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Analysis of NRC Regulatory Guide 1.21 Revision 2

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1. Introduction

For evaluation by the licensee and the regulatory staff of the environmental impact of radioactive materials in effluents and solid wastes, including estimates of the potential annual radiation doses to the public, information on the identity and quantity of radionuclides in liquid and gaseous effluents and solid wastes from nuclear power plants, together with meteorological data representative of principal release points, are needed.

It is essential to have a degree of uniformity in the methods used for measuring, evaluating, recording, and reporting data on radioactive material in effluents and solid wastes. For this purpose, the U.S. Nuclear Regulatory Commission (NRC) released a revised version of the Regulatory Guide 1.21 "Measuring, evaluating, and reporting radioactive material in liquid and gaseous effluents and solid waste" (revision 2) in 2009, updating the revision 1 version released in 1974. This study compares the previous revision 1 (1974) version with the revision 2 (2009) version to elaborate on the application of the guidelines to Korea.

2. Analysis of Main Revisions

In this section, the main revisions to the Regulatory Guide 1.21 are analyzed and means for their application to Korea are explored.

2.1 Introduction of the concept of principal radionuclides according to the risk-informed approach

Operators have to apply the nuclide list and LLD values as detailed in the existing NUREG-1301 report to conduct sample analysis during effluent monitoring. Since the principal radionuclides will vary from site to site, licensees who wish to deviate from the historical method of determining principal radionuclides may adopt a risk-informed approach to identify principal radionuclides (and the associated sensitivity levels) at a site.

If adopting a risk-informed perspective, a radionuclide is considered a principal radionuclide if it contributes either (1) greater than 1 percent of the 10 CFR Part 50, Appendix I, design objective dose for all radionuclides in the type of effluent being considered, or (2) greater than 1 percent of the activity of all radionuclides in the type of effluent being considered.

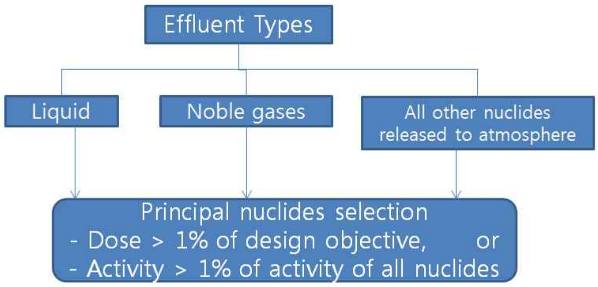

Fig. 1. Method of principal nuclides selection

If a risk-informed approach is used, principal radionuclides should be determined based on an evaluation over a time period that includes a refueling outage (e.g., one fuel cycle). A periodic reevaluation should be performed to determine whether the radionuclide mix has changed and/or to identify new principal radionuclides. If adopting this method, the ODCM should be updated with the list of principal radionuclides within 1 year of their identification.

The concept of "principal radionuclides" does not reduce the requirement for reporting radionuclides detected in effluents. In addition to principal radionuclides, other radionuclides detected during routine monitoring of release points should be reported in the radioactive effluent release report and included in dose assessments to members of the public.

Currently, sample analysis and effluent monitoring in domestic reactors are conducted under the specifications of the NUREG-1301 report, and thus it can be stated that relevant regulatory guidelines are already being met. Although a risk-informed approach has yet to be adopted in domestic reactors, operators can adopt a risk-informed approach by selecting principal radionuclides through the evaluation of effluent and radiation amounts. The risk-informed approach may be applied in cases where atypical radionuclides not listed in the FSAR or radionuclides that are difficult to measure are detected, to determine their principal radionuclide status

2.2 Monitoring of additional radionuclides

In 2009, the NRC of the United States announced a revised version of the Regulatory Guide 1.21 (Measuring, evaluating, and reporting radioactive material in liquid and gaseous effluents and solid waste) and added contents related to ^{14}C. According to this revised version (Rev. 2), the radioactive effluents from commercial nuclear power plants over the same period have decreased to the point that ^{14}C is likely to be a principal radionuclide in gaseous effluents. Because the dose contribution of ^{14}C from liquid radioactive waste is much less than that contributed by gaseous radioactive waste, evaluation of ^{14}C in liquid radioactive waste is not required. Licensees should evaluate whether ^{14}C is a principal radionuclide for gaseous releases from their facility.

