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Post-closure safety assessment of near surface disposal facilities for disused sealed radioactive sources

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HIGHLIGHTS

- Post-closure safety assessment of near surface disposal facility for DSRS was performed.
- Engineered vault and rock-cavern type were considered for normal and well scenario.
- ^{14}C, ^{226}Ra, ^{241}Am were primary nuclides contributing large portion of exposure dose.
- Near surface disposal of DSRSs containing ^{14}C, ^{226}Ra and ^{241}Am should be restricted.

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ABSTRACT

Great attention has been recently paid to the post-closure safety assessment of low- and intermediate-level radioactive waste (LILW) disposal facility for disused sealed radioactive sources (DSRSs) around the world. Although the amount of volume of DSRSs generated from industry, medicine and research and education organization was relatively small compared with radioactive wastes from commercial nuclear power plants, some DSRSs can pose a significant hazard to human health due to their high activities and long half-lives, if not appropriately managed and disposed. In this study, post-closure safety assessment was carried out for DSRSs generated from 1991 to 2014 in Korea in order to ensure long-term safety of near surface disposal facilities. Two kinds of disposal options were considered, i.e., engineered vault type disposal facility and rock-cavern type disposal facility. Rock-cavern type disposal facility has been under operation in Gyeongju city, republic of Korea since August 2015 and engineered vault type disposal facility will be constructed until December 2020 in the vicinity of rock-cavern disposal facility. Assessment endpoint was individual dose to the member of critical group, which was modeled by GoldSim, which has been widely used as probabilistic risk analysis software based on Monte Carlo simulation in the area of safety assessment of radioactive waste facilities. In normal groundwater scenario, the maximum exposure dose was extremely low, approximately 1×10^{-7} mSv/yr, for both disposal options and satisfied the regulatory limit of 0.1 mSv/yr. However, in the drinking well scenario, the maximum exposure dose for engineered vault type disposal facility was assessed as 2.022 mSv/yr where the value exceeded the regulatory limit of 1 mSv/yr. The maximum exposure dose for rock-cavern type disposal facility was calculated to be 0.634 mSv/yr, whose results was relatively very close to the regulatory limit considering high uncertainty of long-term environmental conditions. It was demonstrated that DSRSs including the radionuclides of ^{14}C, ^{226}Ra and ^{241}Am significantly contributed to the large portion of exposure dose to the public based on the long-term safety assessment. Therefore, it was recommended that the near surface disposal of DSRSs containing ^{14}C, ^{226}Ra and ^{241}Am should be restricted and managed by long-term interim storage option in order to minimize their potential radiological health effects.

1. Introduction

Disused sealed radioactive sources (DSRSs) are the sealed radioactive sources that are not used anymore or cannot be used due to their low activities. In Korea, DSRSs have been mainly generated from industrial and medical facilities and radioisotope wastes including DSRSs account for approximately 10% of total volume of radioactive wastes. Although the amount of volume of DSRSs is relatively small compared with that of radioactive wastes generated from commercial nuclear power plants, they should be

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managed and disposed safely and securely because of their high activities and long half-lives.

DSRSs generated from 1994 to 2014, which were investigated through previous study (FNC Tech, 2015), was approximately 4.183×10^{14} Bq and the total number was 52,176. They were thirty four radionuclides including three neutron emitting sources (Sb-Be, Am-Be, Ra-Be) and seven alpha emitting sources (^{210}Po, ^{226}Ra, ^{235}U, ^{238}U, ^{241}Am, ^{244}Cm, ^{252}Cf). The half-lives of DSRSs ranged from 5 days for ^{210}Bi to 4.4 billion years for ^{238}U (FNC Tech, 2015). These show a high variability in properties, and which means that various characteristics should be considered for safe management and disposal. Currently, all DSRSs have been stored in centralized interim storage in Daejeon city and are supposed to be disposed in low- and intermediate level waste (LILW) disposal facility in Gyeongju city after arranging optimum solutions for disposal of DSRSs.

Most researches for radioactive waste in Korea have been focused on the wastes from nuclear power plant. Researches for DSRSs, in contrast, have rarely been carried out and the safe management and disposal of DSRSs continue to be a subject of concern. Since 1990s, international agencies and many countries have paid attention to radiological hazard of DSRSs and performed an action for safe management and disposal of DSRSs (IAEA, 2005). International Atomic Energy Agency (IAEA) developed BOSS (borehole disposal of disused sealed radioactive sources) system for permanent and safe disposal of DSRSs and provided the technology for member states (IAEA, 2011). Moreover, as suitable disposal facility for DSRSs is not capable, many countries such as United States of America, Sweden and Russia classify DSRSs based on activities or half-lives and exclude high activity or long half-life sources for disposal. In other words, disposal of DSRSs with high activities or long half-lives is delayed and long-term storage is conducted prior to disposal (Andrews, 2006; OECD-NEA, 2013; Sobolev et al., 2001).

