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Environmental risks of radioactive discharges from a low-level radioactive waste disposal site at Dessel, Belgium

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ABSTRACT

The potential radiological impact of releases from a low-level radioactive waste (Category A waste) repository in Dessel, Belgium on the local fauna and flora was assessed under a reference scenario for gradual leaching. The potential impact situations for terrestrial and aquatic fauna and flora considered in this study were soil contamination due to irrigation with contaminated groundwater from a well at 70 m from the repository, contamination of the local wetlands receiving the highest radionuclide flux after migration through the aquifer and contamination of the local river receiving the highest radionuclide flux after migration through the aquifer. In addition, an exploratory study was carried out for biota residing in the groundwater.

All impact assessments were performed using the Environmental Risk from Ionising Contaminants: Assessment and Management (ERICA) tool. For all scenarios considered, absorbed dose rates to biota were found to be well below the ERICA 10 $\mu Gy\ h^{-1}$ screening value. The highest dose rates were observed for the scenario where soil was irrigated with groundwater from the vicinity of the repository. For biota residing in the groundwater well, a few dose rates were slightly above the screening level but significantly below the dose rates at which the smallest effects are observed for those relevant species or groups of species. Given the conservative nature of the assessment, it can be concluded that manmade radionuclides deposited into the environment by the near surface disposal of category A waste at Dessel do not have a significant radiological impact to wildlife.

1. Introduction

In 2006, the Belgian Federal Government decided that the long-term management of low-level waste (so-called category A waste in Belgium), should take the form of a near-surface repository within the Belgian municipality of Dessel. Category A waste is to be encased in modular concrete boxes which are stacked inside structures which ultimately will resemble tumuli. The expectation is that operations will start at this facility, which is currently at the licensing stage, in the early 2020s, and that it will be actively monitored for 300 years (ONDRAF/NIRAS, 2010). The present paper reflects a study carried out in the framework of the safety case (Vandenhove et al., 2011), submitted to the Federal Agency of Nuclear Control in Belgium, in support of the application by the Belgian National Agency for Radioactive Waste and enriched Fissile Material (ONDRAF/NIRAS) for a construction and operating licence for the repository.

As well as ensuring that humans are adequately protected from exposure to radioactive contaminants from the Dessel near surface repository, there is a need to ensure that the environment as a whole – including non-human biota species – is also adequately protected. In the past, the system of radiological protection focused exclusively on human health protection but, in recent years, the demand for ecological risk assessment (ERA) has extended to non-human biota, whose protection status is not necessarily linked to that of humans (Copplestone et al., 2007).

The need for investigating potential risks induced by radiological contaminants on non-human biota and ecosystems is now internationally recognized and a set of international guidelines has been developed on this subject (ECB, 2003; Environment Canada, 1997; Howard et al., 2010; IAEA, 1992, 2006; ICRP, 2003, 2008; UNSCEAR, 1996, 2008). Environmental protection is now being referred to in the IAEA Fundamental Safety Principles (IAEA, 2006) as well as in the Recommendations of the International Commission on Radiological Protection (ICRP, 2007). A variety of methodologies are now being used in a regulatory context to fulfil this

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purpose, such as the ERICA assessment tool (Brown et al., 2008), and the RESRAD-BIOTA model (Yu et al., 2004), to quote a few examples. The ERICA approach as embodied by the ERICA assessment tool was chosen for the present study. Such an approach has been compared in international exercises against other models (Beresford et al., 2008b, 2008c; Vives i Batlle et al., 2007; Vives i Batlle et al., 2011).

Efforts have been made to derive a screening value for wildlife protective of the function and structure of the ecosystem rather than the individual level. The ERICA approach proposes such a screening value of 10 μGy h^{-1} (Beresford et al., 2007; Brown et al., 2008; Garnier-Laplace and Gilbin, 2006), further endorsed by the EC PROTECT project (Andersson et al., 2009). In their revised recommendations, the International Commission on Radiological Protection (ICRP) proposed a 'Derived Consideration Reference Level' (DCRL) of 10^{-4} - 10^{-3} Gy d^{-1} for the most sensitive reference animals and plants (ICRP, 2008). These DCRLs are based on radiation effects (e.g. mortality, reproductive success) at the individual level.

The intended use of the DCRLs is different from that of the screening values. Screening benchmarks are essentially a predicted no-effect dose rate. In particular, the 10 μGy h^{-1} used in ERICA is a conservative screening level, which indicates if additional analyses are needed to better understand and quantify the risk for biota. Conversely, the DCRLs are bands of dose rates designed optimise the level of effort expended on environmental protection, dependent on the overall management objectives and the exposure situation (ICRP, 2014), and as such they are not limits.

