Carbon-14 in UK Geological Disposal

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Introduction

- Radioactive Waste Management Limited (RWM) has been established as the delivery organisation responsible for the implementation of a safe, sustainable and publicly acceptable programme for the geological disposal of the higher activity radioactive wastes in the UK.
- C-14 is a key radionuclide in the assessment of the safety of a geological disposal facility for radioactive waste because of the potential radiological impact of gaseous C-14 bearing species during the operational and post-closure periods.
- In 2012 RWM established an Integrated Project Team (IPT) to develop an holistic approach to C-14 management in a geological disposal system. The overall aim of the project was: *"To support geological disposal of UK wastes containing C-14, by integrating our evolving understanding from current and pre-existing projects, in order to develop an holistic approach to C-14 management in the disposal system".*
- In 2017, RWM published an updated Disposal System Safety Case. The Derived Inventory (DI), Environmental Safety Case (ESC), Post-closure Safety Assessment (PCSA) and Operational Environmental Safety Assessment (OESA), in particular, were informed by learning from the C-14 IPT.

Improved understanding

Improved understanding of the inventory, gas generation and migration processes has informed model development and assessment calculations, and is reflected in the Environmental Safety Case. The key gas generation and migration processes are summarised in Figure 1.

Inventory: Improvements were made to the understanding of the quantities of C-14 in the UK inventory, its distribution across waste streams, and the nature of the materials with which the C-14 is associated.

Gas generation mechanisms: There have been improvements in the understanding of gas generation mechanisms, including:

- steel corrosion – the anaerobic stainless steel corrosion rate used in the modelling has been reduced;
- radiolytic gas generation – the parameterisation of the model has been revised; and
- microbial degradation – there is an improved understanding of the conditions required to sustain a microbial population.

Gas migration mechanisms:

Geosphere: The amount of free gas and its migration through the Engineered Barrier System and the geosphere depend strongly on site-specific conditions, and may also depend on the design of the Geological Disposal Facility (GDF). The calculated post-closure consequences were found to be dependent on the migration time relative to the half-life of C-14 and the area over which the C-14 is released to the deep soil. Six illustrative cases were developed, spanning the geological environments that may be considered to host a UK GDF.

Biosphere: A combined experimental (Figure 2) and modelling programme concluded that the bulk of methane generated would be oxidised to carbon dioxide in the soil. A revised assessment model was developed which was consistent with those used by the UK Low Level Waste Repository (LLWR).

Figure 1 Key generation and migration processes affecting the fate of C-14 in the disposal system

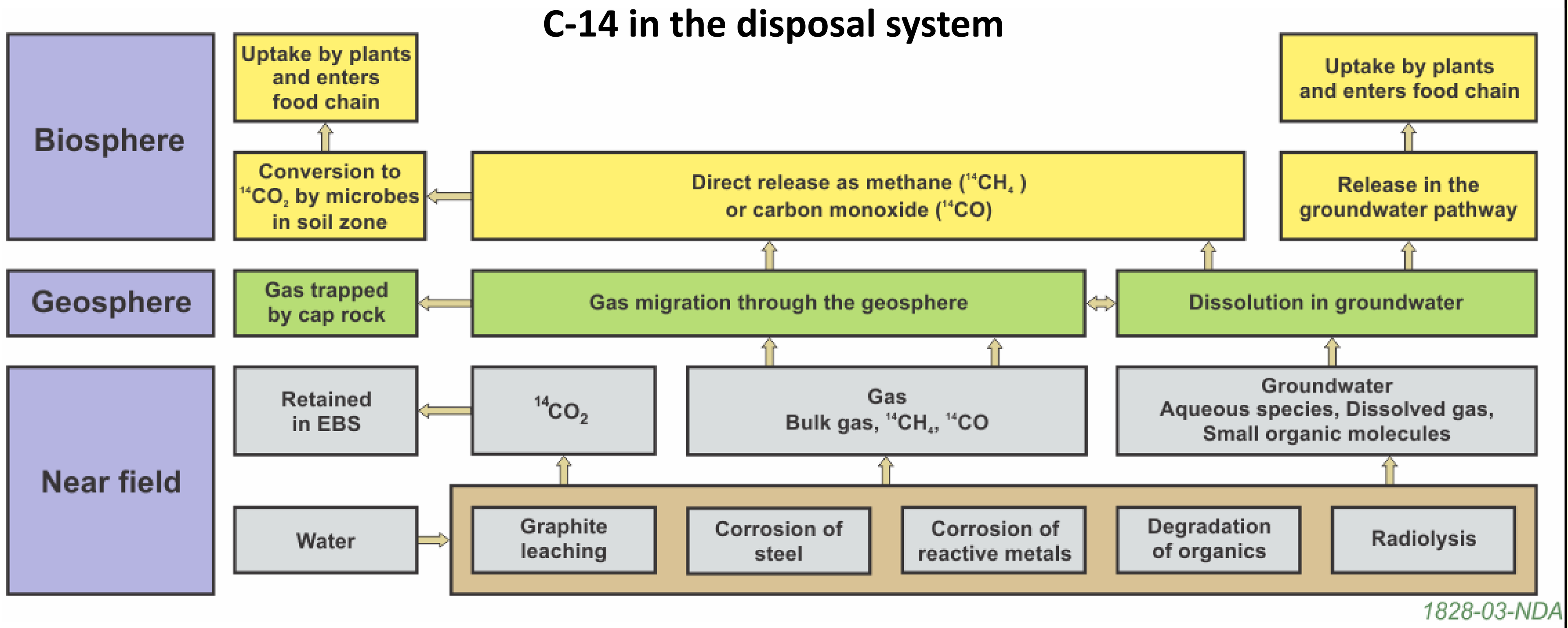
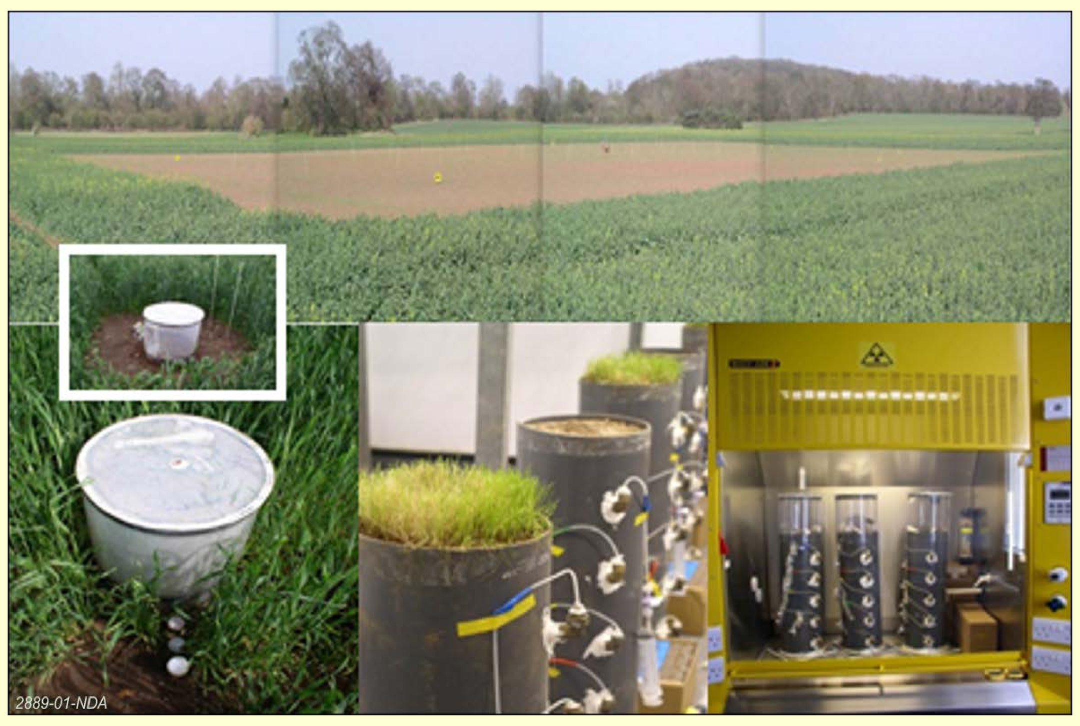