Other exposure pathways are considered significant if a conservative evaluation yields an additional dose increment equal to or more than 10 percent of the total from all exposure pathways(Reg. Guide 1.109). The quantity of ^{14}C discharged can be estimated by sample measurements or by use of a normalized ^{14}C source term and scaling factors based on power generation(see National Council on Radiation Protection and Measurements Report No. 81, "Carbon-14 in the Environment," issued January 1985) or by use of the GALE code from NUREG-0017. If estimating C-14 based on scaling factors and fission rates, a precise and detailed evaluation of C-14 is not necessary. It is not necessary to calculate uncertainties for C-14 or to include C-14 uncertainty in any subsequent calculation of overall uncertainty. Most U.S. NPPs evaluate ^{14}C emissions by using theoretically calculated values according to this guide.

In the case of domestic pressurized water reactors (PWR), C-14 effluent monitoring through sample measurement has been continuing since 2013. Thus they can be seen as adhering to revised regulatory guidelines. As the revised guidelines allow for evaluation of C-14 emissions through theoretical calculations, theoretical calculations for C-14 emission evaluation during the permit application process for new reactor construction and operation can be considered as a viable method. Moreover, should unexpected radioactive gas emissions occur through ventilation points where C-14 sample extraction has not yet been conducted, theoretical calculations can be used to evaluate the amount emitted according to guidelines.

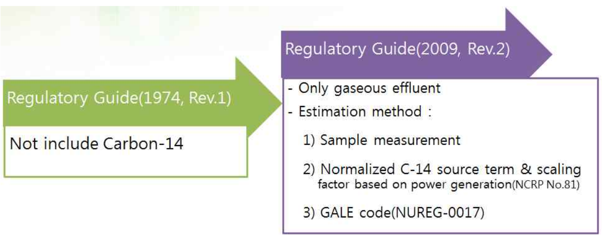

Fig. 2. C-14 emission evaluation options

2.3 Gaseous effluents sampling method

Guidelines of the 2009 revision 2 recommend the application of revised codes as listed in Table 1.

Sampling and storage techniques that could bias quantitative results for effluent measurements should be evaluated and corrections applied as necessary. These biases include inaccurate measurement of sample volumes resulting from pressure drops in long sample lines and loss of particulates or iodine in sample lines resulting from deposition or plate-out. Samplers for gaseous waste should be evaluated for particulate deposition using ANSI N13.1-1999 or equivalent.

Table I: Revise Code and nozzle type

	Rev.1(1974)	Rev.2(2009)
Code & Standard	ANSI N13.1-1969	ANSI N13.1-1999, Reg.Guide 4.15, ANSI N42.18-2004
Nozzle type	Isokinetic probe	Single point Shrouded Nozzle

The main item revised pertains to the recommendation to use shrouded nozzles in the extraction of gaseous samples. The relevant code is current applied to newly constructed domestic reactors, and existing reactors under operation come under the code only when they become targets of PSR testing according to regulatory policies. This should be taken into consideration by operators.

2.4 Hydrology

The 2009 revision 2 also added requirements for hydrologic data. Along with reinforced requirements for analysis of leaks and spills, there arose the need for groundwater monitoring and hydrologic analyses.

Sites should perform a basic site hydrogeological characterization, in advance of leaks or spills, to be prepared to evaluate potential leaks and spills. When surface and groundwater leaks and spills occur in domestic reactors, operators have to carry out groundwater monitoring programs and conduct basic hydrologic and geological evaluations of the site to prepare for the possibility of decommissioning.

