Chapter One

1.1 Introduction:

Nuclear medicine is a branch of radiology which use as diagnostic and therapy for many disease by using radio nuclide which mixed by radio pharmaceutical depend on metabolic process of organ. Unlike MRI and CT, nuclear medicine uniquely provides information about both the function and structure of organ systems within the body .(Cherry et al 2003) While the introduction of 131I for treating thyroid disease in 1946, followed a few years later by 131I thyroid imaging, marks the beginning of Nuclear Medicine, it was the discovery of 99mTechnetium in 1937 and the subsequent development of the first commercial 99mTc generator in 1964 that lead to the tremendous growth of nuclear medicine. For nuclear imaging, Tc99m has become the “universal” isotope because of its virtually ideal physical characteristics for scintigraphic applications (i.e., generator produced, 6-h half-life, 140 keV gamma radiations) and its versatile chemistry that can be manipulated to label a variety of ligands. The Mo/Tc generator can be shipped to laboratories for the production of single dose Tc99m radiopharmaceuticals on site making Tc99m, by far, the most utilized radioisotope in nuclear medicine. Other isotopes require cyclotron or reactor generation, which is more costly, and less available for emergency or rapid administration. Today, there are nearly 100 nuclear medicine imaging procedures available using various single photon emission isotopes and positron emission isotopes. The availability of 18F and specifically, 18F-

fluorodeoxy-D glucose (FDG) has allowed for the practical application of PET. The short half-life of most PET isotopes, with the exception of the 110-minute half-life of 18F, makes them impractical for routine use because they require a cyclotron on site at the hospital.(Cherry et al 2003) Gamma emission imaging has been successfully applied to almost every organ of the body (brain, bone heart, kidney, lung, and neuroreceptors) as well as sites of inflammation, atherosclerosis, thrombosis and cancer. The molecular nature of nuclear medicine imaging leads to unique non-invasive pharmacokinetics modeling applications. In addition, the unique characteristics of PET allow for quantitative analysis of physiological processes, particularly cellular metabolism. The future of nuclear medicine imaging radiopharmaceuticals lies primarily in the development of new legends for Tc99m (for SPECT) and 18F (for PET) to carry the radioisotope to the site of application without compromising the biological activity of the legend molecule rather than in the development or discovery of new radioisotopes (Cherry et al 2003).

1.2 Radioactive waste *:*

The radioactive waste in a nuclear medicine facility comprises many different types of waste. it may be of high activity, such as a technetium generator, or of low activity, such as from biomedical procedures or research (IAEA 2005).

in addition,it may have a long or short half-life and it may be in a solid, liquid or gaseous form. radioactive waste needs to be safely managed because it is potentially

hazardous to human health and the environment. Through good practices in the use of radionuclides, the amount of waste can be significantly reduced but not eliminated (IAEA 2005).
it is important that safe waste management, in full compliance with all relevant regulations, is considered and planned for at the early stages of any projects involving radioactive materials. it is the responsibility of the licensee to provide safe management of the radioactive waste. it should be supervised by the RPO and local rules should be available.
contamination is associated with radioactive spills, animal experiments, emergency surgery of a therapy patient and autopsy of a therapy patient. however, traces of the radionuclides used in a nuclear facility can be found almost everywhere, especially on door handles, taps, some specific equipment and in the patient's toilet. some procedures, such as ventilation scans, might also cause contamination of both personnel and equipment. Whole body measurements of workers have revealed an equilibrium internal contamination of up to 10 kbq of ^{99m}Tc, which will result in an effective dose of ~0.05 msv/a. although this is a small fraction of the external exposure, every precaution must be taken to avoid contamination of the facility.

1.3 Sources of Radioactive Waste:

Radioactive waste is material contaminated with radioactive substances which arises from medical or research use of radionuclides. It is produced, for example, during nuclear medicine, radio immunoassay and bacteriological procedures, and

may be in a solid liquid or gaseous form and be included in the body waste of patients under treatment. Reference should be made to the *Radiation Control Act 1990* and the Radiation Control Regulation 1993.

Radioactive waste, once lead shielded and allowed to decay to a safe level as set by the Regulatory authority, is no longer deemed to be radioactive waste. Some radioactive wastes are classified as hazardous waste in the Waste Regulation.

1.4 handling of Radioactive Waste:

Radioactive substances should be handled in a safe manner to ensure that all personnel have minimal exposure to radiation. A Radiation Safety Officer must be responsible for the safe handling, storage and transport of radioactive waste. There must be a specifically identified area for the storage of radioactive waste, which should be suitably packaged and labelled (IAEA 2000).

The handling, storage and disposal of radioactive materials must comply with requirements of the Radiation Control Act 1990".

Where such requirements do not exist, observe the principles in the National Health and Medical Research Council (NH&MRC) "*Code of 'Practice for the Disposal of Radioactive Wastes by the User*", *(1985).*

1.5 Problem of the Study :

To be aware to the general principle of the handling and the safety of radioactive waste, and to be able to identify store and

dispose of different type of radioactive waste generated in nuclear medicine department.

1.5 Objectives of the Study:

1.5.1 General objective:

To assess waste Management in Nuclear Medicine Department, and provide practical guidance on the management of radioactive waste from Nuclear Medicine Department.

1.5.2 Specific Objectives:

- To measure the activity of the waste before storage.
- To measure the dose of waste before disposal.
- the check the radioactive type and the half life of radioactive nuclei.

Chapter Two

2.1 Decay of Radionuclides

Some 3000 nuclides have been discovered thus far, and most are unstable nuclei decay by spontaneous fission, a-particle, b-particle, or g-ray emission, or electron capture (EC) in order to achieve stability. The stability of a nuclide is governed by the structural arrangement and binding energy of the nucleons in the nucleus. One criterion of stability is the neutron-to-proton ratio (N/Z) of the stable nuclides; the radionuclides decay to achieve the N/Z of the nearest possible stable nuclide. Radioactive decay by particle emission or electron capture changes the atomic number of the radionuclide, whereas decay by g-ray emission does not (Podgora 2012).

Radionuclides may decay by any one or a combination of six processes:

spontaneous fission, a decay, b decay, b+decay, electron capture, and isomeric transition (IT). In radioactive decay, particle emission or electron capture may be followed by isomeric transition. In all decay processes, the energy, mass, and charge of radionuclides must be conserved. Each of these decay processes is briefly described below (Podgora 2012).

2.1.1 Spontaneous Fission :

Fission is a process in which a heavy nucleus breaks down into two fragments typically in the ratio of 60:40. This process is accompanied by the emission of two or three neutrons with a mean energy of 1.5 MeV and a release of nearly 200 MeV energy, which appears mostly as heat (Podgora 2012).

Fission in heavy nuclei can occur spontaneously or by bombardment with energetic particles. The probability of spontaneous fission is low and increases with mass number of the heavy nuclei. The half-life for spontaneous fission is $2*10^{17}$ years for

235U and only 55 days for 254Cf. It should be noted that spontaneous fission is an alternative to a decay or g emission (Podgora 2012).

2.1.2 Alpha (a) Decay :

Usually heavy nuclei such as radon bound together in the nucleus. In a decay, the atomic number of the parent nuclide is therefore reduced by 2 and the mass number by 4. An example of a decay is

$$^{235}_{92}\mathrm{U} \rightarrow {}^{231}_{90}\mathrm{Th} + {}^{4}_{2}\alpha^{2+}$$

An a transition may be followed by b emission or g-ray emission or both. The a particles are monoenergetic, and their range in matter is very short (on the order of 10^{6}cm) and is approximately 0.03 mm in body tissue (Johns et al 1984).

2.1.3 Beta (β) Decay :

When a nucleus is “neutron rich” (i.e., has a higher N/Z ratio compared to the stable nucleus), it decays by b particle emission along with an antineutrino (Johns et al 1984). An antineutrino (v) is an entity almost without mass and charge and is primarily needed to conserve energy in the decay. In b decay, a neutron (n) essentially decays into a proton (p) and a b particle; for example

$$n \rightarrow p + \beta \quad + \nu$$

The b particle is emitted with variable energy from zero up to the decay energy.

The decay or transition energy is the difference in energy between the parent and daughter nuclides. An antineutrino carries away the difference between the b particle energy and the decay energy. The b decay may be follow ed by g-ray emission, if the daughter nuclide is in an excited state and the number of g rays emitted depends on the excitation energy. After b decay, the atomic number of the daughter nuclide is one more than that of the parent nuclide; however, the mass number remains the same for both nuclides.

Some examples of b decay are

$$^{131}_{53}I \rightarrow {}^{131}_{54}Xe + \beta \quad + \nu$$

$$^{59}_{26}Fe \rightarrow {}^{59}_{27}Co + \beta \quad + \nu$$

$$^{99}_{42}Mo \rightarrow {}^{99m}_{43}Tc + \beta \quad + \nu$$

$$^{60}_{27}Co \rightarrow {}^{60}_{28}Ni + \beta \quad + \nu$$

The radioactive decay of nuclides is represented schematically by decay schemes, and examples of the decay schemes of 131I and 99Mo are given in Figs. 2.1 and **2.1.4 respectively :**

The b particles emitted by radionuclides can produce what is called bremsstrahlung by interaction with surrounding medium. Electrons passing through matter are decelerated in the Coulomb

field of atomic nuclei, and as a result, the loss in electron energy appears as continuous x rays.

