Modular Design Approach for processing for small volumes of solid and liquid LLW and disused radioactive sources

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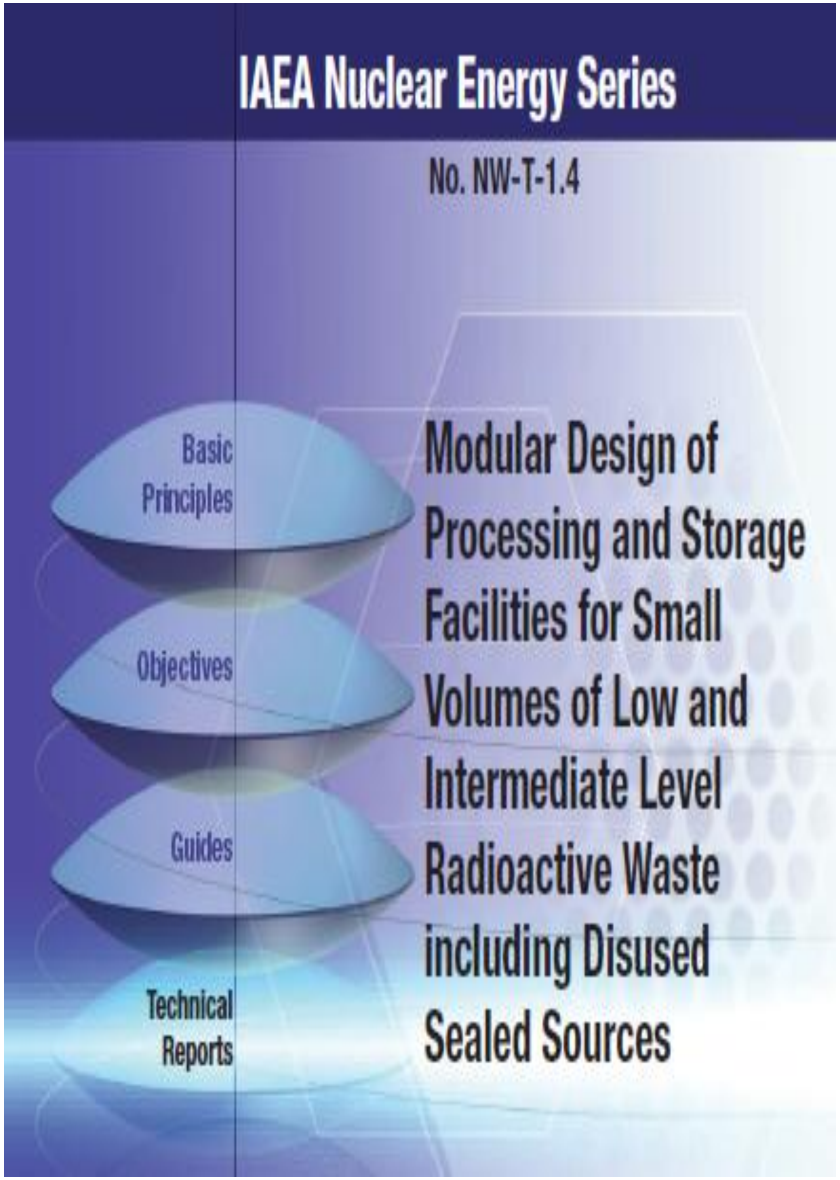
Modular design



http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1628Web-18312413.pdf

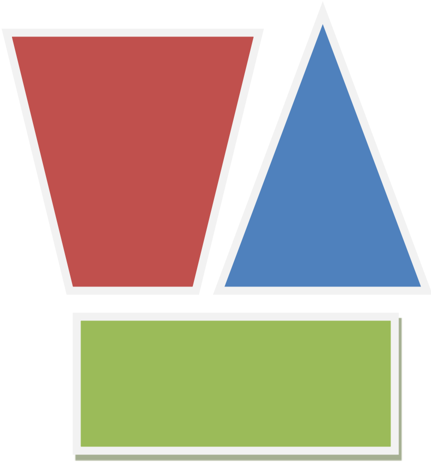
Modular design

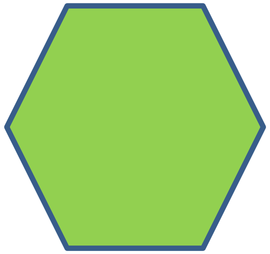
- A number of IAEA Member States **generate relatively small quantities** of radioactive waste and/or disused sealed sources
- **Many** countries still **do not have adequate facilities for processing and storing** of their radioactive wastes – especially in **countries with small quantities** of generated radioactive wastes
- In other Member States the existing waste processing and storage facilities (WPSF) have to be **upgraded** to address new waste streams, incorporate new waste processing technologies, or expand interim storage capacities
- There are **wide variations** in the types and quantities of radioactive waste, so **fixed designs like the ones developed earlier may not be adequate** to very different needs

Modular design- flexibility

- Because of **wide variations** in the types and quantities of radioactive waste **fixed designs like the ones developed earlier may not be adequate** to meet the different needs of these Member States.

- One very effective way to achieve the required waste processing flexibility is to develop a **WPSF design that is based on a variety of modules** for different waste stream treatment and conditioning processes.





Modular design

- Each module can be constructed locally or pre-fabricated then **combined with other modules to meet the country specific needs**.
- Similarly for storage, **different storage module concepts are available**
- Depending on the **type of waste and volume** to be stored, the most appropriate concept can be selected.

