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Radiological Impacts Assessment for Possible Occurrence of Incidents during the Decommissioning Operations in EU-APR

Do Hyun Hwang[a]*, Sukhoon Kim[b]
[a]*KHNP-CRI, 70, 1312 Gil, Yuseong-daero Yuseong-gu, Daejeon 34101, Korea*
[b]*FNC Technology Co., Ltd., Main Building, Institute of Future Energy Technology, 46, Tapsil-ro, Giheung-gu, Yongin-si, Gyeonggi-do, 17084, Korea*
[*]*Corresponding author: crihwang@khnp.co.kr*

1. Introduction

Decommissioning is the final phase in the lifecycle of a nuclear installation, covering all activities from shutdown and removal of fissile material to environmental restoration of the site [1].

According to article 5.4 specified in chapter 2.20 of European Utility Requirements (EUR) [2], all relevant radiological impacts on human being should be considered during the environmental assessment of decommissioning, including external exposure from direct radiation of plant and other radiation sources, and internal exposure due to inhalation and ingestion.

In this paper, radiological impacts on human beings for possible occurrence of incidents during the decommissioning operations from the current standard design of EU-APR, which has been modified and improved from its original design of APR1400 to comply with EUR, are evaluated.

2. Impact Assessment for Possible Occurrence of Incidents during the Decommissioning Operations

2.1 Activities with Potential Environmental Impact

Table 1 includes a list of decommissioning activities that may produce any environmental impact during the possible occurrence of events or accidents. These activities have the potential to result in exposures to workers who are close to contaminated structures or components, and to provide the population and environment with pathways for the release of radioactive materials that are not present during normal operation.

2.2 Methodology

In consideration of both the external and internal exposures, the impact assessment is carried out for the actual or hypothetical persons likely to be exposed in incident conditions. The potential radiological impacts are predicted in effective dose by using dose assessment for the representative person of the public located at 300 m from a site boundary. Though the distance to the site boundary is the parameter to be determined in accordance with the meteorological information, atmosphere dispersion and deposition, the site boundary for EU-APR is conservatively assumed to be 500 m from the reactor considering the value for nuclear power plant in Korea. Fig. 1 shows the Site Plot Plan for EU-APR.

The representative incidents to be assessed are determined by the screening analysis in consideration of the qualitative features and frequency of occurrence. The radiological impact assessment for incident circumstances during the decommissioning are performed on the basis of coefficients for ground level releases of the nine reference isotope groups (e.g. ^{133}Xe, ^{131}I), which are taken from Table B1 in Chapter 2.1 (Appendix B) of European Utilities Requirements (EUR). The contribution of liquid releases during incidents is considered to be negligible referring to the design features of EU-APR and the decommissioning activities for the existing nuclear power plants.

For each incident, the effective dose is calculated by summing the dose due to each nuclide, which is derived by multiplying the release activity by the conversion factor (i.e. dose per unit release activity). For radionuclides included in the release source term for incidents to be assessed, the release activity-to-dose conversion factors [in unit of '(Sv/yr)/TBq)'] by nuclide are derived as follows, and the calculation results are summarized in Table 2.

2.3 [Case A] Radionuclides except ^{3}H and ^{14}C

First of all, the radionuclides excluding ^{3}H and ^{14}C are classified into one of nine reference groups shown in Chapter 2.1 (Appendix B) of EUR. For each nuclide, the value multiplied the following two factors together is adopted as the conversion factor for the release activity.

