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RADIOACTIVE WASTE IN NUCLEAR MEDICINE

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Outline

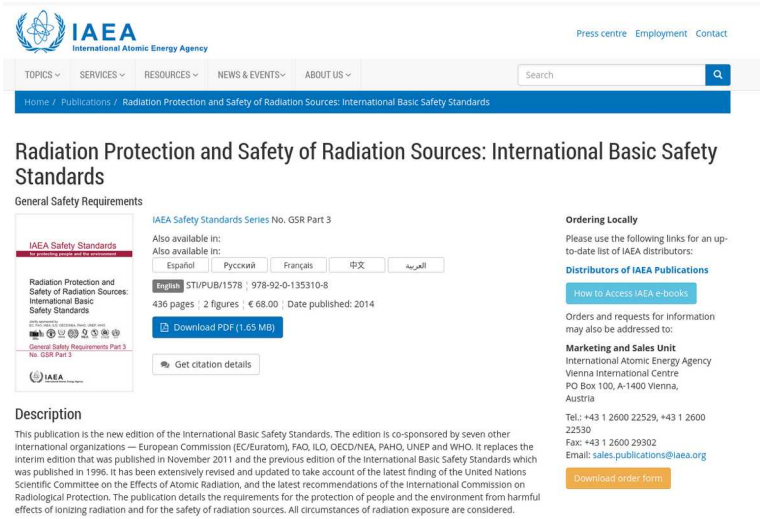
- Definitions
- Where is the waste produced ?
  - Preparation of SPECT radiopharmaceuticals
  - Synthesis of PET radiopharmacuticals
  - Administration of radiopharmaceuticals
  - Patient care
  - Patient excretions
- Waste collection and storage
- Concurrent risks

What do the BSS say ?

From IAEA GSR Part 3 (the BSS)

Requirement 31: Radioactive waste and discharges

Relevant parties shall ensure that radioactive waste and discharges of radioactive material to the environment are managed in accordance with the authorization.



https://www.iaea.org/publications/8930/radiation-protection-and-safety-of-radiation-sources-international-basic-safety-standards

Definitions From IAEA GSR Part 3 (the BSS)

Radioactive waste: For legal and regulatory purposes, material for which no further use is foreseen that contains, or is contaminated with, radionuclides at activity concentrations greater than clearance levels as established by the regulatory body.

Radioactive waste management: All administrative and operational activities involved in the handling,pretreatment, treatment, conditioning, transport, storage and disposal of radioactive waste.

Predisposal management of radioactive waste: Any waste management steps carried out prior to disposal, such as pretreatment, treatment, conditioning, storage and transport activities.

Processing: Any operation that changes the characteristics of waste, including pretreatment, treatment and conditioning.

Storage: The holding of radioactive sources, radioactive material, spent fuel or radioactive waste in a facility that provides for their/its containment, with the intention of retrieval.

Disposal: Emplacement of waste in an appropriate facility without the intention of Retrieval.

Radioactive waste management facility: Facility specifically designed to handle, treat, condition, store or permanently dispose of radioactive waste.

Definitions From IAEA GSR Part 3 (the BSS)

Facilities and Activities

A general term encompassing nuclear facilities, uses of all sources of ionizing radiation, all radioactive waste management activities, transport of radioactive material and any other practice or circumstances in which people may be subject to exposure to radiation from naturally occurring or artificial sources.

- 'Facilities' includes: nuclear facilities; irradiation installations; some mining and raw material processing facilities such as uranium mines; radioactive waste management facilities; and any other places where radioactive material is produced, processed, used, handled, stored or disposed of — or where radiation generators are installed — on such a scale that consideration of protection and safety is required.
- 'Activities' includes: the production, use, import and export of radiation sources for industrial, research and medical purposes; the transport of radioactive material; the decommissioning of facilities; ***radioactive waste management activities such as the discharge of effluents***; and some aspects of the remediation of sites affected by residues from past activities.

Preparation of SPECT radiopharmaceuticals

Several radioactive waste are produced during SPECT radiopharmaceuticals preparation:

- Vials with residual of radiopharmaceuticals
- Syringes used during the manipulation and labelling
- Flasks and bottles of physiological solution, potentially contaminated
- Gloves
- Paper sheets (absorbing / sterile / lint free ...)

