Acceptable Decontamination Factor for Near-Surface Disposal of PEACER Wastes

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SUMMARY

A pyrochemical process has been introduced and utilized so that the transmutation of spent PWR fuel in PEACER can produce mainly low and intermediate level waste for near surface disposal. Major radioactive nuclides from PEACER pyroprocessing are composed of TRU and LLFP. In this study, the requirement for the final waste from PEACER is evaluated based on the methodology for establishment of waste acceptance criteria. Also, sensitivity analysis for several input parameters is conducted in order to determine acceptable decontamination factor (DF) and LLFP removal efficiency and to find out input parameter that extremely have an effect on DF. As a result of the study, LLFP removal efficiency, especially Sr-90 and Tc-99, is proved to be a major nuclide which contributes to annual dose by human intrusion scenario rather than TRU DF. More than 98.5% of LLFP have to be removed to meet below dose constraint within the DF more than 5.0E+03. Besides, because of the relative short half-life of Sr-90, the increasing of the institutional control period is recommended for most important input parameter to determine DF.

I. INTRODUCTION

The spent nuclear fuel of current nuclear reactor is one of challenging issues for the continuous utilization of nuclear power. In order to solve this problem, geological disposal has been suggested and studied for decades. But, because of difficulty in finding its highly qualified sites, the partitioning and transmutation (P&T) technology have been introduced an alternative idea. P&T method of radioactive waste from spent fuel is considered more attractive because of high concern on the public protection and the difficulty in radioactive waste disposal site selection in Korea. Seoul National University (SNU) proposed a new transmutation concept named as PEACER to convert all the final waste into the class of low level waste (LLW).

In order to dispose the final waste from PEACER, The Establishment of Waste Acceptance Criteria for the LLW facility has to be considered first. According to NRC, the human intrusion scenarios determine volumetric concentration limit. On the other hand, the radionuclide migration scenarios impose limit on the total inventory of a radionuclide disposed at the site by means of site specific analysis. The Methodology of NRC traced backward from the dose limit using the human intrusion scenario to find appropriate concentration limit.[1]

PEACER final waste has several special characteristics in establishing concentration limit. It consisted of TRU and LLFP and the mass ratio of each nuclide has been fixed by pyrochemical process. The previous study for waste from PEACER has focused on the feasibility of converting waste into LLW by pyroprocess technology and Practical value of decontamination factor (DF) to meet the concentration limit for class C waste of U.S. NRC.

For this reason, the concentration limit for the final waste from PEACER is evaluated with the methodology for establishment of waste acceptance criteria. DF and LLFP removal efficiency to satisfy the derived concentration limit also are suggested. Finally, the most important input parameter which has a most strong effect on the determination of the concentration limit is analyzed by sensitivity analysis. Because the generated mass ratio of each nuclide is pre-determined and final waste from PEACER is assumed to be homogenous, annual dose by most hazardous scenario is more focused in this study rather than the concentration limit determination by the sensitivity analysis.duction here. Put introduction here. Put introduction here. Put introduction here. Put introduction here. Put introduction here. Put introduction here. Put introduction here. Put introduction here. Put introduction here.

II. CHARACTERISTICS AND GENERATION OF RADIOACTIVE WASTE FROM PEACER

During the back end fuel cycle stage in PEACER, about 99% of uranium in the LWR spent fuel is assumed to be recovered for the future utilization and all TRU are recycled during the pyroprocess to convert all the final waste into the LLW. Tc-99 and I-129 also are assumed to be separated from waste stream and transmuted to stable nuclide because of their high solubility in water with 95% removal efficiency. In the pyrochemical process, decontamination factor of TRU is introduced as an indicator for the process performance. Overall DF in pyorchemical process is defined as the ratio of mass of loaded TRU into the process to TRU lost into waste stream and expressed as follows;

$$DF = \frac{\text{The loaded TRU into pyrochemical process}}{\text{The lost TRU into waste stream}}$$