Typical waste steams

- Previous work by the IAEA has reviewed **typical waste streams generated** by Member States and identified their principal characteristics.
- **Not all Member States produce all of these waste streams.**
- Assumption -the waste streams **require processing to produce conditioned waste packages for storage** if no other alternative management option is available.

Typical waste steams – types and volumes

The waste stream information - used **for developing of module specifications** for waste treatment and conditioning process and the concept designs for these modules

W**aste streams identified by a letter** (**A** - Low volume aqueous liquid; **B** - High volume aqueous liquid etc.), **same letters** used for the waste treatment and conditioning process **modules**.

Very short-lived waste not considered- decay storage until clearance levels are reached

Typical waste steams – types and volumes

Matrix cross ref	Waste stream	Annual quantity to be processed	Waste origin and waste type
A	**Low Volume Aqueous Liquid**	Typically up to **0.5 m³**	**Laboratories, hospitals** etc.
B	**High Volume Aqueous Liquid**	Typically in the range **0.5 -10 m³**	**Laboratories**, **decontamination**, hot cells, research reactor spent fuel storage pool, etc.
C	**Organic Liquid**	Typically less than **0.3 m³**	**LSC** solutions, **oil** (e.g. from pumps), **extraction** solvents
D	**Solid Compactable**	Typically less than **20 m³**	**Paper**, cardboard, **plastics**, **rubber**, gloves etc.
E	**Solid Non-Compactable**	Typically less than **5m³**	**Glassware, metal** scrap etc; (disused sealed sources are separate waste stream)
F	**Ion exchange resin**	Typically less than **0.5m³**	Ion exchange **resins**

Typical waste steams – types and volumes

Matrix cross ref	Waste stream	Annual quantity	Waste origin and waste type
G	**Sludge**	Typically less than **0.5 m³**	**Secondary waste from evaporation** and chemical treatment
H	Disused **sealed** sources - **short lived** isotope	Large variation, for the reference case 20 should be used	**Medical, industrial and research** applications
J	Disused **sealed** sources - **long lived** isotope	Large variation, for the reference case **20** should be used	**Medical, industrial and research** applications
K	**Biological**	Typically less than **0.5m³**	**Medical applications and research**. Type: Animal carcasses, tissues, etc.
L	**High activity sealed sources**	Typically **1-2** sources **/ y**	**Medical, industrial** and research applications

Processing Module Options

A **wide range** of waste processing technologies are **available**

Not all of these technologies are considered suitable for this module design approach, i.e. some technologies such as **evaporation and incineration**, that may be used for treating radioactive wastes elsewhere have been reviewed and assessed as being **unsuitable**, generally because they are **too costly and too complex** to implement for the relatively **small volumes** of waste that are anticipated

Ten process modules discussed

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International Atomic Energy Agency

Waste Stream and Process Matrix

		1	2	3	4	5	6	1	2	3	4
		Liquid and West Solid Waste						Solid Waste			
Cross Ref.	Waste Stream	Chemical Treatment	Ion Exchange	Reverse Osmosis	Cross-flow Filtration	Filtration	Solidification	Encapsulation	Low Force Compaction	Unshielded Booth	Mobile Hot Cell
A	Low Volume Aqueous Liquid						A6				
B	High Volume Aqueous Liquid	B1	B2	B3	B4	B5	B6				
C	Organic Liquid				B4	B5	A6				
D	Compactable Solid								D2	D3	
E	Non-Compactable Solid							E1		D3	
F	Ion Exchange Resins						A6				
G	Sludge						A6				
H	Disused Sealed Source - Short Lived Isotope (half- life ≤30 y)							E1		D3	
J	Disused Sealed Source - Long Lived Isotope (half-life > 30 y)							E1		D3	
K	Biological (Carcasses)							E1			
L	High Activity Disused Sealed Source										F1

IAEA
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Processing Modules and applications

Module No.	Processing module	Principal waste stream	Additional compatible waste streams
A1	**Solidification** Cementation of limited quantities of liquid waste within small containers (typically <20 L).	Sludge (small volumes); Low volume aqueous liquid; Ion exchange resin (small volumes).	Organic liquid.
B1	**Chemical treatment** Batch treatment (typically <500 L) of aqueous liquid to adjust pH or decontaminate by precipitation of radionuclides.	High volume aqueous liquid.	
B2	**Ion exchange** Batch treatment (typically <500 L) of aqueous liquid to decontaminate by removal of soluble radionuclides by ion exchange.	High volume aqueous liquid.	
B3	**Reverse osmosis** Batch treatment (typically <500 L) of aqueous liquid to decontaminate by removal of soluble and insoluble radionuclides by reverse osmosis.	High volume aqueous liquid.	
B4	**Cross-flow filtration** Batch treatment (typically <500 L) of aqueous liquid to decontaminate by removal of soluble and insoluble radionuclides by membrane filtration.	High volume aqueous liquid.	Organic liquid.

Processing Modules and applications

B5	**Filtration** Batch treatment (typically <500 L) of aqueous liquid to decontaminate by removal of solids by cartridge filtration.	High volume aqueous liquid.	Organic liquid.
B6	**Solidification** In-drum cementation of liquid or sludge waste to produce a solid waste product.	High volume aqueous liquid.	Sludge (large volumes) Ion exchange media (large volumes).
D2	**Low force compaction** In drum compaction of 'soft' compactable waste to reduce waste volume.	Compactable solid.	
D3	**Unshielded booth** Enclosure for manual sorting and segregating of solid waste prior to further processing or conditioning.	Compactable solid.	Non-compactable solid. Disused sealed source (low dose rates).
E1	**Encapsulation** Encapsulation of waste within a cement grout.	Non-compactable solid.	Disused sealed source under special conditions.
L4	**Hot cell module** Shielded cell with remote handling facility for the dismantling and repackaging of high activity sources.	High activity disused sealed sources.	