In many cases, these waste can be collected in containers that are placed directly within the manipulation hot cell:

- These containers should be idoneous for collection of sharp waste
- Removal of wastes container from the cell may be an hazardous operation

SPECT radiopharmaceuticals preparation

Other waste include

- Vials with residual of ready to use radiopharmaceuticals (^{131}I, ^{111}In, ^{67}Ga, ^{90}Y,…)
- Non used ^{131}I capsules

The latter should be maintained within their shielded container and stored within a shielded cabinet / cell, but separatley from non expired radiopharmaceuticals. After a waiting time to allow for some decay, they can be discarded in the appropriate radioactive waste container

- Expired ^{99}Mo/^{99m}Tc generators

After removal from the hot cell, these should be stored in the temporary radioactvive wastes storage, until retirement by the supplier or transport to a waste depot

SPECT radiopharmaceuticals preparation

Example of container for sharps, placed inside a shielded hot cell.

The operator can dispose of contaminated items in a "well" on the workbench surface, and they fall for gravity in the underlying container

PET radiopharmaceuticals preparation

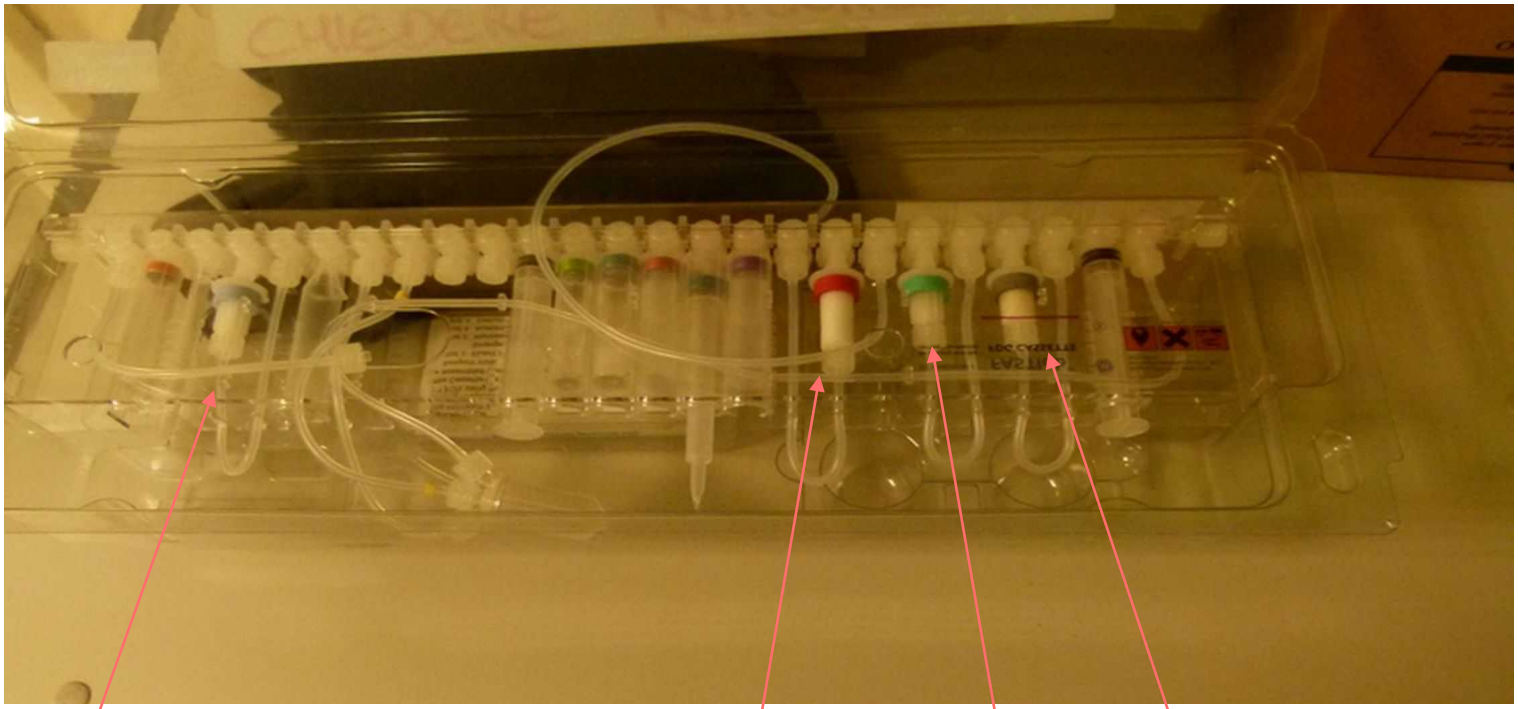
Waste is produced in the synthesis of PET radiopharmaceuticals as well:

