Characterisation: Challenges and Opportunities – A UK Perspective

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Abstract

Characterisation plays a very important role in the nuclear industry supporting: the development and implementation of decommissioning strategies/plans (and the optimisation of associated costs through reduction in technical risks); regulatory compliance demonstration; waste prevention/minimisation; evaluation and optimisation of worker radiation doses; and maintaining public confidence. Recognising these important drivers, the UK regulators are working with the UK Nuclear Decommissioning Authority (NDA) to undertake a review of characterisation practice in the UK nuclear (decommissioning) industry. The objective of the characterisation review is to understand the current characterisation challenges and to determine strategic and tactical opportunities (including sharing of standards and guidance, capabilities, learning from experience, good practice, research and development, training, quality assurance) to optimise characterisation practice. The work is being undertaken through review of nuclear operator's characterisation practice, with input from the NDA, the UK regulators, nuclear operators and representatives from the supply chain, and through consideration of good practice case studies. To support this, a catalogue of relevant national/international guidance documents is also be compiled. Finally a workshop with representatives from all parties has taken place to consider the findings and establish a common understanding of challenges and opportunities and to start to consider how they can be addressed. The review is establishing a collective (UK regulator's, NDA; nuclear operator's and supply chain) understanding of opportunities to improve characterisation practice in the UK. The characterisation review process is described and early results are presented and discussed. Subsequent work in 2016 will be required to prioritise the opportunities and to build a consensus to facilitate development and implementation of an improvement plan. The aim is to ensure robust, efficient and effective characterisation practice in the UK nuclear industry as the decommissioning challenge increases.

Introduction

The United Kingdom (UK) has embarked on a significant decommissioning programme to address its nuclear legacy and has the mission to deliver this through safe, sustainable and publicly acceptable solutions. The Nuclear Decommissioning Authority (NDA) was created in 2005 as the UK body responsible for improving the understanding of the civil public nuclear

liabilities, and for developing and implementing an estate-wide strategy and plans to deal with them. The nature and scale of the task to decommission the legacy facilities inherited by the NDA was poorly understood and highly uncertain [1]. Characterisation is the fundamental process by which material is probed and measured and involves the determination of its physical, chemical, biological and radiological properties. Consequently, characterisation is playing a key role in understanding the UK's nuclear legacy. It is central to the development and implementation of decommissioning strategies/plans and in supporting the management of the waste arising from these activities. In particular it facilitates the reduction in project technical risks and supports the optimisation of project costs.

Similarly the UK nuclear site regulators (Environment Agency (EA); Office for Nuclear Regulation (ONR); and Scottish Environment Protection Agency (SEPA)) recognise the importance of characterisation and the role that it plays in:

- Regulatory (environmental, safety, security & transport) compliance demonstration;
- Supporting decommissioning activities and ensuring associated radioactive wastes are being managed (and minimised) appropriately to protect people and the environment;
- Ensuring worker safety, including the evaluation and optimisation of worker radiation doses; and
- Maintaining public confidence.

Recognising these important drivers, the UK nuclear site regulators are working with NDA in undertaking a review of characterisation practice in the UK nuclear (decommissioning) industry. This builds on earlier work such as the formation of a nuclear industry characterisation working group which has shared and promote good practice. The objective of the latest characterisation review is to understand the current characterisation challenges and to determine strategic and tactical opportunities to improve characterisation practice. This paper provides the provisional findings from this work.

Methodology

In early 2015 the EA commenced a top level assessment of characterisation practice across the nuclear industry in England using readily available information. The assessment was primarily undertaken to underpin the EA's future work programmes but also reflected the recognised importance of characterisation and the perceived potential to improve current practice. Summary evidence was collated from the following sources:

- Regulatory intelligence, including information from nuclear site regulators, covering compliance assessment and enforcement action over the last few years;
- Findings from a review of operator's and regulatory assurance processes;
- Engagement with national/international nuclear industry characterisation networks; and
- Past reviews of characterisation practice and needs.

The outcome of this initial assessment highlighted challenges and opportunities to improve characterisation practice covering standards and guidance, capabilities, learning from experience/good practice, research and development, training, and quality assurance.

The regulators and the NDA discussed the findings of the initial assessment and it was agreed that a more detailed review should be undertaken by the NDA with the support of regulators and the nuclear industry. The primary objective of this review is to develop a consensus understanding, between nuclear site operators, NDA, regulators and the supply chain, on the most important challenges and opportunities for solid waste characterisation in the short, medium and long term. To achieve this it was recognised that an understanding of

how challenges may be met and opportunities realised would be required. In order to bound the review it was agreed that the focus should be primarily on solid waste characterisation. However, given the significant decommissioning challenge and the potential to support radioactive waste prevention/minimisation, the review also considered characterisation of materials that will become waste (e.g. facility characterisation).

