Safety Analysis of Radwaste Storage Buildings in KAERI : Fire Case

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1. Introduction

Since the recent earthquake in Gyeongju, safety concerns for radioactive waste reservoirs have increased. For that reason, the Nuclear Safety Commission (NSC) is asking relevant agencies to conduct a safety analysis for natural disasters.

Korea Atomic Energy Research Institute, Korea Hydro & Nuclear Power Co., Korea Nuclear Fuel Co., Ltd., and KORAD are conducting safety evaluations for their respective storage buildings.

In this paper, we discuss the method and results of the safety evaluation of the radioactive waste storage at the Korea Atomic Energy Research Institute in case of a fire.

2. Method

Accident analysis identifies all potential risks associated with the storage, establishes accident scenarios and assessment models and evaluates the radiation effects of surrounding residents of the storage. It has its purpose to prove it.

The accident analysis of the storage consists of three steps. In the first stage, Hazard Definition is used to identify potential hazards that could lead to an accident. In the second stage, Hazard Assessment of Unmitigated Event, which includes event selection process, is performed. In the third step, the accident scenarios were established for the high-risk events identified in the non-audit audit potential risk assessment, and a quantitative accident assessment was conducted accordingly.

Generally, the potential exposures due to radioactive waste of the storage can be broadly categorized as on-site workers and out-of-bounds boundaries. However, in this study, the decision-maker for the accident impact assessment is defined as an individual at the boundary of the storage restricted area.

The internal effective dose by breathing can be calculated using following equation 1.

$$H_{th} = X/Q \times Br \times \sum(Q_i DCF_{thi}) \qquad (1)$$

Where, X/Q is atmospheric dispersion factor for 2hrs at the boundary of restricted area (sec/m^3), and Qi is the amount of released radio nuclide i for 2 hrs (Bq), and DCF_{thi} is the dose conversion factor of radio nuclide i(mSv/Bq), and Br is breathing rate, NRC usually used 3.47E-04 m^3/sec for average individual breathing rate after 0~8hrs after accident.

The effective dose by external exposure can be calculated by equation 2.

$$H_{ed} = X/Q \times \sum(Q_i DCF_{edi}) \qquad (2)$$

Where, X/Q is atmospheric dispersion factor for 2hrs at the boundary of restricted area (sec/m^3), and Qi is the amount of released radio nuclide i for 2 hrs (Bq), and DCF_{edi} is the dose conversion factor of external exposure from semi-finite radioactive source (mSv/Bq).

Table 1 MAR and DCF-E and I for radioactive nuclides of operational radwastes

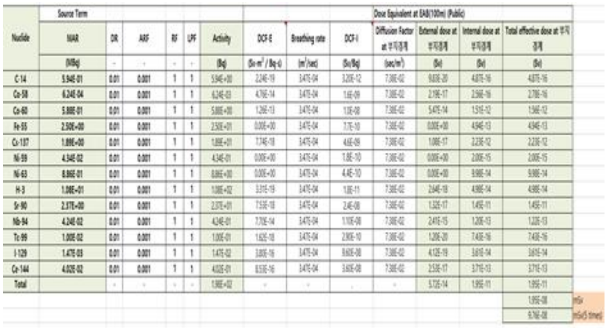
Nuclides	MAR (MBq)	Activity (Bq)	DCF-E (Svm³/Bqs)	DCF-I (Sv/Bq)
C-14	5.94E-01	5.94E+00	2.24E-19	3.20E-12
Co-58	6.24E-04	6.24E-03	4.76E-14	1.6E-09
Co-60	5.88E-01	5.88E+00	1.26E-13	1.0E-08
Fe-55	2.50E+00	2.50E+01	0.00E+00	7.7E-10
Cs-137	1.89E+00	1.89E+01	7.74E-18	4.6E-09
Ni-59	4.34E-02	4.34E-01	0.00E+00	1.8E-10
Ni-63	8.86E-01	8.86E+00	0.00E+00	4.4E-10
H-3	1.08E+01	1.08E+02	3.31E-19	1.8E-11
Sr-90	2.37E+00	2.37E+01	7.53E-18	2.4E-08
Nb-94	4.24E-02	4.24E-01	7.70E-14	1.10E-08
Tc-99	1.00E-02	1.00E-01	1.62E-18	2.90E-10
I-129	1.47E-03	1.47E-02	3.80E-16	9.60E-08
Ce-144	4.02E-02	4.02E-01	8.53E-16	3.60E-08

The radioactive source can be calculated using equation (3)

$$Q = MAR \times DR \times ARF \times RF \times LPF \qquad (3)$$

Where :
MAR = Material at Risk, DR = Damage Ratio
ARF = Airborne release fraction
RF = Respirable Fraction, LPF = Leakpath factor

The material at risk is the amount of radioactive material (in grams or curies of radioactivity for each radionuclide) available to be acted on by a given physical stress. The damage ratio is the fraction of the material at risk impacted by the actual accident-generated conditions under evaluation. The airborne release fraction is the coefficient used to estimate the amount of a radioactive material that can be suspended in air and made available for airborne transport under a specific set of induced physical stresses. It is applicable to events and situations that are completed during the course of the event. The respirable fraction is the fraction of airborne radionuclides as particles that can be transported through air and inhaled into the human respiratory system and is commonly assumed to include particulate matter less than or equal to 10 micrometers in diameter.