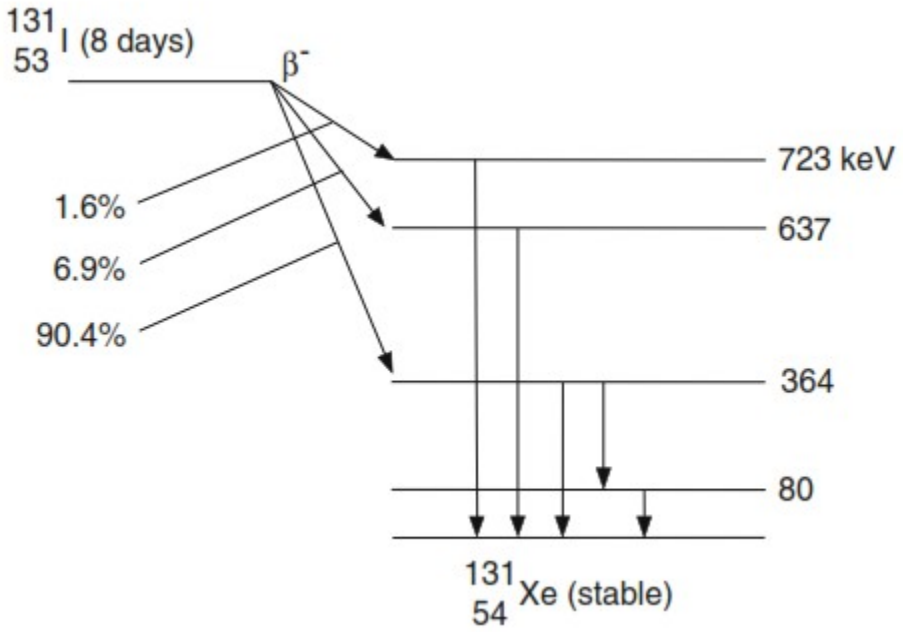

FIGURE 2.1. Decay scheme of ^{131}I. Eighty one percent of the total ^{131}I disintegrations decay by 364 keV γ ray emission. The half life of ^{131}I is shown in parentheses.

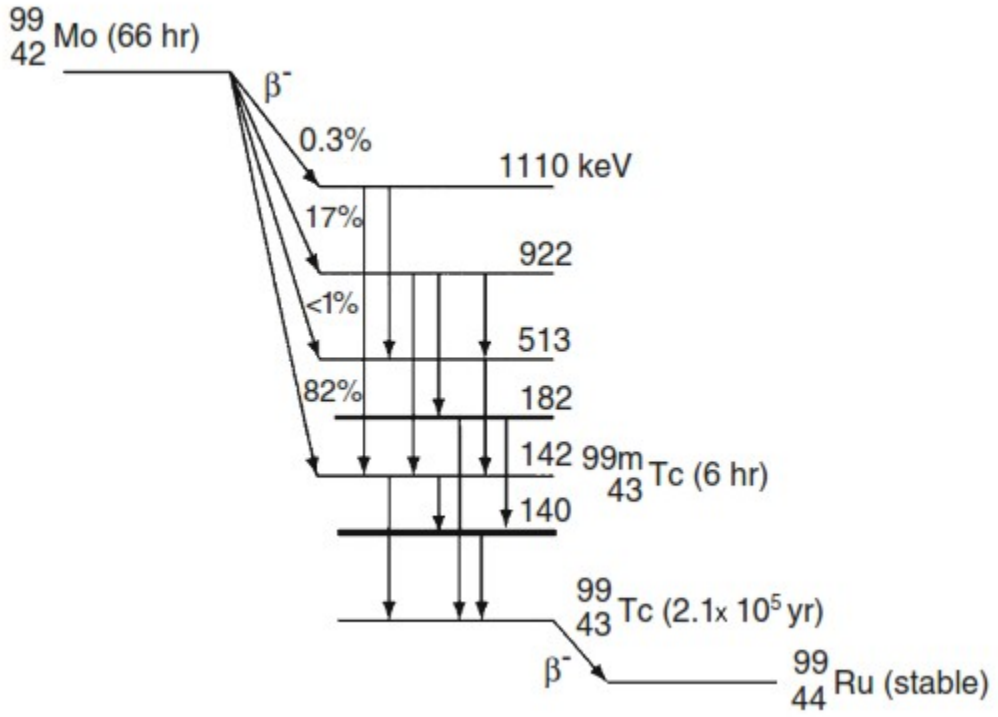

FIGURE 2.2. Decay scheme of ^{99}Mo. There is a 2 keV isomeric transition from the 142 keV level to the 140 keV level, which occurs by internal conversion. Approximately 87% of the total ^{99}Mo ultimately decays to ^{99m}Tc and the remaining 13% decays to ^{99}Tc. (The energy levels are not shown in scale.)

These x rays are called bremsstrahlung (German for “braking” or “slowing down” radiation) and are used in radiographic procedures. The probability of producing bremsstrahlung increases with increasing electron energy and increasing atomic number of the medium. In tungsten, for example, a 10-MeV electron loses about 50% of its energy by bremsstrahlung, whereas a 100-MeV electron loses more than 90% of its energy by this process (Johns et al 1984).

2.2 Quantities and units :

Although most of the requirements of the Standards are qualitative, the Standards also establish quantitative limits, and guidance levels. For these purposes, the main physical quantities used in the Standards are the rate of nuclear transformation of radionuclides (the activity) and the energy absorbed by a unit mass of a substance from the radiation to which it is exposed (the absorbed dose). The unit of activity is the reciprocal second, representing the number of nuclear transformations (or disintegrations) per second, which is termed the becquerel (Bq). The unit of absorbed dose is the joule per kilogram, termed the gray (Gy) (Podgora 2012).

The absorbed dose is the basic physical dosimetric quantity of the Standards However, it is not entirely satisfactory for radiation protection purposes because

effectiveness in damaging human tissue differs for different types of ionizing radiation(Podgora 2012).

Consequently, the absorbed dose averaged over a tissue or organ is multiplied by a radiation weighting factor to take account of the effectiveness of the given type of radiation in inducing health effects; the resulting quantity is termed the equivalent dose. The quantity equivalent dose is used when individual organs or tissues are

irradiated, but the likelihood of injurious stochastic effects due to a given equivalent

dose differs for different organs and tissues. Consequently, the equivalent dose to

each organ and tissue is multiplied by a tissue weighting factor to take account of
the organ's radiosensitivity. The sum total of such weighted equivalent doses for all
exposed tissues in an individual is termed the effective dose. The unit of equivalent
dose and of effective dose is the same as that of absorbed dose, namely joule per kilogram, but the name sievert (Sv) is used in order to avoid confusion with the unit of absorbed dose (Gy) (Podgora 2012).

When radionuclides are taken into the body, the resulting dose is received throughout the period of time during which they remain in the body. The committed
dose is the total dose delivered during this period of time, and is calculated as a
specified time integral of the rate of receipt of the dose. Any relevant dose restriction
is applied to the committed dose from the intake.

The total impact of the radiation exposure due to a given practice or source depends on the number of individuals exposed and on the doses they receive. The collective dose, defined as the summation of the products of the mean dose in the various groups of exposed people and the number of individuals in each group, may therefore be used to characterize the radiation impact of a practice or source. The unit of collective dose is the man-sievert (man-Sv) (Podgora 2012) .

2.3 Basic Principles of Radiation Protection :

The principles of radiation protection and safety on which the Standards are based are those developed by the ICRP and by INSAG. The detailed formulation of these principles can be found in the publications of these bodies and they cannot easily be paraphrased without losing their essence. However, a brief — although simplified — summary of the principles is as follows: a practice that entails or that could entail exposure to radiation should only be adopted if it yields sufficient benefit to the exposed individuals or to society to outweigh the radiation detriment it causes or could cause (i.e. the practice must be justified)1; individual doses due to the combination of exposures from all relevant practices should not exceed specified dose limits; radiation sources and installations should be provided with the best available protection and safety measures under the prevailing circumstances, so that the magnitudes and likelihood of exposures and the numbers of individuals exposed be as low as reasonably achievable, economic and social factors being taken into
account, and the doses they deliver and the risk they entail be constrained (i. e. pro-
tection and safety should be optimized); radiation exposure due to sources of radia-
tion that are not part of a practice should be reduced by intervention when this is

justified, and the intervention measures should be optimized; the legal person autho-
rized to engage in a practice involving a source of radiation should bear the primary
responsibility for protection and safety; a safety culture should be inculcated that
governs the attitudes and behaviour in relation to protection and safety of all
individuals and organizations dealing with sources of radiation; in-depth defensive
measures should be incorporated into the design and operating procedures for radia-
tion sources to compensate for potential failures in protection or safety measures ;and protection and safety should be ensured by sound management and good engineering, quality assurance, training and qualification of personnel, comprehensive safety assessments and attention to lessons learned from experience and research (Euratom 1996).