Key Strategy Considerations

•RAW management **strategy has to be developed** prior planning the RAW processing activities

•The strategy has to be c**onsistent with the objectives and constraints** of the waste producing facility.

•The strategy has to be **consistent with the national policy and strategy**.

•It has to **consider the entire life cycle**, from waste generation to waste disposal.

Key Strategy Considerations

•Safety- optimization of the **dose to operators and the public**

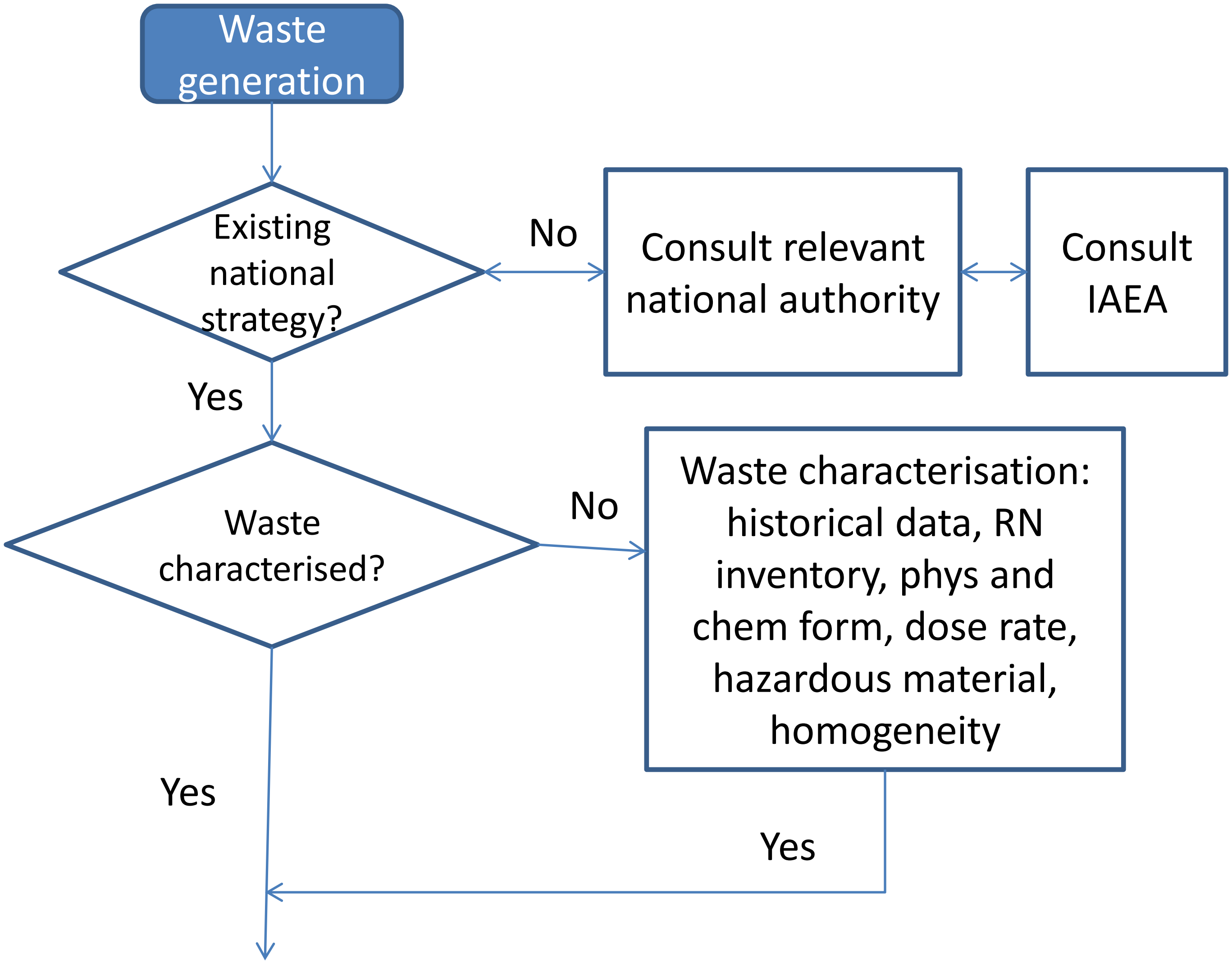
•Environmental protection- liquid and gaseous **discharges**, **volumes of waste**, secondary waste volumes, availability of disposal facilities;

•Regulatory regime- existing or emerging **regulatory framework**;

