Evaluation of the discharged Radioactivity during the Concentration of the Very Low-level Liquid Radioactive Waste (VLLW) by a Natural Evaporator at the KRR-1&2 Site

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1. Introduction

The decontamination and decommissioning (D & D) project of the Korea Research Reactors-1&2 (KRR-1&2) was started in 1996 just after their permanent shut-down in 1995. But the real decommissioning work was started in mid 2001 after a long period of decommissioning design and its review by the Korea Institute of Nuclear safety for its license [1].

As the effects on health and safety of both workers and the public and on the environment are somewhat predominant factors for the success of the D & D of the KRR-1&2, the evaluation of all the industrial and radiological safety aspects is very important.

One of the important key factors to be carefully considered is the radioactive waste treatment during the D & D activities. Solid waste management for the decommissioning of the KRR-1&2 was described well in the recent paper of Park et al.[2].

This paper summarizes the evaluation of the discharged radioactivity to the atmosphere and its radiological risks during the operation of the natural evaporator installed at the KRR-1&2 site.

2. Natural Evaporation

2.1 Radioactive Liquid Wastes at the KRR-1&2

According to the D & D plan, all the radioactive liquid wastes which are already on site such as the reactor cooling water and liquid waste stored in the different storage tanks and ponds, or which will be produced during the decommissioning activities will be measured for their radio-activities to decide their final destinations: discharge or treatment.

A non-contaminated liquid waste will be checked and discharged to a drain without further treatment. While, the radioactive liquid wastes already stored or which will be generated during the D & D activities are classified by 2 categories: VLLW(<0.2 Bq/cm^3) on the one hand, LLW(>0.2 Bq/cm^3) on the other hand.

<Table 1> shows the existing quantities of the operational liquid waste and their radioactivity measurement results for the different tanks and pools.

As shown in <Table 1>, the liquid wastes from the long lived liquid waste storage tank (16.2 m^3) and those from the short lived liquid waste tank (4.0 m^3), 20.2 m^3 in total, will be considered as low level liquid waste(LLW). While, the rest (300.83m^3) will be classified as the VLLW.

Table 1. Radioactivity of the operational liquid waste

Location	Quantity (m^3)	α (Bq/m^3)	β (Bq/m^3)	γ (Bq/m^3)	H-3 (Bq/m^3)	Re-marks
KRR-1 Reactor Pool Bulk-Shielding Tank Spent Fuel Storage Pond	 17.75 24.45 26.00	 4.37E+02 ND ND	 ND 2.30E+03 ND	 ND ND ND	 1.70E+06 - -	 VLLW VLLW VLLW
KRR-2 Reactor Pool Spent Fuel Storage Pond	 162.68 57.00	 ND ND	 1.46E+04 3.96E+02	 Cs-137:1.62E+04 ND	 4.07E+06 -	 VLLW VLLW
Others Long lived Storage Pond Short lived Storage Pond KRR-1 Old Storage Tank	 16.20 4.00 2.95	 1.12E+03 3.41E+02 6.81E+02	 9.14E+04 1.89E+05 1.29E+02	 Co-60:1.56E+05 Co-60:6.59E+04 Zn-65:3.77E+04 Cs-134:3.48E+04 ND	 - - -	 LLW LLW VLLW VLLW VLLW
Radioactive Liquid Waste Treatment Facility Tank	10.00	ND	1.43E+03	Cs-137:2.88E+04	-	VLLW
Total	321.03					

The general flow diagram of the radioactive liquid waste treatment during the D & D of the KRR-1&2 is shown in Figure 1.

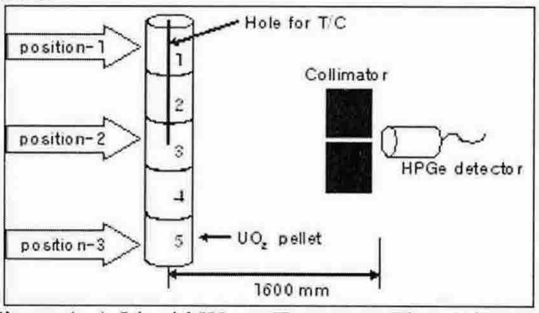

Figure 1. A Liquid Waste Treatment Flow Diagram

The VLLW will be evaporated on site by the natural evaporator, then the final concentrate will be solidified by cement to avoid any sedimentation of the radio-nuclides in a drain and to avoid a public inquiry the consequences.