2.4 Type of Radioactive Waste :

2.4.1 General : 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 are greater than the radiological hazard due to the presence of radionuclide contamination (IAEA 2005).

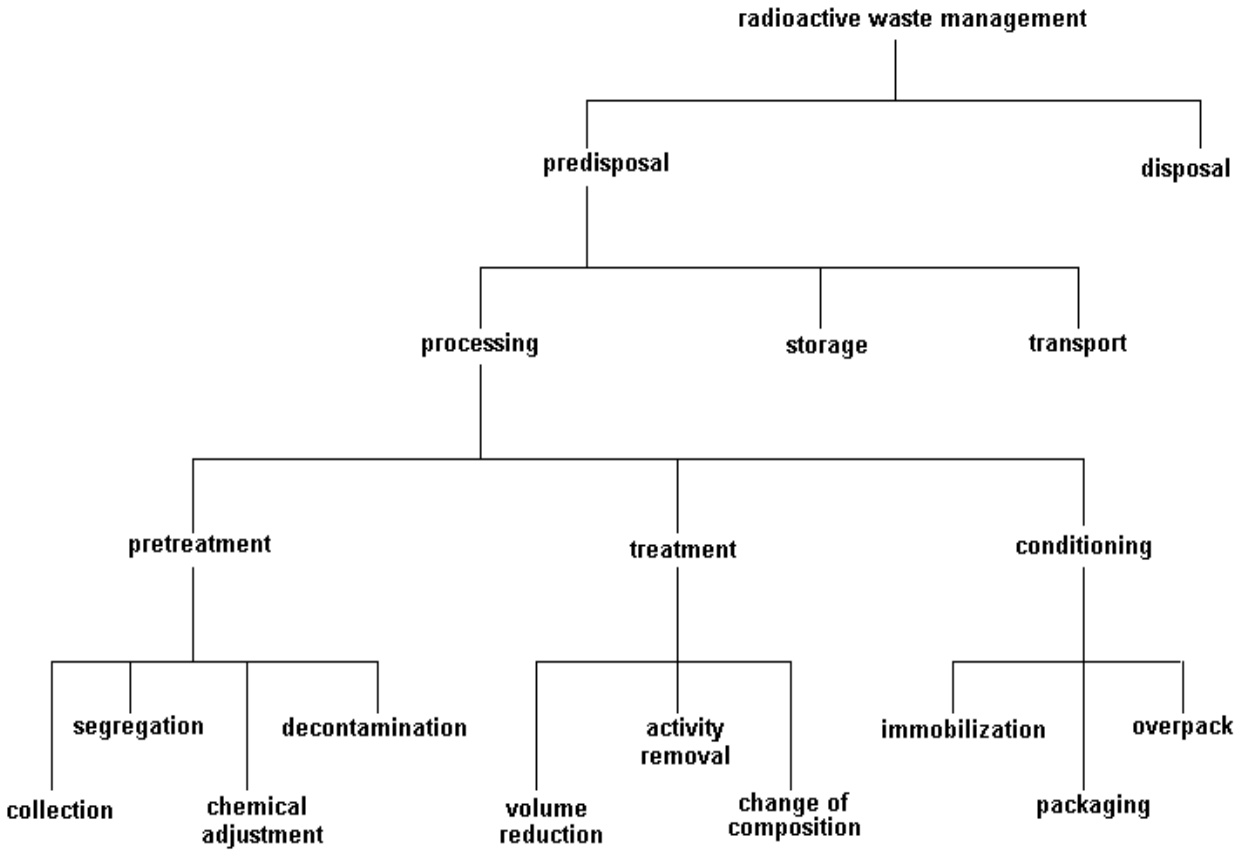

Figure 2.3 prescribes processes which may be required to ensure that waste can be disposed of safely.

2.4.2 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 oils and scintillation fluids. Waste that includes both radioactivity and

a hazardous chemical component is usually referred to as a mixed waste (IAEA 2005).

2.4.3 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.

2.4.4 Solid waste :

At health care, medical and research facilities, solid waste is generated in the form of paper and plastic, animal carcasses, 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.

2.4.5 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 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;

__ Sources with half-life >100 days, with low or high activity.

2.4.6 Decommissioning waste :

Use of accelerators in medicine may also produce radioactive waste, specifically during decommissioning of these facilities. The use of accelerators can create an activation problem of surrounding materials, particularly with neutrons of energy higher than 10 MeV.

2.5 Assessment and Optimization and of Radioactive Waste :

Radioactive waste from the medical sector does not present a significant long term
waste management problem when compared to wastes generated from nuclear fuel cycle operations. The most important characteristics of biomedical waste are its short half-life and low radiotoxicity. Biomedical waste typically contains low energy _ and

_ emitters and is generally of low total and specific activity. Important considerations are the volumes of waste and other hazardous properties associated with the waste such as biological and chemical risks (IAEA 1982).

An effective programme for biomedical radioactive waste management is based on the principles of waste prevention and minimization, whilst providing for the protection of personnel and the environment, consistent with the requirements of the regulatory authority . Such management should integrate all associated hazards that are found in the waste. A generic diagram detailing the basic steps in biomedical radioactive waste management (IAEA 1982).

The basic principles of radioactive waste management are described elsewhere and include providing for the protection of the general public and the environment [6].

A comprehensive waste management programme requires a thorough prior assessment to ensure that the primary focus is waste prevention and minimization whilst providing for protection from all associated hazards of the waste. This assessment will include an analysis of the total radionuclide inventory and pattern of use, waste types and amounts generated and the potential routes for disposal. This review will seek to harmonize the waste management activities of all areas within a facility (IAEA 1982).

Such an evaluation is best carried out at the planning stage of a facility allowing for the incorporation of specific features which

will enhance waste management throughout the facility. In most circumstances, however, the evaluation will be carried out on an existing facility which may have individual laboratories with their own specific waste management practice and instructions. For such circumstances, harmonization of waste management activities becomes even more important. Only when all uses of radionuclides have been evaluated can it be ascertained what waste minimization practices need to be implemented and how waste management can best be organized.

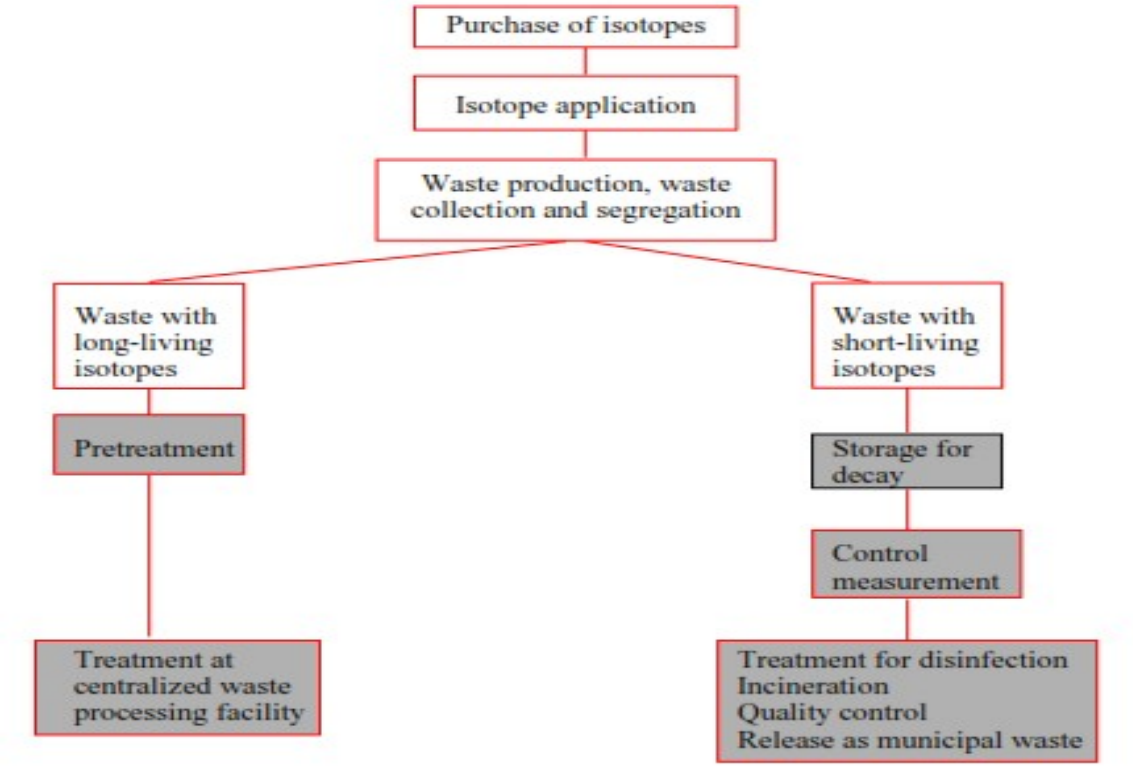

Fig. 1. Management of biomedical radioactive waste.