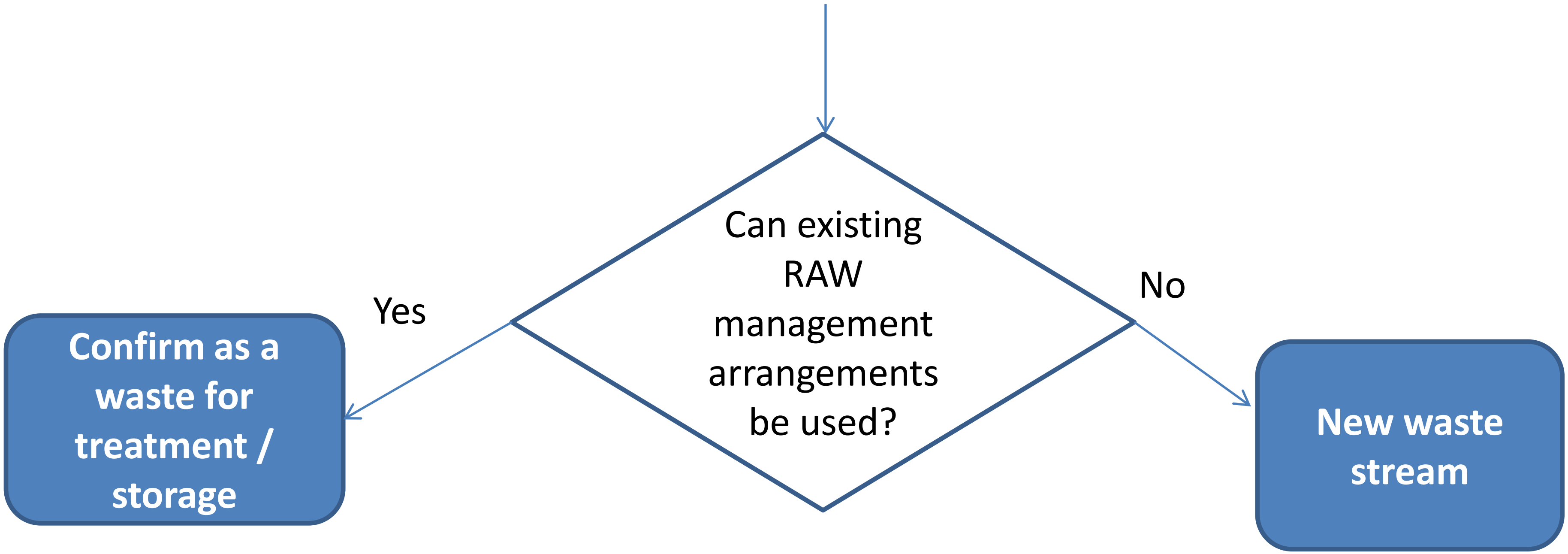
•Technology- flexibility and robustness, ease of operation and maintenance, **availability of existing equipment** or facilities

•Economics- purchase **cost**, operating costs, decommissioning liabilities, timing of costs;

Selection of appropriate processing module



Selection of appropriate processing module



Waste Acceptance Criteria

The waste **acceptance criteria for the WPSF** will be established as **part of the safety case** such that the facility can handle the waste safely.

WAC might specify:

- packages are **not too large** or too heavy
- external **dose rates** are acceptable
- the waste is appropriately packaged, **no leaking /no contamination**
- **chemical and physical nature**
- other **hazardous materials**, etc.

RAW segregation

- **Soft, compressible/compactable** waste segregated from **non-compactable waste and from biological** waste
- Containers of **liquid waste** separated from **solid waste**
- **Organic liquid** segregated from **aqueous liquids**
- **Long lived sources** (half-life >30 years) segregated from **short lived** (half-life ≤30 years) sources.

Management of solid RAW

Solid waste - sorted and **segregated** depending on **characteristics and** proposed **treatment**.

Compactable

Compressible or compactable waste- placed into a 200 L drum and **in-drum compacted** to maximize the waste loading within the drum

Biological matter

Pre-treatment with **formaldehyde or lime** prior **encapsulating in 200 L drums** using the encapsulation module

