

## **Management of Low-Level Radioactive Waste from Research, Hospitals and Nuclear Medical Centers in Egypt – 13469**

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### **ABSTRACT**

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.

### **INTRODUCTION**

A wide variety of radioisotopes are being used extensively in hospitals, research and nuclear medical centers in Egypt. As a result, radioactive wastes are generated which should be managed and disposed of with a particular care in order to protect the mankind, the biosphere and the environment from the detrimental effects of ionizing radiation. Law No. 4/1994 is the first Egyptian law for the protection of the environment and mankind from the hazard of ionizing radiation. A new law, Law No.7, was issued in 2010 which also concerned with the protection of the environment (protection of air, water, and ground) from all aspects of pollution, including pollution with dangerous waste as radioactive waste. According to this law, the nuclear safety and radiation control center at the Egyptian atomic energy authority, is separated as the new regulatory body under the supervising of the prime minister.

According to the above laws, the Hot Laboratory & Waste Management Center (HLWMC) at the Atomic Energy Authority has the responsibility of collecting and management of all types of radioactive waste from all Egyptian territory. The usual types of solid radioactive wastes are plastic tubes, papers, gloves, clothes, generators, laboratory glassware, empty containers and some secondary wastes produced during treatment of liquids. Unwanted or spent radioactive sealed sources are also recovered to the HLWMC for conditioning, storing and disposing of.

### **DEFINE THE PROBLEM**

A large portion of Egypt's current production of radioactive waste comes from nuclear medical centers, hospitals and research activates. Egypt had accumulated a significant amount of low level and short lived level radioactive waste over years of research and activities from medical and industrial uses of radioactive materials (Fig.1). The waste accumulation and the mess in the storage facility increased the hazard from dose accumulation and unnecessary exposure to ionizing radiation, absence of suitable working area for management of such waste and increased the biological and infection hazard to workers from sharp waste (needles, broken glass, etc.).

Another important challenge was the waste volume which may cause in future the absence of enough space to collect and store of the radioactive waste. To minimize the risk from such hazard wastes and avoid any future problems, the following measures were taken:

- Clean up the storage facility at the HLWMC which used for storing radioactive waste.
- Minimize and reduction of the waste volume.
- Develop detailed technical procedures for management of all kinds of medical waste
- Preparing a radiological controlled area for segregation of all kinds of radioactive medical waste.
- Minimize the radiation exposure to workers according to the ALARA concept.
- Overcome the biological and infection hazard for workers.
- Secure enough space to continue receiving of such kinds of radioactive waste in future.



**Fig.1. Accumulated waste from past research and medical institutes activities.**

## **APPLICATIONS OF RADIOACTIVE ISOTOPES IN MEDICINE**

Before any clear improvement can be made in radioactive medical waste management, consistent and scientifically based definitions must be established as to what is meant by using radioisotopes in hospitals and nuclear medical centers, what are the types of radioactive waste generated from the activities of these institutes and from research centers and how to manage these wastes according to its physical form and hazard. The applications of various radionuclides (Table-1) in medical diagnoses/treatment and researches are as follows [1]:

## **Diagnostic Applications**

### **In-vitro Radioassay Procedures Using Commercial Radio Immunoassay (RIA) Kits**

The RIA techniques normally use commercially available kits. The work is usually carried out in the designated area of a laboratory with bench coverings and trays providing adequate contamination control. Iodine-125 is the main radionuclide used in such kits. Kits are usually available in packages for 10-100 assays. After the stock expiry date, vials containing I-125 must be kept for decay as radioactive waste. In general the radioactive waste arising from these applications is either liquid or adsorbed onto solid such as tissue papers and polypropylene tubes. Other radionuclides such as H-3, Carbon-14, Phosphorus-32, Cobalt-57 and Selenium-75 etc are also used for RIA.