Figure 2.4 Mangement of radioactive waste

The radioactive waste management programme must be comprehensive and should

consider all aspects, starting with radionuclide purchase through to the final clearance of waste packages from the facility to disposal or discharge. Clearance of radioactive waste from further regulatory control can only be achieved through a careful programme of waste flow control and measurement of residual radioactivity. Biomedical waste is usually best managed on-site by decay storage, with minimal transport risks and ALARA exposure levels. Since quantitative estimation of isotope activity can be difficult where waste packages contain a mixed combination of _-_ emitters, segregation at the time and place of waste production is essential.

An important component of effective waste management is the preparation of universal documented procedures. Such procedures will detail requirements for practices such as waste segregation at source and appropriate containers/receptacles for accumulation of waste. All staff should be appropriately trained in the implementation of these procedures. Responsible personnel should be identified for each stage in the waste management process, with management committing total support to the implementation of the overall waste policy (IAEA 1982).

As part of the evaluation of a waste management programme, it is necessary to collect information specific to each facility. This data will provide the basis for determining potential opportunities for further waste management optimization. The data should be recorded in a data management system allowing for follow-up of waste flows from source to final disposal, and should include:

__ Data on all characteristics of the waste generated and radionuclides used within the facility;
__ Reference to authorizations and details of authorized waste disposal routes;
__ Organizational responsibility for the radioactive waste management programme
(collection, transport, storage for decay, clearance);
__ Reference to procedures that are currently in use for management of radioactive waste;
__ Specifications of how the radionuclide content and activity of individual waste packages is quantified and verified;
__ Data on dose rate and contamination;
__ Types of packaging used for each type of medical radioactive waste;
__ Data on decay storage and pretreatments of medical radioactive waste;
__ Reference to quality control procedures, and if in place, audit as part of an overall
quality assurance programme;
__ Data to verify whether all regulatory requirements are being met;
__ Certification of measurements made.
The subject of the waste management programme evaluation . Collation of data obtained by utilization of these guidelines will give an overall picture of radionuclide usage and management requirements. The data will enable a full review of current

practices to be undertaken with a view to implementing an overall strategy for purchasing control of radionuclides and management of radioactive wastes (IAEA 1992).

It is essential at an early stage to co-ordinate with the on-site radiation protection supervisor(s)/advisor and seek support in taking the necessary steps. These people will have >first hand = knowledge of the working environment and be able to provide specific advice on where information can be obtained relating to any non-radiological hazards which might necessitate the continuation of the current waste segregation and management procedures. By collaboration, the practical implementation of optimization of waste management can be taken forward, with additional training of staff as required (IAEA 1992).

In some instances, modification to the radioactive storage room, or the organizational arrangements for its use, will be necessary before it would be appropriate to alter the period that waste is held on the premises to permit radioactive decay. Although these improvements may have cost implications, they can often be met by savings that will be made by decaying short half-life radionuclides (T < 100 days) such that they can be disposed of at clearance levels (IAEA 1992).

The overall development of a waste management strategy is not a static process. It should be subject to periodic review, at least annually, to ensure optimization of waste management practices, e.g. by cost-benefit

analysis and continued compliance with regulatory requirements. Usage of individual disposal routes, i.e. incineration, landfill, a repository for low level radioactive waste and sewers for discharge to drain, should be reviewed when disposal routes change their pricing structure to ensure cost-effective and environmentally sound use of disposal routes, whilst maintaining full compliance with regulations governing both the radiological and non-radiological hazards that may be associated with the wastes (IAEA 1992) .

2.6 Segregation and Packaging of Radioactive Waste :

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 (Section 3) 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. This is achieved by increasing the volume of very low level radioactive waste by addition of other non-radioactive wastes to comply with specific activity limits laid
down by the regulatory authority (IAEA 1993).

2.6.1 Waste prevention and minimization:

Waste prevention is an essential precursor of any radioactive waste management
strategy. When designing experiments or planning patient diagnosis, the need to use
radionuclides should always be justified and only the required quantities should be procured (IAEA 1993).
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. Furthermore, the public is becoming increasingly sensitive to disposal of radioactive materials to the environment. This is of concern to the waste producing establishment, both in terms of public perception of their corporate image, and in respect of contributing to sustainable environmental and global development. Some alternatives for waste production include calorimetric or chemiluminescent assays as substitutes for radioimmunoassay , or substitution of radionuclides with shorter half-life, such that the shorter decay times will permit storage for decay and disposal at clearance levels (IAEA 1993).

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 (IAEA 1996).

Waste minimization can be achieved by considering the following fundamental principles:

(1) 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. This includes the selection and control of materials, and the implementation of appropriate procedures. Emphasis should be placed on the segregation of different types of materials to reduce the volume of radioactive waste and to facilitate its management.

(2) Minimizing the spread of radioactive contamination, which leads to the production of radioactive waste. This should be achieved, as far as possible, by maximizing efforts of containment and minimizing the creation of secondary waste. It is desirable to use all means to prevent contamination, provided such measures are economically justified.

(3) As far as it is practicable, separating valuable materials from waste and to clear valuable materials for recycling and reuse. This principle is of limited application in the case of biomedical waste, however it may be appropriate in some circumstances, for example during decommissioning of medical irradiation facilities.

(4) 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.

In particular, practical implementation of waste minimization can be achieved by

minimizing:

__ the activity of the waste by using short-lived radionuclides whenever possible, which can be decayed prior to disposal;

__ the volume of waste, in part by ensuring that non-essential non-radioactive materials are not taken into controlled areas, hence reducing potential cross contamination and the need for decontamination or disposal.

Reduction at source is the most effective step in achieving waste minimization. Proper design may minimize the generation of waste by several orders of magnitude.

2.6.2 Dilution :

Dilution can be considered as the release of radionuclides to the environment (gases or liquids) while maintaining proper clearance levels (Section 8.1) 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. However, in some countries,

the regulatory process authorizes the practice for disposal of wastes to landfill or via a municipal incinerator which may be exempt from further regulatory control. 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. In India this waste is subject to a restriction of a maximum of 500kBq/0.1m3, with a single item limit of 50 kBq whereas in the UK, the limits are 400 kBq/0.1 m3, with a single item limit of 40 kBq. The above limits are increased by a factor of ten where the radionuclide is tritium. Such practices can be carried out only when authorized by the regulatory authority, having due consideration for the environmental impact (IAEA 1996).

The clearance levels proposed by the IAEA [8] will be developed and implemented by Member States following guidance put forward in the revised European Union (EU) Basic Safety Standards Directive [9] in terms of quantities and concentrations of activity per unit mass (kBq/kg). This guidance will be nuclide specific and irrespective of the physical form, and should permit disposals of low quantities to be made without prior authorization, reporting or licensing (IAEA 1996).

2.7 Principles for collection and segregation of waste :

To minimize waste arisings 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 (IAEA 1994).

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.

Segregation of waste at the point of generation is an essential component of the waste
management process. 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. In most instances, it is convenient to segregate wastes according to their half-life, e.g.:

__ wastes with a half-life of about 10 hours or less;
__ wastes with a half-life of less than 10 days;
__ wastes with a half-life of less than 100 days;
__ waste with a half-life of greater than 100 days.
Further considerations for segregation should include such criteria as:
__ Non-radioactive and radioactive materials;
__ Radionuclide and activity content;
__ Physical and chemical form;
__ Spent sealed sources;
__ Non-radiological hazards (toxic, biological, carcinogenic, infectious, flammable, etc.).

2.7.1 Liquid wastes :

Liquid biomedical waste should be collected and segregated in accordance with the
particular procedures accepted at the establishment, considering not only current
requirements, but likely developments in the future [11]. Liquid radioactive wastes that meets clearance levels (Section 8.1) 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, can not be assured, biohazardous radioactive waste must not be discharged directly into a drainage/sewerage system.

Liquid waste should be collected, segregated and characterized, as far as possible at the point of origin according to its physical, chemical, biological and radiological properties.

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;

__ Flammability.

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. For small volumes of immiscible liquids, segregation can be achieved by using simple laboratory equipment (e.g. separating funnel).

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.

Biologically contaminated radioactive liquid waste must be collected separately and
should be treated to deactivate (e.g. autoclaving, chemical disinfection) all infectious
contaminants (IAEA 1994).

2.7.2 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 a moisture sorbent such as vermiculite may be advantageous. Refrigerating or freezing carcasses and similar remains is recommended (IAEA 1994).

2.8 Discharge of waste below the clearance level to environment :

Sources and practices may be removed from the system of regulatory control provided the radiological impact of these practices/sources is sufficiently low as not to warrant any further control. Such removal of sources and practices from regulatory control is called “clearance” (IAEA 1998).

