Sellafield Ltd

Decontamination for the Nuclear Industry

A Perspective For The ModCaD Workshop

20th-22nd April 2021

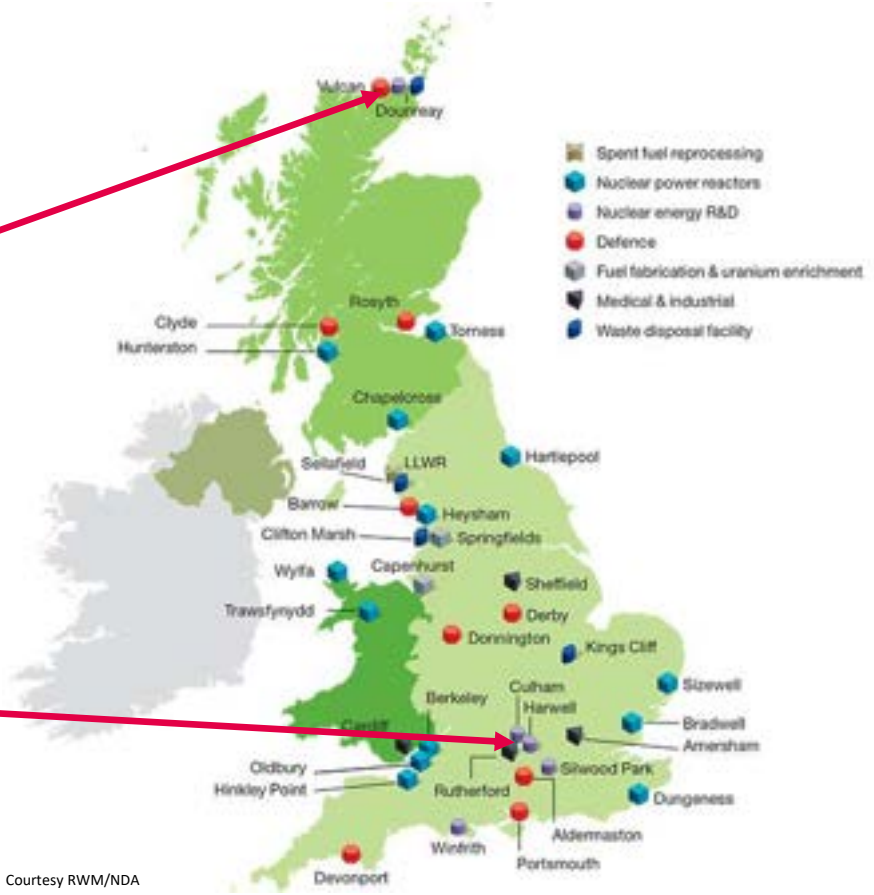
Topics

- Location and purpose of UK nuclear sites
- The Sellafield Nuclear Decommissioning requirement
- What is Decontamination?
- Understanding situational constraints
- Requirements for decontamination
- How to contribute

UK Nuclear Decommissioning

- History - A few reflections on the past to appreciate how and why we have the decommissioning legacies of today.
- Scale - How many sites and of what size are in the UK
- Uncertainty - What we do and don’t know about the contaminating material(s)
- Decontamination - How to make it a reality?

UK Nuclear History



Courtesy RWM/NDA

Sources Of Nuclear Materials

- Civil Nuclear Industry (Sellafield, Dounreay, Harwell..)
- Aspects of the UK Weapons & Propulsion Programmes (AWE, MoD)
- State based legacy items
- “Public” owned items prior to regulation
- CBRN(e) events