### **Preparation and/or Dispensing of Radiopharmaceuticals for In-vivo Applications**

Radiopharmaceuticals products are mainly used for in-vivo diagnosis and scanning/scintigraphy. The radionuclides used for imaging work are dominated by Technetium-99m, normally eluted in a sterile environment from a generator containing Molybdenum-99 in a column. Technetium-99m can be prepared in a number of forms appropriate for particular applications. The usual range of administered doses for technetium radiopharmaceuticals is 40-800 MBq. Other columns commercially available for radiopharmaceutical preparations are Tin-113/Indium-113m, Tellurium-132/Iodine-132. Other radionuclides used in scintigraphy include Gallium-67, Selenium-75, Iodine-131, Strontium-85, Xenon-133, Mercury-197, Thallium-201 and Mercury-203 etc.

### **Therapeutic Applications**

Therapeutic applications of radionuclides in medicine utilize a number of unsealed sources in much higher activities than those used for diagnosis. Iodine-131 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 to 11 GBq. Some radionuclides such as I-131, P-32, Sr-89, Yt-90, I-131 etc., are used for therapeutic applications. Radioactive sealed sources, teletherapy and brachytherapy, are also used for cancer treatment.

### **Research Applications**

A wide range of unsealed radionuclides are used for research purposes in biological research, agriculture, chemistry and pharmaceutical development facilities. Isotopes such as H-3, S-35, P-32 and P-33 are widely used for DNA sequencing in research.

## **TYPES OF LOW LEVEL RADIOACTIVE WASTE ARISES FROM HOSPITALS, RESEARCH AND NUCLEAR MEDICAL CENTERS**

Various radionuclides are used in nuclear medicine for diagnoses and treatment like I-125, I-131, H-3, C-14, P-32, Co-57, Se-75, Tc-99m, Ga-67, Sr-89, etc., (Table-1). Because of the wide variety of nuclear applications, the amounts, types and even physical forms of radioactive wastes vary considerably. They include solid, liquid and gaseous wastes. In many instances, the potential additional hazards, either from the chemical, biological or physical properties which are greater than the radiological hazard due to the presence of radionuclide contamination [2].

**Solid Waste:** Radioactive Solid waste mainly consists of used Technetium generators, empty vials, swabs, syringes, gloves, laboratory clothing, bench covers, absorbents contaminated with radioisotopes.

**Table I: Principal Radionuclides Used in Medicine and Biological Research**

Radionuclide	Half Life	Principal Application	Typical Quantity per Application
H-3	12.3 a	Clinical measurements, Biological research Labeling on site	Up to 5 MBq Up to 50 GBq
C-14	5730 a	Medical Biological research Labeling	Less than 1 GBq Up to 10 MBq
F-18	18 h	Positron emission Tomography	Up to 500 MBq
Na-22	2.6 a	Clinical measurements	Up to 50 KBq
Na-24	15 h	Biological research	Up to 5 GBq
P-32	14.3 d	Clinical Therapy	Up to 200 MBq
P-33	25.4 d	Biological research	Up to 50 MBq
S-35	87.4 d	Clinical measurements Medical and biological research	Up to 5 GBq
Ca-45	163 d	Biological research	Up to 100 MBq
Ca-47	4.5 d	Clinical measurements Biological research	Up to 1 GBq Up to 100 KBq
Co-57	271.7 d	Clinical measurements	Up to 50 KBq
Co-58	70.8 d	Biological research	---
Fe-59	44.5 d	Clinical measurements Biological research	Up to 50 MBq
Ga-67	3.3 d	Clinical measurements	Up to 200 MBq
Sr-85	64.8 d	Clinical measurements Biological research	Up to 50 MBq
Y-90	2.7 d	Clinical therapy and measurements Medical and Biological research	Up to 300 MBq
Nb-95	35.0 d	Medical and biological research	Up to 500 MBq
I-123	13.2 h	Medical and biological research	Up to 500 MBq
Tc-99m	6.0 h	Clinical measurements, Biological research Nuclide generators	Up to 1GBq
In-111	2.8 d	Clinical measurements Biological research	Up to 500 MBq
I-125	60.1 d	Clinical measurements Biological research	Up to 500 MBq
I-131	8.0 d	Clinical measurements Clinical therapy	Up to 10 GBq
Sn-113	155.0 d	Medical and biological research	Up to 500 MBq
Xe-133	5.3 d	Clinical measurements	Up to 400 MBq
Sm-153	19 d	Clinical measurements	Up to 8 GBq
Au-198	2.7 d	Clinical measurements	Up to 500 MBq
Tl-201	3.0 d	Clinical measurements	200 MBq
Hg-197	2.6 d	Clinical measurements	Up to 50 MBq

