New Approach over Permanent Disposal of All Nuclear Wastes in the ROK

Yong S Hwang & H Nam
Korea Atomic Energy Research Institute
yshwang@kaeri.re.kr

1. Introduction

The ROK has had a long history to manage radioactive wastes generated from the operation of NPPs and industrial application. After around 20 ill-functioned approach, the rock cavern type repository which will be associated with the trench style ones in the future in Gyeongju was finally selected. Still, there will be future challenge to dispose of all UNFs and wastes from the D&D of the retiring NPPs in the future. Currently, the so called Swedish KBS-3 type repository is recognized as a reference concept for the final disposition of the UNFs and no active plan is yet to be discussed for all the D&D wastes. In this paper, the alternative concept development is proposed to dispose of all future wastes into a single repository composed of multiple layers. The main advantages of this new approach shall be that one repository is good enough handling all wastes and its foot print area shall be obviously minimal and finally, its post closure safety shall be significantly improved.

2. Current System

Since Swedish SKB introduced the so called KBS-3 concept in 1982[1], it has acted as a reference for the direct disposal of the UNFs(Used Nuclear Fuels) around the world. The similar system concept, KRS was developed for the ROK by KAERI[2] and its long term post closure safety was studied[3].

The KRS repository aims at dispose of UNFs from PHWRs and PWRs. Since the KRS adopts the KBS-3 concept, it relies on the good functioning of the engineered barriers such as bentonite buffer and a composite copper canister. The bentonite in the KRS is expected to be from the domestic resources so that its characteristics are not the same as those from the MX-80, the reference sodium bentonite.

The main disadvantage of implementing the bentonite as a major engineered barrier is that its allowable maximum temperature should be less than 100 degree in Celsius not to deteriorate its chemical features. This temperature criteria acts as a big huddle to minimize the foot print are in the repository. Currently, for the disposal of UNFs from PWRs, the tunnel spacing is around 40 meter and the deposition hole spacing is around 8 meter acting as a major problem requiring a significant foot print area. Also, the chemical function of the bentonite buffer is not so excellent since it cannot retard the most important radionuclide, I-129 at all even though it works well for the highly absorbing TRUs.

In this sense, even though the existing KBS-3 and the corresponding KRS might be good for the countries like Sweden and Finland which do not have any restriction to acquire a large scale repository, it might be far better to introduce the different disposal concept requiring the minimum foot print area while still enhancing the safety of a future repository for the heavily populated countries such as the ROK.

In addition, there is other issue for the final management of all radioactive wastes. So far, there is no active discussion over the final management of the radioactive wastes to be generated from the decommissioning of NPPs. Also, there are a certain wastes not adequate to be disposed of in Gyeongju. How to manage these radioactive wastes is also a big burden for the ROK.

3. New Proposition

The optimum solution to manage the UNFs as well as wastes from the decommissioning and all is to secure a single site for all and then try to implement a multi-layer repository. The three story multi-layer repository shall be good to minimize the foot print area and to maximize the safety while avoiding other technical difficulties. The upper lay shall accommodate the low- and intermediate-level wastes not suitable for the disposal in the current Gyeongju repository. The middle layer shall host the PHWR UNFs. The foot print area for the middle repository is limited to around 1 km^2. The lower layer shall serve for the radioactive wastes such as the UNFs from PWRs.

The depths of three layers shall be 200, 500, and below 1,000 meters to fully assure the safety while assuring the safe and stable operation of material transportation. The spacing between layers shall be good enough not to create any significant thermal, hydraulic, and mechanical interferences from other layers.

Due to the significant technical development in the field of the shale gas industry, it is now practical to drill a borehole down deep to the several kilo-meters. The full drilling technologies are ready especially for the soft rocks such as sedimentary rocks even though they also work well for the hard rocks. Fortunately, the ROK has significant portion of sedimentary rocks around Korean Peninsula. There is a well-known sedimentary layer in the Southern part of the country, for example.