Sellafield – A Period Of Rapid Expansion

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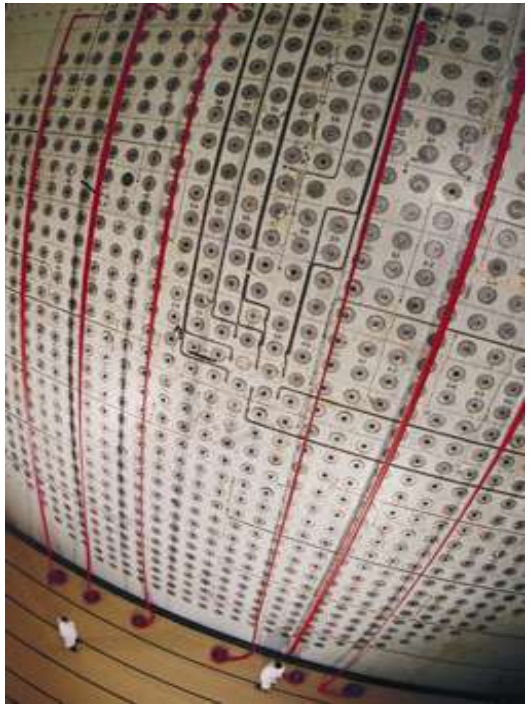

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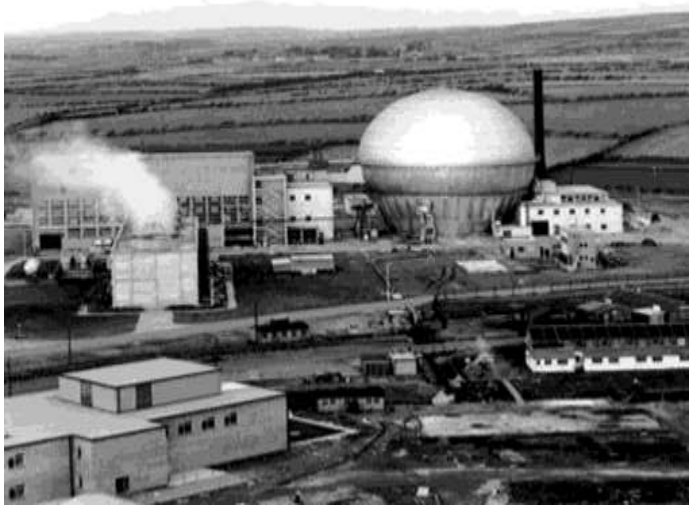

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- 1964 – Magnox Reprocessing Plant

Sellafield Today

- Still a leader in the Industry
- Now more heavily engineered and enclosed plants
- Have an appearance of being slow - because it is highly regulated
- Emphasis on safety, environment and long term consequences, but also;
  - Handling legacies
  - Traceability & audit trail
  - Robust packaging
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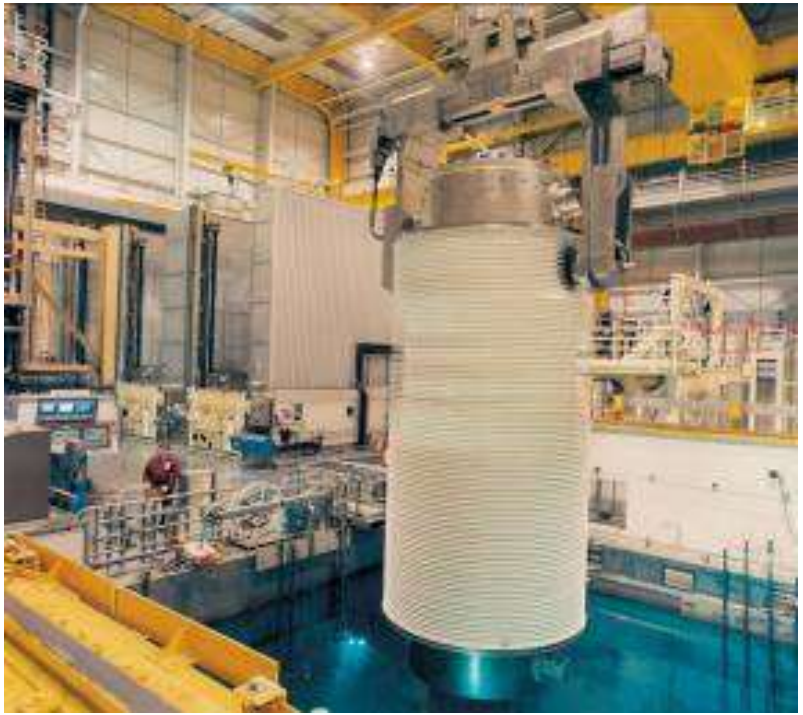