In Korea, rock-cavern type disposal facility, as LILW disposal facility, has been operated in Gyeongju city since August 2015 and engineered vault type disposal facility will be constructed until December 2020 in the vicinity of rock-cavern type disposal facility. As management duration based on national plan was expired for the centralized interim storage, DSRSs should be transported to a disposal facility. Therefore, before permanent disposal of DSRSs, optimum disposal plan for DSRSs should be established with full consideration in the properties of DSRSs based on long-term safety assessment.

For domestic disposal of radioactive waste, post-closure safety assessment should be conducted in accordance with regulatory requirements in Notice No. 2014-56 of Nuclear Safety and Security Commission (NSSC). Annual individual dose should be less than 0.1 mSv under normal condition and 1 mSv under human intrusion condition. Even though the assessment period doesn't have to exceed 1000 years after closure, it could be longer if the peak dose happens after 1000 years (NSSC, 2014). In this study, post-closure safety assessment was carried out using GoldSim program in order to induce optimum disposal option for DSRSs. Assessment endpoint was individual dose to the member of critical group. It was assumed that DSRSs were disposed of near surface disposal facility; engineered vault type disposal facility or rock-cavern type disposal facility respectively, and then long-term safety was evaluated by comparing the results with the legal limits.

2. Modeling methodology

2.1. System description

Modeling systems for engineered vault type and rock-cavern type were based on Gyeongju LILW disposal facility. Most environmental data were applied on the basis of Safety Analysis Report (SAR) of engineered vault type and rock-cavern type (KORAD, 2015; KHNP, 2008). Modeling systems were respectively composed of four parts according to the pathway of radionuclides; source-term, near-field, far-field and biosphere. Radionuclides in the engineered vault type disposal facility (source-term) go down to engineered barrier system (near-field) following groundwater flow and then go through unsaturated zone and aquifer (far-field) and eventually lead to ecosystem of sea or well (biosphere). In case of the rock-cavern type disposal facility, radionuclide pathway is similar except that far-field is only host rock because the disposal zone is below aquifer. Some radionuclides are adsorbed

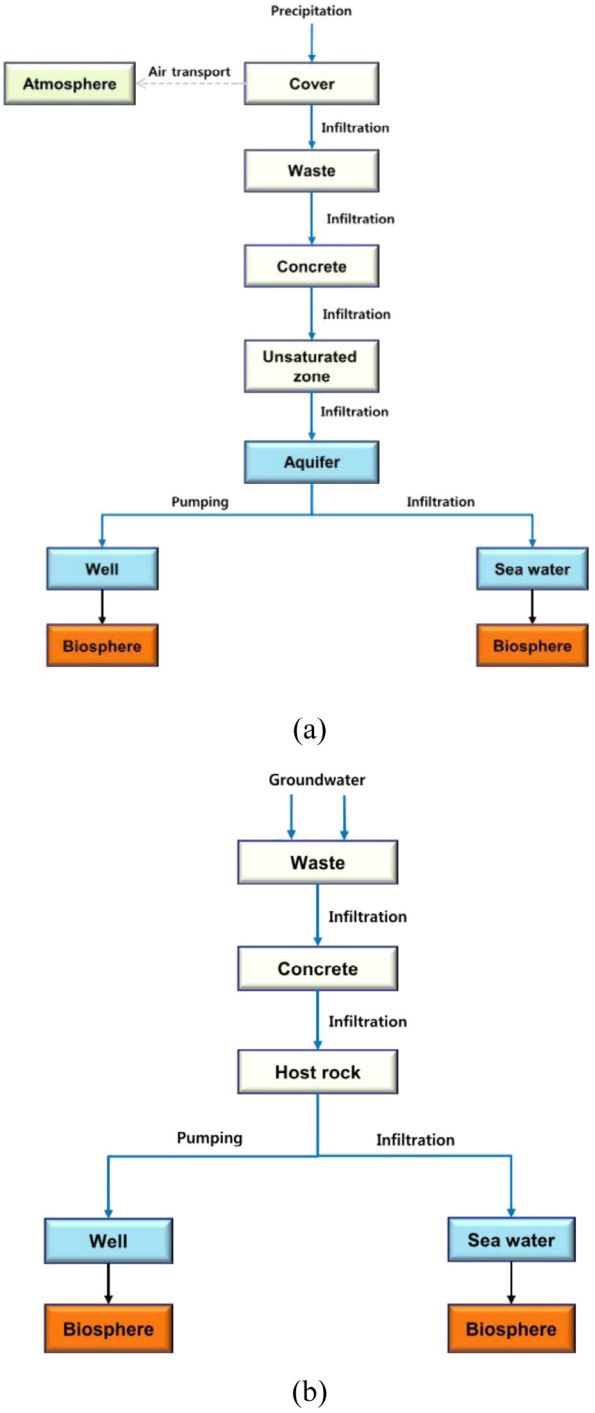

Fig. 1. Schematic diagram of conceptual model for (a) engineered vault type disposal facility and (b) rock-cavern type disposal facility.