The basic criteria for determining whether sources and practices should no longer be subject to regulatory control are identical to the exemption criteria set out in the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources They are as follows:

(a) the radiation risks to individuals caused by the practice or source should be sufficiently low as to be of no regulatory concern;

(b) the collective radiological impact of the practice or source be sufficiently low as not to warrant regulatory control under the prevailing circumstances; and

(c) the practices and sources be inherently safe, with no appreciable likelihood of scenarios that could lead to a failure to meet the criteria in (a) and (b).

A practice or a source within a practice may be exempted from regulatory control (or cleared) without further consideration provided that the following criteria are met in all feasible situations:

(i) the effective dose expected to be incurred by any member of the public due to the practice or source is of the order of 10 _Sv or less in a year, and

(ii) either the collective effective dose committed by one year of the performance of the practice is no more than about 1 man.Sv or an assessment for the optimization of protection shows that exemption is the optimum option (IAEA 1998).

2.8.1 Clearance level :

Setting clearance levels for the discharge of radionuclides is a difficult process. IAEATECDOC-1000 discusses the clearance of materials resulting from the use

Of radionuclides in medicine, industry and research [8]. This document is a considerable step forward after areview period extending over the last 10 years. It presents both numerical values and a number of conditions to be considered when establishing particular clearance levels, such as:

__ No appreciable likelihood of scenarios that could lead to a failure to meet the criteria (i) and (ii) discussed above in Section 8.1;

__ It is assumed that radionuclides are more or less uniformly distributed throughout a moderate quantity of the material;

__ If more than one radioactive waste producing establishment is discharging into the same environment, the combination should be taken into account;
__ If larger quantities of materials are involved, the clearance levels might no longer be appropriate.
When the predicted exposure from released material is not certain to be trivial, then
disposal at a specialized repository must be considered.
Many countries have previously defined clearance levels for radionuclides which are based on annual limits of intake (ALI) or fractions of ALI or refer to statistically significant differences from background activity. It is the responsibility of the regulatory authority to define clearance levels and site specific discharge authorizations (IAEA 1998).
The recent European Commission approach to the exemption of radiation sources from regulatory control extends the exemption concept to non-nuclear fuel cycle materials and introduces a new clearance approach. These regulations should be mandatory in all European Member States by May 2000.
In the revised Basic Safety Standards Directive, the European Commission sets
minimum requirements for conditions where reporting, licensing, and prior authorization are not needed. The Annex to the Directive contains a list of nuclides with values of quantities (Bq) and concentrations of activity per unit mass (kBq/kg) that are not to be exceeded. More detailed information on existing practices

on exemption in the European Community countries can be found in Reference.

Examples of generic clearance levels for selected radionuclides are provided in Ref. [8]derived for airborne releases, for liquid releases and for moderate quantities of solid waste. In general practice, these levels will usually differ depending on specific site authorizations.

As a rule, local authorities in each country establish clearance levels depending on

location and capacity of facilities. In Russia each facility has a temporary license for a few years with the indication of clearance levels for every radionuclide. In Belgium discharge of liquid releases to drain below 1/100 ALI public/L is allowed without dilution provided ALARA can be demonstrated.

For quality certification of waste to be released, it is necessary to have an appropriate

system for measurement of very low activity in samples of waste. Some commercial

measuring systems have recently been developed for measuring the radionuclide content in medical and biological waste. It has been demonstrated that even low energy _'s such as I bremsstrahlung emitted from packages of radioactive waste containing _ emitters, or even low energy _'s such as 35 S can be measured in plastic waste containers. Isotope characterization by spectrometry allows verification both qualitatively and quantitatively of the presence of particular radionuclides in a

waste container. If a selective collection of isotopes has been made the amount can be measured far below clearance levels in low density waste forms. It is however not possible to detect tritium in waste containers. Procedures and quality control should be sufficient to comply with the usually very high clearance levels for tritium.

The quantitative measurement of initial activity can also result in an optimized choice of the decay period. The decay period of collected waste is generally defined by the rule: “10 half-lives of the longest lived radionuclide present”. Measurements can confirm that this is sufficient to comply with clearance levels. The final clearance measurement should confirm that the residual activity does not exceed release criteria. Attention should be given to long living impurities in short living isotopes such as 114m In (T½ 49 d) in 111 In (T½ 2.7 d).

Generic clearance without authorization, i.e. exemption [30, 31] could be very useful for small users of radionuclides who are normally producing wastes which are bulky but have a very low level of radioactivity. Most hospital facilities will have to apply clearance levels authorized by authorities on a case by case basis, taking into account local conditions and particular scenarios.

A quality assurance programme of radioactive waste flow, including separation and

segregation of waste dependent of half-life of radioisotopes involved, combined with sensitive activity measurement, allows

for waste management to be organized in such a way that clearance levels for waste as non-radioactive can be reached. Risk assessment of potential maximum releases of radionuclides should be prepared to convince the regulatory authority, as well as improve public confidence, that the discharges are environmentally sound (IAEA 2000).

Previous Study :

Arnal Arnal (2000) carried out Streams containing I^{125} coming from radioimmune analysis (RIA) classified as low-medium activity radioactive waste are generated by different treatments applied in “in vitro” techniques. The consequence is an accumulation of solutions containing I^{125} whose storage at sanitary centers poses an important problem. On the basis of the specific activity of the wastes and the dumping authorization of the facility, there are three possible ways of handling: direct discharge, discharge after temporal storage during which the activity of the solution decays, and the management by the authorized company (ENRESA). When the third way is applied, membrane treatment should be considered. Using membranes, important reduction coefficients in

volume, about 10:1, can be achieved. The aim of this work is the declassification of I^{125} solutions as a radioactive liquid waste using membrane techniques (J.M. Arnal Arnal , J.M. Campayo Esteban , J. Lora García , M. Sancho Fernández , I. Iborra Clar , I. Alcaina Miranda , 2000).

Aziz et al , 2002 was study The first use of ionizing radiation in Jordan was in the medical applications when the first Xray machine was installed in a big governmental hospital more than fifty years old, and the solid sealed radiation sources were used in medicine applications (brachytherapy) are the first radioactive wastes generated over the kingdom in the absence of any appropriate national legislation on radiation protection and waste safety. The nuclear energy and radiation protection law was adopted by the Jordanian Parliament in 1987 and authorized the Ministry of Energy and Mineral Resources (MEMR) as the national competent authority to implement the law in co-operation with other national institutions.

details the draft of the regulations on management and safe disposal of radioactive wastes in Jordan which was formulated with the assistance of the IAEA experts and adopted by the national commission on radiation protection and these regulations are in the final stage of approval by the council of ministries according to the law mentioned above.(Aziz et al ,2002).

Banzil et al, 2006 was carried out the Radioactive waste, like many other hazardous wastes, is of great concern in Tanzania because of its undesirable health effects. The stochastic effects due to prolonged exposure to ionizing radiation produce cancer and hereditary effects. The deterministic effects due to higher doses cause vomiting. skin reddening, leukemia, and death to exposed victims. The aim of this paper is to an overview of the status of radioactive wastes in Tanzania, how they are Qenerated and managed to protect humans and the environment. As Tanzania develops, it is bound to increase the use of ionizing radiation in research and teaching, industry, health and agriculture. Already there are more than 42 Centers which use one form of radioisotopes or another for these purposes: Teletherapy (Co-60), Brach-therapy (Cs-137, Sr-89), Nuclear Medicine (P-32. Tc-99m, 1- 31 1125, Ga-67, In-I I , TI-206), Nuclear gauge (Am-241, Cs-137. Sr-901 Kr-85), Industrial radiography (Am-241, C137, Co-60, r92), Research and Teaching 1-125, Am241/'Be. Co-60. Cs-137, H-3 etc). According to 1AEA definition, these radioactive sources become radioactive waste if they meet the following criteria: if they have outlived their usefulness, if they have been abandoned, if they have been displaced without authorization., and if they contaminate other substances. Besides the origin of radioactive wastes, special emphasis will also be placed on the existing radiation regulations that guide disposal of radioactive waste, and the radioactive nfrastructure Tanzania needs for ultimate radioactive waste management. Specific

examples of incidences (theft, loss, abandonment and illegal possession) of radioactive waste that could have led to serious deterministic radiation effects to humans will also be presented(F.P. Banzil, F.M. Bundala 1, P. Msaki 2A.M. Nvandal , 2006).