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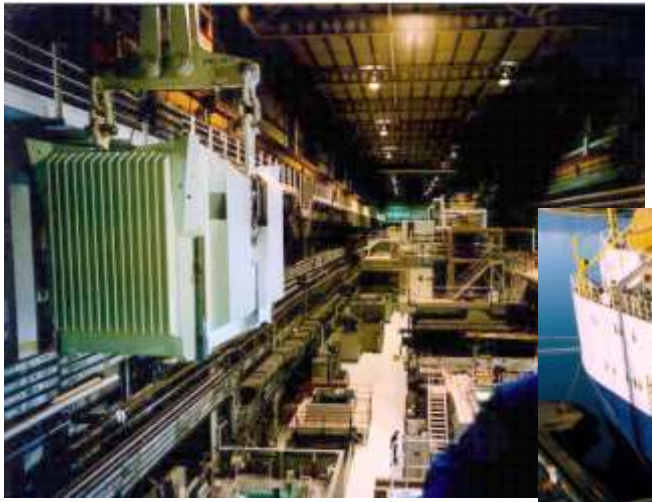
Unintended Legacies

- Aging assets need to refurbishment
- Making old assets compliant to todays standards
- Changing physio-chemical form of the waste materials, e.g. sludges
- Records from early operations incomplete

Safety, Environment & Assurance



Sellafield – Lessons From The Past

- UK was a leading edge pioneer in nuclear developments
- There was much to be understood
- Secrecy was important. Not all records have survived.
- We should avoid blame. The drivers at the time were very powerful and a genuine belief the problems concerning waste would be quickly resolved.
- Many of the issues have evolved from radio-chemical processes over time
- We know more of the unforeseen challenges and build new plants with decommissioning in mind.

Setting Out The Challenge

Principle Questions

- What?
- On what substrate?
- How much?
- Where?
- When is decontamination required?

Sellafield Today – A Complex Site

- Built on a former WW2 Explosive Ordnance Manufacturing site
- 7 Reactors – all in the process of being decommissioned
- 2 Fuel fabrication plants
- 3 Reprocessing plants – last one will cease later this year
- Plutonium plants
- Numerous High, Intermediate and Low level waste treatment and storage facilities
- 3 Liquid effluent plants
- Labs, infrastructure items (rail, road etc..), offices etc.

What Is The Contamination?

Source: https://www.sigmaaldrich.com/content/dam/sigma-aldrich/articles/biology/marketing-assets/periodic-table-elements-mk.png