The first phase of the characterisation review has used the output from the initial EA assessment and some initial input from NDA's project team to generate a characterisation issues register. In addition, existing characterisation standards and guidance has been collated and a catalogue established as a knowledge management tool. The issues register has been used to develop a format for structured interviews with characterisation experts across the UK nuclear industry, whilst the characterisation catalogue has supported the exploration of the awareness and consistency of the application of standards and guidance across the industry. The output from this process has been collated, providing a summary of UK characterisation practice and the perceived challenges and opportunities for improvement.

The second phase of the review has used a workshop to bring together characterisation experts from the nuclear industry. It included nuclear site operators, the supply chain, academics, the regulators and NDA. The workshop has been used to start to develop a consensus on good practice, challenges and opportunities for improvement. Initial work has also been undertaken to establish the preliminary priorities for future action. This used a simple ranking scheme covering the benefits to the industry (Small, Medium or Large); the timescales to implement (Near, Medium or Long term); and the required resource (Small, Medium or Large). Whilst the final report of the characterisation review will not be available until mid 2016, the early results and provisional findings are discussed below. Table 1 summarises the preliminary results detailing: the identified challenges and opportunities; possible solutions; and ranking of the benefits, timescales to implement and resource requirements. Subsequent work in 2016 will be required to agree the prioritisation of the opportunities and to build a consensus to facilitate development and implementation of an improvement plan.

Early Results and Discussion

The early results and provisional findings from the characterisation review are given below. Discussion covers the following aspects of characterisation: standards and guidance; capabilities; learning from experience/good practice; research and development; training; and quality assurance.

Standards and guidance

UK regulatory and industry guidance is available to support radiological characterisation at nuclear sites. However, typically the standards and guidance either set out top level regulatory expectations [2&3] or provide detailed guidance on sub-topics of the characterisation process [4]. This means that the existing national radiological characterisation is not comprehensive and consequently reliance is placed on international guidance or local site practice to support current gaps. For example, IAEA [5] and NEA [6] documents are being used to support strategic planning and the Data Quality Objectives (DQO) methodology [7] to develop more detailed characterisation plans. Furthermore, the UK and a number of other countries have significant nuclear decommissioning programmes but much of the current national and international characterisation standards and guidance have been developed to support nuclear operations. Without a national consensus regarding the applicability of wider guidance, this situation can lead to inconsistencies in characterisation practice and does not necessary align with the UK's needs. Some examples of current gaps in UK standards and guidance are:

- Characterisation standards/guidance to support decommissioning
- Characterisation strategies;
- Characterisation plans;
- Use of Scaling factors (fingerprints); and
- How to address uncertainty, including contamination heterogeneity and inaccessible areas.

Potential opportunities for addressing this situation are:

- Establishing and maintaining a UK consensus (a catalogue and guide) to what international standards and guidance should supplement UK standards and guidance and categorising these resources based on provenance; and/or
- Developing UK standards/guidance to provide: contextual guidance to UK nuclear site operators; address the current gaps; and point to good practice. Currently the development of a Nuclear Industry Code of Practice on Characterisation is under consideration. There is also a desire that such guidance should draw from practical case studies to support the sharing of good practice and learning from experience. This is discussed further in the next section.

Good practice sharing and learning from experience

The UK has established fora of radiological characterisation experts focused on topics such as solid waste characterisation, radioassay and discharge monitoring. These fora primarily interact through face to face meetings where characterisation experts share experiences and developments and in some cases develop industry guidance [4]. A number of these experts are also involved in international characterisation networks. There are also national groups which support the UK's involvement in the development of British and International Standards. However, co-ordination across the national characterisation groups is fairly limited and the networks are diffuse meaning it is challenging to ensure that experts are fully connected and strong cohesion exists across the expert groups. Some industry databases sharing characterisation practice have also been established [8]. These mechanisms support the sharing of good practice and learning from experience within and between organisations. Potential opportunities for improvement are:

- Transitioning the existing characterisation topic fora into networks/communities sharing issues and developing common solutions, where appropriate, and communicating through a range of media; and
- Improving the co-ordination and communication between radiological characterisation topic groups and establishing stronger connectivity between characterisation experts.