In the previous study, PEACER pyroprocessing system which assumed to have 10^5 of DF was conceptually proposed[2] and 2.3E+05 of DF was suggested considering several requirements to be satisfied by NRC Class C limit assumed with disposal facility volume 1.6E+05m^3. In order to evaluate the total generated wastes from the pyroprocessing, we assumed that 20 LWR of 1 GWe capacity, 40 years lifetime with spent fuel discharged at 33,000MWD/MTU burnup with 30 years cooling time and 12 PEACER has 60years lifetime. The nuclide inventory by LWR was obtained by ORIGEN2 code. The estimation of generated actinide mass in case of PEACER is analyzed at equilibrium state by REBUS code conducted by Kyoung-hui University, considering the time interval between each process in pyroprocessing. Sr-90, Cs-135, Cs-137 and Sm-151 were assumed to be recovered with 95% removal efficiency during the process to satisfy regulation for heat load and assumed volume of disposal site because of its higher activity and decay heat than the other LLFP's. Table 1 and Table 2 show total TRU and LLFP waste production, respectively, from pyroprocessing when the value of DF=2.3E+05 and 95% LLFP removal efficiency was applied..

III. PERFORMANCE ASSESSMENT

For the assessment of human intrusion scenarios, the LILW disposal facility has been followed the conceptual design study of the near surface disposal facility in Korea.[3] The disposal facility shown in Figure 2 is reconstructed from conceptual reference design and is composed of radioactive drum. This facility is excavated into the ground, lined with about 0.5m concrete and cover with thickness of 6m. The approximate dimensions of the disposal facility are 200m by 400m, and the depth of facility is assumed to be 8m. The total volume of disposal facility is 6.4E+05m^3. During the institutional control period, it is assumed that upper cover system of 2m thickness of soil can be removed by erosion processes.[4] Reference intruder scenarios are identified with the review of well-established ones considered in other countries and/or organizations for near surface disposal. Six scenarios such as potential intruder events-well drilling, post-well drilling, road construction, post-construction, housing and gardening, and farming scenarios- were selected as possible for the facility. Well drilling scenario is that the intruder drills a well at the top of the facility. In this scenario, it is assumed that drilling is to penetrate the disposal facility. Road construction scenario assumes that the intruder constructs a road directly over a waste disposal site. Waste Packages and engineered barriers are assumed to be completely degraded and mixed together during the construction work time. Post-well drilling and post-construction scenarios are the extension of well drilling and house construction scenario, though hose construction scenario is ruled out in the main scenario categories due to small scale of construction comparing with road construction scenario. Housing and gardening scenario is considered as equivalent as residential scenario. Farming scenario is similar to gardening scenario except that the former has longer intruder occupancy time and larger contaminated area than the latter and contained dose by ingestion of meat and animal products.[5]

The direct radiological impact on the intruder depends on the institutional control period. In the basic assessment, human intrusion into the disposal facility is assumed to occur at time after loss of institutional control of 300years.[5] Also, 5mSv/yr as a dose constraint for the disposal facility was applied.

The GENII computer code is used to evaluate annual dose by exposure pathways. Table 3 presents input parameter for GENII code.[6] Concentration limit for each radioactive nuclide are calculated by backward method from the dose limit using the human intrusion scenario

IV. DERIVATION OF ACCEPTANCE CRITERIA

In order to derive the acceptance criteria for near-surface disposal facility, methodology studied by KINS/NETEC and conceptual design of disposal facility are used [3][4]. Figure 2 and 3 show the concentration limit by human intrusion scenario and the total inventory (activity) limit by radionuclide migration scenario respectively.

500mrem/yr and 100rem/yr are applied as the dose constraint in each scenario. It is assumed that human intrusion occurs at time after end of institutional control of 500 years.

In deriving total inventory limit, borosilicate glass matrix for waste stabilization is considered as a source term analysis [5]. Additionally, the sum of the fraction rule for mixture of radionuclide is applied to determine DF values [6].

V. CONCLUSIONS

The concentration limit and total inventory limit for PEACER final waste to dispose it into near-surface disposal facility are derived. In order to satisfy these acceptance criteria, TRU DF and LLFP removal efficiency have to be achieved more than 1.0E+04~1.0E+05 and 96%, respectively. Figure 4 and 5 show DF value for each radionuclide and table 1 shows the combined result considering two criteria together. Acceptable TRU DF is located within possible DF range. However, comparing to conceptual design factor, LLFP, especially Tc-99 and I-129, have to be removed from the waste stream 3~4% more than designed factor.

