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Overview of European concepts for high-level waste and spent fuel disposal with special reference waste container corrosion

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ABSTRACT

This paper provides a brief overview of current repository and engineered barrier system (EBS) designs in selected high-level waste (HLW) and spent fuel (SF) disposal concepts from European countries, with special reference to key metallic waste containers and corrosion processes. The paper discusses assessments of copper, iron and steel container corrosion behaviour under the environmental conditions expected, given likely repository host rocks and groundwaters, and comments on the significance of corrosion processes, the choice of waste container materials, and areas of research. Most of the HLW and/or SF disposal programmes in European countries are pursuing disposal options in which the primary waste container is designed, in conjunction with the surrounding EBS materials, to provide complete containment of the waste for at least the period when temperatures in the disposal system are significantly raised by radioactive decay.

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1. European HLW/SF disposal programmes

The Belgian Agency for Radioactive Waste and Enriched Fissile Materials, Ondraf/Niras, is considering the feasibility of disposing of HLW and spent fuel, together with long-lived low and intermediate-level radioactive wastes, in a deep geological repository excavated in the Boom Clay formation. A key component of the EBS design for HLW and spent fuel is the supercontainer [1]. In the supercontainer, containment is achieved by placing the canisters of HLW or spent fuel assemblies in a carbon steel overpack and surrounding the overpack with a Portland Cement concrete buffer and an outer stainless steel envelope (Fig. 1). Carbon steel has been chosen for the overpack because its corrosion behaviour in the highly alkaline environment that will be conditioned by the surrounding cement is well known, and because carbon steel is expected to be much less prone to localised corrosion processes than other steels [2].

Both Finland and Sweden are moving towards geological disposal of SF using the KBS-3 concept. In the KBS-3 concept, it is planned that after 30 to 40 years of interim storage, SF will be disposed of at a depth of about 500 m in crystalline bedrock, surrounded by a system of engineered barriers (Fig. 2.). The principle barrier to radionuclide release is a cylindrical copper canister. Outside the copper canister is surrounded by a bentonite clay buffer, which is designed to provide mechanical protection for the canisters and to limit the access of groundwater and corrosive substances to their surfaces.

In May 2001, the Finnish Parliament accepted a decision in principle for deep geological disposal of SF in the bedrock at Olkiluoto, near the site of the existing nuclear power plant operated by Teollisuuden Voima Oy (TVO). Posiva, the Finnish company with responsibility for radioactive waste disposal, has published several key reports on its plans, including a plan for a repository safety case and an expected evolution report [3–5].

In Sweden, the Swedish Nuclear Fuel and Waste Management Company (SKB) has recently submitted a license application for the construction of a spent fuel encapsulation plant, and SKB plans to submit a further license application in 2009 for the construction of a final repository for spent nuclear fuel. In connection with the first of these applications, SKB published a safety report, known as SR-Can [6,7], in which the safety of a KBS-3 type spent fuel repository at two potential Swedish sites is assessed. A second safety report, SR-Site, will be published in 2009 as an essential component of the license application for construction of the repository. The two sites under consideration for the Swedish repository are at Forsmark and Laxemar.

The UK Government has recently transferred responsibility for radioactive waste disposal to the Nuclear Decommissioning Authority (NDA). The NDA has launched new Radioactive Waste Management Directorate, which is building on the work of the former organisation Nirex. In 2006, Nirex developed a 'UK reference HLW/SF geological repository concept' by adapting the KBS-3 concept in terms of canister length, diameter and structure of the

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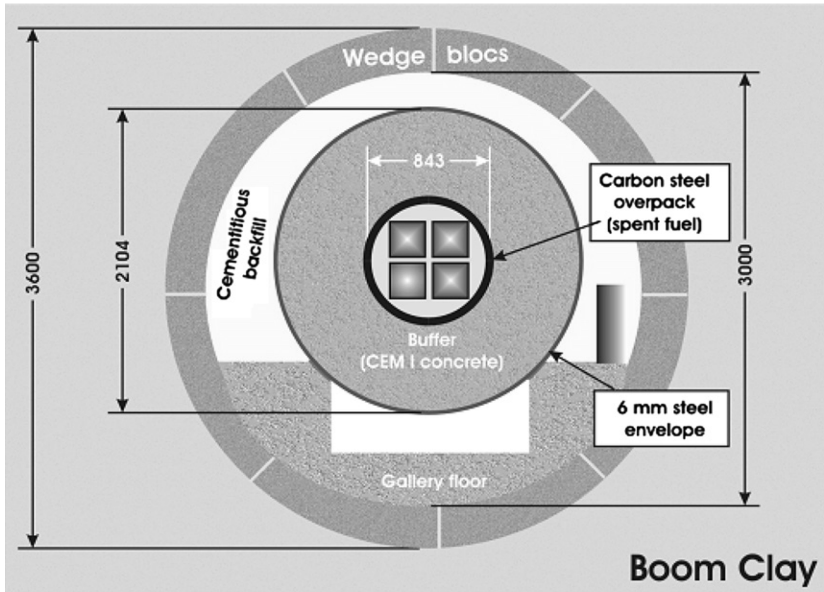