Resources and Capability

There is an increasing demand for characterisation resource and expertise as the UK continues to address its nuclear legacy. Typically, radiological characterisation (and radioactive waste management more widely) relies on the use of nuclear site based expertise/infra-structure for routine characterisation and support from the supply chain for larger and more challenging projects or for the utilisation of more specialised characterisation techniques. Therefore there is significant reliance on the supply chain to deliver improvements through the creation of a competitive commercial marketplace. However, supply chain investment to-date (since publication of UK Government's revised LLW policy in 2007) in developing new characterisation techniques and capability has been limited. Therefore, the UK has limited resources, capability and infrastructure to support radiological characterisation. This is particularly the case for the characterisation of Higher Activity Wastes (HAW) which needs specialised facilities and/or equipment to ensure protection of operators undertaking characterisation work. This is a key area as significant environmental and costs benefits may be realised through effective HAW characterisation

which can lead to de-categorisation of waste and simplification of downstream waste treatment, storage and disposal.

Another current limitation is that whilst the UK has an established radioactive waste inventory [9], this has been developed primarily to meet three yearly international reporting requirements. Consideration is currently being given to identify potential improvements to the UK inventory which could include development to enable greater use as a strategic planning tool. Furthermore, nuclear sites decommissioning schedules have been subject to significant change. Overall, this situation makes it difficult for the supply chain to understand future demand and therefore to commit substantial investment to expand existing capabilities and/or undertaking research and development. Potential opportunities for improvement are:

- Improving the medium to long-term planning and developing the UK radioactive waste inventory into a more dynamic strategic planning tool. This could support improved understanding of the commercial opportunities for supply chain investment with the objective of more efficient and effective processes for the management of radioactive wastes including radiological characterisation;
- Encouraging strategic partnership arrangements, between nuclear sites, companies and research and development institutes, to support the more streamline development of new characterisation techniques; and
- Ensuring that commercial contracting arrangements support the development of new techniques and allow for return of such investments, whilst also encouraging new organisations, in particular from other industries, to bring new or adapted characterisation techniques in play within the nuclear sector.

Implementation

There is some variation in characterisation planning across the nuclear industry. There are a number of aspects to this. Firstly, it is not always evident that characterisation is taking place within a wider strategy that fully considers the subsequent lifecycle of the material or waste and the associated characterisation needs. Similarly a comprehensive systematic planning approach is not always applied. This can result in the lack of utilisation of provenance/precedence [1] and poor specification of the characterisation plan (including sampling strategy, determinands, limits of detection and uncertainty) leading to unnecessary characterisation or the need to duplicate characterisation effort.

Characterisation is used to demonstrate that Waste Acceptance Criteria (WAC) for downstream processing (e.g. treatment or disposal plants) is met. New WACs are being developed as new waste treatment processes and disposal routes are opened up to support decommissioning. In addition, WACs are being revised to accommodate expanding requirements to characterise and report non-radiological determinants. This means there is a need to ensure that the current WACs are reflected in waste consignor's arrangements, anticipate future changes and also to consider how historical characterisation information is interpreted within the context of revised WACs.

The treatment of the uncertainty in characterisation data can be challenging but is important. For example, understanding and compounding uncertainty in sampling, characterisation measurements and scaling factors can take considerable resources. In situations where scaling factors are applied this is further complicated by temporal (due to radioactive decay

[1] Provenance - Knowledge of the use (including location) and controls which have been applied to an article or substance to determine its potential to have become activated and/or contaminated by radioactivity, and the nature of any potential activation or contamination. Precedence - Data, documentation and experience collected from sites who have previously undertaken relevant characterisation work drawing comparisons and learning from good practice and areas for improvement.

and/or radionuclide migration) or spatial variations in the radionuclide concentrations within waste streams (or materials destined to become waste). Heterogeneity of contamination (e.g. the presence of discrete waste that is significantly more active that the surrounding waste) is a difficult aspect to deal with when trying to decide how to sample and how to interpret the results obtained. Appropriate characterisation needs to be undertaken to ensure that it can deliver the required level of confidence and this in turn will be dependent on the characterisation objectives.

Opportunities for improvement include:

- Reaching a consensus on the treatment of uncertainty in waste characterisation data which take account of uncertainties in sampling, analysis and scaling factors (including the potential spatial and temporal variation in scaling factors). This could be established through industry guidance which also considered acceptable levels of uncertainty and how these might vary according to the characterisation objectives;
- Developing approaches to sorting and segregation to minimise issues with heterogeneity; and
- Establishing UK guidance on characterisation planning and practical guidance on characterisation implementation to address aspects such as: heterogeneity of contamination; and inaccessible areas.

