Requirement of decontamination factor for near-surface disposal of Proliferation Resistant, Environmental friendly, Accident Tolerable, Continual and Economical Reactor(PEACER) wastes

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ABSTRACT

A pyrochemical process has been introduced and utilized so that the transmutation of spent Pressurized Water Reactor(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. 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.

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. Because of difficulty in finding its highly qualified sites, the partitioning and transmutation (P&T) technology have introduced an alternative idea. P&T method of radioactive waste from spent fuel is considered more attractive because of high concern of public protection and the difficulty in radioactive waste disposal site selection in Korea. Seoul National University (SNU) proposed a new transmutation concept named PEACER to convert all the final waste into a class of low level waste (LLW).

The PEACER final waste form has several special characteristics that establish its concentration limits. It consists of TRU and LLFP, and a mass ratio of each nuclide that has been fixed by the pyrochemical process. A previous study involving waste from PEACER focused on the feasibility of converting waste into LLW by pyroprocess technology and achieving a decontamination factor (DF) to meet the concentration limit for class C waste of U.S. NRC.

In order to dispose of the final waste from PEACER, the establishment of a Waste Acceptance Criteria (WAC) for the LLW facility has to be considered first. According to the

NRC, the human intrusion scenarios determine the volumetric concentration limit. On the other hand, the radionuclide migration scenarios impose limits on the total inventory of radionuclides disposed at the site by means of site specific analysis. To find the appropriate concentration limits [1], a NCR methodology is used. This methodology traces backwards from the dose limit using the human intrusion scenario.

For this reason, the concentration limits for the final waste form from PEACER is evaluated with the methodology for establishment of WAC. The DF and the LLFP removal efficiencies are also recommendedin order to satisfy the derived concentration limits. Finally, the most important input parameter which has the most influence on the determination of the concentration limits is analyzed by sensitivity analysis. Because the generated mass ratio of each nuclide is pre-determined and the final waste form from PEACER is assumed to be homogenous, the annual dose by most hazardous scenario is the main focus of this study rather than the concentration limit determinations by sensitivity analysis.

CHARACTERISTICS AND GENERATION OF 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 components 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 nuclides. This is because of their high solubility in water (with 95% removal efficiency). In the pyrochemical process, decontamination factors of TRU components are introduced as an indicator for the process performance. The overall DF in the pyrochemical process is defined as the ratio of the mass of the loaded TRU components into the process to the TRU components lost into waste stream and is expressed as follows in equation 1;

$$DF = \frac{\text{The loaded TRU into pyrochemical process}}{\text{The lost TRU into waste stream}} \quad \text{(Eq. 1)}$$

In the previous study, PEACER pyroprocessing system was conceptually proposed having a DF of 10^5 [2]. However, a DF of 2.3E+05 was suggested considering the several requirements of the NRC Class C limits and a disposal facility volume of 1.6E+05m^3. In order to evaluate the total generated wastes from pyroprocessing, we assumed 20 LWR of 1 GWe capacity, 40 years lifetime with spent fuel discharged at 33,000 MWD/MTU burn up with 30 years cooling time, and 12 PEACER has a 60 year 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. Figure 1 shows the conceptual flow chart of back-end fuel cycle of PEACER system.