Fig. 1. Schematic diagram showing a cross section through a disposal tunnel (gallery) containing supercontainer with spent fuel (4 assemblies) [1].

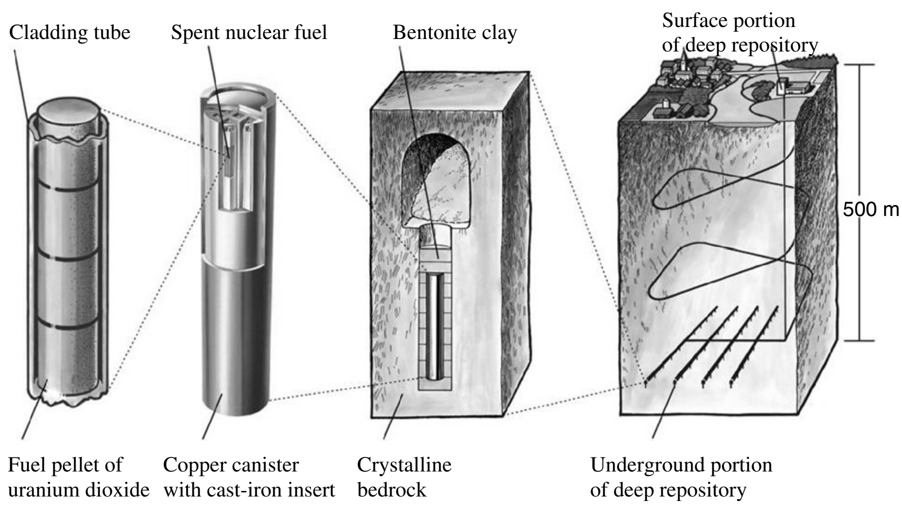

Fig. 2. The KBS-3 concept for disposal of spent fuel [6].

insert to handle HLW and spent fuel from the UK's advanced gas cooled reactors (AGRs) and pressurised water reactor (PWR) [8].

The French national radioactive waste management agency, Andra, is investigating reversible and irreversible radioactive waste storage/geological disposal in deep granite and clay formations. According to a new French law, which was passed in June 2006, Andra should apply for licensing in 2015/2016 and a deep geological repository should be operational in 2025. The most recent published assessment of the French concept for disposal in clay is the Dossier 2005 Argile [9–12]. French investigations into disposal in clay have included development of an underground laboratory in the Callovo-Oxfordian Clay, at Bure. French concepts for HLW and SF disposal are illustrated in Fig. 3.

Carbon steel has been adopted as the first choice material for the overpack in France because, under the relevant geochemical conditions, it is less prone to localized corrosion than materials that passivate (e.g., stainless steels, nickel based alloys).

The Swiss National Cooperative for the Disposal of Radioactive Waste, Nagra, has assessed the feasibility of siting a repository for SF, HLW and LL-ILW in the Opalinus Clay formation in northern Switzerland [13,14]. The Swiss concept for disposal of HLW involves containing the HLW glass within a stainless steel flask and placing the flask within a 250 mm-thick carbon steel canister. The Swiss reference design concept for SF canisters involves a cast carbon steel body, with a machined central square channel fitted with cross-plates to permit emplacement of either 4 PWR or 9 boiling water reactor (BWR) fuel assemblies (Fig. 4). Carbon steel was selected as a canister material because there is long industrial experience with its fabrication, it has high-strength, and it has a relatively low and predictable corrosion rate in anoxic environments. When emplaced in the repository, both the HLW and SF containers would be surrounded by a bentonite clay backfill.

Table 1 provides a summary of relevant aspects of the EBS and the physico-chemical conditions expected during disposal for the programmes described above.

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