Another challenge is in understanding the impact of the use of outdated characterisation techniques and the limitations of existing techniques (such as the characterisation of inaccessible areas – in particular for alpha contamination). Development of new techniques is required to support:

- In-situ characterisation of facilities/waste etc. to support waste management hierarchy and sorting & segregation;
- In-situ characterisation of HAW legacy facilities/wastes in remote and inaccessible facilities;
- Non-destructive condition monitoring of HAW packages and waste forms in store or disposal facility;
- Use of scaling factors, extending to non-radiological characterisation and improved handling of associated uncertainty and variation; and
- Characterisation of boundary wastes (close to the boundaries of Intermediate Level Waste (ILW)/Low Level Waste (LLW) & LLW/Out of scope).

It is also recognised that the development of new techniques requires early engagement of all interested stakeholders to establish early agreement that the technique is appropriate thereby avoiding project delays and costs that can arise from disagreements regarding the suitability of a technique once it has been deployed.

Quality Assurance

Characterisation in the UK is typically carried out within robust quality assurance framework. The level of quality assurance of characterisation in the UK broadly depend on the objectives of the characterisation, with the highest levels of quality assurance generally being applied to waste disposals and discharges to ensure protection of people and the environment. Quality assurance tools include: inspection/audits of processes, procedures, people and equipment; accreditation/certification to specific quality standards (e.g. ISO17025 [10] and MCerts [11]); inter-laboratory comparison exercises; and duplicate sampling and independent measurements to verify characterisation information. More specifically, for waste disposals and discharges the EA undertakes independent waste assurance to verify that the declared disposals and discharges of radioactivity to the environment are accurate. This is in addition, to inspecting the characterisation quality arrangements of the nuclear site operator, and for

waste disposal, the characterisation quality assurance arrangements of the waste consignee. However, the focus of quality assurance undertaken by nuclear site operators is based on the auditing of paperwork with limited independent characterisation/assurance being undertaken. There is currently also limited availability of reference materials and opportunities to participate in characterisation inter-comparison exercises. Opportunities for improvement include:

- Reaching a consensus and establishing guidance on good practice regarding the need for independent assurance to verify primary characterisation data; and
- The generation of solid waste reference materials to facilitate waste characterisation inter-comparison exercises and provide confidence in the accuracy of characterisation data.

Conclusions and Way Forward

A structured review of radiological characterisation practice across the UK nuclear (decommissioning) industry is underway and is establishing a collective (UK regulator's, NDA; nuclear operator's and supply chain) understanding of opportunities to improve characterisation practice in the UK. Subsequent work in 2016 will consolidate the findings and understanding and seek to build a consensus to facilitate development and implementation of an improvement plan. The aim is to ensure robust, efficient and effective characterisation practice in the UK nuclear industry as the decommissioning challenge increases.

References

[1] Nuclear Decommissioning Authority, *Strategy effective from April 2011,* Nuclear Decommissioning Authority, United Kingdom, 2011.

[2] Environment Agency, *Radioactive Substances Regulation – Environmental Principles*, Regulatory Guidance Series, No RSR 1, 2010.

[3] Office of Nuclear Regulation, Environment Agency, Scottish Environment Protection Agency and Natural Resources Wales, *The management of higher activity radioactive waste on nuclear licensed sites*, 2015.

[4] UK Nuclear Industry, *Clearance and Radiological Sentencing: Principles, Processes and Practices for Use by the Nuclear Industry*, Nuclear Industry Code of Practice, 2012.

[5] International Atomic Energy Agency, *Strategy and Methodology for Radioactive Waste Characterisation*, IAEA-TECDOC-1537, IAEA, Vienna, 2007.

[6] Nuclear Energy Agency, *Radiological Characterisation for Decommissioning of Nuclear Installations*, Report of the Task Group on Radiological Characterisation and Decommissioning (RCD) of the Working Party on Decommissioning and Dismantling (WPDD), Organisation for Economic Co-Operation and Development, 2013.

[7] United States Environmental Protection Agency, *Guidance on Systematic Planning Using the Data Quality Objectives Process*, EPA QA/G-4, Office of Environmental Information, Washington, DC, 2006.

[8] *Environment Agency Requirements Working Group*, http://www.rwbestpractice.co.uk/

[9] Nuclear Decommissioning Authority, *UK Radioactive Waste Inventory*, http://www.nda.gov.uk/ukinventory/

[10] International Standards Organisation, ISO17025: General requirements for the competence of testing and calibration laboratories, 2005.

[11] Environment Agency, *Monitoring Certification Scheme*, https://www.gov.uk/government/collections/monitoring-emissions-to-air-land-and-water-mcerts, 2015.

Table 1: Preliminary Results Summary detailing: the identified challenges and opportunities; possible solutions; and ranking of the benefits, timescales to implement and resource requirements.