Non-compactable

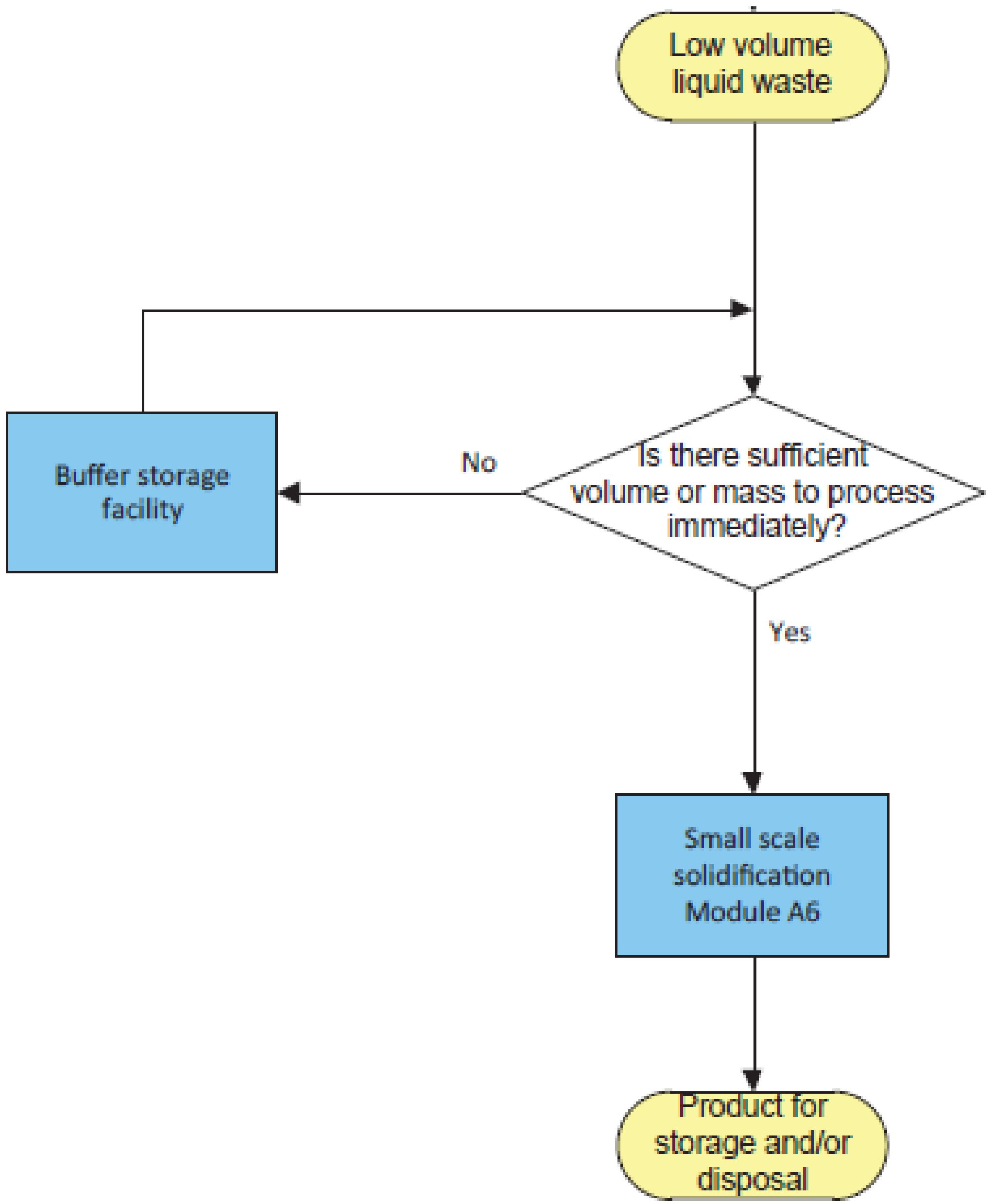
Non-compactable waste- placed into a 200 L drum and then **encapsulated in cement** grout using the encapsulation module

Low volume liquid RAW management

Decision making- is there **sufficient volume to process immediately?**

- **Low volume aqueous** waste is often received in suitable containers, such as UN certified plastic bottles, that **typically hold up to 10 L**.
- It is recommended that several similar containers are **collected together and processed at the same time**, reducing the number of times the process module needs to be shut down and washed out after operation.
- In general, it is recommended that quantities of liquid waste are **not accumulated for extended periods of time** because of the risk of loss of containment and spread of contamination.
- As the **rate of generation** of liquid waste **is small**, the liquid waste should be treated by **direct solidification**.

Low volume liquid RAW management



Short lived sources

The best route for **very short lived** radionuclides ($T_{1/2}$ <1 year) is **decay storage**.

Short lived sources that do not fall into this category can be stored in **200 L drums** with a pre-cast annular concrete **lining** for additional shielding

Placement of disused sealed sources in a 200 L drum with annular shielding.

Long lived sources

- May require **repacking from original source holders into long term storage shields** in the mobile hot cell module.

- Placed into a 200 L drum with a pre-cast annular shielding to **enable the recovery** of the source in the future for further conditioning **prior to final disposal**.

- **Stored in their original long term storage containers,** If **too large** to be packaged into 200 L drums.

Organic liquid RAW

- Treatment to make **suitable for disposal** – incineration or solidification in cement.

- If a discharge route with **authorized discharge** limits is available, the next step is to determine whether **filtration** will be able to decontaminate the bulk of the liquid sufficiently to make it acceptable for discharge.

- **Absorption on clay or bentonite followed by solidification in cement**.

Module **A6** Solidification

One of the possible stages in treatment of **small quantities of liquid or wet solid waste** will be to solidify it in order to **immobilise** the waste and its radioactive contamination and to **prevent dispersion**.

Suitable for:

- **Low volume aqueous** waste- **A**
- **Organic** liquid waste- **C**
- **Ion exchange** resin- **F**
- **Sludge- G**

A6 Solidification - **General description**

- Waste is placed into **10 L waste containers** and **cement grout added**.
- Reference case - **0.1 m^3 per year**.
- Generates **20 to 30** small waste **containers per year**, depending on the volume of liquid or wet solid waste
- If solidify 5 containers per day - less than **six operating days per year** will be required
- **Target waste** stream - **organic liquid** (scintillation solutions, oil from pumps, extraction solvents, etc.)

A6 Solidification- **Mixing**

This solidification module will **mix organic liquid waste with** a pretested **cement** mixture in a 10 L container using a ‘**total loss**’ **paddle mixer**, which **remains in the container** after mixing and **becomes part of the solid waste** package.

The waste and cement can be mixed using a **standard power drill or laboratory mixer** with a removable paddle drill bit.

A6 Solidification- **Equipment**

In outline, this module includes the **following equipment**:

- 10L waste **containers**
- **Waste container filling station**
- **Chemical containers for dosing**
- **Cement powder containers**
- **Curing area** where waste containers can stand and cure.
- **Grout mixing equipment** to prepare small volumes of grout
- The module's equipment can be **housed** within containment such as a Module **D3–Unshielded booth or a fume cupboard**.