Elamin et al, 2004 carried out The regulatory framework as established by the Sudan Atomic Energy Commission (SAEC) Act, promulgated in 1996, is described in the report. Three levels of responsibility in meeting radiation protection requirements are established: the Board, the Radiation Protection Technical Committee as the competent authority in the field of radiation protection, and the SAEC Department of Radiation Protection and Environmental Monitoring as the implementing technical body. The report also refers to environmental activities, patient doses in diagnostic radiology, the management of disused sources, emergency preparedness and orphan sources, and the national training activities in the radiation protection field.(O.I. ELAMIN, E.A. HAJMUSA, LA. SHADDAD, 2004)

Steve et al, 2008 was study These calculations were based on the whole-body dose. We also estimated the production of these radionuclides from all naturally occurring elements with atomic numbers less than 84 (Po) in the first wall of a typical fusion reactor, and thereby derived concentration limits for these

elements in first-wall materials, if the first wall is to be suitable for Class-C disposal. In Part II we use the "effective dose equivalent" (EDE), which is a much better indication of the risk from radiation exposure than the whole-body dose, to calculate specific activity limits for all long-lived radionuclides up to Cm-248. In addition, we have estimated the production of long-lived actinides and fission products from possible thorium and uranium impurities in first-wall structures. This completes our study of long-lived radionuclides that are produced from all elements that occur in the earth's crust at average concentrations greater than one part per trillion.(Steve FETTER, E.T. CHENG and F.M. MANN , 2008).

Charles Streeper , 1999 was carried out A lower-activity analogue of the trans-national problem of spent fuel management and disposal is the global problem of radioactive sealed source [source: The IAEA definition of a sealed source is ‘‘Radioactive material that is permanently sealed in a capsule or closely bonded and in a solid form.’’ Taken from glossary of Nuclear Waste Data Management found at http://www-ewmdb.iaea.org/showhelp.

disposal. Sources are found in almost every country in the world because of their beneficial medical and commercial or industrial applications. Some of the isotopes used have short half-livesdiridium-192 (Ir-192), 73.8 days while others have very long half-livesdamericium-241 (Am-241), 432 years or plutonium-239

(Pu-239), 24,130 years. It is critically important, particularly for longer-lived isotopes, to find final disposition pathways. Lack of a permanent disposition pathway such as recycling or irretrievable disposal creates numerous problems, including the potential loss of regulatory control, which increases the risk of inadvertent or deliberate misuse of the material.

The misuse of radioactive materials has the potential for substantial public health and economic damage. Disused sources also pose an inherent risk to the end-users from a liability, safety, and public health perspectives. This paper examines various disposition pathways employed by several key source manufacturing or possessing nation-states for disused sources. Examples of source disposition pathways include long-term storage, deep geological disposal, borehole disposal and shallow land burial. The OffSite Source Recovery Project (OSRP), part of the office of Global Threat Reduction Initiative (GTRI), acts as an intermediary in the recovery and ultimate disposition of US origin sealed radiological materials.

Several concepts that could help mitigate the challenge of a lack of long-term disposition options for sources are available, but these tools have not yet been applied by most nation-states. For example, regional consolidation and repatriation of sources to the country of manufacture would ease or eliminate the need for in situ disposal or storage in a number of developing nation-states (Charles Streeper , Julia Whitwortha , J. Andrew Tompkins , 1999).

Shoukat Khan, 2000 was study the Most of the tertiary care hospitals use radioisotopes for diagnostic and therapeutic applications. Safe disposal of the radioactive waste is a vital component of the overall management of the hospital waste. 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 (Shoukat Khan, AT Syed, Reyaz Ahmad, Tanveer A. Rather, M Ajaz, and FA Jan , 2000).

Hasan et al, 2014 was study The application of radioisotopes and radiation sources in medical diagnosis and therapy is an important issue. Physicians can use radioisotopes to diagnose and treat diseases. Methods of treatment, conditioning and

management of low level radioactive wastes from the use of radiation sources and radioisotopes in hospitals and nuclear medicine application, are described.

Solid Radioactive waste with low-level activity after accumulation, minimization, segregation and measurement, are burned or compressed in a compactor according to the international standards. Conditioned drums are transported to the interim storage site at the Egyptian Atomic Energy Authority (EAEA) represented in Hot Labs & Waste Management Center (HLWMC) for storage and monitoring (M.A.Hasan, Y.T.Selim and Y.F.Lasheen 2014).

Gabriel Borowski , 2013 The paper presents a survey of radioactive waste disposal technologies used worldwide in terms of their influence upon natural environment. Typical sources of radioactive waste from medicine and industry were presented. In addition, various types of radioactive waste, both liquid and solid, were described. Requirements and conditions of the waste's storage were characterised. Selected liquid and solid waste processing technologies were shown. It was stipulated that contemporary methods of radioactive waste utilisation enable their successful neutralisation. The implementation of these methods ought to be mandated by ecological factors first and only then economical ones (Gabriel Borowski , Michal Wosko, 2013).

Chapter three

Materials and Methods

3.1 **Material Used:**

3.1.1 Monitor 4 : Monitor 4 & 4EC / Analog Radiation Detector - a ß y x Detector

Halogen-quenched uncompensated GM tube with thin mica window 1.5-2.0 mg/cm^2 thick. Effective diameter of window is 9.1 mm (.36 in.).

Figure 3-1 & Monitor 4 / Analog Radiation Detector - a ß y x , at Nuclear Medicine department Royal Care

- Easily to use Thermo Scientific ™ FHT 111 CONTAMAT contamination Monitor . it is aclassic “work horse” for the measurement of surface contamination with alpha, beta and gamma isotopes . it is an ideal tool for surface detection in many industries around the world . it is quick and has an extensive memory .

3.1.2. FHT 111 CONTAMAT:

Full specifications:

Description FHT 111 CONTAMAT Contamination Monitor Height 4.4 in Height (Metric) 111 mm .

Depth 8.5 in Depth (Metric) 216 mm

Operating Temperature 14^0 to 122^0F

Stoarge Temperature -13^0 to $+140^0$ F

Operating Temperature (Metric) -10^0 to $+50^0$ C

Weight 2.1 Ib weight (metric) 950 g

Width 5.4 in width (Metric) 138 mm

Air Pressure 700 to 1060 hpa

Battery Life 150 hours of continuous operation with natural background battery type 5 AA cells or 5 NiCd rechargeable cells detectors butane flow type counter tubes with refillable gas reservoir . window area 100 or 166cm2Xenon counter tubes with permanent gas filling , window area 100 or tritium counter tube with refillable gas reservoir .

Display type range 0to 19.999 s-1Bq/cm2 , Humidity up to 90% , non considering item description FHT 111 M Contamat contamination monitor .

Figure 3.2 : Thermo Scientific ™ FHT 111 CONTAMAT contamination Monitor at Nuclear Medicine department Alnilein Centre

3-2 Type of study:

This is descriptive and descriptive study

3-3 Place and time of study:

This study was performed at Nuclear Medicine department of Royal care international hospital and Alnilein Medical Diagnostic Centre – Nuclear Medicine department during the period from (April-2014 up to April-2015).

3-4 Data collection:

The data were collected by Analog Radiation Detector at (RCIH) & Halogen-quenched GM tube at (NMDC) .

Chapter four

Result and Discussion

4.1 Results :

4.1.1: Radiactive Waste measurements:

The objective to this study to manage the waste in nuclear medicine andconsider the Radioactive materials potentially hazardous if they are not controlled. In addition to the controls on the use of radioactive materials, it is very important that the disposal of waste containing radioactive materials is also controlled And the results was as follow :

Table 4.1 show radionuclide and Activity information at Alnilein Medical Diagnostic Centre – Nuclear Medicine Department

NO	Radionuclide & half life	Date of Storage	Measurement of the bag	Disposal date
1	TC^{99m} – 6 hr	07-04-2015	518 KBq/cm^2	11/04/2015
2	TC^{99m} – 6 hr	14-04-2015	113 KBq/c	18/04/2015

			m^2	
3	TC^{99m} – 6 hr	22-04-2015	22.7 KBq/c m^2	26/04/2015
4	TC^{99m} – 6 hr	04-05-2015	20.3 KBq/c m^2	8/05/2015
5	TC^{99m} – 6 hr	11-05-2015	244 KBq/c m^2	15/05/2015
6	TC^{99m} – 6 hr	24-05-2015	760 KBq/c m^2	29/05/2015
7	TC^{99m} – 6 hr	16-06-2015	6.71 KBq/c m^2	20/06/2015
8	TC^{99m} – 6 hr	30-06-2015	7.93 KBq/c m^2	03/07/2015

Table 4.2 show radionuclide and Activity information at Royal Care Hospital – Nuclear Medicine Department

NO	Radionuclide & half life	Date of Storage	Measurement of the bag	Disposal date
1	TC^{99m} – 6 hr	10-01-2015	0.1 KBq/c m^2	15/01/2015
2	TC^{99m} – 6 hr	24-01-2015	0.133 KBq/c	22/02/2015

			m^2	
3	TC^{99m} – 6 hr	01-04-2015	0.1 KBq/c m^2	15/01/2015
4	TC^{99m} – 6 hr	18-04-2015	0.083 KBq/c m^2	25/04/2015
5	TC^{99m} – 6 hr	21-04-2015	0.05 KBq/c m^2	28/04/2015
6	TC^{99m} – 6 hr	24-05-2015	0.05 KBq/c m^2	31/05/2015
7	TC^{99m} – 6 hr	16-06-2015	0.083 KBq/c m^2	04/08/2015
8	TC^{99m} – 6 hr	18-07-2015	0.083 KBq/c m^2	04/08/2015