Challenges and opportunities	Proposed solution	Benefit	Timescale	Resource
		S/M/L	N/M/F	L/M/H
Standards and guidance				
Principles from external guidance documents and standards are commonly embedded into internal processes and procedures. There is a requirement to continually review current standards and ensure they are incorporated within these documents.	Continual review (not scored –routine)			
There are an extensive number of external guidance documents which are used across the industry, therefore it can be difficult to assess the quality/usefulness of available documentation.	Assessment held on portal	L	N	M
To ensure standards and guidance documents are practical and useful by providing real examples of how characterisation activities have been done successfully. However, there is a general agreement that the material should not be prescriptive.	Revision of standards and guidance	M	F	H
Generally the guidance documents identified consider the characterisation of radiological materials, but do not address the need to measure non-radiological properties of nuclear material and consequently may not adopt an appropriate characterisation programme. There is an opportunity to make non-radiological guidance more visible to the industry.	Portal	L	N	M
To create a single **"portal"** to access standards and guidance.	Portal	L	N	M
Good practice sharing and learning from experience				
The effectiveness of internal communication processes to disseminate information on industry wide good practice within organisations is variable across the industry. Every organisation faces a challenge to ensure that this process is effective.	Internal networks / hubs	S	M	M
Increased communication of good practice sharing and learning from experience across the industry has clear benefit. The key barriers to achieving this are time 'away from day job' and identifying a clear business need.	Optimise forum / network relevance (not scored)			
A web-based information hub to store information from forums/groups was identified as an effective means for sharing good practice which could be applied more widely across the existing forums/networks.	Web based hubs	L	M	M

Challenges and opportunities	Proposed solution	Benefit	Timescale	Resource
		S/M/L	N/M/F	L/M/H
There is an opportunity to define role/objectives clearly and advertise existing groups/forums to maximise attendance and their effectiveness.	map	L	N	L
To improve cohesion between characterisation networks/groups/forums.		L	F	M
Resources and capability				
To **ensure** the industry manages Suitably Qualified & Experienced Person (SQEP) capability and intelligent customer capability and that knowledge and experience of characterisation are not lost.	Training and development	L	F	H
To ensure knowledge and data are retained.	Improved record keeping	L	M	M
There is an assumption held in parts of the industry that the supply chain and internal resource will be available to fill gaps in capability on timescales coherent with projects. This is not always possible if the supply chain perceive a lack of commitment or work variability from the industry.	Means of reassuring supply chain	L	F	H
To ensure laboratory capability evolves with on-site & disposal requirements, characterisation approaches, tools and techniques.	Investment in equipment and training	L	F	H
To improve communication between internal/external analytical service providers and the wider characterisation community in order to recognise available resource and capability.	Networks / hubs	L	N	M
Implementation				
To consider where characterisation activities are appropriately integrated within the project lifecycle. It was highlighted that there needs to be a drive to ensure characterisation is embedded throughout the whole process. This approach is currently not employed across the entire industry.	Conference/workshop	M	N	M
To continually consider changes to disposal requirements to ensure waste characterisation data are appropriate, and historical characterisation is reviewed.	Continual review	M	M	M
Application systematic planning approaches to characterisation is variable across the industry. There is scope to increase understanding of the process and where it can be applied through additional training.	Training	L	N	M

Challenges and opportunities	Proposed solution	Benefit	Timescale	Resource
		S/M/L	N/M/F	L/M/H
There is the opportunity to use the existing communities of practice and forums to further promote early engagement between interested parties in the development of new characterisation techniques.	Early engagement	L	N	M
To develop guidance in areas of uncertainty management such as inaccessible areas and heterogeneity.	Creation of guidance	L	M	M
Physical-chemical characteristics				
It is conceded that there are potentially only a limited number of laboratories and capability that are able to accept the samples for non-radiological analysis. Waste Acceptance Criteria (WAC), transport regulations, and in-situ disposal needs to consider non-radiological species.	Increased capability	L	F	H
To improve waste producer's and the Low Level Waste Repository's understanding of the reasons behind non-radiological capacities and requirements set by disposal facilities.	Conference participation	M	N	M
Quality Assurance				
To ensure there is appropriate understanding of the uncertainties in data collected and increased recognition of the uncertainties associated with all steps of the characterisation process.	Nuclear Industry Code of Practice (NICoP)	M	M	H
To manage pessimisms in all stages of the characterisation process in order to minimise 'ghost' capacity.	NICoP	M	M	H
To ensure appropriate accreditation and proficiency testing of analytical and radio-analytical techniques.	Enhanced Inter-comparisons and use of reference materials	M	F	H