- The coefficient for ground level release of each reference group (beyond 800m from the reactor) shown in Table B1 of Chapter 2.1 (Appendix B) of EUR: As mentioned previously, since the site boundary for EU-APR is assumed to be 500 m considering the value for nuclear power plant in Korea, the coefficient for 800 m from the reactor which is 300 m from the site boundary is applied as basic input data for the calculation.
- The multiplier derived based on the dose conversion

factors by the exposure pathway: the four pathways considered in these calculations are as follows; cloudshine from plume immersion, groundshine from ground deposits, inhalation, and ingestion. The conversion factors for the former and latter two pathways are taken from Federal Guidance Report No. 12 [3] and ICRP Publication 119 [4], respectively. Out of these radionuclides, in case that the dominant exposure pathway due to discharges to the atmosphere can be determined by Table I-III of IAEA Safety Report Series No. 19 [5], ratio of the conversion factors for the corresponding pathway (i.e. the nuclide to the representative nuclide of the group) is applied as the multiplication factors. And, in case of radionuclides that the dominant pathway is not presented in Table I-III of IAEA Safety Report Series No. 19 [5], the maximum value out of the ratio of the conversion factors for four pathways (i.e. the nuclide to the representative nuclide of the group) is applied as the multiplier.

2.4 [Case B] ^{3}H and ^{14}C

It is not possible for ^{3}H and ^{14}C to categorize into one of the nine reference groups shown in Chapter 2.1 (Appendix B) of EUR. Accordingly, since the calculation method for [Case A] as above cannot be used, the release-to-dose conversion factors (in unit of 'Sv/Bq') for activity release into the atmosphere, which are derived in process of construction project for a nuclear power plant in Europe, are applied to these two nuclides. From the conversion factors, ratio of the coefficient for ^{3}H and ^{14}C to that for ^{131}I (in case that release height is 20 m and duration of the release is 1 hr) is used as the multiplier for each nuclide.

3. Results of Impact Assessment for Possible Occurrence of Incidents during the Decommissioning Operations

For the representative incidents during the decommissioning operations of EU-APR selected through the screening analysis, the results of dose assessment of the representative person of the public located at 300 m from the site boundary are summarized in the Table 3. From this table, it is found that the results for all scenarios to be assessed are within the dose limit (i.e. 100 μSv in a year above background) to a member of public.

Accordingly, it can be assured that the exposure situation during the incident circumstances may be considered to be negligible radiological concern.

4. Conclusions

In this paper, radiological impacts on human beings for possible occurrence of incidents during the decommissioning operations were evaluated from the current standard design of EU-APR based on the simple transport model and practical generic methodology for assessing the radiological impact provided by IAEA. The results of dose assessment fulfilled the dose limit for all scenarios.

Acknowledgement

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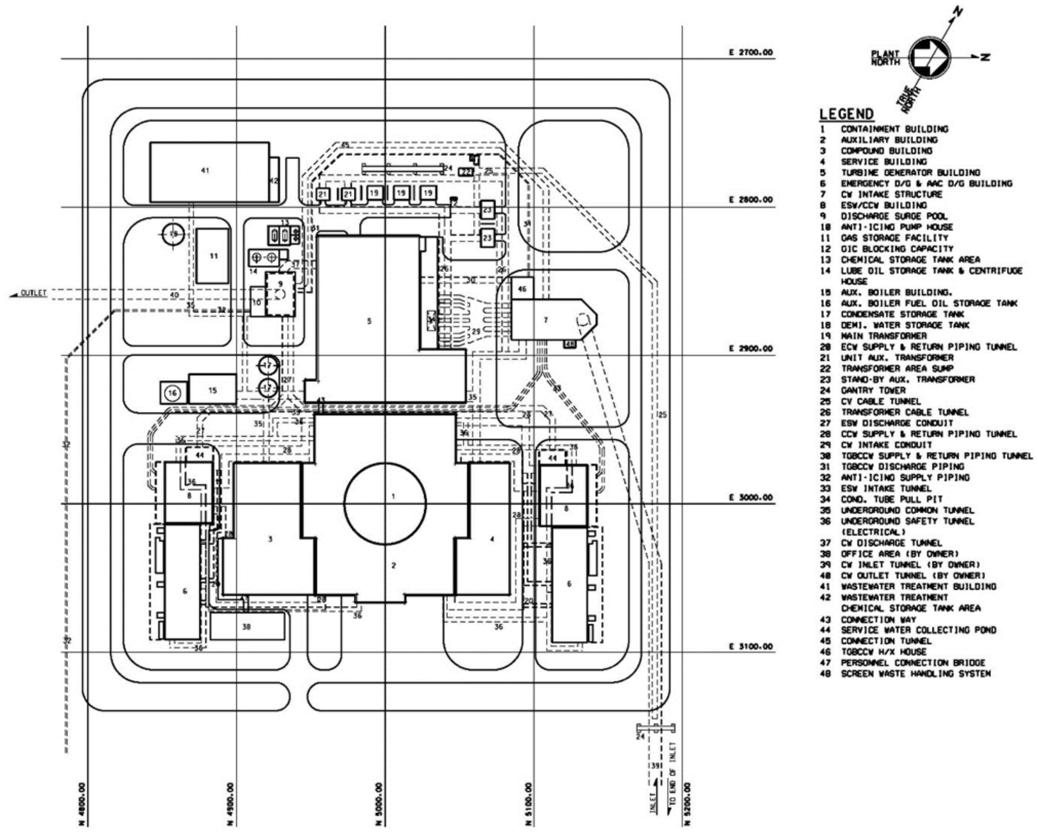

