	Medical diagnosis Biological research Labeling	Less than 1 MBq Up to 50 GBq Up to 50 GBq	(Exhaled CO_2) Solid, liquid Solvent
^{15}O	122 s	Positron emission tomography	Up to 500 MBq	Solid, liquid
^{18}F	1.8 h	Position emission tomography	Up to 500 MBq	Solid, liquid
^{22}Na	2.605a	Medical diagnosis	Up to 1MBq	Solid, liquid
^{24}Na	15.0 h	Biological research	Up to 5 GBq	Liquid effluent
^{32}P	14.3 d	Clinical therapy	Up to 200 MBq	Solid, liquid
^{33}P	25.4 d	Biological research	Up to 50 MBq	effluent
^{35}S	87.4 d	Medical and biological research	Up to 5 GBq	Solid, liquid effluent
^{36}Cl	$3.01\ 10^{5}$ a	Biological research	Up to 5 MBq	Gaseous, solid, liquid
^{38}K	7.6 m	Positron emission tomography	Up to 1 GBq	Solid, liquid
^{42}K	12.4 h	Clinical measurement	Up to 5 MBq	Solid, liquid
^{43}K	22.2 h	Clinical measurement	Up to 5 MBq	Solid, liquid
^{45}Ca	163 d	Biological research	Up to 100 MBq	Mainly solid,
^{45}Ca	4.54 d	Medical diagnosis	Up to 100 MBq	some liquid
^{46}Sc	83.8 d	Medical and biological research	Up to 500 MBq	Solid, liquid

51Cr	27.7 d	Clinical measurements Biological research	Up to 5 MBq Up to 100 MBq	Solid Mainly liquid ,effluent
57Co 58Co	271.7 d 70.8 d	Clinical measurements Biological research	Up to 50 MBq Up to 5 MBq	Solid, liquid effluent
59Fe	44.5 d	Clinical measurements Biological research	Up to 50 MBq	Solid, mainly liquid effluent
67Ga 68Ga	3.3 d 68.2 m	Clinical measurements Positron emission tomography	Up to 200 GBq Up to 2 GBq	Solid, liquid, effluent Solid, liquid
67Cu	2.6 d	Clinical therapy Monoclonal antibodies	Up to 1 GBq	Solid, liquid
75Se	119.78 d	Clinical measurements	Up to 10 MBq	Solid, liquid
75Br 76Br	98 m 16.2 h	Medical diagnosis Medical diagnosis		Solid, liquid Solid, liquid
77Br	57 h	Clinical measurement	Up to 5 MBq	Solid, liquid
81mKr	13.3 s	Lung ventilation studies	Up to 6 GBq	Gaseous
82Rb 82mRb 86Rb	76 s 6.2 h 18.7 d	Positron emission tomography Clinical measurement Medical and biological research	 Up to 50 MBq	Solid, liquid Solid, liquid Solid, liquid
85Sr	64.8 d	Medical diagnosis/research	Up to 50 MBq	Solid, liquid
89Sr	50.5 d	Clinical therapy	Up to 300 MBq	Solid, liquid
90Y	2.7 d	Clinical therapy Medical and biological research	Up to 300 MBq	Solid, liquid
95Nb	35.0 d	Medical and biological research	Up to 50 MBq	Solid, liquid
99mTc	6.0 h	Clinical measurements Biological research Nuclide generators	Up to 100 GBq	Solid, liquid

111In	2.8 d	Clinical measurements Biological research	Up to 50 MBq	Solid, liquid
123I 124I 125I 131I	13.2 h 4.2 d 60.1 d 8.0 d	Medical and biological research Medical diagnosis/research Clinical measurements Clinical therapy	Up to 500 MBq Up to 11.1 GBq	Solid, liquid Occasionally vapor
113Sn	155.0 d	Medical and biological research	Up to 50 GBq	Solid, liquid
127Xe	36.4 d	Medical diagnosis	Up to 200 MBq	Gaseous, solid
133Xe	5.3 d	Clinical measurements	Up to 400 MBq	Gaseous, solid
141Ce	32.5 d	Medical research	Up to 50 MBq	Solid, liquid
153Sm	47 h	Clinical therapy	Up to 8 GBq	Solid, liquid
169Er	9.3 d	Clinical therapy, palliative treatment	Up to 500 MBq	Solid, liquid
186Re	3.8 d	Clinical therapy, palliative treatment	Up to 500 MBq	Solid liquid
188Re	17 h	Clinical therapy	Up to 500 MBq	Solid, liquid
198Au	2.7 d	Clinical measurements, therapy	Up to 500 MBq	Solid, liquid
201Tl	3.0 d	Clinical measurements	Up to 200 MBq	Solid, liquid
203Hg	46.6 d	Biological research	Up to 5 MBq	Solid, liquid

Appendix A -2

Table (2.2)shows the sealed sources used in medicine and medical research.

Application	Radionuclides	Half-life	Source activity	Comments
Bone densitometry	^{241}Am ^{153}Gd ^{125}I	433.0 a 244.0 d 60.1 d	1–10 GBq 1–40 GBq 1–10 GBq	Mobile units
Manual brachytherapy	^{198}Au ^{137}Cs ^{226}Ra ^{60}Co ^{90}Sr ^{103}Pd ^{125}I ^{192}Ir ^{106}Ru ^{90}Y	2.7 d 30.0 a 1600 a 5.3 a 29.1 a 17.0 a 60.1 d 74.0 d 1.01 a 2.7 d	50–500 MBq 30–300 MBq 50–500 MBq 50–1500 MBq 50–1500 MBq 50–1500 MBq 200–1500 MBq 5–100 MBq 10–20 MBq 50–500 MBq	Small portable source
Vascular brachytherapy	^{32}P ^{89}Sr ^{192}Ir	14.3 d 50.5 d 74 d	200 MBq 150 MBq 0.1–1 TBq	Catheterization
Remote after loading brachytherapy	^{137}Cs ^{192}Ir	30.0 a 74.0 d	0.03–10 MBq 0.1–200 TBq	Mobile units
Teletherapy	^{60}Co ^{137}Cs	5.3 a 30.0 a	50–1000 TBq 500 TBq	Fixed installations
Whole blood irradiation	^{137}Cs ^{60}Co	30.0 a 5.3 a	2–100 TBq 50–1000 TBq	Fixed installations
Research	^{60}Co	5.3 a	Up to 750 TBq	Fixed installations

	^{137}Cs	30.0 a	Up to 13 TBq	
Calibration sources Anatomical markers Sources as standards in instrument	^{63}Ni ^{137}Cs ^{57}Co ^{226}Ra* ^{147}Pm ^{36}Cl ^{129}I	96 a 30.0 a 271.7 d 1.6 × 103 a 2.62 a 3.01 × 105 a 1.57 × 107 a	<4 MBq <4 MBq Up to 400 MBq <10 MBq <4 MBq <4 MBq <4 MBq	Fixed installations in instruments or mobile sources
Gamma radio surgery knife	^{60}Co	5.3 a	Up to 220 TBq	Skull cap

Appendix -B

Fig (2.1) example of a flow chart for managing medical radioactive waste.