Table 4.3 show radionuclide and Activity information at Royal Care Hospital – Nuclear Medicine Department

NO	Radionuclide& half life	Date of Storage	Measurement of the bag	Measurement of Disposal date
1	I^{131} – 8 Days	04-12-2014	12.6 KBq/c m^2	25/03/2015
2	I^{131} – 8 Days	24-01-2015	0.133 KBq/c m^2	30/04/2015
3	I^{131} – 8 Days	02-04-2015	1.667 KBq/c m^2	02-07-2015
4	I^{131} – 8 Days	06-05-2015	0.0667 KBq/c m^2	02-08-2015
5	I^{131} – 8 Days	06-08-2015	0.05 KBq/c m^2	10-11-2015

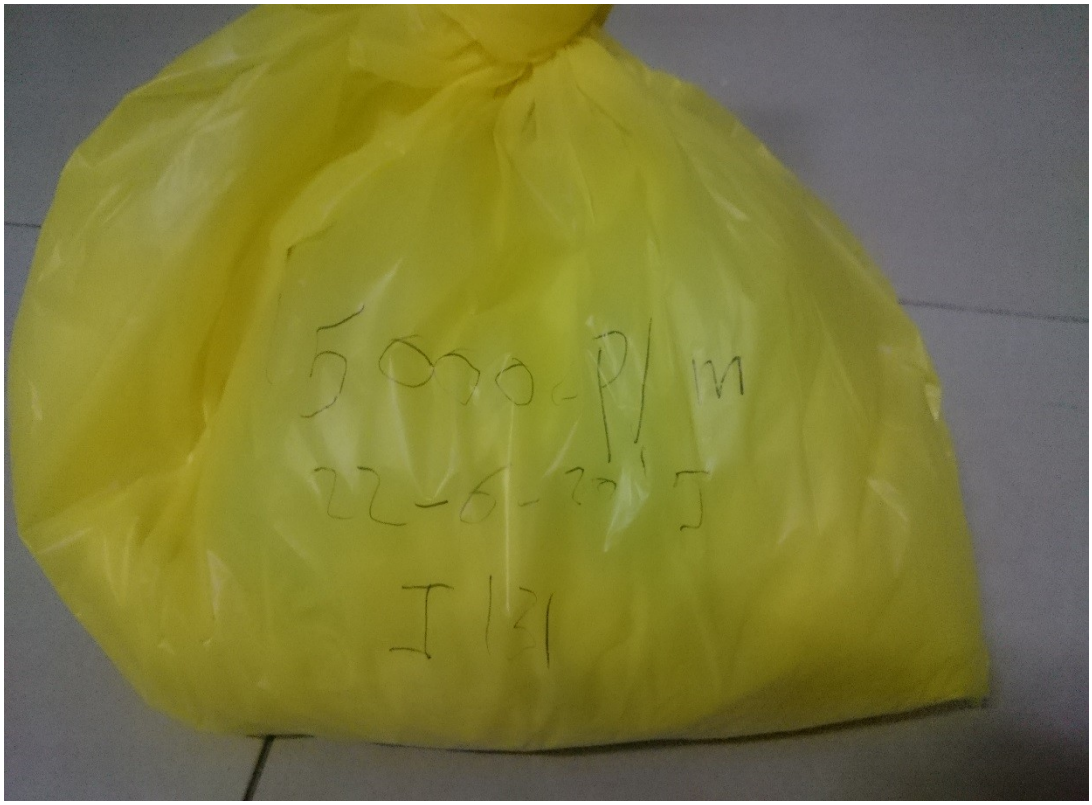

Figure 4.1 show radioactive waste radionuclide and dose information at Royal Care hospital

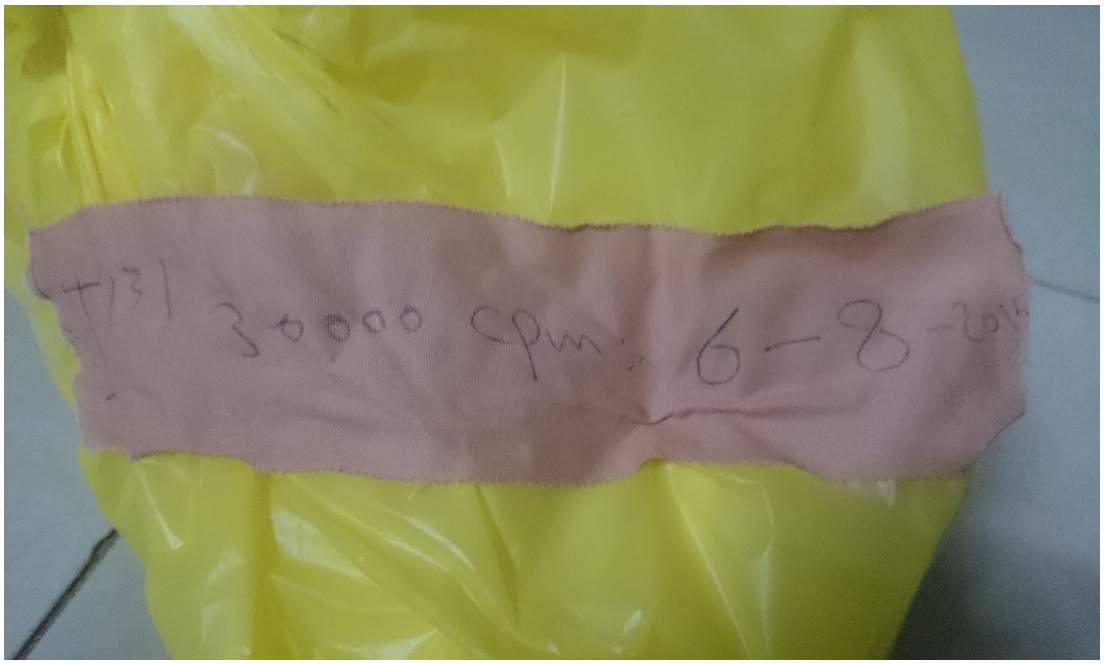

Figure 4.2 show radioactive waste radionuclide and dose information at Royal Care hospital

Figure 4.3 show radioactive waste radionuclide and dose information at Royal Care hospital

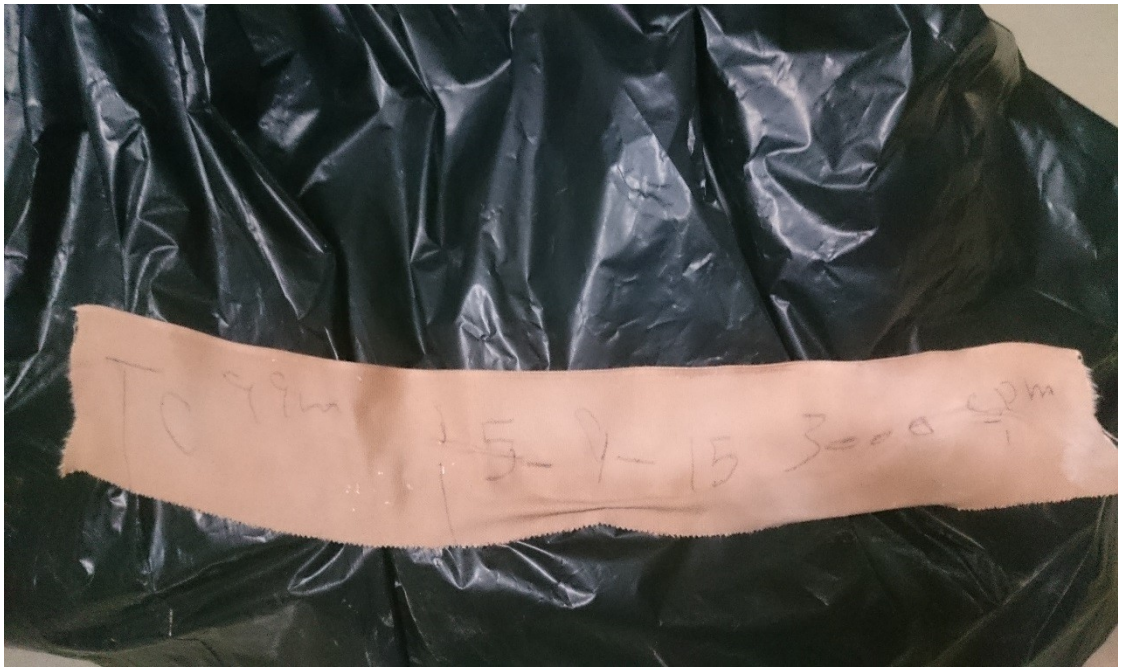

Figure 4.4 show radioactive waste radionuclide and dose information at Royal Care hospital