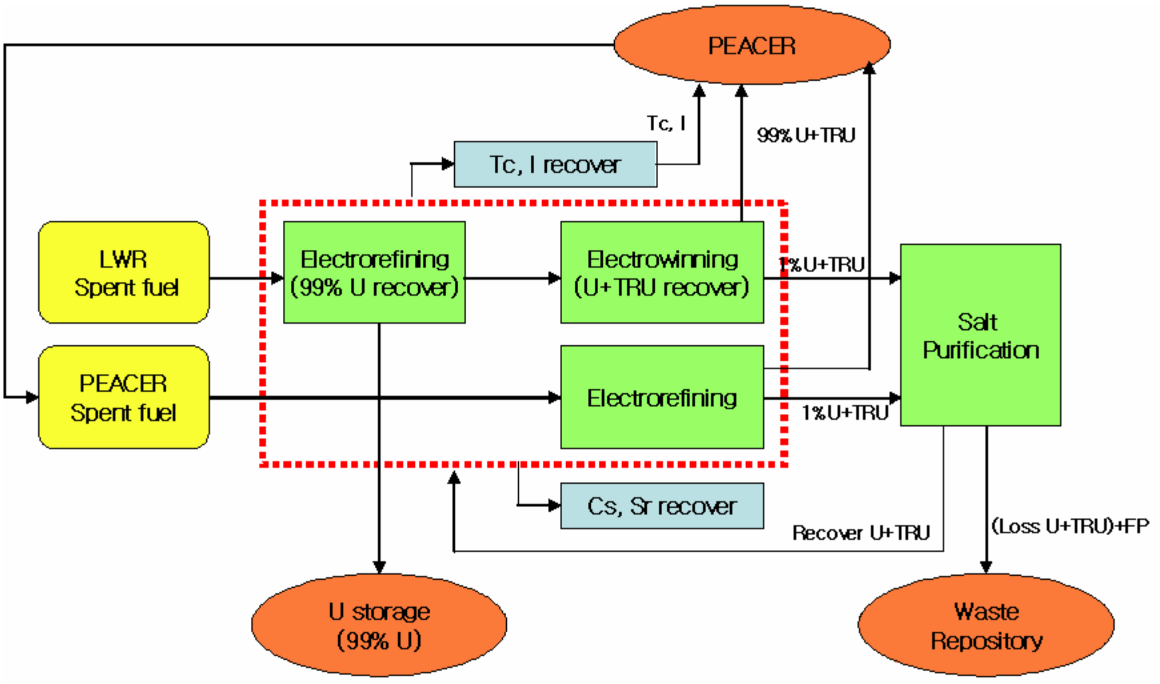

Fig. 1. Flow sheet of back end fuel cycle in PEACER

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] 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 500years.[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. Concentration limit for each radioactive nuclide are calculated by backward method from the dose limit using the human intrusion scenario

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 100mrem/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].