- Vials with residuals of radiopharmaceuticals
  Syringes used during the preparation and QC
- Ion exchange columns used in the synthesis modules / cassettes
- Vent needles / filters
- Gloves

Typically :

- Practically all of these waste, apart ion exchange colums, can be collected and discarded as conventional waste after 24 hours
- Ion exchange columns typically contain small traces of long lived radionuclides (e.g. ^{54}Mn, ^{57}Co, ...) coming from the targte / foils. Columns should be collected separatley in a container for waste with moderately long $T_{1/2}$
- In the synthesis of radiopharmaceuticals with ^{68}Ga the columns can contain measurable activities of ^{68}Ge

Example of synthesis cassette



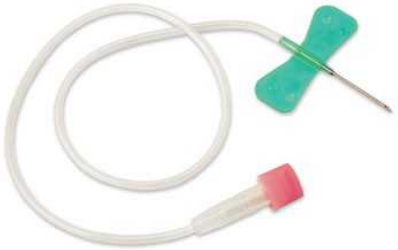
Ion exchange columns can easily been removed from the cassette and diposed separatley in a container for waste with moderately long $T_{1/2}$

PET generators

- ^{68}Ge, $T_{1/2}$ = 279.95 d , at equilibrium with daughter ^{68}Ga, $T_{1/2}$ = 68 min
- Initial activity 1850 or 1110 MBq
- Period of use: 9 months (typical)

Administration of radiopharmaceuticals

Waste produced during administration procedures:



- Syringes used for patient injection
- “butterfly” needles and connecting tubing
- Three way connectors
- Cotton swabs
- gloves
- In the case of Iodine-131, plastic or paper cups used in oral administration

In many cases, these waste have a very short half life:

- ^{99m}Tc and ^{18}F can be collected in a container for hospital waste and discarded as such, after a short waiting time (24 – 72 hours).
- Particular attention should always be given to sharp waste: idoneous containers, certified to resist to perforation by needles, should always be used; transferring waste form one container to another should be avoided.

Patient care and assitance

Patients are “unsealed” radiation sources …

During patient care, operators should always wear working clothes e ALWAYS wear gloves.

Patients may contaminate several items:

- Their own clothes
- Catheters, urine bags, other medical devices
- Diapers

- In the case of inpatients treated with ^{131}I, dishes, cutlery, cups, sheets and blankets etc. maybe contaminated as well.

All of these should be collected as radioactive; disposable items should be managed as radioactive waste.

Particular attention should be given to elderly and pediatric patients.

Patients excreta

Urine and feces are in general contaminated and should be considered as radioactive waste:

• Diapers and urine bags

• In some Countries, depending on local legilsation, the number of patients, type of radionuclides and total water consumption (dilution), it may be necessary for the NM Department to have special collection tanks that allow discharge in the sewage system after decay time (and sampling)

• When in-patients are transferred to other departments, dilution due to distribution in the diferent areas of the hospital makes the radioactive concentration in waste negligible. Storage tanks may be requested only in the NM, that collects many patients.

Patients excreta

From IAEA SSG-46, par. 4.280

Patients' excreta, such as urine containing ^{131}I:

- For diagnostic patients, in the majority of cases there is no need for the collection of excreta and ordinary toilets can be used.

- For therapy patients, policies vary in different Countries, but in principle the approaches used follow the dilution or decay methodologies (e.g. either by collecting and storing excreta or by designing facilities with drainpipes terminating in a delay tank).

- In most situations, it is better to dilute and disperse the waste activity in a continuous sewerage system, rather than concentrate and store excreta for decay.

- Precautions may be required where sewerage systems allow rapid processing of effluent with subsequent mixing with river water or usage for irrigation of land used for growing vegetables

Decay tanks - sizing estimate

Different approaches are possible in order to calculate the number and volume of decay tanks.