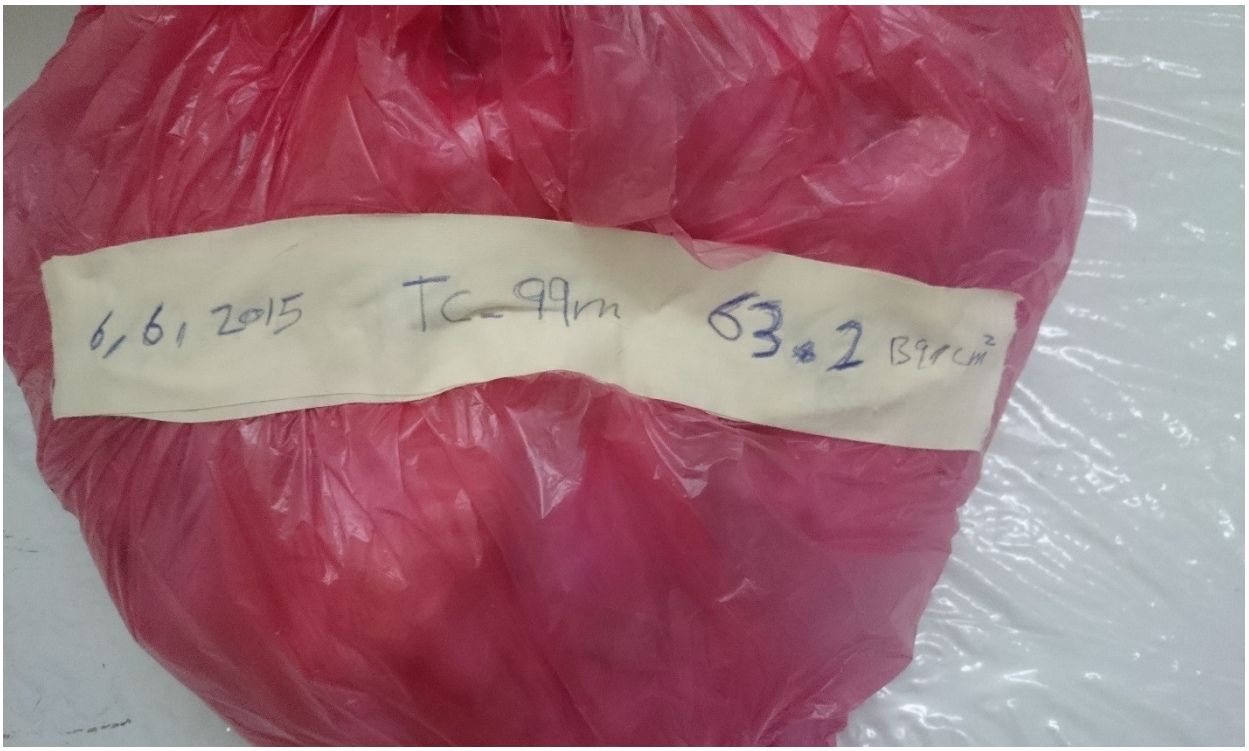

Figure 4.5 show radioactive waste radionuclide and dose information at Alnilein Medical Diagnostic centre

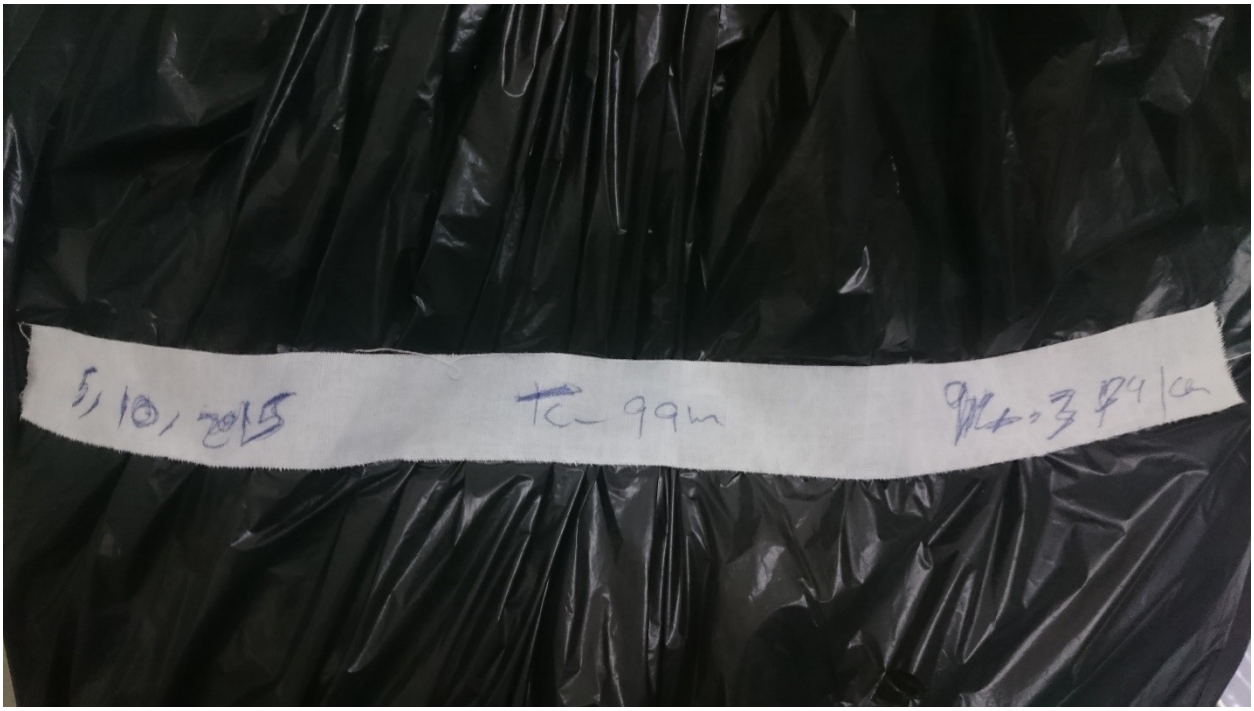

Figure 4.6 show radioactive waste radionuclide and dose information at Alnilein Medical Diagnostic centre

Chapter Five

Discussion, Recommendation and Conclusion

5.1 Discussions:

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, without imposing undue burdens on future generations.

be discharged to the environment or whether it is to be disposed of in a landfill or a specially built facility , a 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 show TC^{99m} Radionuclide half-life, Date of Storage, Measurement of the bag and Measurement of Disposal date in Alnilein medical diagnostic center

Table 4.2 show TC^{99m}Radionuclide half life , Date of Storage , Measurement of the bag and Measurement of Disposal date in Royal care international hospital .

Table 4.3 show I^{131} Radionuclide half life , Date of Storage , Measurement of the bag and Measurement of Disposal date in Royal care international hospital .

In second part in the result it was collection of radioactive waste in one bag regardless of type of radioactive waste (gloves , syringe , vials …etc) without segregation of each type in a bag .

And this situation in the both royal care and alnilein , and the RSO there its not following the International Recommendation in processing of radioactive waste in segregation operation between different component that contaminated by the radioactive material .

Figures 4.1 & figure 4.2 show radioactive waste from I^{131} and they are labeling by radionuclide name and the activity of radionuclide and date of disposal and clearance after 10 half life at Royal Care hospital.

Figures 4.4 show radioactive waste from TC^{99m} and they are labeling by radionuclide name and the activity of radionuclide and date of disposal and clearance after 10 half life at Royal Care hospital.

Figure 4.5 & Figure 4.6 show radioactive waste from TC^{99m} and they are labeling by radionuclide name and the activity of radionuclide and date of disposal and clearance after 10 half life at Alnilein diagnostic center.

And the Disposal here is the final step in radioactive waste management in which radioactive waste is discharged into the environment , without the intention of retrieval and without reliance on long term surveillance and maintenance.

Conditioning of waste involves processes that transform radioactive waste into a form suitable for handling, transportation, storage and disposal. These include immobilization of radioactive waste, placing it in containers and providing additional packaging.

5.2 Conclusion :

This study were done in two hospital Royal Care International Hospital and Alnilein Medical Diagnostic Centre , in RCIH using two types of radionuclide TC^{99m} and I^{131}

Alnilein Medical Diagnostic Center of radionuclide TC^{99m} .

Discharged the radioactive waste to the environment done after 10^{th} half life's ,and the results show that in both hospital the radioactive waste collected in one bag regardless of type of

radioactive waste (gloves , syringe , vials …etc) without segregation of each type in a bag .

The TC^{99m} discharge for the environment after four days for two hospital , and for I^{131} the discharge after Three month .

Waste its not segregation at all and it should be segregated where its generated.

5.3 : Recommendation:

- Waste segregation should occur in the workplace where the waste is generated. Further segregation may be necessary at the waste management facility.
- Waste should be segregated according to the following characteristics.

- Differentiate between Active and Non-Active discharge waste.
- Separate between type of waste according to Radiation types and energies.

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