A6 Solidification- **Filling station**

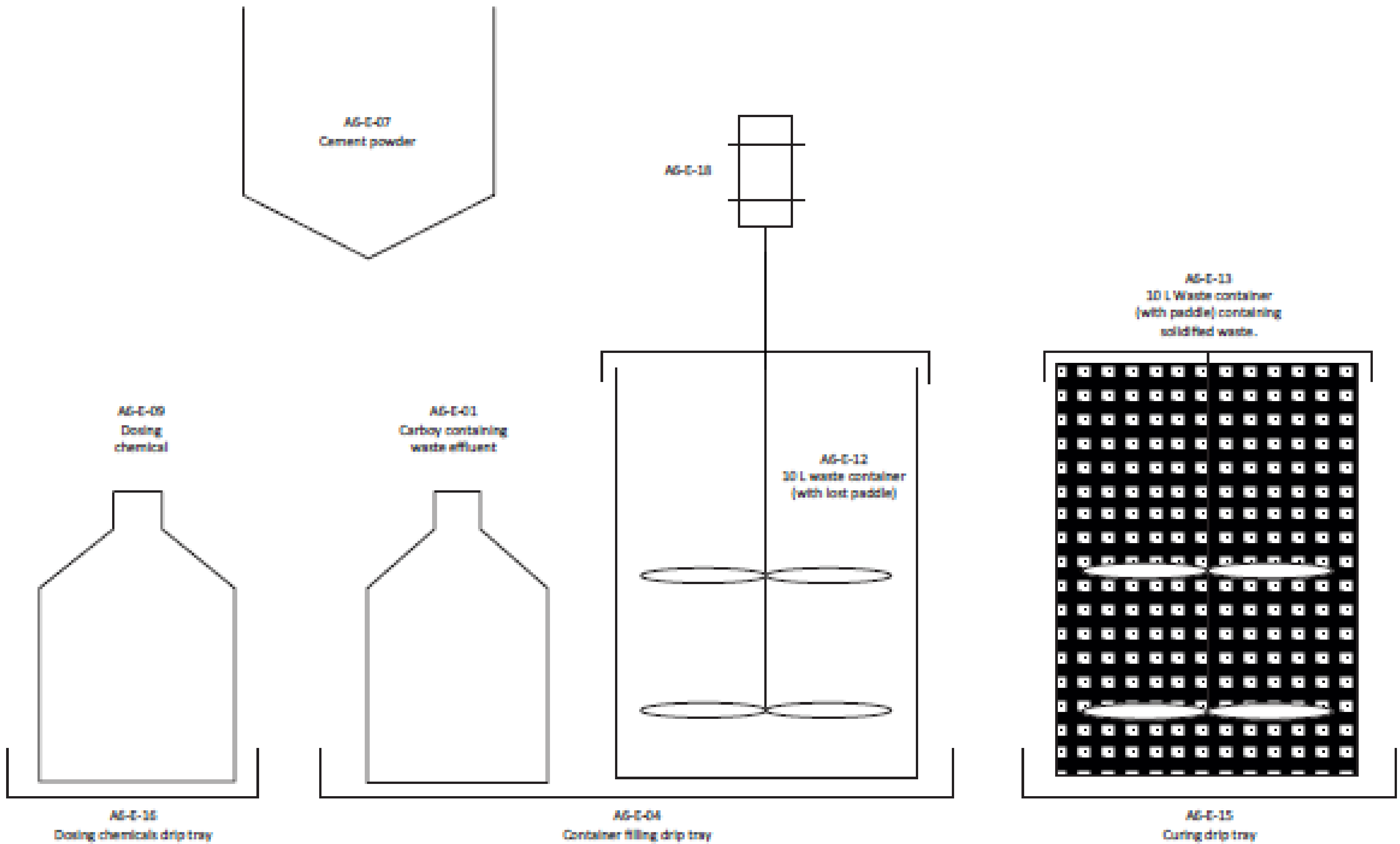
A waste container filling station consists of:

- Waste containers, A6-E-12, **10 L** in mild steel, polyethylene or polypropylene.
- The nature of the container is not significant as it is intended that ultimately the **final product will be over packed by grouting into a 200 L steel drum in Module E1–Encapsulation**
- A **splash guard** in mild steel, polyethylene or polypropylene **to fit over the waste container** during powder addition and mixing
- A **mixing paddle** in mild steel, which will be used **to mix the cement powder into the liquid waste** in the container and will **remain in the container** while the cement sets

A6 Solidification- **Spillage containment**

A **tray**, A6-E-04, in stainless steel, polyethylene or polypropylene is located under the waste container **to contain any splashes, spillages or leakage** during mixing.

A6 Solidification- Schematic view



10L waste container

A6 Solidification- **Facility considerations**

- All equipment should **fit on a work bench**
- The module can be **housed** in a Module D3–**Unshielded booth or in a fume-hood**
- Finished **solidified waste containers** to be **placed directly into a 200 L drum for encapsulation** with other non-compactable waste, thus avoiding transport
- A suitable manual **trolley for moving waste containers** is needed
- Radiochemical laboratory for sample and **analysis**
- **Testing will be required** - **compressive strength and leach rate**

A6 Facility considerations

- **Process water** is required for chemical make-up and rinsing equipment
- **Hand held radiation monitors** are required to control radiation levels of the incoming waste and the final containers to comply with the WAC.
- **Dry storage for cement powders** is required outside the containment.
- **Storage for equipment spares**, sample bottles and lab equipment
- **A bunded storage area** is required for up to five 10 L carboys (or equivalent volume) of liquid waste awaiting treatment and sample analysis.
- **Accumulation of untreated liquid waste should not be encouraged**. Therefore, storage space should be limited.
- **Personnel protective equipment (PPE)**