ACKNOWLEDGMENTS

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Table 1. Input parameter for GENII code

	Drilling	Road Con	Post Drilling	Post Con	H & Gardening	Farming	Input Parameter
Near Field Parameter	300,00	300,00	300,00	300,00	300,00	300,00	Inventory disposed n years prior to the beginning of the intake period(yr)
	0	0	1	1	0,99	0,99	Fraction of roots in upper soil (top 15cm)
	0	0	0	0	0,01	0,01	Fraction of roots in deep soil
	5,70E-03	0,00E+00	2,30E-04	0	0	0	Manual redistribution : deep soil/surface soil dilution factor
	100	2500	2500	2500	2500	20000	Source area for external dose modification factor (m2)
Waste Form Availablity	0	0	0	0	0	0	Waste form / package half life (yr)
	8	8	8	8	8	8	Waste thickness (m)
	4,5	4,5	4,5	4,5	4,5	4,5	Depth of soil overburden (m)
External Exposure	1	90	3245	3245	3245	5825	Plume (hr)
	40	90	3245	3245	3245	5825	Soil contmination (hr)
Inhalation	1	90	4390	4390	4390	6570	Hours of exposure to contamination per year
	1,00E-04	1,00E-03	1,00E-04	1,00E-04	1,00E-04	1,00E-04	Mass loading factor (g/m3)

	Food	Grow time (day)	Irrigation Rate(in/yr)	Irrigation Time(mo/yr)	Yield (kg/m2)	Production (kg/yr)	Consumption hold up(day)	Consumption Rate(kg/yr)	Scenario
Food Ingestion	leaf	60	10,6	0	4,5	0	1	31,7	Post drilling, Post Con, H & G, Farming
	Root	90	19,3	0	4,5	0	14	24,5	Post drilling, Post Con, H & G, Farming
	Fruit	155	34,1	0	1,1	0	14	16,6	Post drilling, Post Con, H & G, Farming
	Grain	150	60	0	0,4	0	14	47,1	Farming

	Product	Consumption Rate (kg/yr)	Consumption holdup (day)	Stored Feed Diet Fraction	Stored Feed Grow Time (day)	Stored Feed Irrigation Rate(in/yr)	Stored Feed Irrigation Time(mo/yr)	Stored Feed Yield (kg/m3)	Stored Feed Stroage (day)	Scenario
Animal Product Ingestion	Beef	33,1	7	0,83	180	60	5,5	2,4	22,4	Farming
	Poultry	22	3	1	180	60	5,5	0,42	2,4	
	Milk	63	1	0,83	180	60	5,5	3,2	23,9	
	Egg	8	3	1	180	60	5,5	0,42	8	
	Fresh Forage									
	Beef			0,17	90	14,4	3	4	0	
	Milk			0,17	90	14,4	3	3,48	0	

Table 2. Acceptable TRU DF and LLFP removal efficiency

Nuclide		Possible DF	Concentration Limit	Total Inventory Limit	Acceptable DF
LLFP	Sr	-	96%	-	90%
	Tc			98.5%	98~99%
	I			98.5%	98~99%
	Cs			92%	92%
TRU	U	1.43E+4	1.0E+4	1.0E+3	1.0E+4
	Pu	1.67E+5		1.0E+5	1.0E+5
	Np	1.43E+5		1.0E+4	1.0E+4
	Am/Cm	2.94E+4		-	1.0E+4

