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Radiological Impacts Assessment during Normal Decommissioning Operation for EU-APR

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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.

According to article 5.4 specified in chapter 2.20 of European Utility Requirements (EUR) [1], 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 during normal execution of 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. Design for Decommissioning and Expected Decommissioning Activities

2.1 Best Available Techniques

The following features are integrated into the current standard design of EU-APR in order to minimize doses during the decommissioning phase in accordance with ALARA (As Low As Reasonably Achievable) principle. The Best Available Techniques (BATs) are focusing on minimizing the source of radiation through minimizing the spread of contamination, using remote control techniques, minimizing the production of radioactive waste, and etc.

- To facilitate decommissioning
  - Space of at least 90 cm away from all equipment to allow ease of access for decommissioning tasks
  - Removal of large equipment in one-piece without disassembling; equipment hatch opening of 8.0 m in diameter to accommodate the removal of a steam generator assembly
  - Use of Integrated Head Assembly (IHA)
    - IHA simplifies the structural configuration of upper closure head region and improves the decommissioning convenience.
    - Removal in one-piece, and reduction of occupational radiation exposure as well as component storage area and removal time
  - Provide at least two (2) personnel access openings of 3.05 m in diameter; located sufficiently much apart from each other so that during any event at least one of them provides an emergency exit from the containment
  - Easy access for staircase & escape route; Personnel and equipment have easy access from outside the Auxiliary Building through to inside the Containment Building and easy removal of smaller items.
  - Spaces for storage of decommissioning and lay-down areas
    - In Compound Building, a decontamination facility, a large hot area workshop, and a contamination equipment storage room are provided.
    - In Auxiliary Building, the clean/hot areas are provided for space for setting up and storage of decommissioning equipment, or for lay-down areas for smaller items removed.
    - In Turbine Building, the clean areas are provided once the turbines have been removed.
  - Separation of radioactive and non-radioactive systems & areas for implementing ALARA
    - Experience-driven design and physical separation between the hot and the clean areas to reduce occupational radiation exposure dose
    - Drain systems keep the liquid separated according to their potential radioactivity.
  - Materials design and waste management
    - Minimization of use of lubricating oils where contaminated
    - Segregation of materials to facilitate future waste management
    - Minimization of materials that lead to hazardous or mixed waste
    - Provision for recycling and reuse of relevant materials
    - Keeping samples of the materials used during construction
  - Minimization of embedded and/or buried piping
    - Use of double-walled piping, or piping in low porosity concrete trenches with epoxy coating or steel liner plate to contain multiple pipes