The identification of a generic dose rate for the purposes of screening (i.e. identifying sites where additional assessment is required) is inevitably robust only insofar as current knowledge permits. Robustness here refers to the need for ensuring that assessments demonstrate whether regulated practices are having an impact on the environment or not, bearing in mind that prevention or limitation of effects on the population is the standard protection goal (Copplestone et al., 2007).

The ERICA assessment tool contains a link to a database of radiation dose effects (Copplestone et al., 2008; FREDERICA, 2006; Garnier-Laplace et al., 2008). Dose rates to biota exceeding the 'no effects' benchmark levels can be compared with the information from this database, in order to predict the likely consequences of higher radiation levels to wildlife.

By now, screening approaches for the assessment of radiological protection of the environment have become commonly used in a regulatory context in European countries such as England and Wales, Sweden and Finland (Beresford et al., 2008a; Copplestone et al., 2004) and elements of some of them are being routinely used in other countries such as Canada (Wismer et al., 2005), Korea (Keum et al., 2011), Lithuania (Nedveckaite et al., 2010) and elsewhere (Beresford et al., 2008d; ICRP, 2008; Vives i Batlle et al., 2011). However, prior to this study, only a few environmental risk assessments have been carried out for near-surface, low level radioactive waste (LLW) disposal sites around the world in order to study the potential effects of ionising radiation on wildlife.

In the UK, a study of the impact of radioactive discharges and disposals on ecosystems and wildlife species was carried out for the Drigg site, which is their principal disposal facility (Barber, 2009). The recent 2011 Environmental Safety Case for UK LLW also includes an assessment of impacts to non-human biota (LLW, 2011). Similar studies of exposure to non-human biota include the repository for low and intermediate waste in Forsmark, Sweden (Saetre et al., 2013), the near-surface Maisiagala radioactive waste repository in Lithuania (Nedveckaite et al., 2013), the Chalk River waste disposal site in Canada (Chambers et al., 2008; Hart et al., 2005) and, in the USA, the Hanford site (Antonio et al., 2005) and the Bear Creek waste disposal site (Jones and Schofield, 2003). In all cases, the estimated dose rates appeared generally to be below or (in some cases) marginally above the relevant benchmarks, from which it is concluded that the current or predicted discharge levels for these LLW repositories do not result in significant risks to the environment.

The Category A waste disposal site in Dessel, Belgium required demonstration of protection at the level of the environment as well as humans, and the present paper is presented to test the hypothesis that this site does not pose a significant radiological risk from the environmental point of view.

2. Materials and methods

2.1. Source term characterisation

For the assessment of the potential impact on wildlife, a reference scenario for Category A waste for gradual leaching (ONDRAF/NIRAS, 2011) was used to estimate the near-field flux (Bq y^{-1}). For each radionuclide, the peak radionuclide flux over time is taken for the assessment of wildlife impact, irrespective of the time shift between peaks of individual radionuclides, which is a rather conservative assessment approach.

We evaluated the potential exposure pathways, corresponding to the three main biosphere receptors: the private well (irrigation scenario) and the wetlands and river fed by groundwater coming from the repository location. The private well is hypothetically situated at the point of highest impact. In the case of river, the impact is calculated assuming that the entire flux from the near field is entering at one specific river section (i.e. no groundwater dispersion taken into account). For wetlands, the maximum concentration in the uppermost layer of the aquifer is estimated for the region where wetlands may occur, derived from maps of estimated groundwater depths and maximum reasonable groundwater concentrations (Vandenhove et al., 2011).

The effects of radioactive decay and ingrowth or potential sorption processes occurring in transit between the waste repository and the well, wetlands or river were not included in the groundwater transport calculations. This relates to the use of a dilution factor calculated for a constant injection rate source of non-reactive tracer at the repository location (Vandenhove et al., 2011). Moreover, it was assumed throughout that there is an immediate equilibrium distribution of the radionuclides between the river water and bed sediment of the Witte Nete River.

We hence set forth to assess the impact on terrestrial fauna and flora in three situations: (a) following soil contamination due to irrigation with contaminated groundwater extracted from a private well, assumed to be at maximum activity concentration for each individual radionuclide; (b) following soil contamination of the local wetlands after radionuclide migration through the aquifer and (c) following contamination of the local river (Witte Nete) after radionuclide migration through the aquifer.[1] In addition, we considered impacts on the groundwater fauna and flora itself.

For the three exposure pathways considered, we calculated concentrations in groundwater in a private well at 70 m from the repository (well pathway), in the groundwater flowing underneath the wetlands (wetlands pathway) and the fluxes to rivers (river pathway) for each of the primary radionuclides (i.e. the long-term safety relevant radionuclides, plus their long-lived progeny warranting separate consideration in decay chain modelling). The groundwater calculations are elaborated in detail elsewhere

[1] The locations of the repository, local river and wetlands are shown in Gedeon et al. (2011).