The necessary parameters are:

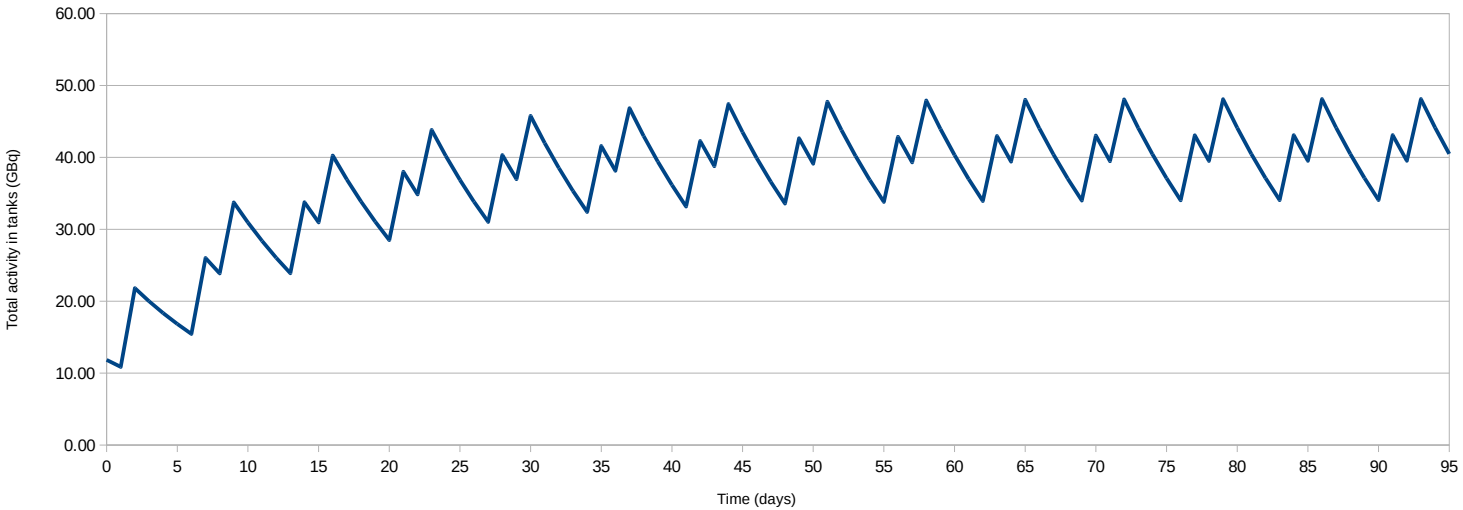
- Typical activity administered and physical half-life of the radionuclide
- Fraction of activity excreted in urine
- number of patients treated in a week and average length of hospitalization
- Average water consumption per person in one day (very variable in different regions)
- Concentration limit for discharge (Bq/cm^3)

The output results are:

- total volume needed
- number of tanks

Decay tanks - sizing estimate

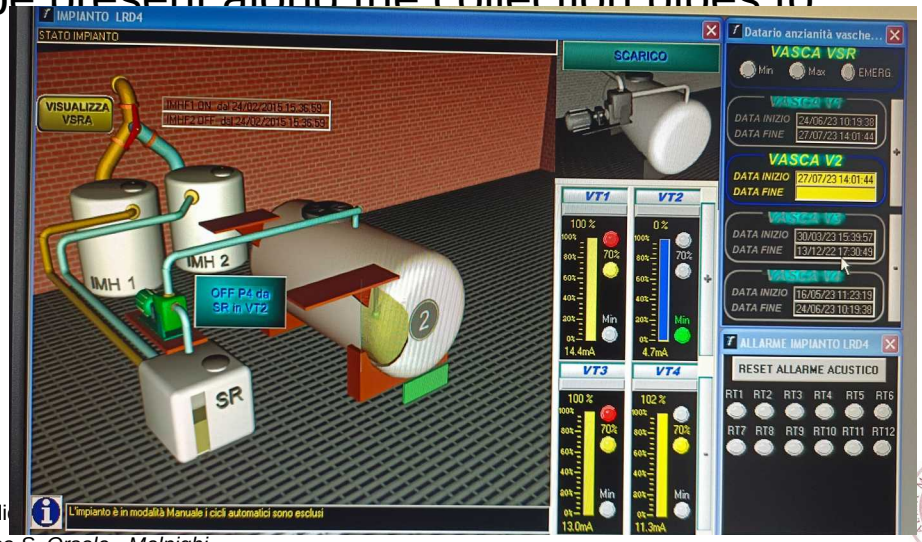
A calculation method, based on a recursive calculation, is illustrated, also with an example, in the IAEA document TecDoc 1714 (*note that this method is not an IAEA recommendation: different approaches are equally feasible*).