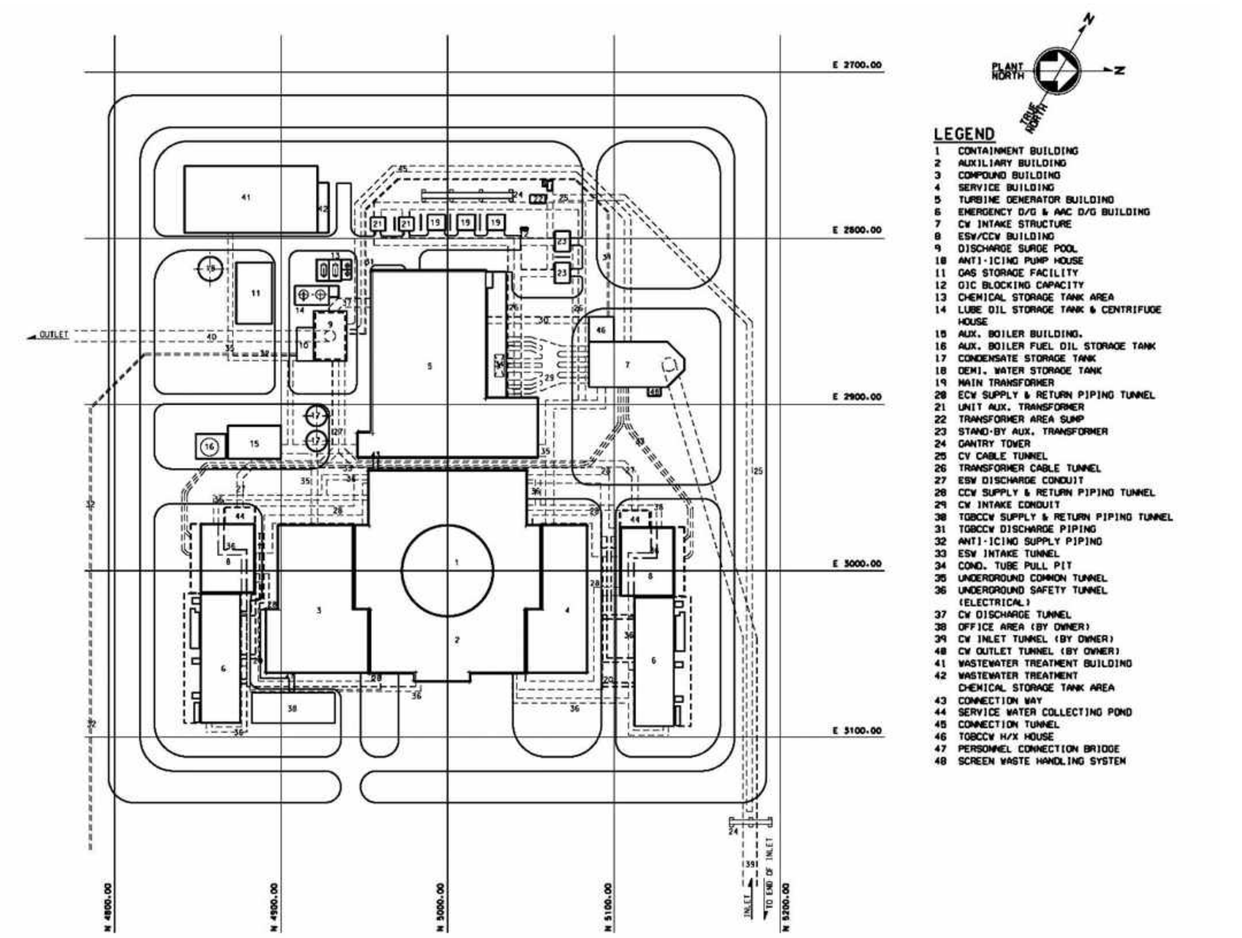

Fig.1 Site Plot Plan for EU-APR

Table 1 Decommissioning Activities with Potential Environmental Impact during Normal Performance of the Operations

Activity	Expected Environmental Impact
Decontamination of primary circuit	Normal execution: none
Dismantle reactor coolant system	• Normal operations: potential for airborne radioactivity releases as a result of cutting activities for dismantling. • Large items (e.g. steam generators) removed whole once connections to primary circuit have been cut.
Dismantle reactor vessel and internals	Normal execution: none; the reactor vessel and internals to be removed as one with no additional cutting operations after separation from primary circuit pipework.
Dismantle non-primary circuit reactor building components	• Cutting operations may release airborne contamination. • Apart from the bio shield concrete, this is unlikely to be radioactive if not in contact with contaminated fluids.
Deplant other nuclear island buildings	Normal execution: potential for airborne radioactivity releases as a result of cutting activities for dismantling.
Decontaminate nuclear island buildings	Depending upon decontamination procedure, this could include fluid leaks into the subsurface or airborne releases if, for example, scabbling is employed.
Remove spent fuel from site	Normal execution: disposal of spent fuel
Demolish nuclear island buildings	Airborne environmental discharges from demolition
Decommission Intermediate-Level Waste (ILW) management facilities	Radioactivity releases from dismantling operations of contaminated materials
Decommission spent fuel buffer storage facilities	Radioactivity releases from dismantling operations of contaminated materials

    - ▪ Trench is equipped with concrete cover and seal to minimize infiltration of precipitation, and with one sump and one pump to direct water to Turbine Building.

- To minimize contamination and activation
  - Neutron absorbing material around reactor pressure vessel
    - ▪ Use of borated polyethylene which contains high contents of hydrogen and boron
    - ▪ Reduces the occupational radiation exposure as well as the activation for the biological shield wall
  - Reduction of source term
    - ▪ Corrosion-resistant alloys containing very low cobalt impurities in primary loop
    - ▪ Addition of (depleted or natural) zinc injection system to CVCS
    - ▪ Surface finishings
    - ▪ Minimization of use of gate valve, concentric reducer, orifice, and etc.

- To prevent spread of contamination
  - Segregation of clean areas from contaminated areas
  - Ventilation system from low contaminated areas to higher contaminated areas
  - Use of stainless steel liners
  - Avoidance of use of porous material
  - Leak detection instrument for early detection of leaks and contamination

2.2 Activities with Potential Environmental Impact

Table 1 shows a list of decommissioning activities that may produce any environmental impact during normal performance of the operations. These activities have the potential to result in exposures to workers who are close to contaminated structures or components.

3. Radiological Impacts Assessment during Normal Execution of the Decommissioning Operations

For the representative exposure scenarios during normal execution of the decommissioning operations, the estimated values of the radiological discharges which are derived from experience data on decommissioning activities for existing nuclear power plants and the additional analyses are used.

In consideration of both the external and internal exposures, the impact assessment is carried out for the actual and hypothetical persons likely to be exposed in normal conditions. Since the distance to site boundary is the site-specific parameter depending on the meteorological information, atmosphere dispersion and deposition, the side boundary for EU-APR cannot be determined yet in the design phase. Therefore, the potential radiological impacts are conservatively predicted in effective dose by using dose assessment for the representative person of the public located at 300m from the release point.

For both the gaseous and liquid discharges of radionuclides (excluding ^{3}H) during the normal circumstances, the simple transport model and practical generic methodology for assessing the radiological impact provided in IAEA Safety Report Series No. 19 [2] are applied. The four pathways considered are as follows; cloud shine from plume immersion, ground shine from ground deposits, inhalation, and ingestion. An overview of the general assessment approach and the main parameters required to perform an assessment are schematized in Figure 2.