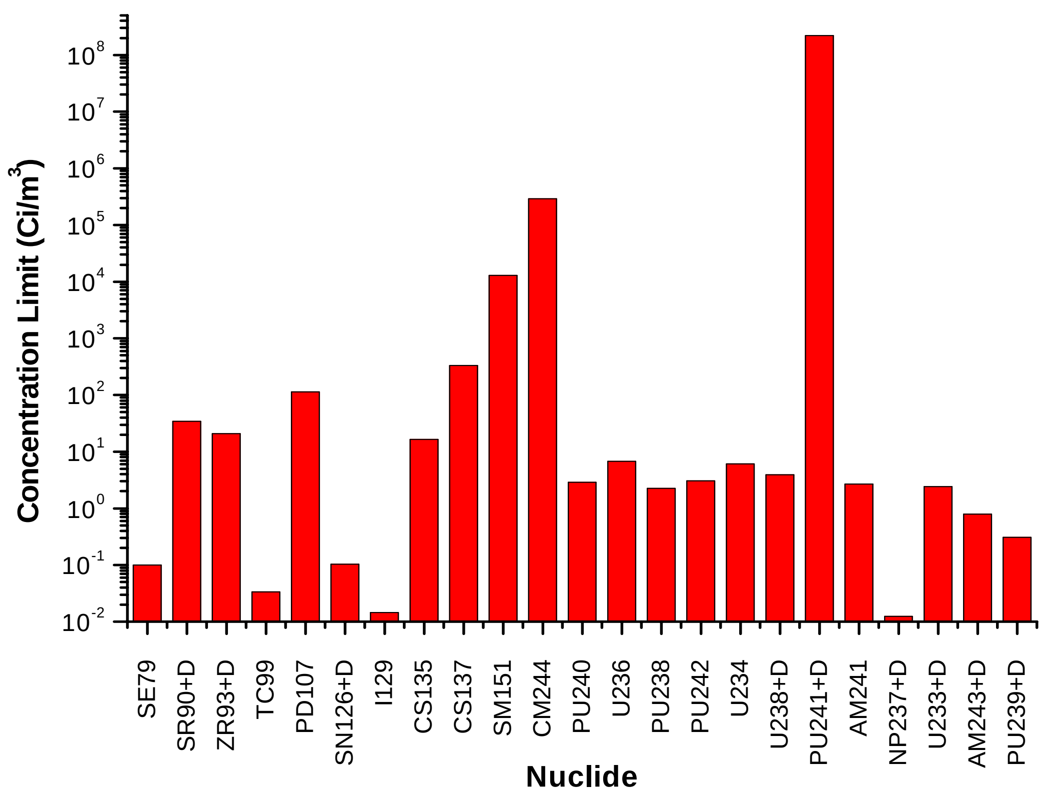

Fig. 2. Concentration limit for radionuclide from pyroprocessing

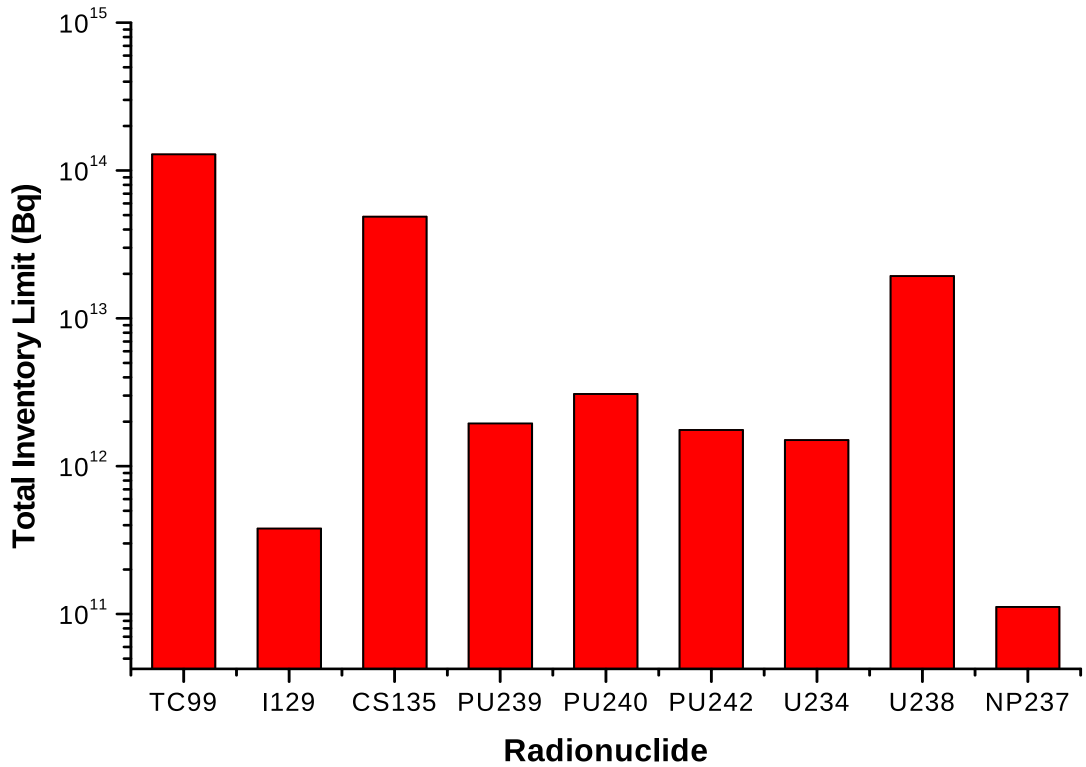

Fig. 3. Total inventory limit

CONCLUSION

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. Table I 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.

Table I. 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

ACKNOLWLEDMENTS

This work was financially supported by MOCIE through IERC program.

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