Previously, the huddle to construct a repository in a very deep geological medium was coming from the small diameter of the drilled borehole. The outer-diameter of a traditional NX size bole is just around 76 mm. This limit has halted the practical disposal of UNFs in a very deep geologic medium. However, due to the innovation of drilling technologies, it is now possible to implement the borehole with a diameter of 36’’ for many practical field applications in the oil and shale gas industries. The potential future technical innovation shall give us more flexibility to accommodate the larger blocks such as a UNF assembly from PWRs,

There is the other way to overcome the size limit of a borehole. When the proper treatment solution for the UNFs is applied, the diameters of the final products, solid forms of high-level radioactive wastes shall be reduced significantly to fit into a currently available bore-hole. This can be also done by currently available technologies. At this moment, the so-called pyro-processing technologies have been developed in association with the future implementation of the Sodium Fast Reactors. The technologies developed for that so called Generation IV reactor system develop shall be implemented for this very deep geologic disposal.

There shall be the step by step approach to check the effects of the currently available technologies from the pyro-processing research. For example, only the first part of processing shall be implemented. In this application, so called volatile fission products such as Cs and I can be collected and then solidified into a solid wastes tailor made for the very deep disposal and the other fission products such as Sr and Tc can be solidified also for very deep disposal.

Finally, the rest of the radioactive materials such as U, REs, and TRUs can be solidified to be disposed into the upper layer of the proposed repository with other decommissioning wastes. The other case shall be to use the vol-oxidation, electrolytic reduction and electro refining together. Then the uranium can be separated from the other heavy materials such as TRUs and REs. If the safety analysis for the first case is not so good enough, then it will be worth-while to test for the second case.

How to design a very deep layer shall be another mission. Unlike the very deep borehole concept to drill a borehole to the depth of 5 km, the new approach is proposed in this new study. A vertical borehole shall be drilled to the depth of 1 km or more. Then, a connecting horizontal hole is drilled as currently applied in the shale gas extraction. The typical 8 degree connect hole shall be excavated to connect the vertical and horizontal boreholes. Throughout the active progresses in the shale gas industries, this drilling technologies are already well established.

The deeper the borehole is emplaced, it shall be good to assure the safety of the repository system via longer migration time of the released nuclides and the dilution through the migration in geologic media. Also, if the borehole is passing through the percolation layer which in practice divides the ground water above and below, the safety of that system shall be enhanced significantly.

In this new idea the role of the bentonite as a chemical buffer shall be ignored, even though it can still be used for a backfilling materials to fill up the any void volume. The impact not to give any credit to the bentonite buffer to slow down the potential migration of the released radionuclides shall be negligible. When the credit to the bentonite is recognized, then limit of thermal temperature shall be away from the designing of the repository system. It shall encourage the compact layout for the repository significantly.

The cost to drill a borehole system proposed in this paper (Deep Isolation System [4]) is not so expensive due to the recent boom in technology development to save the cost in the shale gas industry. How to properly identify the optimum depth of the lower layer shall be the interesting subject for the future study since it is also related with the total cost of the repository construction.

4. Technical Challenge

In this summary paper, the future study of the single repository for all is proposed. Even though technologies are already available, still, there shall be many technical challenges for the detailed future research such as;

(1) Detailed study on the thermal impact in the very deep ground and its implication to the safety,
(2) Comprehensive research on the creep behavior of soft rocks and its impact on the EDZs around boreholes,
(3) Comprehensive estimate to understand the impact of the depth of the system over cost and safety,
(4) Full analysis to understand the real impact of steps in pyro-processing for the safety and the foot print minimization,
(5) Further development of comprehensive technologies over vol-oxidation, reduction, and if needed, refining, to further enhance the safety of the proposed single repository, and
(6) Full demonstration of solidification of wastes to maximize the safety of the radioactive wastes with minimum dissolution rates for the proposed solid wastes.

REFERENCES

[1] Swedish SKB, “Final Storage of SNF KBS-3,” Stockholm, 1882.
[2] J W Choi et al, “High-Level Radwaste Disposal Technology Development,” KAERI/RR-2765/2006, Daejeon, 2006.
[3] Y Hwang et al., “Uncertainty in Scenarios and Its Impact on Post Closure Long Term Safety Assessment in a Potential HLW Repository,” Journal of KNET, April 2003.
[4] Deep Isolation Inc, “SNF Disposal in a Deep Horizontal Drillhole Repository Sited in Shale,” Berkeley, Feb 2020.