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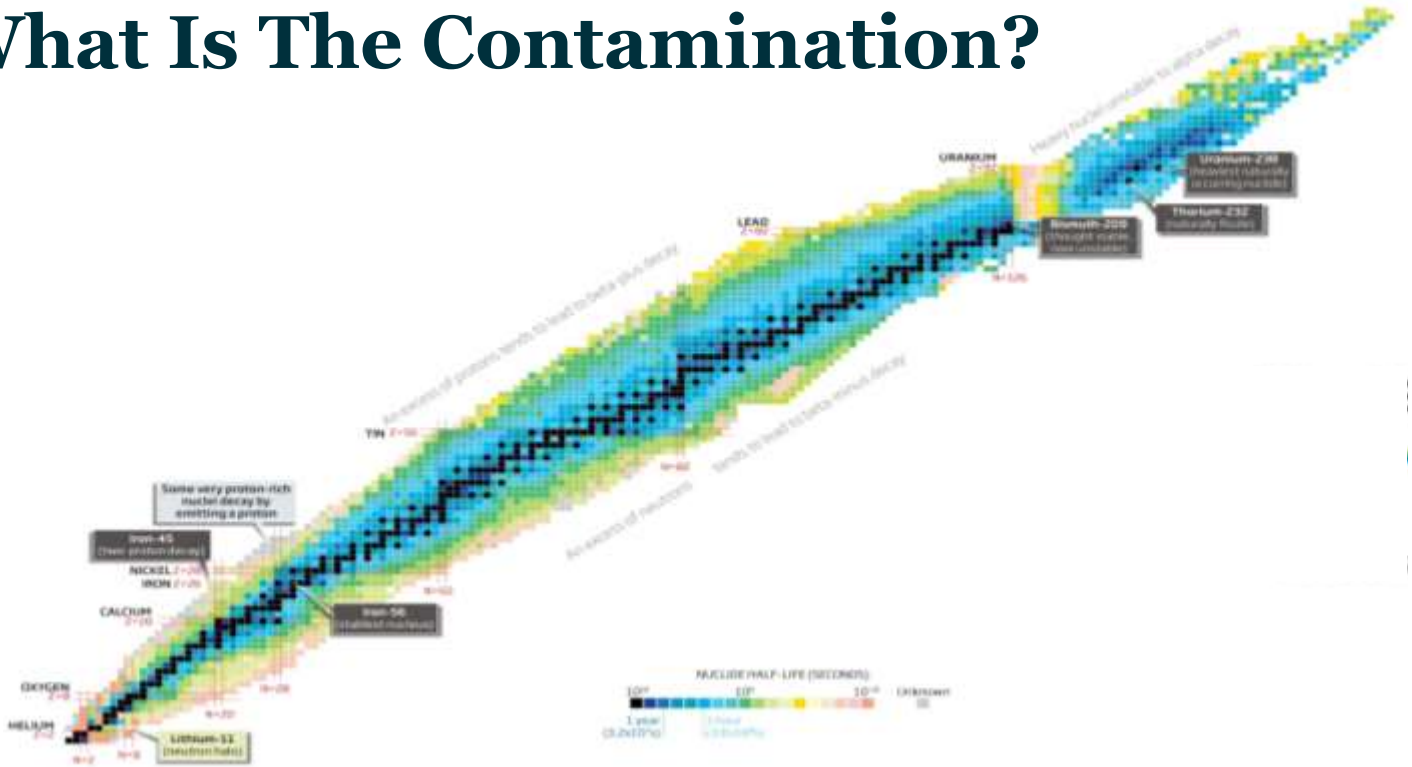
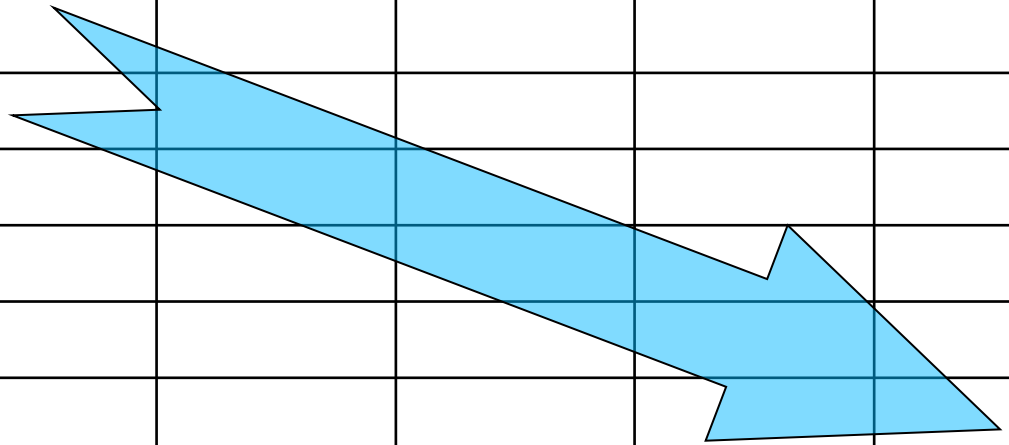


What Is The Contamination?