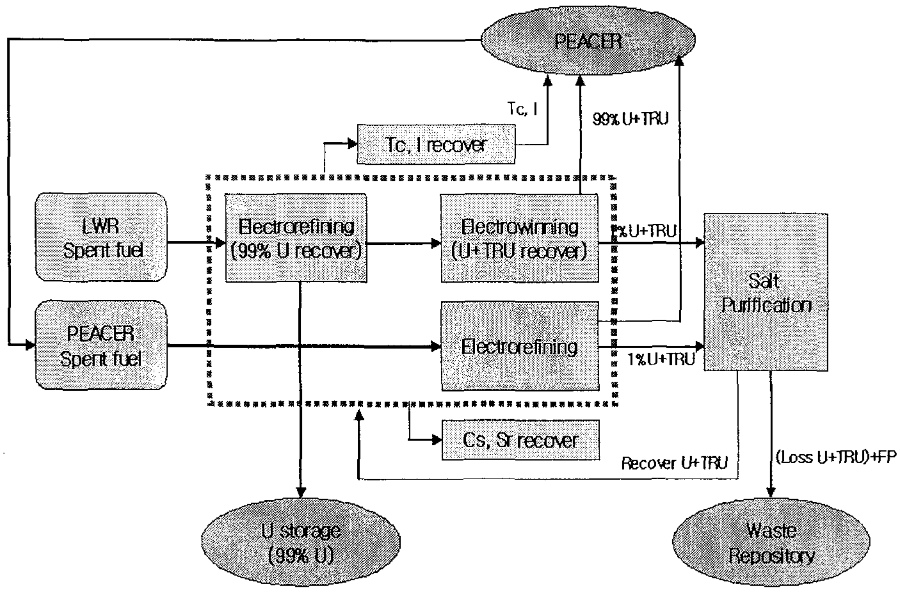

Figure 1. Flow sheet of back end fuel cycle in PEACER

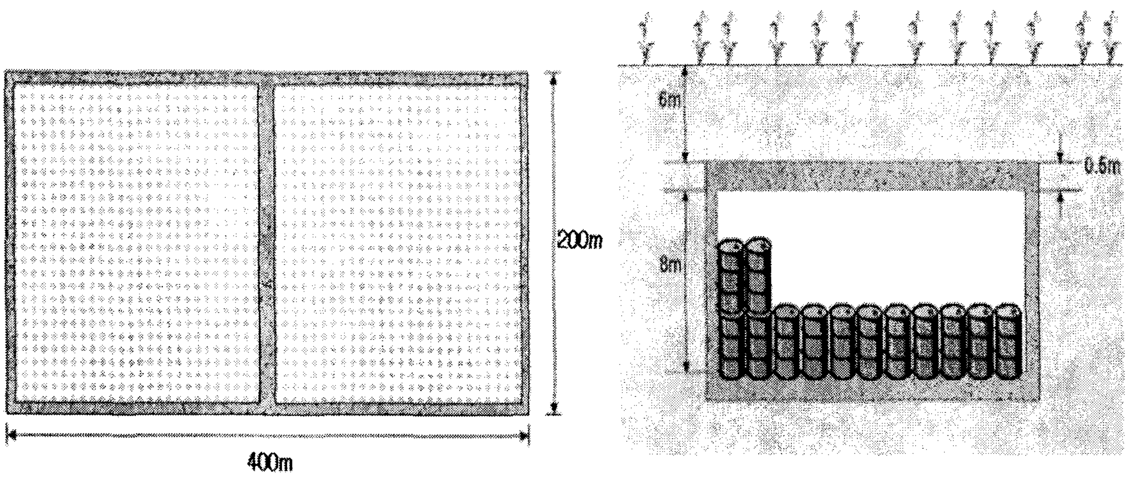

Figure 2. The scale of the conceptually designed disposal facility

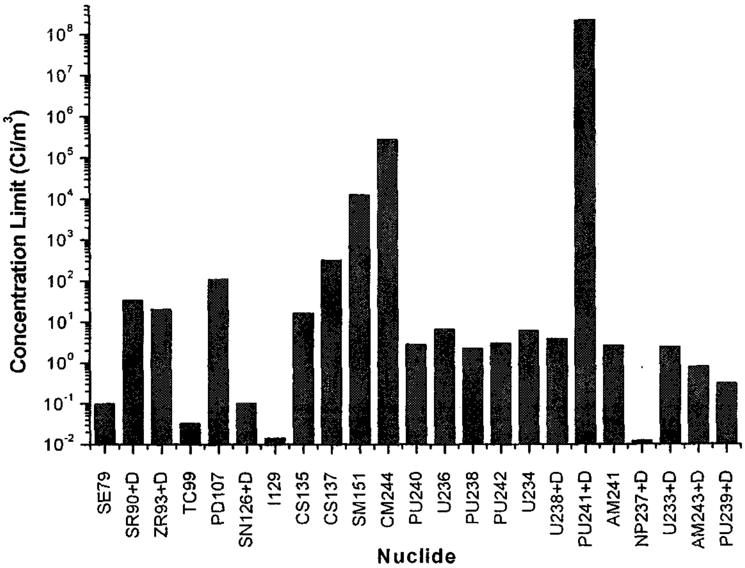

Figure 2. Concentration limit for radionuclide from pyroprocessing