**Liquid Waste:** Liquid waste includes washing from active labs, excreta of patients injected/ingested with radiopharmaceuticals, surplus solutions of radionuclides from diagnostic, therapeutic and research applications which are likely to be sterile, aqueous based solutions containing low levels of radionuclides, e.g. from washing of apparatus, and organic based solutions which may or may not be miscible with water, e.g. liquid scintillation counting residues and residues from organic synthesis

**Gaseous Waste:** Gaseous waste generally includes working with, tritium and tritiated water, iodine, krypton-81m and xenon-133.

### **Non-Radiological Hazards**

The non-radiological hazards of biomedical radioactive waste can be divided into the following categories:

**Physical Hazards:** Physical hazards include the possibility of cuts and puncture injuries such as those from needles, broken glass, scalpel blades or blood lancets (sharps). Physical hazards will also include injuries sustained as a result of manual handling of heavy objects such as shielding, containers, etc.

**Chemical Hazards:** Chemical hazards include the potential for adverse chemical reactions or injuries which may be posed by the presence of acids, alkalis, oxidizers or oxidizable organic matter. These hazards may be associated with liquid or vapors containing dangerous chemicals. Chemical hazards may arise from the mixing of incompatible wastes.

**Biological/Infectious Hazards:** Any waste generated in a health care facility which is contaminated with human blood, other body fluids, or any potentially infectious material is determined as “biohazardous”. When handling any biohazardous waste, Universal precautions should be observed. Universal Precautions are an infection control concept which assures that all human blood, body fluids or other biohazardous wastes are treated as if they are infected with HIV, Hepatitis B virus or other biohazardous pathogens.

Animal carcasses and human pathological remains are also sources of biological and/or infectious hazards, and again must be handled using Universal Precautions. Universal Precautions involves use of protective equipment and standard operating procedures to protect the health of the worker. These precautions include: hand washing, wearing of disposable gloves, use of protective gloves, and use of face masks, protective eye glasses, etc. Personnel routinely handling radioactive waste containing biohazardous biomedical waste should be offered appropriate immunization and testing for diseases such as hepatitis B and tuberculosis [3, 4].

## **GENERAL SAFETY CONSIDERATIONS**

The following general safety considerations should be applied while managing radioactive waste from hospitals, research and nuclear medical centers [5]:

- Exposure to ionizing radiation should be kept as low as reasonably achievable (ALARA).
- Handling and management of radioactive waste should be carried out in suitably ventilated and access controlled areas.

- Clearly defined and documented working procedures for the management and disposal of radioactive waste approved from HLWMC should be practiced.

## **MINIMIZATION OF RADIOACTIVE WASTE**

An essential component of radioactive waste management is to minimize the generation of radioactive waste as practicable. The waste minimization will reduce the activity and the volume of waste for collection, storage and disposal and as a result will reduce the management cost and environmental impact. The waste minimization can be achieved by considering the following fundamental principles:

- i. Keeping the generation of radioactive waste to the minimum practicable, in terms of both its activity and volume.
- ii. Minimizing the spread of radioactive contamination, which leads to the production of radioactive waste.
- iii. Separating non-radioactive material from radioactive waste as practicable
- iv. Using short lived radionuclides instead of long-lived radionuclides.
- v. Procuring minimum quantity of radioactive material to be used for each application.
- vi. Avoiding unnecessary duplication of radionuclide procurement and its use.
- vii. Minimizing the amount of radioactive waste once it has been created through optimizing the use of available treatment technology.