Decay tanks

A decay tank system is typically composed of:

- two himoff type separators (to separate the solid component from the liquid one)
- a number of tanks of adequate volume, with filling level sensors
- the tanks should be placed inside a containment system (pool), capable of containing any spills.
- lifting pumps, connection pipes and shut-off valves, designed to bypass each tank in case of problems
- an equipment for sampling and controlling the concentration of radioactivity before discharge into the sewer system
- Furthermore, inspection points must be present along the collection pipes to allow any blockages to be resolved



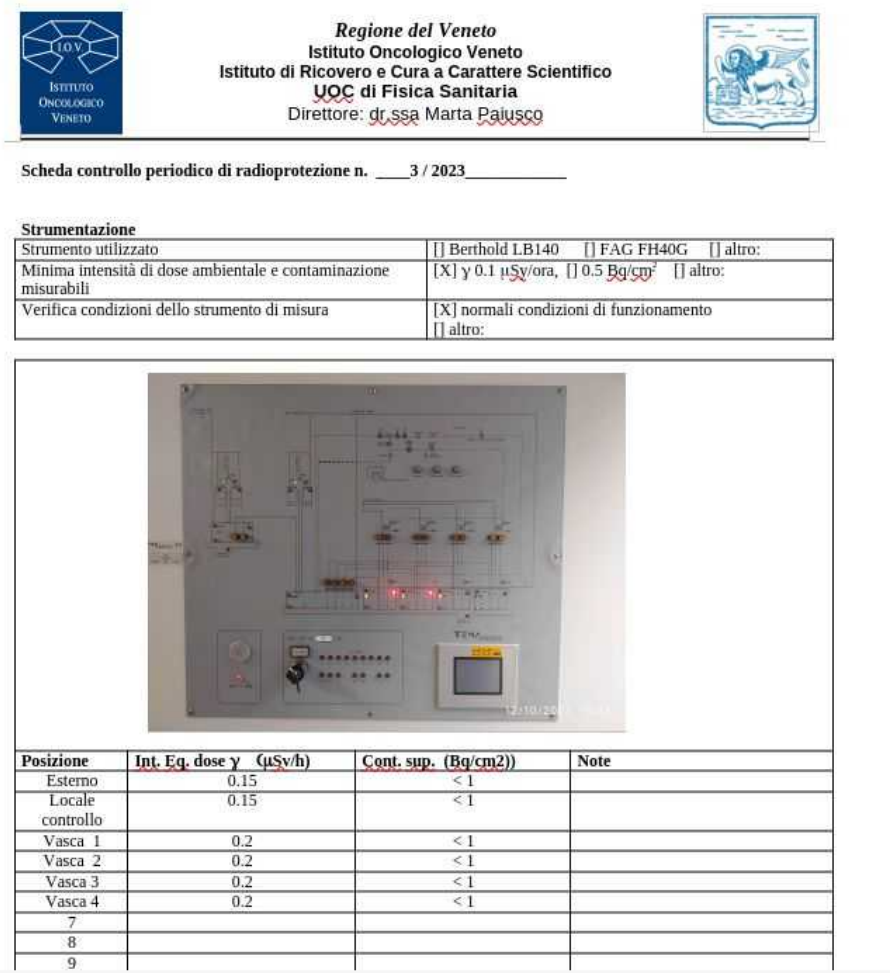
Decay tanks – radiation protection and safety

Decay tank systems require physical surveillance of radiation protection.

Beyond ambient dose and surface contamination levels, the following must be kept under control:

- which himoff separator is in use and the closing date of the other, in order to plan its emptying (using vacuum trucks)
- tank filling level and time (to identify any water leaks)
- maintenance status of pumps and valves.
- ...

Furthermore, spaces housing decay tanks may be confined spaces within the meaning of Directive 89/391/EEC and related. There may be risks of falling, suffocation ... a specific risk assessment is required.



Regione del Veneto
Istituto Oncologico Veneto
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UOC di Fisica Sanitaria
Direttore: dr.ssa Marta Paiusco

Scheda controllo periodico di radioprotezione n. ___3 / 2023_____

Strumentazione

Strumento utilizzato	[] Berthold LB140 [] FAG FH40G [] altro:
Minima intensità di dose ambientale e contaminazione misurabili	[X] γ 0.1 µSv/ora, [] 0.5 Bq/cm² [] altro:
Verifica condizioni dello strumento di misura	[X] normali condizioni di funzionamento [] altro:

Posizione	Int. Eq. dose γ (µSv/h)	Cont. sup. (Bq/cm2))	Note
Esterno	0.15	< 1	
Locale controllo	0.15	< 1	
Vasca 1	0.2	< 1	
Vasca 2	0.2	< 1	
Vasca 3	0.2	< 1	
Vasca 4	0.2	< 1	
7			
8			
9			

Alternative to decay tanks

Example of a commercially available toilet system that can be connected directly to the sewage system. It includes two different stages of filtration:

- pre-filtration of excrements and toilet paper
- the filtration of radioactivity and medicinal residues

Such type of system is easy to install, almost plug&play, and avoid the investment for tanks.