Module A6 — Disadvantages of the process

Trials shall be performed to **find the right waste-cement formulation** and confirm that it **meets waste acceptance criteria** for interim storage/disposal

- The waste becomes **non-recoverable**

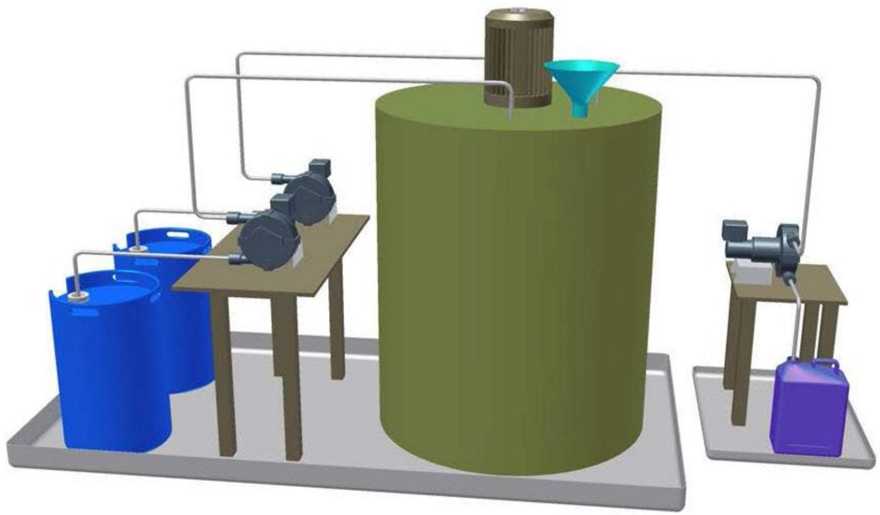
Module **B1** – **Chemical treatment**

- To **separate** significant proportion of the radionuclide contaminants
- The remaining bulk volume will either be **suitable for discharge** or will require further ‘**polishing’ by ion exchange or fine filtration**
- **Process** aqueous waste **in batches**
- The main components of the module are a **chemical treatment tank, piping** and **pump** for decanting the supernatant from the treated liquid. The same dip pipe and pump are also used to **discharge the sludge**.
- All equipment is contained in a **drip tray** that provides **containment in the event of leaks** or spills.

B1 Waste feed characteristics

Total liquid volume	Typically **0.5–10 m^3 per year**, for the reference case 5 m^3 per year should be used
Peak treatment rates	Typically **2–8 h per batch**
Feed activity content	**Low levels of activity**
Physical form	**Liquid**, mainly aqueous, but could have small quantities of oils or contain solid particles
Chemical content	Aqueous solutions, can contain **acids** and some **complexing agents** (i.e. EDTA, oxalic)
Activity content	A decontamination factor **10 to 100**
pH	pH of the **treated** product **– neutral (6 to 9)**

B1 Treated effluent characteristics



Model of module B1 - chemical treatment

An **adjustable dip pipe** should be used for:

- Decanting supernatant from treated aqueous liquid after gravity settling
- Discharging waste sludge

The module equipment consist of:

- **Storage containers for the aqueous waste**, 45 L, high integrity, UN certified reusable containers of **double walled** polythene construction for hazardous liquid chemicals.
- **Chemical storage container**, approved plastic carboy , resistant to the chemicals contained, shatterproof and easily cleanable for reuse.
- Self-priming **feed transfer pumps,** peristaltic**,** typically 1000 L/h to **transfer the aqueous waste to the chemical treatment tank** from the waste storage container.
- A **chemical treatment tank**, impeller to ensure uniform mixing of chemicals, tank capacity between 100 and 500 L
- **Pipes and tubing,** stainless steel or plastic

B1 Treated effluent characteristics

Storage containers
for aqueous waste

<u>The module equipment consist of:</u>

- **Sludge waste receipt container**, 45 L double walled UN certified reusable polythene containers for hazardous liquid chemicals.
- **Drip tray**, capable of collecting 110% or the total liquid
- **Hand held radiation monitor**
- A **pH probe**
- **An emergency stop button**

B1 - Facility considerations

- **Waste receipt** area for aqueous waste
- **Storage with a collecting tray** for the temporary storage of up to 20 carboys
- **Manual trolley** for moving containers
- **Forklift** for large containers
- Equipment for **sampling and analysis** of treated waste
- **Provision of water** for the process and for rinses

B1 - Considerations

- M**aterial safety data sheets** to ensure appropriate handling of chemicals.
- **Access control** to the area
- **PPE**, e.g. gloves, goggles, mask, safety shoes.
- **Appointed radiation protection supervisor**
- The aqueous waste - **sampled and analysed** prior to treatment
- Based on the sample results the **chemical treatment method should be planned** by a chemist.
- M**ultiple containers has similar characteristics** - **treat in the same batch**

B1 - Process description

Typical steps for the removal of contaminants from solution include the following:

- **Acidification**
- **Addition of chemicals** to combine with the radionuclides and **form a sludge**
- **Addition of alkali** to raise the pH and **precipitate the radionuclides**

