Preliminary Studies on Lower Limits of Detection for Gaseous Radioactive Effluent Based Upon Risk-based Approach

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1. Introduction

Nuclear power plant ("NPP") generate various types and amounts of radioactive waste during operation. Liquid and gaseous radioactive wastes are treated in each system and released into the environment in the form of effluents. Discharged liquid and gaseous radioactive effluents cause exposure to populations to various exposure pathway. In order to regulate the effects of radioactive effluents, the provisions of radioactivity concentration and offsite dose are used in domestic and abroad.

In order to obtain the reliability of the measured radioactivity concentration and offsite dose, the sensitivity of the Lower Limit of Detection (LLD) should be secured at a certain level or more. If radioactivity concentration or offsite dose measured using LLD which is not secure the appropriate sensitivity, the accuracy of results cannot have sufficient reliability. For the proper monitoring of the released each nuclide, LLDs are prescribed in domestic and abroad. LLDs for each nuclide are defined in Korea Hydro and Nuclear Power Co. Ltd. (KHNP), Radiological Effluent Control Plan for Younggwang NPP Units 5 and 6 in case of domestic and defines in USNRC (United States Nuclear Regulatory Commission) NUREG-1301 in case of Unites States [1, 2]. But the values are uniform values that do not take into account the characteristics of the NPP, radioactive effluent and that effects.

In 2017, Cheong proposed the deriving methodology of risk-based detection limits for liquid radioactive effluents [3]. That methodology derives the risk-based detection limits using the level of contribution to both radioactivity concentration and offsite dose.

In this study, proposing the deriving methodology of risk-based LLD for gaseous radioactive effluent. Also, deriving the risk-based LLD and confirm the validity of risk-based LLD and present LLD using the APR1400 case.

2. Method

The risk of gaseous radioactive effluent is defined by totally six criteria, the radioactivity concentration and five kinds of offsite dose (Gamma air dose, Beta air dose, Total body dose, Skin dose by noble gases and Organ dose by radioiodine and particulates). In this study, six values were calculated using the releasing of the gaseous radioactive effluent and the virtual environment data in the APR1400 Design Control Document tier 2 (DCD).

As the mentioned at the prior research, the methodology for gaseous radioactive effluent based upon risk-based approach is divided 2 steps. First, in a single nuclide condition, deriving the risk-based LLDs for each risk (six criteria). Second, in the multiple nuclides condition, evaluating the sensitivity of the gaseous radioactive effluent totally.

First of all, in order to derive the risk-based LLD for each risk, specifies the minimum margin for risk when the radioactivity concentration which will be measured at the monitoring tank is same with the LLD. This value is called the safety factor (s). Safety factor means that it is necessary to have a sensitivity which can measure within the rage of not exceeding designated value (i.e., 0<s<1) of risk value by nuclides in the single nuclide condition. It can be calculated each risk-based LLD with the designated margin. The smallest values for each nuclide among the calculated LLD become the risk-based LLD.

In this case, target nuclide is all nuclides (37) in the gaseous radioactive effluent to be discharged. Equations for deriving risk-based LLDs are in Table 1.

Table 1. Equations for deriving the risk-based LLD under the single nuclide condition

Condition	Equation	
Radioactivity concentration	$LLD_{ECL,i} \le \frac{s}{f \cdot (X/Q)} \times ECL_i$	(1)
Offsite dose	$LLD_{D,i} \le \frac{s}{f} \times \frac{DC_D}{PDF_{D,i}^{path}}$	(2)

After that, evaluate the risks due to gaseous radioactive effluents totally when using risk-based LLDs as radioactivity concentration according to confirm the sensitivity of the used LLDs as a monitoring standard. Standard level in multiple nuclides condition is also called safety factor (S) and it also means that in order to evaluated as LLD which is have designated sensitivity, it is need to be able to measure within the rage of not exceeding designated value (i.e., 0<s<S<1) of risk value caused by all nuclides in the multiple nuclides condition. If values calculated in each risk greater than safety factor, it can judge that used LLDs do not have sufficient sensitivity to measure the radioactivity concentration in risk-based point of view. The application of a risk-based approach for gaseous radioactive effluent under the multiple nuclides condition can be obtained by extending the prior study, which deals the methodology of deriving the risk-based LLD for liquid radioactive effluent.

3. Results

3.1 Risk-based LLD of APR1400 in Single Nuclide Condition

Based on the gaseous radioactive effluent discharged from APR1400 nuclear power plant, risk-based LLDs for each nuclide is shown in Figure 1. Present LLDs in NUREG-1301 are indicated by a solid red line and the risk-based LLDs derived by six criteria (radioactive concentration, Gamma air dose, Beta air dose, total body dose, skin dose by noble gases and organ dose by radioiodine and particulates) are expressed as a various notation.

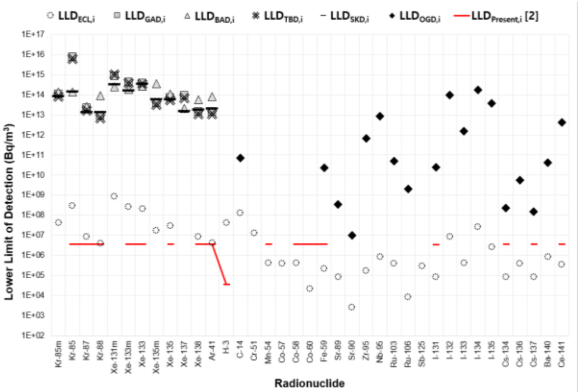

Fig. 1. Present and derived Risk-based LLD in single nuclide condition by Equation (1) and (2).

As mentioned like, risk-based LLD for each nuclide is determined as the smallest value among derived LLDs nuclide. Respectively, risk-based LLDs are determined by the radioactivity concentration for 36 nuclides and by the skin dose due to noble gas for only 1 nuclide. Also among 17 nuclides which present LLDs values are specified, 9 nuclides have lower value (i.e., more sensitivity) than the derived risk-based LLDs in radioactivity concentration and four offsite doses by noble gas and 0 in radioactivity concentration and one offsite dose by radioiodine and particulates. The nuclide representing the most significant difference between present LLD and risk-based LLD is ^{60}Co, and the risk-based LLD is about 170 times lower. This indicates for single nuclide that all risks due to noble gas can be measured with sufficiently sensitivity and it can have confidence to results. On the other hand, the risk due to radioiodine and particulates, especially the radioactivity concentration denotes a possibility that the present LLDs cannot be performed sufficiently measurement from the risk-based point of view.

In multiple nuclides condition, safety margin which is relevant with safety factor can be calculated by methodology in previous study. Results calculated by previous study, risk-based LLDs have enough sensitivity to all risk except the radioactivity concentrations. It can also be deduced that this value is lower than the value derived by using present LLD.

4. Conclusion

In this study, derivation methodology of risk-based LLD derivation method for gaseous radioactive effluent is proposed. The risk-based LLD allows detecting of the nuclides graded by contribution, taking into account the environmental impact of the effluent on the radioactive concentration and contribution to offsite doses. A case study was conducted based on the gaseous radioactive effluent and the hypothetical condition in APR1400 DCD. Risk-based LLD was derived for 37 nuclides. Respectively, risk-based LLD for 36 nuclides for the radioactivity concentration, and 1 nuclide for the skin dose due to radioiodine and particulates are determined. Also, among 17 nuclides which specified the present LLD values already, 8 nuclides have lower risk-based LLD values than present LLD. All 8 nuclides are radioiodine and particulates. It represents the probability that risk cannot be got confidence when measured by using present LLD for radioiodine and particulates.

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