### **Segregation of Radioactive Waste**

Another essential component of radioactive waste management process is segregation of radioactive waste. The segregation of radioactive and non-radioactive waste should be applied at the point of origin. The segregation of radioactive waste should be based on:

- i. Non-radioactive and radioactive
- ii. Half-lives of the radionuclides (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; and waste with a half-life of greater than 100 days)
- iii. Activity contents
- iv. Physical and chemical form

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:

- i. Radionuclide content and activity
- ii. Half-life of radionuclides and suitability for decay storage
- iii. Organic/aqueous liquids
- iv. Non-homogeneity of waste (sludge)
- v. Infectious hazard;
- vi. Chemical hazards;
- vii. Flammability.

## **MANAGEMENT STRATEGY OF RADIOACTIVE WASTE**

There are two principal ways to deal with the radioactive waste. In the first method, waste containing radioactive materials with short half- lives is stored under controlled conditions until it has decayed to background level so that controlled release to the environment can be carried out. In the second method, the waste containing radioactive materials with long half-lives is disposed of in special disposal facility, after conditioning and converting to acceptable waste form for disposing of.

### **General Principles of Waste Management**

A clear facility policy for waste management should be available for proper implementation of a waste management system. The policy should describe in detail the methods of waste segregation, collection, storage, and disposal, according to the resources available in each health facility.

Roles and responsibilities of the different team members responsible for waste management should be clarified. One main person should be assigned to be responsible for waste management in each facility.

All used sharps must be discarded without re-sheathing in a puncture resistant container that is readily accessible. All clinical waste, e.g., waste contaminated with blood and/or bloody fluids, should be discarded into a colored bag (e.g. red or yellow).

A room for interim storage of radioactive waste should be available. Each type of waste should be kept in separate containers properly labeled to supply information about the radionuclide, activity concentration etc. Flammable goods should be kept apart.

Records should be kept where the origin of the waste can identify.

## **CONDITIONS OF THE RADWASTE STORAGE ROOM**

The radioactive waste storage room should include the following features [6];

- Storage site should not be accessible to unauthorized personnel (control of animals should not be overlooked).
- It should be of sufficient size and solely used for storing the radioactive waste.
- Method of storage should prevent accidental releases to the surroundings.
- Records of wastes stored must be kept to ensure that the storage facilities are not overloaded.
- The room should be so chosen as to minimize the hazards arising from flooding and fire accident, be well illuminated, either by natural or artificial light, and be properly ventilated.
- The room should be properly marked with conspicuous signs stating that radioactive wastes are stored there and used only for the storage of radioactive wastes.
- Periodic inventories of the containers should be performed and recorded, e.g., regular inspection of liquid containments to ensure that leaks have not occurred.

- 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.
- Appropriate monitoring devices (radiological, chemical and physical) should be provided as needed.
- Appropriate inventory/log book of stored waste should be maintained.
- Provision for floor protection should be made in the event of accidental floor contamination.
- 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. These flammable wastes should be stored in a specific area of the facility that is physically separated from the other wastes and equipped with a high quality fire detection and suppression system.
- The consumption and dispersion of radioactive substances via insect/rodent excretions can result in the spread of both radioactive contamination and potentially infectious materials. Any defects in construction materials and the door storage facility should be repaired. Commercially available poisons, often in prepared trays, are available and should be placed both within and outside the radioactive waste storage facility.
- Contaminated clothing should not be released to a public laundry. These items should be segregated into batches, as: 1) to the different radionuclide contaminants, and 2) the date of their storage-to-decay, to avoid cross-contamination. They are stored until the radioactivity has fall into safe levels. If the clothing, linen, etc. cannot be decontaminated to a safe level it should be treated as radioactive wastes.

## **TECHNICAL PROCEDURE FOR MANAGEMENT OF SOLID WASTE**

**Segregation:** The segregation of radioactive waste arises from medical and nuclear centers require using of suitable containers (strong bins) throughout the working area to segregate discarded radioactive material. 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. The containers should be puncture-resistant and leak proof on three sides, e.g., tin cans with lids, or plastic bottles
- The container should be labeled with the radiation symbol.
- 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 clasp against the body. Bags must never be thrown or deliberately dropped during handling operations;
- Proper shielding should be provided for the containers to keep the radiation level within limits i.e., 10  $\mu\text{Sv/h}$ . However, efforts should be made to maintain ALARA.
- Waste bags and sharps containers should be discarded when they become three quarters full and at least once daily or after each shift. The reason for this is to reduce the risk of



plastic bags splitting open and of an injury from a protruding sharp item in sharps containers.