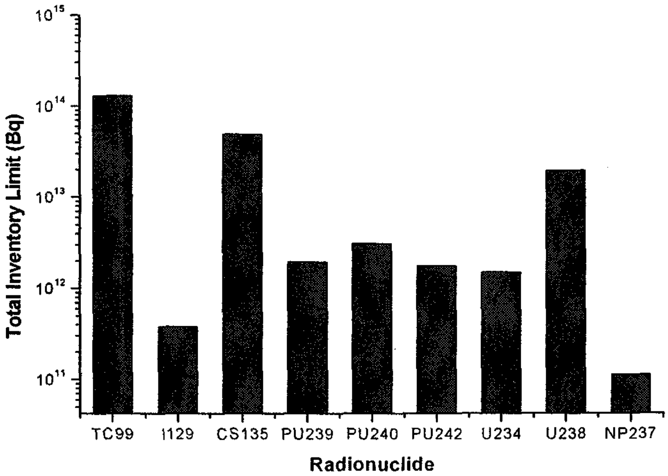

Figure 3. Total inventory limit

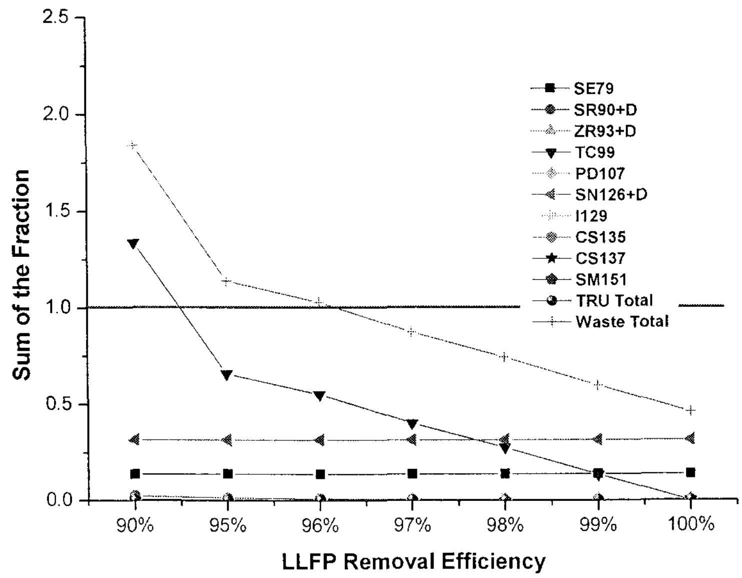

Figure 4. TRU DF and LLFP removal efficiency by concentration limit

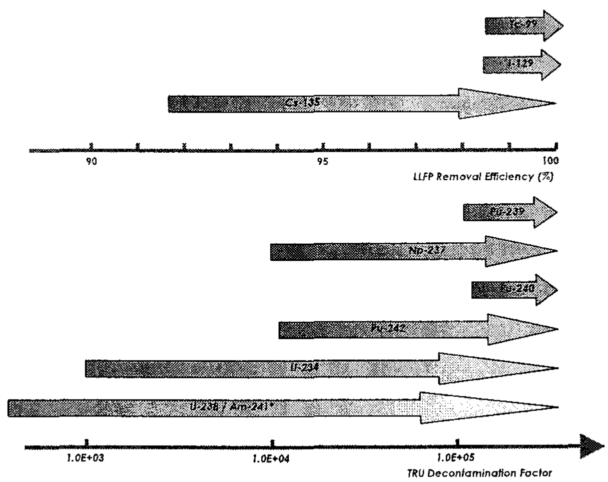

Figure 5. TRU DF and LLFP removal efficiency by total inventory (activity) limit