Nuclide	Source Term MAR	DR	ARF	RF	LPF	Activity	DCF-E	Breathing rate	DCF-I	Dose Equivalent at EAB(100m) (Public) Diffusion Factor at 부지경계	External dose at 부지경계	Internal dose at 부지경계	Total effective dose at 부지경계
	(MBq)	-	-	-	-	(Bq)	(Sv·m³ / Bq·s)	(m³/sec)	(Sv/Bq)	(sec/m³)	(Sv)	(Sv)	(Sv)
C-14	5.94E-01	0.01	0.001	1	1	5.94E+00	2.24E-19	3.47E-04	3.20E-12	7.38E-02	9.83E-20	4.87E-16	4.87E-16
Co-58	6.24E-04	0.01	0.001	1	1	6.24E-03	4.76E-14	3.47E-04	1.6E-09	7.38E-02	2.19E-17	2.56E-16	2.78E-16
Co-60	5.88E-01	0.01	0.001	1	1	5.88E+00	1.26E-13	3.47E-04	1.0E-08	7.38E-02	5.47E-14	1.51E-12	1.56E-12
Fe-55	2.50E+00	0.01	0.001	1	1	2.50E+01	0.00E+00	3.47E-04	7.7E-10	7.38E-02	0.00E+00	4.94E-13	4.94E-13
Cs-137	1.89E+00	0.01	0.001	1	1	1.89E+01	7.74E-18	3.47E-04	4.6E-09	7.38E-02	1.08E-17	2.23E-12	2.23E-12
Ni-59	4.34E-02	0.01	0.001	1	1	4.34E-01	0.00E+00	3.47E-04	1.8E-10	7.38E-02	0.00E+00	2.00E-15	2.00E-15
Ni-63	8.86E-01	0.01	0.001	1	1	8.86E+00	0.00E+00	3.47E-04	4.4E-10	7.38E-02	0.00E+00	9.98E-14	9.98E-14
H-3	1.08E+01	0.01	0.001	1	1	1.08E+02	3.31E-19	3.47E-04	1.8E-11	7.38E-02	2.64E-18	4.98E-14	4.98E-14
Sr-90	2.37E+00	0.01	0.001	1	1	2.37E+01	7.53E-18	3.47E-04	2.4E-08	7.38E-02	1.32E-17	1.45E-11	1.45E-11
Nb-94	4.24E-02	0.01	0.001	1	1	4.24E-01	7.70E-14	3.47E-04	1.10E-08	7.38E-02	2.41E-15	1.20E-13	1.22E-13
Tc-99	1.00E-02	0.01	0.001	1	1	1.00E-01	1.62E-18	3.47E-04	2.90E-10	7.38E-02	1.20E-20	7.43E-16	7.43E-16
I-129	1.47E-03	0.01	0.001	1	1	1.47E-02	3.80E-16	3.47E-04	9.60E-08	7.38E-02	4.12E-19	3.61E-14	3.61E-14
Ce-144	4.02E-02	0.01	0.001	1	1	4.02E-01	8.53E-16	3.47E-04	3.60E-08	7.38E-02	2.53E-17	3.71E-13	3.71E-13
Total		-	-	-	-	1.98E+02	-	-	-	-	5.72E-14	1.95E-11	1.95E-11
													1.95E-08 mSv
													9.76E-08 mSv(5 times)

Fig. 1 Parameters for the calculation for each nuclides

We used average value of destructive analysis results of flammable operational radwastes and average concentration values for flammable decommissioning radwaste. KAERI has 3 storage builds for operational radwastes and 2 for radwastes from decommissioning. The maximum storage capacities are 11,010, 1,404 and 3,320 drums for operational radwastes storage, 2,250 and 2067m^3 for decommissioning, respectively.

We assumed the radwastes were fully stored as maximum capacity and multiply 5 for conservative evaluation. The damage ratio is 1% for fire case and ARF*RF is 0.001. The LPF usually 1 for conservative evaluation.

For the internal dose conversion factor[1], we adopted the value from ICRP publication 119[2] "Compendium of Dose Coefficients based on ICRP Publication 60". For external dose coefficients, we adopted from EPA parameters.[3] And we used 7.38E-02 as the atmosphere dispersion factor (50m, 2hrs)

3. Results and Discussion

The analysis results are summarized in table 2 and 3.

Table 2 Results of operational radwastes storage

Storage	1	2	2-1
Effective Dose(mSv)	**1.07E-03**	**1.37E-04**	**3.24E-04**
% vs 25mSv	**4.30E-05**	**5.48E-06**	**1.30E-05**

Table 3 Results of decommissioning radwastes storage

Storage	1	2
Effective Dose(mSv)	**1.6E-1**	No Flammable wastes
% vs 25mSv	**7E-02**	-

As summarized in Table 2, the safety analysis results for operational radwastes in case of fire, the results shows very low effective dose even if release to air. The regulation criteria is 25 mSv and all results lower than the regulation criteria.

For the decommissioning radwastes, the effective dose is higher than that of operational radwastes but still lower than the regulation criteria. Furthermore, there are no flammable waste at the storage #2, so that can be consider that there are no radioactive materials release in case of fire.

4. Conclusion

We performed safety analysis for the radwastes storage buildings at KAERI for the fire case. All calculation performed with conservative assumption and expectation. The results of operational radwastes storage shows much lower effective dose than regulation criteria. (less than 1E-06 %). While, the effective dose of the decommissioning radwastes storage higher than that of operational radwastes but still lower than regulation criteria. Thus, all storage buildings in the KAERI are safe in case of fire. The other accident case like earthquake will be considered for the safety analysis.

REFERENCES

[1] H. Smith, Age-Dependent Doses from Intake of Radionuclides, ICRP 72, 1997

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[3] K. F. Eckerman and J. C. Ryman, External Exposure to Radionuclides in Air, Water, and Soil. EPA-402-R-93-08, 1993