- Multiple different radiological environments e.g.;
  - Ponds
  - Silos
  - Reactors
  - Wet or dry chemical processing plants
- Wide range of Chemical forms
  - Metallic
  - Oxide
  - Nitrate
  - …

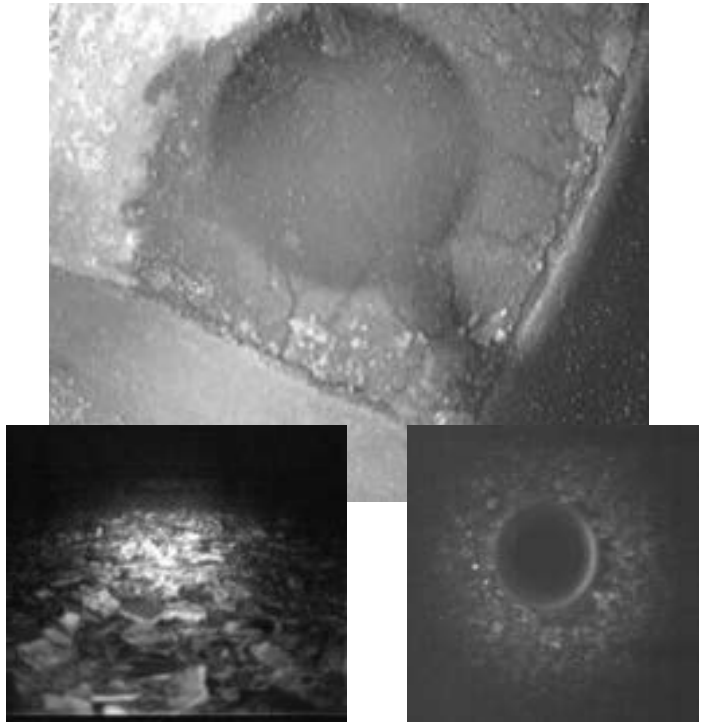
How Much Is On What?

Category	Contamination Level				
	Clean	kBq	MBq	GBq	TBq etc.
Metals					
Asbestos					
Plastics					
Concrete					
Containers					
….					



What Is The Contamination?

- In general, can't see, taste or smell radioactivity
- Early pilot scale plant work may have only shown 'trace' solids that need to be removed
- After 30-50 years of reprocessing operations we see accumulations of solids
- Contamination can also be;
  - A sludge / slurry e.g. Magnox cladding sludge
  - Adsorbed onto a surface
  - Absorbed e.g. into concrete
  - Mechanically entrained e.g. impacted
  - Chemically bound e.g. scales
  - Chemically entrained e.g. decades of chemical process liquors



Sellafield - What Does The Plant Look Like?

- Not a conventional Chemical Processing plant
- Each building is split into cells, housing a sub process
- Generally, there is no human access into the cells
- Vessels and pipework vary in size, length and material carried




When Is A Solution Required?

- Power reactors are being decommissioned to a immobilise core, with all other facilities removed
- The early plants are the most difficult to decommission
- 100+ year programme
- Cost for UK ~£100bn

When	Facility / Mission
Now	Legacy Facilities
	THORP Reprocessing
2021	Magnox Reprocessing
	AGR Dismantler
	Pond Storage Facility
	Site Ion Exchange Plant
	Plutonium Stores
	Uranium Stores
	Ponds for Interim Storage
2100+	Plutonium Residue Stores

What Is Decontamination?

Put simply;-

- “Mobilisation or removal of a contaminating species from a substrate in part or in full in a controlled way to support a **safety driver** or **business** requirement.”

- Many other permutations and **not** restricted to radiological contamination.

NB Decommissioning is the removal and disposal of items.

Why Do We Need Decontamination?

Reasoning can include;

- To enable other operational activities
- Re-use equipment
- Reduce radiation dose to workforce
- Reduce overall risk
- Make decommissioning easier
- Change to a lower waste classification

AIM: To achieve an optimal approach mindful of all factors based on trials and experience.