- In case of treatment by incineration, heavy duty cardboard, waxed cardboard or polyethylene/polypropylene containers, clearly labeled as sharps containers, should be used to collect these wastes.
- 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
- Never put hands into a container that holds medical waste

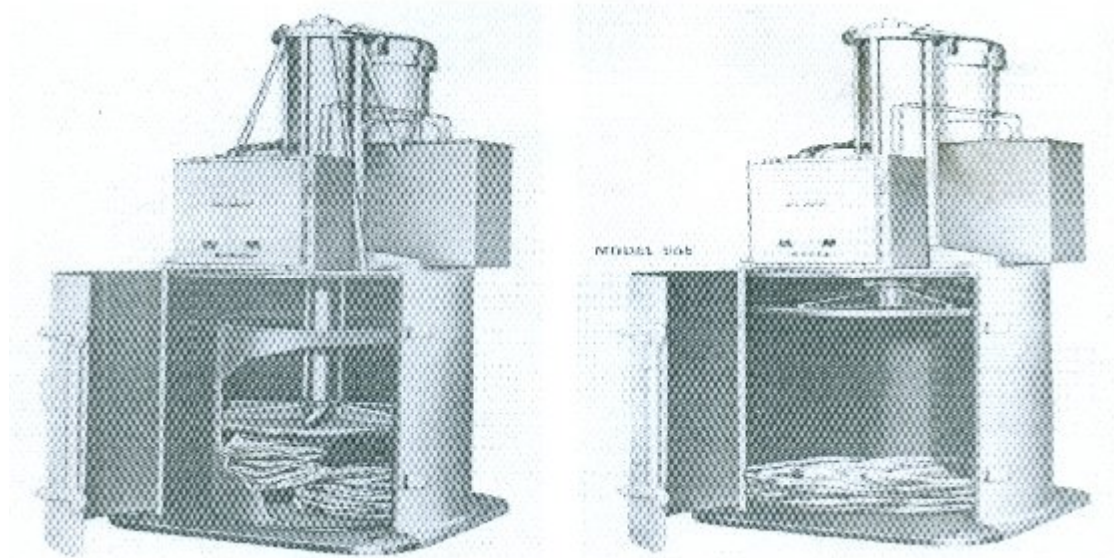
**Storage:** The storage for decay is particularly important for radioactive waste resulting from medical/research uses of radionuclides. Many of the radionuclides used are of small activities and short lived.

- The radioactive waste should be stored for decay purposes until the activity decays to the background level and can be considered inactive for final disposal as normal waste.
- The storage for decay is suitable for wastes containing radionuclides with half-lives of less than or equal to 100 days. At activity concentrations of 3.7 to 37 MBq/m<sup>3</sup> (0.1 to 1 mCi/m<sup>3</sup>), storage for decay purpose of ten half-lives is sufficient as it reduces the initial activity down to 1/1000.
- 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 treatment, conditioning and disposal.
- For the storage of radioactive waste, strong containers (e.g. Iron drums) with appropriate shielding to achieve ALARA should be used for each radionuclide. However, different radionuclides having almost same half-life can be stored in one container for decay purposes.
- The collected radioactive waste (plastic bags) should be shifted to these containers (e.g. Iron drums) for decay. Each container should be marked with the name of radionuclide and radiation symbol as well as the date of storage.
- In general, the radionuclides having half-lives up to 3 days (e.g. Tc-99m ) should be stored for three months and radionuclides having half-lives up to 10 days (e.g. I-131, Tl-201, Ga-67 and Mo-99) should be stored for six months
- Radionuclides with half-lives more than 10 days should be stored for at least 10 half-lives as specified above

**Treatment:** Compaction and shredding as a mechanical treatment method alone are not considered viable or major radioactive biomedical waste treatment methods. The primary reason for this restriction is that any microorganisms contained within the waste may be spilled or released during these processes and contamination may be widely dispersed. Mechanical processes are often combined with chemical treatment to disinfect or sterilize the waste (Fig. 2).