However, the cost of cunsumables (replacemente filter cartridges) must be considered.

Example of assessment of the activiy released by a capsule

Let us consider opening a ^{131}I capsule container under a fume hood that <u>has not specific filters</u>

Capsule activity	3700	MBq
	3.70E+09	Bq
Max release factor	3.00E-05	
Max activity released	1.11E+05	Bq
Extraction air flow	30	m^3/h
	30000	dm^3/h
Time of operation	0.25	hour
Max activity concentration	14.8	Bq/dm^3

US Department of Energy. DOE-HDBK-3010-94 Volume I (Reaffirmed 2013), Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities, Volume I .

consider dm^3 since, given the density of air, it is ~ 1 kg

Bio-assay Laboratories

In Radioimmunoassay and in some research laboratories there is production of radioactive waste:

- Vials with residual of radioadiagnostic products
- Syringes used in the manipualtioni
- Tubes and vials of samples
- Micropipettes tips
- gloves
- Absorbing paper
- Some liquid waste (supernatant liquid on top of RIA tubes)

Most used radionuclides:

- ^{125}I, $T_{1/2}$ = 60 days
- ^{3}H, $T_{1/2}$ = 12.3 year
- ^{32}P, $T_{1/2}$ = 14.3 days

The waste produced should be delivered to a collection facility or to a company authorized for collection and disposal

Sealed sources

Several types of sealed sources are used in Nuclear Medicine.

At the end of their period of use, these have to be discharged as radioactive waste.

Since half lives are typically relatively long, storage in the hospital is possible only temporarily; most adopted solutions are:

- Include withdrawal in the purchase contract with the supplier
- withdrawal by a company authorized to dispose of radioactive waste
- Store the source until clearence level (if applicable)

Collection of solid wastes

There are several types of PRIMARY containers:

- standardized metal drums (frequently supplied of the authorized company in charge of the collection): these drums, UN approved, have a volume of 60 liters, are equipped with "ski-type" hermetic closure. They are automatically proof against sharp waste. They should be closed and handed over to the company in charge only when they are actually full.

Collection of solid wastes

There are several types of PRIMARY containers:

• Cardboard container for hospital waste: these can be used to collect very short half lived waste; they are not sharp resistant, so could be used only in location in which is granted that sharps are not discarded.

Collection of solid wastes

There are several types of PRIMARY containers:

• Containers for sharp waste: can be used for short half lived waste that can be disposed after short waiting time. Ideal to collect syringes, needles, cannulas, injection lines etc, used in patient administration (^{99m}Tc, ^{18}F, etc.)

Collection of liquid wastes

Most used PRIMARY containers for liquid waste include:

- UN approved 60 L drums, containing 25 L tanks
- Other plastic tanks of small size, for occasional collection
- Urine bags, that have potential use also in some laboratory activites

Tank inserted in the barrel, inside a plastic bag and surrounded by an absorber

Collection of solid wastes

SECONDARY containers are re-usable shielded drums, used to accomodate disposable primary containers.

Radioactive wastes should never be thrown directly in the shielded container, without palcing an adequate primary container in it.

lever control operated by a pedal, which avoids manual opening

Collection of liquid waste

Drums of the standard type (*already presented as regards of solid waste*) are frequently used as SECONDARY container for liquid waste.

This results practical, since in most cases these waste come from laboratory uses (e.g. I-125). The radiation emitted by the radionuclides of interest is not penetrating and, given the half life, these waste will in most cases given to an authorized company (*).

(*) Note: Storage time for I-125 ~ 2 years. In the case of H-3 the half life is 12 years and organic solvent are typically present.

Temporay waste storage at the Hosptial

Temporary, short time storage of waste is made at the Hospital in some cases:

• Small volume containers for sharps with short half life can be used for a short period in the same place of use (e.g.an administration room), with limited shielding. When the conainer is full, it can be closed and stored for 1 – 3 days in a temporray storage room and, after this decay time, disposed as hospital waste.

• Big volume cointainers will accumulate waste for days and have to be placed within a shielded secondary container.

• Metallic drums from waste management external companies are used for relatively long lived radionuclides. They will collect waste for days / weeks and will then emit a certain amount of radiation; they are then typically protected wit a secondary, shielded container, and placed in a dedicated, temporary stirage room.