Fig.1 Site Plot Plan for EU-APR

Table 1 Decommissioning Activities with Potential Environmental Impact during Possible Occurrence of Events or Accidents

Activity	Expected Environmental Impact
Spent fuel removal	• High external dose rates leading to exposure of public. • Criticality leading to off-site release and high external dose rates • Releases from dropped assemblies
Decontamination of primary circuit	• External radiation from transfer of active material around primary circuit and outside the containment building • Environmental discharges of active fluid • Contamination hazard from leaks and spills
Steam generators, reactor circulator pumps, and pressurizer	• External radiation and contamination • Release of airborne activity from dropped load
Primary circuit pipework and other primary circuit components	As steam generators
Reactor Pressure Vessel (RPV) integrated head package	High external radiation from activation products
RPV and internals	• High external radiation from activation products • Spread of contamination from residual liquid
Reactor vessel bioshield concrete	High external dose and airborne contamination
Non-primary circuit containment building components including In-containment Refueling Water Storage Tank (IRWST)	External radiation from residual liquids, sludges, filters
Active liquors and sludges	External radiation from residual liquids, sludges, filters
Removal of plant from other nuclear island buildings: Auxiliary, compound and services buildings	External dose and contamination
Decontaminate and demolish nuclear island buildings	External dose and contamination
Decommission ILW management facilities	High external radiation and contamination
Removal of spent fuel off site	High external radiation and contamination
Decommission spent fuel buffer storage facilities	Contamination
Remediation of site	Contamination from previous incidents

Table 2 Release Activity-to-Dose Conversion Factors [in unit of (Sv/yr)/TBq)] by Radionuclide used in the Dose Assessment for Possible Occurrence of Incidents