Figure 2: Field and Laboratory Experiments Results



The 'AND' approach

The IPT concluded that for the radiological impact of gaseous C-14 to be an issue:

- there must be a significant inventory of C-14; **AND**
- that waste has to generate C-14 bearing gas; **AND**
- a bulk gas has to entrain the C-14 bearing gas; **AND**
- these gases must migrate through the engineered barriers in significant quantities; **AND**
- these gases must migrate through the overlying geological environment (either as a distinct gas phase or as dissolved gas); **AND**
- these gases must interact with materials in the biosphere (i.e. plants) in a manner that leads to significant doses and risks to exposed groups or potentially exposed groups.

Table 1 Conclusion from applying 'AND' approach to the main UK waste groups

<table>
<tr><td>'AND' Question</td><td colspan="2">Do these gases lead to significant risks to potentially exposed groups in the post-closure phase?</td></tr>
<tr><td>Graphite</td><td rowspan="3">Impact is site specific.</td><td>Risks assessed to be below the risk guidance level provided the release is not focused over a small area.</td></tr>
<tr><td>Irradiated steel</td><td>The radiological risk is expected to be tolerable in most environments.</td></tr>
<tr><td>Irradiated Magnox</td><td>Risks expected to be tolerable provided releases are to an area comparable to the GDF footprint and the proportion of the C-14 released as $^{14}CH_4$ or ^{14}CO is limited, or there is a significant hold-up of gas in the geosphere.</td></tr>
<tr><td>Irradiated uranium</td><td colspan="2">Provided uranium corrodes anaerobically after emplacement, it will all have corroded before closure.</td></tr>
</table>

References

1. RWM, *Geological Disposal: Carbon-14 Project Phase 2: Overview Report*, NDA/RWM/137, 2016
2. NDA, *Geological Disposal: Carbon-14 Project – Phase 1 Report*, NDA/RWMD/092, 2012
3. RWM, *Geological Disposal: Generic Environmental Safety Case Main Report*, DSSC/203/01, 2016
4. RWM, *Geological Disposal: Generic Operational Environmental Safety Assessment*, DSSC/315/01, 2016
5. RWM, *Geological Disposal: Generic Post-closure Safety Assessment*, DSSC/321/01, 2016
6. RWM, *Geological Disposal: Gas Status Report*, DSSC/455/01, 2016

Summary

Understanding from the Carbon-14 Integrated Project has led to:

- an improved understanding of C-14 distribution in the UK inventory and behaviour in the geosphere and biosphere as described in the Gas Status Report; and
- an improved off-site gas release rates for C-14-bearing gases in RWM's ESC, including the OESA and PCSA.

Scope for further work on C-14 has been identified in:

- updating the assumed effective release height for C-14 bearing gases during the operational period (from 15 to 30 m) in the OESA; and
- carrying out further research to better understand the effect of gas pressurisation within the facility and its potential implications for C-14 release.