B1 – Disadvantages of the process

- Gravity settling **may not remove all solid particles**
- **Further treatment** of the effluent **might be required**, e.g. filtration or ion exchange
- Creates a **sludge waste stream that must be processed further** to condition it for disposal
- May involve **toxic or corrosive** chemicals

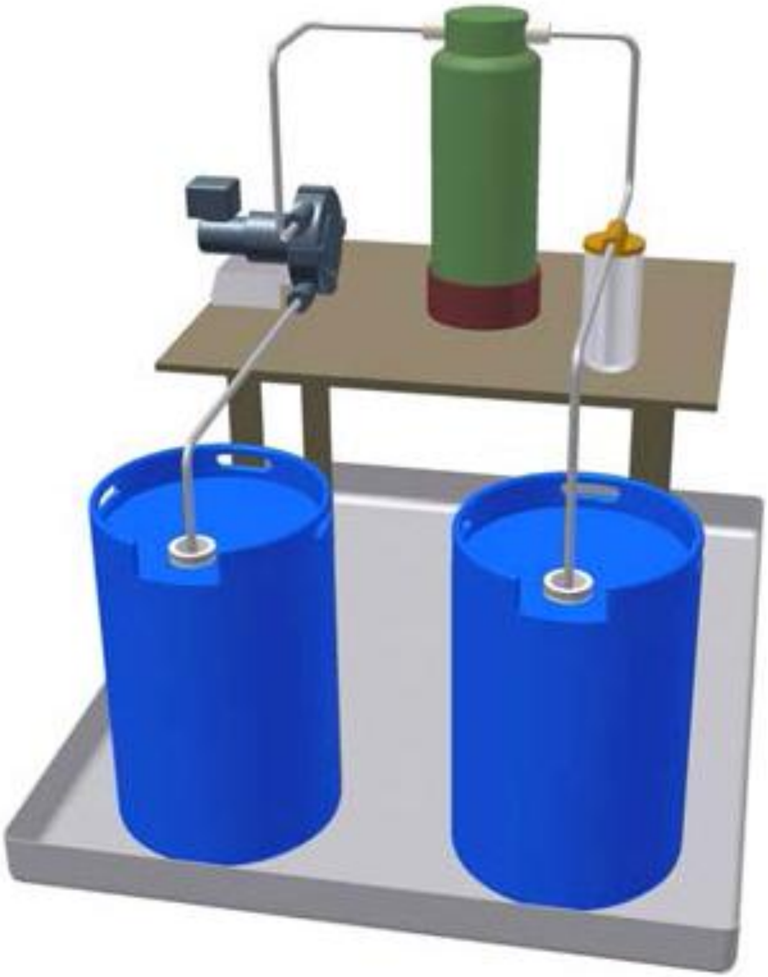
MODULE B2 - ION EXCHANGE

- **Removes soluble** contaminants by sorption on ion exchange material
- Purified solution is often **suitable for immediate discharge**
- The ion exchange module is used **to pump liquid from a carboy via the ion exchange column**, collecting the treated liquid waste in another carboy
- **Main components** - a **p**ump, an ion **exchange column** and a cartridge **filter**
- The **filter remove any ion exchange material fragments** that may get flushed from the ion exchange bed
- The module is **located on a tray** for containment in the event of leaks or spillages

MODULE B2 - Waste feed characteristics

Total liquid volume	Typically **0.5–10 m^3 per year**, for the reference case 5 m^3 per year should be used.
Timing	Arrives periodically **in batches of about 50 L**.
Peak treatment rates	**100 L/h**
Feed activity content	**Low levels of activity,** single or multiple radionuclides.
Physical form	**Liquid, aqueous**. It is assumed that it contains **no oils** or other immiscible species.
Solids content	**No solids**
Chemical content	No chemical content except small amounts of complexing agents.

MODULE B2 – Schematic view



The module equipment consist of:

- **Storage container for the aqueous waste** 45 L high integrity UN certified double walled polythene construction for hazardous liquid chemicals
- **An ion exchange column** in stainless steel or plastic (may require shielding depending on the activity).
- **Pressure sensor** to monitor the pressure drop across the ion exchange column (**indicates the ion exchange column is becoming blocked**);
- **Hand held radiation monitor** for periodic monitoring of the build-up of activity

MODULE B2 – Equipment

The module equipment consist of:

- **Feed pump** (i.e. peristaltic), rated at typically 100 L/h
- **Transfer pipework**, size 15 mm, in stainless steel or plastic
- The materials of **construction for the ion exchange column will depend** on the activity, **plastic will not be suitable at high radiation doses**
- M**ixed ion exchange resins** for general service **or selective** ion exchange materials to remove specific radionuclide species
- **Loose resin or in cartridges**
- Disposal of cartridges may cause a problem because it is not possible to immobilize the resin beads using cementation, therefore **loose ion exchange material is preferable**

MODULE B2 – Consideration

- **Radiochemical laboratory needed**
- **Wash water required**
- **Containers** of nominal **capacity up to 200 L** for the collection of spent ion exchange resins and flushing water
- **Suitable area for short term storage** of containers holding spent ion exchange resins and flushing water. Localized **shielding may be required**

MODULE B2 – Disadvantages

- **Creates a secondary waste stream** (spent ion exchanger) that must be processed
- **Less effective at high salt loadings**
- **Low effluent pH** or the presence of **complex agents (EDTA, oxalic acid) can elute cations** from the cation exchange resin
- Ion exchange material for selective radionuclide removal **may be expensive**

Thank you!