Incineration is the most important treatment method for biomedical radioactive waste. The HLWMC is working on installing a new incineration for low level medical radioactive waste. Incineration uses controlled, high-temperature combustion to destroy organics in the waste

materials. It is the preferred method of treating biomedical wastes including medical radioactive wastes because it produces a totally sterile residue with stack emissions being kept to acceptable environmental standards.



**Fig.2. Typical in-drum compactor and crusher used at a centralized facility for compaction of solid radioactive waste.**

Modern incineration systems are well-engineered processes designed to completely and efficiently burn the waste whilst producing minimum emissions.

- Incineration not only sterilizes medical waste but also provides volume and weight reductions of greater than 90 percent. This process converts obnoxious waste, such as biomedical waste, to innocuous ash and renders sharps
- If the activity of the ash does not exceed clearance levels, then it can be disposed of in a landfill. In exceptional cases when this practice is not appropriate for the given type of incinerator, the wastes may be chemically neutralized and fixed in concrete for final disposal.
- Some types of incinerators may treat solid as well as small amounts of liquid radioactive wastes that are collected at various medical centers and research institutes.
- Three products are produced from the incineration operation — ash, soot and condensate. The average radionuclide partitioning is 90–95% for ash, 1–5% for soot and 0.1–2.0% for condensate.
- The use of volatile radionuclides in a fume cupboard or extraction cabinet, such as radio-iodine or tritium compounds or solutions, results in release of vapors which are usually trapped on a charcoal or HEPA filter. The filters are changed periodically and are stored to decay prior to disposal in the incinerator at clearance levels.

**Disposal:** Disposal means the emplacement of waste in an approved specified facility (for example, near surface or geological repository) without the intention of retrieval ("confine and contain"). Disposal may also include the approved direct discharge of waste into the environment (as normal waste) after decay to the regulatory non-radioactive limits.

After ensuring that the radioactive waste has completed its decay period, the radioactive waste can be disposed of as normal waste after monitoring its residual activity. All the radiation symbols, if any, should be removed from the radioactive waste packages (plastic bags) before disposal as normal waste. The waste disposal record should be properly maintained.

The radioactive waste generated due to RIA applications should be disposed of as normal waste after properly measuring its residual activity [7].

### **PROCEDURE FOR MANAGEMENT OF SPENT TECHNETIUM GENERATORS**

- The remains of Mo-99 generators require a longer period of time before it can be considered non-radioactive.
- 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.
- When dismantling the generators, keep a radiation detection survey meter "on" at the work area. Dismantle the oldest generators first, then work forward chronologically (Fig.3).
- Hold each individual column in contact with the radiation detection survey meter in a low background ( $< 0.5 \mu\text{Sv/hr}$ ) area. If the survey meter reading could not be distinguished from background, the column could then be discarded as an ordinary waste.
- 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. Remove or deface the radiation labels on the generator shield before disposal.
- Assume a generator with 20 GBq Mo-99 at reference time. The half-life of Mo-99 is 2.75 d and the exemption activity is 1 MBq (BSS). The time for interim storage should then be 40 d. The dose rate at 1 m from the unshielded column will then be  $0.04 \mu\text{Sv/h}$ . Hence, the external exposure will be very small when dismantling the generator.



**Fig.3. Procedure for management of spent Tc-generators.**

## CONCLUSION

Modern day hospitals are increasingly using radioisotopes for diagnostic and therapeutic applications. All of this will lead to an increase in the amount of radioactive hospital waste. This waste will have to be conditioned and disposed of in accordance to the guidelines provided by the International Atomic Energy Agency (IAEA) and regulated by national regulatory body of Egypt. An effort within the National legal framework will ensure that the radiation exposure to humans and environment remains within the permissible limits. Safe disposal of the radioactive waste is a vital component of this effort.

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