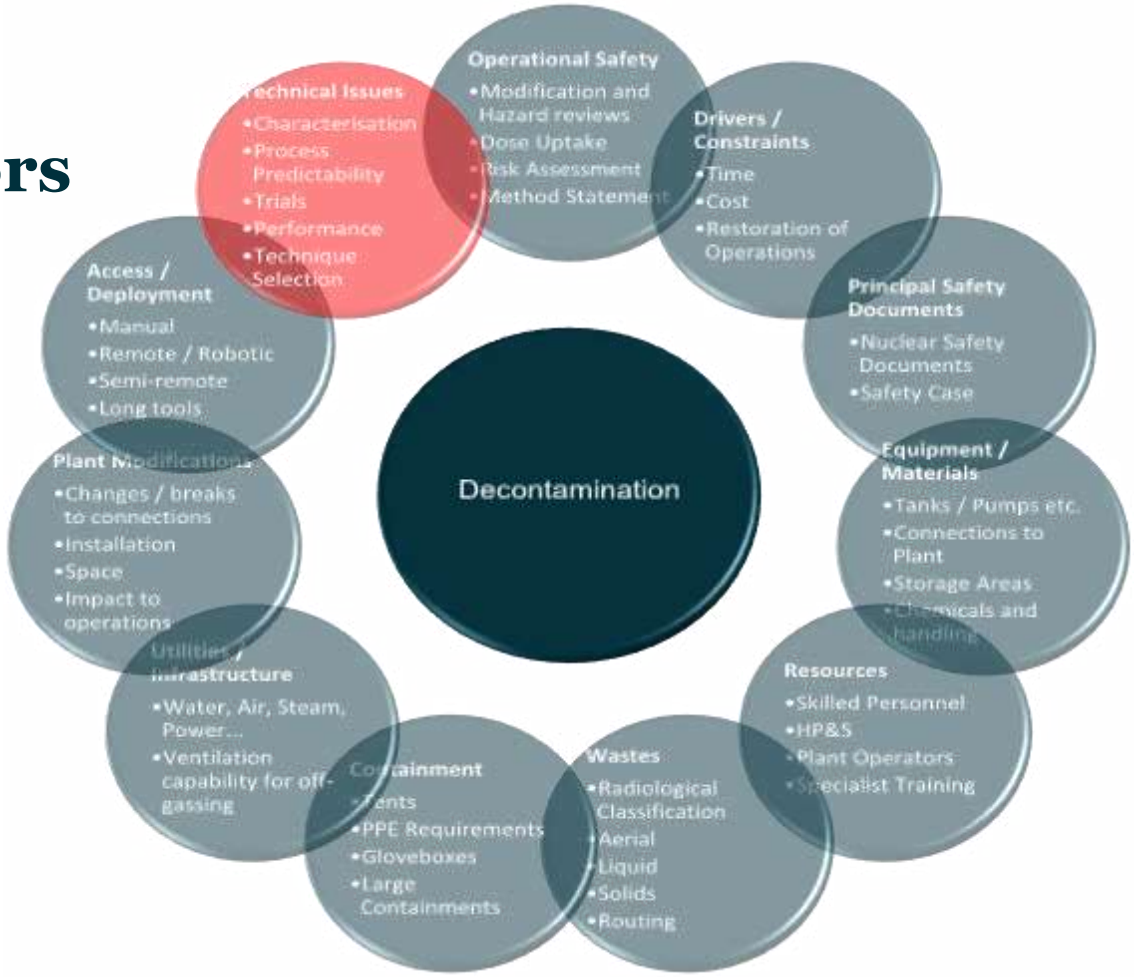
Factors To Consider

Characterisation:	• Knowing how much of what, is where?
Deployment:	• The tools needed to access contamination site and deliver the required technology / technique
Decontamination	• Which technique e.g. water jetting, fixing, chemicals, scabbling…
Waste Routes:	• What waste routes are available? Will the wastes generated be acceptable?