Concerning the LLW, it will be firstly treated by the existing ion-exchange column whose treatment capacity is 360 ℓ/h with its decontamination factor(DF) of 40 to reduce its maximum radioactivity, then will be concentrated by the natural evaporator.

Laundry and shower radioactive liquid wastes will firstly be treated by the existing membrane facility whose capacity is 200ℓ/h, to remove the surfactant and major parts of the radioisotopes, then measured again for their radioactivity to decide whether or not to discharge, or to concentrate further by the natural evaporator.

2.2 Natural Evaporator

The design factors for the construction of the natural evaporator are shown in Table 2. Based on these design factors, a total evaporation surface of about 600 m^3, with a 50% engineering margin, was calculated by the empirical formula [3].

Table 2. The design factors for the construction of the natural evaporator

Evaporation capacity	200 m^3/y
Volume reduction factor	100
Expected maximum evaporation rate	0.25 m^3/hr
Decontamination factor	10^4
Exhaust air rate	6.56 m^3/sec

The schematic diagram of the natural evaporator is shown in Figure 2. The plant consists of an evaporation surface, a liquid radioactive waste supply system and an air exhaust system. The evaporation surface is made of 0.85m (W), 1.5m (L) cloth and is installed vertically in a series with an interval of 45mm.

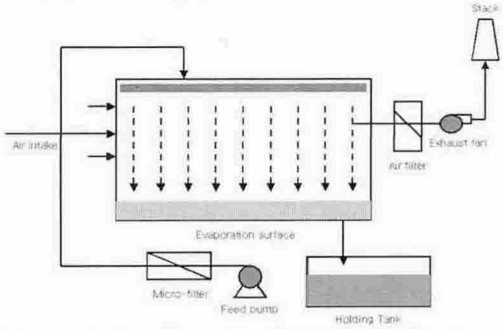

Figure 2. A schematic diagram of the evaporation unit

The evaporation cloths are vertically hung with a tension by means of pipes which were perforated in a series at their upper parts. The radioactive liquid waste is supplied through the feed pump which is connected to the holding tank. The liquid waste at the top of the evaporator flows down forming a thin liquid film on the evaporation surface. At the same time air from outside is supplied by means of an exhaust fan to increase the evaporation rate.

2.3 Calculation of the released radioactivity

The radioactivity of the liquid waste to be treated (C_{in}) can be divided by 3 ways : released with air (C_{air}), absorbed by the evaporation surface (C_{sur}) and accumulated to a concentrate (C_{con}). The material balance of the radioactivity can be expressed by $C_{in} = C_{air} + C_{sur} + C_{con}$. From this equation C_{air} can be easily calculated by measuring the C_{sur} and C_{con}.

<Table 3> shows the results of the VLLW concentration by the natural evaporator from April 2001 to September 2002. The total quantity of the VLLW treated was 93.01 m^3 with the major nuclides of Co-60, Cs-137 and Cs-134.

Table 3. VLLW treatment results by the natural evaporator

Inlet		Outlet		
Operation period	4. 2001-9.2002	Evaporation Surface	Cloth Weight(kg)	47
VLLW Quantities(m^3)	93.01		Radioactivity(Ci)	3.80E-05
Specific Activity(Bq/m^3)	2.14E+04	Concentrate	Quantity(m^3)	0.9
Radioactivity(Ci)	5.76E-05		Radioactivity(Ci)	1.24E-05

From the result of the radioactivity measurement, C_{air} is 7.2E-06Ci, which means that the only 12.5% of the initial radioactivity is entrained to the atmosphere.

The maximum concentration released in the discharged air at the stack level was calculated and published by Jung et al.[4]. According to the paper, the specific activity entrained to the atmosphere was 4.637×10^{-14} μCi/cc-air, and the effective dose for an individual was 1.01×10^{-3} μSv/y. By the experimental result, only 12.5% of this specific activity (5.8×10^{-15} μCi/cc-air) is dispersed to the air. And the effective dose for an individual is 1.26×10^{-4} μSv/y with the same proportionality.

3. Conclusion

The experimental results show that the radioactivity entrained to the atmosphere is 5.8×10^{-15} μCi/cc-air, corresponding to about 0.00006% of the maximum permissible concentration regulated by Korean nuclear law (2×10^{-9} μCi/cc-air). On the basis of the estimated release concentration, the effective dose for an individual is 1.26×10^{-4} μSv/y, far below the regulated dose limit of 1 mSv/y. In conclusion, the operation of the natural evaporator for the treatment of the VLLW during the decommissioning of the KRR-1&2 demonstrates that there is no impact not only to the environment but also to the general public.

Acknowledgement

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