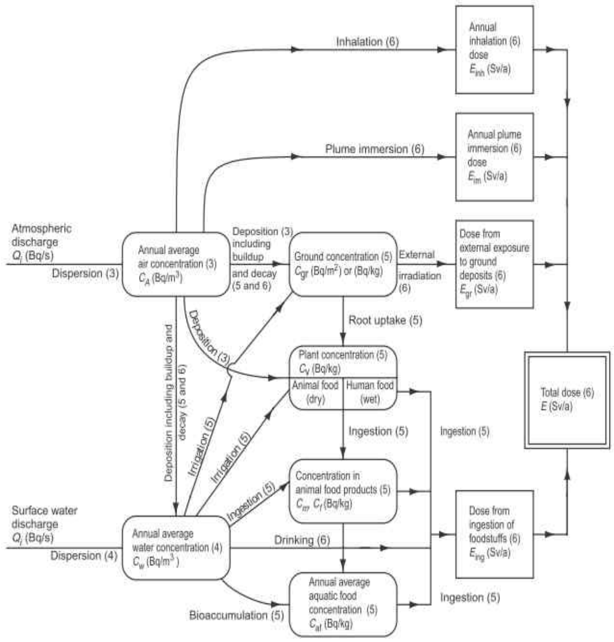

Fig.2 Overview of the General Assessment Approach for the Normal Execution of the Decommissioning Operations

For estimating the radiological dose from discharge of ^{3}H, special consideration should be taken since ^{3}H can be incorporated into a great variety of different chemical compounds within the human body. The dose rate for ^{3}H to the body of a representative member of the critical group is assessed using the specific activity model provided in Annex III of IAEA Safety Report Series No. 19 [2]. For simplicity and yielding conservative dose estimates, an exposed individual is assumed to be in steady state equilibrium with the maximum level of environmental specific activity of ^{3}H. It is also assumed that ^{3}H is incorporated into the organism through its association with water molecules (i.e. water vapor present in the atmosphere, and water of the aquatic environments).

In the assessment, since the specific site is not determined yet, various types of the liquid discharge pathway (i.e. river, estuary, small lake, large lake, and coastal water) are considered. In case of the liquid discharge into coastal waters, it might be necessary to evaluate the external doses from activity concentrations in shoreline sediments. However, since there is no information on the maritime activities and the existing experiences show that the radiological impact from the shoreline deposit is insignificant, the exposure dose from the shoreline activity due to the liquid discharge are neglected. In addition, unlike other discharge pathways, it is assumed that coastal waters are not used as the irrigation water and drinking water consumed by the animal

As mentioned above, since the site-specific information is not available, the default values recommended in IAEA Safety Report Series No. 19 [2] and the reasonable assumptions are applied as input data on the environmental conditions.

For the standard design of EU-APR, the results of dose assessment for planned exposure situations during the normal execution are summarized in the Table 2. 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 normal circumstances may be considered to be negligible radiological concern.

4. Conclusions

In this paper, radiological impacts on human beings during normal circumstances of the decommissioning operation 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.

In the future, radiological impacts on human beings for the possible occurrence of events or accidents during decommissioning will be evaluated.

Acknowledgement

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REFERENCES

[1] "European Utility Requirements (EUR) for LWR Nuclear Power Plants", Vol. 2, Rev. D, October 2012.
[2] IAEA Safety Reports Series No. 19 Generic Models for Use in Assessing the Impact of Discharges of Radioactive Substances to the Environment. 2001.

Table 2 Summary of the Dose Assessment Results for the Normal Execution of the Decommissioning Operations

Discharge Type		Dose by the Exposure Pathway [mSv/yr]						Effective Dose [mSv/yr]	
		Plume Immersion	Ground Deposits	Inhalation		Ingestion			
				Adults	Infants	Adults	Infants	Adults	Infants
Gas		4.44E-08	3.39E-03	2.59E-06	9.25E-07	3.74E-03	3.17E-03	1.37E-07	7.14E-03
Liquid	River	-	-	-	-	2.13E-04	1.01E-04	3.64E-02	3.66E-02
	Estuary	-	-	-	-	1.52E-04	7.23E-05	2.60E-02	2.61E-02
	Small lake	-	-	-	-	8.57E-06	6.27E-06	2.33E-04	2.42E-04
	Large lake	-	-	-	-	3.35E-04	1.60E-04	5.74E-04	5.77E-02
	Coastal water	-	-	-	-	6.92E-04	2.47E-04	5.74E-04	5.81E-02

Cases to be assessed		Effective Dose [mSv/yr]	
No.	Description	Adults	Infants
1	Gaseous discharge + Liquid discharge into River	4.37E-02	4.36E-02
2	Gaseous discharge + Liquid discharge into Estuary	3.32E-02	3.32E-02
3	Gaseous discharge + Liquid discharge into Small lake	7.38E-03	7.38E-03
4	Gaseous discharge + Liquid discharge into Large lake	6.49E-02	6.47E-02
5	Gaseous discharge + Liquid discharge into Coastal water	6.52E-02	6.48E-02