Nominal Radioactive Waste Types

LLW	ILW	HLW
<4,000 Bq/g Alpha	*>4,000 Bq/g Alpha*	*>ILW*
<12,000 Bq/g Beta/Gamma	*>12,000 Bq/g Beta/Gamma*	*+ Heat generating*

Plant Factors

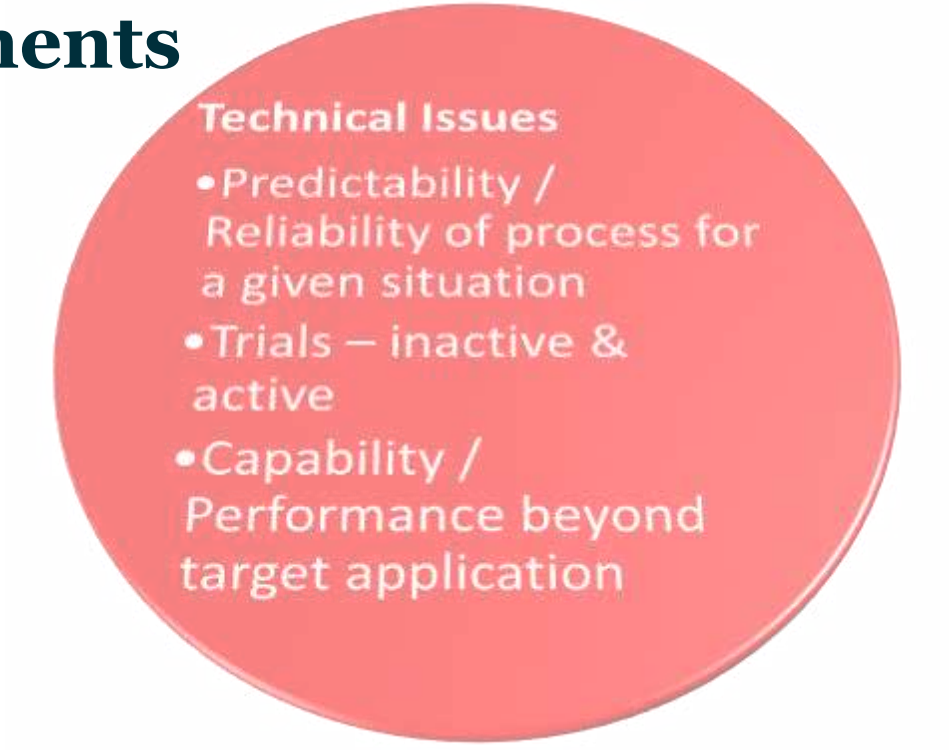


Other Factors

Waste Management Hierarchy

Waste Acceptability

Technical Requirements



Classes Of Decontamination Technique

Chemicals	• Mild, Medium, • Aggressive • Foams • Gels
Abrasives	•Wet and dry •Sand •Garnet •Bead
Mechanical / Physical	•Scabbling •Needlegun •Laser •Microwave
Fixatives & Strippable Coatings	•To fix for handling (short term) or long term operation requires a recognised coating. •Peel off for re-use / contamination control
Water Jetting	•Blockage removal •Coatings removal •High Pressure and Ultra High Pressure Water Jetting •Cutting

Chemicals

Pro's	Con's
Useful for flooding lutes or difficult to reach areas	Effluent routing critical
Range of chemicals & effectiveness	Many chemicals are incompatible with plant both singularly and in plural
Hotspot treatment → bulk use	Introduces additional chemical hazards, skilled personnel and infrastructure
	Need to understand the plant impacts and consequences for final wasteforms
	Suppliers rarely tell you the 'whole' truth of what's in proprietary products

Examples of use;
Mild – low risk areas, guided plant use, up to 10's m^2
Medium – moderate risk, controlled use with plant consequence (1-10m^2)
Aggressive – very high risk, severe plant consequence, small quantities (<<1m^2)
Chelating Agents – not permitted

Abrasives

Pro's	Con's
Range of media to control aggression	Noise
Variable motive forces air, mechanical or water	Secondary contamination from
Mostly a surface cleaning method	Capture of media, variable recycle rates
	Very Robust Containment and ventilation systems required
	Hazardous to operate
	Wet abrasives hard to handle in nuclear

Examples;
Wet Abrasive Blasting – polishes (relatively gentle) – clean Calor gas bottles
Dry Abrasive Blasting – removes coatings, leaves rough surface
Abrasive Water Jet Cutting – mostly for cutting metals – Used sparingly due to hazard