2.5 Measurement Uncertainty

The measurement uncertainty (revision1 called measurement error) associated with the measurement of radioactive materials in effluents should be estimated. The total or expanded measurement uncertainty associated with the effluent measurement should ideally include the cumulative uncertainties resulting from the total operation of sampling and measurement. Expanded uncertainty should be reported with measurement results. The objective should be to evaluate only the important contributors and obtain a reasonable measure of the uncertainty associated with reported results. Detailed statistical and experimental evaluations are not required. The overall objective should be to obtain an overall estimate of measurement uncertainty. The formula for calculating the total or expanded uncertainty classically includes the square root of the sum of squares of each important contributor to the measurement uncertainty. Licensees may obtain additional information from NUREG-1576 and ANSI/HPS N13.1-1999 if there is a need to improve the estimate of uncertainty.

Currently, uncertainty reports are not being conducted on domestic reactors. Thus operators would have to carry out an uncertainty analysis including sampling, volumetric measurements, flow rate measurements, laboratory processing uncertainties and keep records of the results thereof for application of these guidelines.

3. Glossary of Terminology

The Regulatory Guide 1.21 revision 2 includes the following definitions of major terminology. As this terminology has only been partially adopted in Korea, this could lead to confusion. Thus the definitions in the guide should be referred to for accurate usage of terminology.

3.1 Releases vs. Discharges

In the previous revision of the Regulatory Guide 1.21, the terms “release” and “discharge” were synonymous. Revised regulatory guide uses the term “release” to describe an effluent from the plant (regardless of where the effluent is deposited), whereas the term “discharge” is used only to describe an effluent that enters the unrestricted area. Although the term “release” includes effluents to either (1) the on-site environs or (2) the unrestricted area, for purposes of this regulatory guide, the use of the term release” will generally be reserved for those instances when an effluent is released from the power plant into the on-site environs.

3.2 Controlled release/discharge

A radioactive release/discharge is considered to be “controlled” if (1) the release/discharge was conducted in accordance with methods, and without exceeding any of the limits, outlined in the ODCM, or (2) if one or more of the following three items are true:

1. The radioactive release/discharge had an associated, pre-planned method of radioactivity monitoring that assured the release/discharge was properly accounted and was within the limits set by 10 CFR 20 and 10 CFR 50.
2. The radioactive release/discharge had an associated, pre-planned method of termination (and associated termination criteria) that assured the release/discharge was properly accounted and was within the limits set by 10 CFR 20 and 10 CFR 50.
3. The radioactive release/discharge had an associated, pre-planned method of adjusting, modulating, or altering the flow rate (or the rate of release of radioactive material) that assured the release/discharge was properly accounted and was within the limits set by 10 CFR 20 and 10 CFR 50.

3.3 LLD and MDC

Lower limit of detection (LLD) -The *a priori* smallest concentration of radioactive material in a sample that will yield a net count, above system background, that will be detected with 95% probability with only a 5% probability of falsely concluding that a blank observation represents a real signal.

Minimum detectable concentration (MDC) - The smallest activity concentration measurement that is practically achievable with a given instrument and type of measurement procedure. It depends on factors involved in the survey measurement process (surface type, geometry, backscatter, and self-absorption) and is typically calculated following an actual sample analysis (a posteriori).

4. Conclusions

This study consists of an analysis of the 2009 Revision 2 version of the U.S. NRC Regulatory Guidelines 1.21 and an exposition of methods for its application in the domestic environment. Major revisions were made to allow for the adoption of a risk-informed approach. Radionuclides with lower than 1% contribution to emission or radiation levels can be selected as principal radionuclides. Requirements for analysis of leaks and spills have been reinforced, with additional groundwater monitoring and hydrological data analysis becoming necessary. Additionally, Carbon-14 has been added to the list of monitored gaseous radionuclides, with guidelines for emissions evaluation. As for regulations regarding uncertainty, requirements have been expanded from a simple statistical error analysis to an overall uncertainty analysis. The results of this study indicate that part of these regulations can be applied to effluent management in local reactors, thus operators would have to carry out deeper analyses and make preparations for the eventuality.

ACKNOWLEDGMENT

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