NMC VF

Example: several shielded secondary containers, each containing a suitable primary container, used for the separate collection of waste with increasing half-life.

Also note the shielded bags containing the old Co-57 flood sources, awaiting collection by an authorized company.

Temporay waste storage at the Hosptial

From IAEA “Nuclear Medicine respirce Manual” ed. 2020, Human Health Series No. 37

The storage of radioactive waste before delivery to an authorized company or disposal as "conventional" waste, after a waiting time for decay, cannot be done in any unqualified zone, but requires dedicated and appropriately planned spaces.

The storage room should have :

- A secure door;
- Adequate lighting;
- An electrical system with a high degree of protection;
- Containment against flooding;
- A fire extinguishing system.

Internal procedures and rules

- The RPE should prepare detailed instruction on the modality of collection of each type of radioactive waste.

- Copy of these rules should exposed in all main waste production places and in the temporary storage room.

- It should be remembered that a phenomenon described over time by an exponential law never reaches zero, except for time = ∞

- In practice, in a time = $3 \cdot T_{1/2}$ the residual activity is approximately 10% of the initial radioactivity, for t = $6 \cdot T_{1/2}$ is is approximately 1% of the initial radioactivity and for t = $10 \cdot T_{1/2}$ has approximately 0.1% of the initial radioactivity, etc.

- The final objective must be to comply with the discharge limits set by local regulations (frequently expressed in kBq/kg)

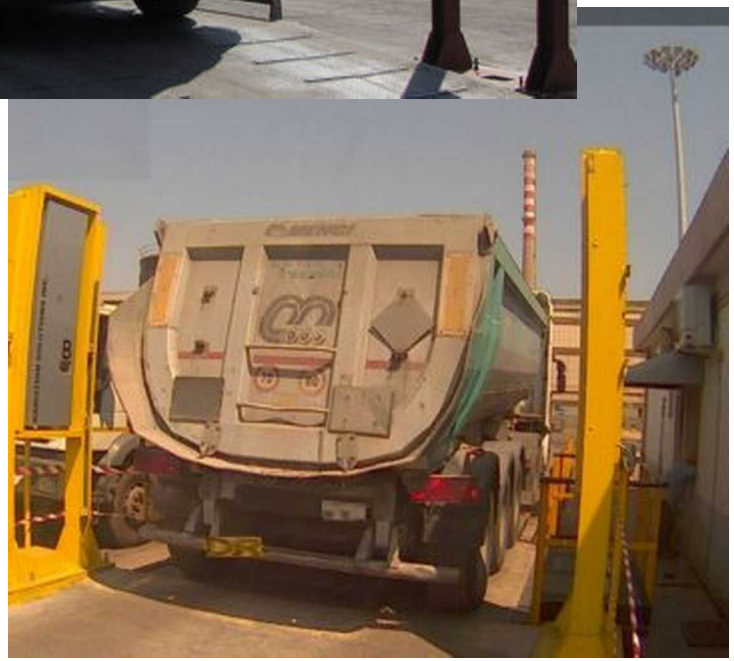
Radionuclide	*Origin of waste*	*Hal life [d]*	*Max activity [MBq]*	*Typical weight of a container [kg]*	*Weight concentration of activity [kBq/kg]*	*Concentration of activitiy intended for disposal [kBq/kg]*	*Number of days needed for disposal*	*Minimum suggested time for the procedure (days)*	*No. of 60 L containers produced per year*	*Expected total annual mass (kg)*	*Total residual activity of waste at disposal (MBq/year)*
^{99m}Tc	Residues from activities in Radiopharmacy	0.25	74	6	12333	1	3	7	50	300	0.300
^{99m}Tc	Residues from diagnostic activities	0.25	74	6	12333	1	3	7	100	600	0.600
^{18}F	Residues from diagnostic activities	0.076	74	6	12333	1	1	3	100	600	0.600
^{68}Ga	Residues from diagnostic activities	0.047	74	6	12333	1	1	3	75	450	0.450
^{123}I	Residues from diagnostic activities	0.54	37	6	6167	1	7	15	1	6	0.006
^{131}I	Residues from outpatient therapy activities	8.02	37	6	6167	1	101	120 – 150	4	24	0.024
^{90}Y	Residues from outpatient therapy activities	2.67	37	6	6167	1	34	120 – 150	1	6	0.006
^{153}Sm	Residues from outpatient therapy activities	1.93	37	6	6167	1	24	120 – 150	1	6	0.006
^{177}Lu	Residues from outpatient therapy activities	6.65	37	6	6167	1	84	120 – 150	1	6	0.006
^{223}Ra	Residues from outpatient therapy activities	11.44	7.4	6	1233	1	117	120 – 150	2	12	0.012
									Total	2010	2.01