Group No.*	Nuclide	Multiplier	Group No.*	Nuclide	Multiplier	Group No.*	Nuclide	Multiplier
6	Ag-108m	2.775E-03	7	Eu-154	4.463E-04	8	Pu-241	3.375E-01
6	Ag-110m	1.088E-03	7	Eu-155	2.213E-05	3	Rb-88	5.209E-01
7	Am-241	3.093E+01	6	Fe-55	8.137E-05	6	Ru-103**	1.800E-04
1	Ar-37	5.292E-12	6	Fe-59	4.776E-04	6	Ru-106	2.100E-03
1	Ar-39	4.766E-10	-	H-3	5.944E-07	4	Sb-125	4.964E-05
9	Ba-133	1.367E-05	2	I-131**	5.000E-05	6	Sc-46	7.984E-04
9	Ba-137m	2.081E-05	2	I-132	3.077E-04	5	Sr-89	2.507E-05
9	Ba-140**	6.200E-06	2	I-133	8.077E-05	5	Sr-90**	2.700E-04
-	C-14	1.829E-04	2	I-134	3.571E-04	5	Sr-91	1.237E+00
9	Ca-41	4.531E-07	2	I-135	2.192E-04	6	Ta-182	7.500E-04
9	Ca-45	4.498E-06	1	Kr-85	4.958E-09	6	Tc-99m	4.712E-05
8	Ce-141**	1.200E-03	7	La-140**	8.100E-04	4	Te-129	7.019E-06
8	Ce-143	4.537E-03	6	Mn-54	3.272E-04	4	Te-129m	2.526E-04
8	Ce-144	3.301E-04	6	Mo-99	5.824E-05	4	Te-131	4.788E-05
6	Co-57	7.500E-05	3	Na-24	3.380E+00	4	Te-131m**	1.600E-04
6	Co-58	3.808E-04	7	Nb-94	3.608E-02	4	Te-132	2.663E-05
6	Co-60	1.008E-03	7	Nb-95	2.805E-04	6	W-187	1.824E-04
6	Cr-51	1.208E-05	6	Ni-63	3.699E-05	1	Xe-133**	6.500E-08
3	Cs-131	1.006E-02	8	Np-239	2.690E-03	7	Y-91	9.720E-04
3	Cs-134	1.174E+00	8	Pa-233	3.271E-03	7	Y-91m	1.961E-04
3	Cs-136	1.643E+00	8	Pu-238	1.725E+01	7	Y-93	4.860E-04
3	Cs-137**	1.200E-04	8	Pu-239	1.875E+01	6	Zn-65	2.320E-04
7	Eu-152	3.093E-02	8	Pu-240	1.875E+01	7	Zr-95	2.711E-04

Note) * Sequential number of the group shown in Chapter 2.1 (Appendix B) of EUR
** The representative nuclide of each reference group

Table 3 Summary of the Dose Assessment Results for the Representative Scenarios during Possible Occurrence of Incidents in the Decommissioning Phase

Initiating Events		Effective Dose [mSv/yr]
Code	Description	
A2	[Fuel-related events] Fuel handling accident in spent fuel pool	1.42E-04
B1	[Dismantling events] Dropping of contaminated components/equipment	1.81E-08
B2	[Dismantling events] Dropping of contaminated concrete rubble or slab (e.g., activated concrete rubble) during replacement	8.14E-02
B3	[Dismantling events] Dropping of wastes containers in radioactive waste storage areas	5.88E-05
B4	[Dismantling events] Dropping of a HEPA filter containing accumulated radioactive particles	1.37E-03
B5	[Dismantling events] Failure of ventilation and filtering system	5.22E-09
B6	[Dismantling events] Accidental cutting of the contaminated components	3.91E-09
B7	[Dismantling events] Accidental cutting or blasting of the contaminated concrete when any contamination control system is not available	8.23E-04
D1	[Leaking events] Solid management system leaks	3.40E-04
D3	[Leaking events] Gross spill/leaks of liquid waste processing system or temporary tanks containing radioactive liquids	3.18E-09
D4	[Leaking events] Gross leaks from the SFP during storage of spent fuel in the spent fuel pool	2.46E-04
E1	[Decontamination events] Gross leaks from in-situ decontamination of contaminated system	1.75E-11
E2	[Decontamination events] Decontamination of contaminated surfaces in a building and a structure	1.45E-06
E3	[Decontamination events] Failure of vacuum system during decontamination of contaminated wall and floor	1.21E-08
G1	[Fires (or explosions) events] Fire - small	5.34E-03
G2	[Fires (or explosions) events] Fire - medium	2.67E-02
G3	[Fires (or explosions) events] Fire - large	5.34E-02
G4	[Fires (or explosions) events] Explosion	1.48E-02