Physical / Mechanical

Pro's	Con's
Mechanical methods suited to concrete, sparingly on metals	Requires direct access to the surface
Physical methods good for surfaces only	Vibration and noise
	Secondary contamination containment and ventilation issues, particularly lasers
	Lasers and microwaves require additional conventional safety controls
	Wear and consumables parts

Examples;
Physical – Ultrasonics, Lasers, Microwave
Mechanical - Peening, shaving, scabbling, needlegun

Coatings

Pro's	Con's
Contain loose and fixed contamination (not bulk material)	Recovery of coatings is usually manual
Can usually be recoated for longevity / ease of retrieval	Not suited to complex geometry items, introduction to process lines
90^{+}% retention factors of loose contamination peeling up	Wastes may become high specific activity due to low mass of coating
Recovery of coating is optional. If permanent, then called a fixative	Ability to spray coatings is variable, e.g. temperature
Simple to apply (with guidance)	Cure times can be hours to days
A number of "approved" products available with waste assessments	Some coatings have odours / VOCs that require multipurpose respirators

Examples;
Used widely in Decommissioning, contaminated plant recovery etc to control loose contamination

Water Jetting

Pro's	Con's
High levels of application e.g. pipes, surfaces and vessel internals	Aerosols affect ventilation and respirator filters and requires containment
Process is repeatable	Higher flow rates needed to mitigate secondary contamination for scabbling
Performance spans rinsing through to cleaning to cutting / scabbling	Requires skilled and trained personnel. Very few with genuine Nuclear credibility
Waste is essentially water	Performance of HPWJ is not the same as UHPWJ. Standoff is critical
Can clean inside of pipes given access, up to 50 metres	Hazardous if mis-used / poorly operated

Examples;
Blockage removal, coatings removal, scabbling, heavy equipment, bulk tank, concrete cutting
Ultra High Pressure - upto 3000 Bar with flow rates upto 30 litres per minute – very aggressive used for scabbling hard coatings removal
High Pressure - <1200 Bar flow rates can reach 150 litres per minute for bulk tank cleaning, usually upto 50 litres per minute for most purposes

Challenges Summarised

- ~1 Mm^3 contaminated concrete above and below ground – Can we predict the depth of contamination? [includes brick and mortar structures]
- Heterogeneity in particulate deposits in plants – how to mobilise dense solids spanning a wide range of particle sizes?
- Air disturbances can mobilise loose contamination – how do we predict the plume from opening previously sealed ‘cell doors’?
- Aerosols from water jetting – impact to ventilation systems using pressures 100-3,000 Bar (1,500-45,000 psi) and water flow rates 4-50 litres per minute?
- Fume and particle generation from laser systems for decontamination – impact to ventilation systems and how to abate at point of use?

Academic Works

Numerous links to commercial and academic suppliers exist for decontamination and sludges. Some indicated below;

- Direct or Part Funded Research
  - Ice Pigging & Truffles (Smart Ice Pigging) [Bristol]
  - Mapping of contamination in concrete [Bristol]
  - Contamination of stainless steels [Manchester]
  - Decontamination of stainless steels [Manchester]
  - The effects on stainless steel of impinging water jets [Manchester]
  - Incorporation of media into foams and application of gels for decontamination [Manchester]
  - Sludge transport related topics [Leeds]
  - D-EEP – mapping of sub-surface contamination in walls [Commercial]
  - Laser decontamination performance trials [Commercial]

Academic Works

- Topics In Preparation
  - Modelling of contamination of concrete and brickwork to / from contaminated groundwater
  - Aerosol transport and impacts to ventilation systems
  - Non-conventional decontamination methodologies of concrete

- Other professional relationships of a sensitive nature exist with DEFRA, AWE and DSTL.

Summary

- Many challenges to face from legacies as well as future plants
- Multiple methods will be required
- Long timescales for requirement
- Opportunities in various plant types, e.g. wet, dry, chemical.
- Need to demonstrate the reliability and robustness of your process
- Many other factors must be considered by a Nuclear Site before use

So What Now?

- Ever considered Nuclear as an application before?
- Do you have a novel method?
- Have you undertaken trials for other industries you think might be relevant?
- Contact;

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