Waste monitoring systems

- These system allow for a quick check of residual radioactivity in typical hospital waste containers
- The calibration for different radionuclides may be problematic
- Geometric factors may influence accuracy
- Results in terms of activity / activity concentration are acceptable, but within moderate limits of accuracy

Portal monitors

- These system allow for inspection of the presence of radioactivity in trucks and containters
- The calibration of these systems is not standardized and, on the whole, is not metrologically acceptable. They typically compare with frequently updated background measuerements; do not try to assess activity, but make a approximate dose rate measurement. Calibration is typically perfomed only at ^{137}Cs energy.
- Excellent as qualitative detectors, inadequate from the quantitatiuve point on view.
- Geometric factors and self absorpition to be considered.
- No attempt to produce results in terms of activity / activity concentration. Limited (if any) identification of radionucldes. In case of short lived radionuclides, even if there is a clearence level of tens or hundreds Bq/kg, if the signal is superior to e.g. 3 sigma of the background, an alarm is produced.



The European Waste Code (EWC)

Starting from 1975, the EC Directives on waste have introduced a codification, called the "European Waste Catalog".

NM staff should be familiar with the “conventional” classification of waste. This gives the catergorization of waste once they are “no more radioactive”.

CONTAINER	EWC CODE	WASTE DESCRIPTION
	18 01 03*	**Infectious Waste** Infectious or potentially infectious healthcare waste **Examples:** Dressings, swabs, cotton wool, used protective clothing.
	18 01 04	**Offensive Waste** Non-infectious healthcare waste **Examples:** Continence pads, sanitary towels, empty saline and blood bags.
	18 01 03*	**Sharps Uncontaminated by Medicines** Syringes and sharps objects NOT contaminated with medicinal residue. **Examples:** Phlebotomy sharps, lancets, acupuncture needles, scissors, razors and scalpels.
	18 01 03*/09	**Sharps Contaminated with Non-hazardous Medicines** Syringes and sharps objects, contaminated with Non-cytotoxic / Non-cytostatic medicinal residue. **Examples:** Used syringes, broken ampoules.
	18 01 03*/08*	**Sharps Contaminated with Hazardous Medicines** Syringes and sharps objects, contaminated with Cytotoxic and Cytostatic medicinal residue. **Examples:** Used syringes, broken ampoules.
	18 01 09	**Non-hazardous Medicinal Waste** Non-cytotoxic and Non-cytostatic tablets and liquid medicinal waste in original packaging. **Examples:** Tablets, liquids, refused medicines (liquids must be contained), empty medicine bottles, medicated IV bags.

Concurrent risks: biohazard

• The principal modality of exposure is puncture, even if absorption through the wounded skin or through the mucosa of the eye.

• In the case of puncture or wound, the risk increases with the deepth of the lesion. Some initial bleeding is helpful in limiting the possibility of attack.

• Type of needle / device: the bigger the gauge of the needle, the higher the risk.

• Use of personal protection devices: it has been demonstrated that the use of gloves, even if it is not protecting against puncture, decreases the risk of contamination up to 50 – 70 %. In fact, gloves tyipically capture a certain quantity of the biological contaminating fluid (barrier effect).

• Type of patient: the risk of microbiological contamination is higher in the case of infective patients.

Concurrent risks: biohazard

Recapping the needle: it would always be avoided.

Nevertheless, there are practices in which it is necessary to reacp the needle; among these, some preparations of drugs and radiopharmaceuticals, composed of several steps, in which the same syringe is used for the dispensing of a drug before administration must be recapped !

The task then is to be done only when absolutely necessary and in such cases recapping should never be done oppsing the needle to the cap, supported by one hand, but only using special, on-purpose supports.

Concurrent risks: lead

- The lead-shielded container is a useful resource that must be recycled.
- However, lead is a toxic metal and must be handled with care.
- In national legislation, there may be restrictions on the possibility of storing the lead and work it..

Conclusions

- management of radioactive waste should be considered from the planning stage
- Carefully take into account any specific mode of waste production in each phase of the activities
- It is useful to classify and collect waste separately in function of their half-life
- Always adopt and use containers approved for the type of use
- Always remember concurrent risks