

Establishment of Sampling Scenarios for Nuclear Activity Verification

Suhui Park, Jiyoung Han, Yongmin Kim*

Department of Radiological Science, Daegu Catholic University
dduhuiing@naver.com

1. Introduction

The Nuclear Non-proliferation Treaty (NPT) has been executed, and global interest in denuclearization is increasing [1]. As a result, research on measurement/evaluation technology for detecting nuclear material and history tracking of illegally traded nuclear/radioactive material is being conducted in Republic of Korea. Nuclear activity inspections have been carried out by process sampling, analysis and weighing suggested by the IAEA [1]. However, if the nuclear facility is not declared or the nuclear material manufacturing activity at the declared facility is not disclosed, the process sample cannot be collected. Therefore, by grasping the nuclear activity history from the environmental monitoring data, it is possible to verify the denuclearization of the Democratic People's Republic of Korea(DPRK). Current radiation environment monitoring is carried out in terms of environmental radioactivity against the impacts of leaked nuclear material moving and spreading and polluting the environment [2]. When attempting to confirm the nuclear activity of a facility from this environmental monitoring data, establish nuclides, index samples, and analytical evaluation methods according to the characteristics of the facility to be inspected, instead of measuring environmental radioactivity [1]. And it is needed to review the technology that can track nuclear activity from these data [1].

In this study, we tried to scale and analyze environmental samples including nuclear substances leaked to the surrounding environment during nuclear activity and develop a sample collection procedure for nuclear activity tracking and monitoring in closed facility of surrounding countries.

2. Settings for scenario establishment

For scenario establishment, it is necessary to consider the facilities where nuclear activity is being carried out. Based on these facilities, a scenario should be established to collect environmental samples. It is also necessary to know the environmental samples according to the environment of the sampling point.

2.1 Nuclear facilities of DPRK

Since major nuclear facilities being considered for denuclearization of DPRK are located within the Yeongbyeon nuclear complex, it is necessary to consider sampling based on these facilities. We tried to

select a collection site in consideration of the distribution of nuclides in major facilities.

Table 1. DPRK non-nucleation related facility for recent two years (2019 to 2020) operation history [2]

| Classification | | 2019 Report (19.08,19.) | 2020 Report (20.09,03.) |
|----------------|--|---|---|
| Yeongbyeon | 5MWe reactor | No signs of operation since early December 2018 | reactor shutdown |
| | Radiochemistry Lab | No signs of reprocessing activity | No signs of reprocessing activity |
| | Uranium Enrichment Facility | signs of continuous operation | signs of continuous operation |
| | Chemical treatment suspect facility | No signs of construction/facility maintenance since early 19 | Spot signs of chemical treatment activity |
| | Experimental Light Water Reactor | No signs of operation | No signs of operation |
| | Reactor cooling facility (Kowloon River water intake, drainage facility) | September ~ November 2018 Additional construction activities near the Guryong River were caught | No signs of facility operation |

2.2 Sampling point selection

Nuclide facility of operating history is evidence of nuclide activity. So, based on this selects sampling point. Looking at the recent two years of operating history, signs of activities are captured at uranium concentrate facilities and chemical processing suspicion facilities. So, we tried to make a sample collection plan based on these facilities. The deposition of radioactivity along the site is also evidence of nuclear activity. Therefore, deposition must also be considered. This can be confirmed through the isotope ratio signature and analysis result for each sample collected in an informal situation.

Table 2. Collected Sample Isotope Consumption Signature and Analysis Results (Non-Official) [3]

| Sample | Material | Radioisotope signature | Analysis result |
|--------|----------|------------------------|-----------------|
|--------|----------|------------------------|-----------------|

| | | | |
|--|--------------------------------------|--|---|
| Soil, water (groundwater, seawater, river water), aquatic plants | UO ₃ , UO ₂ | U-235/U-238, Th-230/U-234, Th-228/-234 | Whether nuclear activity, scope of nuclear activity, change before and after nuclear material processing, and whether uranium ratio is maintained |
| Spent nuclear fuel | U, Pu compounds | U-233/-236, U-234/Pu-238, U-235/Pu-239, Am-241/Pu-241 | |

2.3 Sampling

Once the sampling site has been determined, a sampling plan should be developed. In this study, we tried to establish an environmental sampling plan considering the informal situation. In this study, the sample collection plan included attaching a sample number to prevent sample confusion and using a ion exchange resin filter for water samples [1]. KAERI's report states that in the case of water samples, the radioactivity dissolved in the water is adsorbed and collected using a filter filled with ion exchange resin [1]. Recording the exact location and environmental changes at each sampling point and drawing up and photographing the sampling point if necessary were also considered in this study [1].

3. Scenario establishment

In this study, it is necessary to select a point where there is evidence of nuclear activity used as a weapon in the facility as a point for confirming nuclear activity. Therefore, it was attempted to select an enrichment facility and a facility suspected of chemical treatment, which are facilities with clear signs of nuclear activity. Considering the informal situation at the time of sampling, the types of samples are divided into environmental samples and spent nuclear fuel. However, since the currently conducted research is nuclear verification through environmental samples, environmental samples such as soil, water, and aquatic plants, excluding spent nuclear fuel, were preferentially considered. Considering the priority among these environmental samples, there is a difference in the surrounding environment depending on the facility, so it is necessary to collect the environmental samples in consideration of this.

4. Result

In order to determine the site for sampling, it seems possible to check the nuclear activity of the facility if the site where a significant amount of radioactivity has accumulated in the surrounding environment is explored. Therefore, in the selection of the sampling point, it seems desirable to designate a facility where nuclear activity can be confirmed so far. In addition, since the sample is a scenario establishment in the case where a nuclear facility is not declared or nuclear material manufacturing activities at a reported facility are not disclosed, environmental samples are collected first to secure priority. Since this environmental sample changes according to the environment of the facility, it is necessary to collect it in consideration of this point.

5. Conclusion

In a situation where research on the confirmation of nuclear activity is being carried out, it is necessary to determine the presence or absence of the activity of unofficial nuclear facilities. In this study, a sample collection scenario near a nuclear facility was established to verify DPRK's denuclearization. The scenario was set considering the degree of radioactive deposition and the fact that it is an informal situation. And since the scenario changes according to the surrounding environment of the facility, we tried to establish the scenario taking this into consideration. In addition, since environmental samples change according to the surrounding environment of the facility, it is necessary to collect samples in consideration of environmental changes. However, if several factors are needed depending on factors such as sample changes due to changes in the surrounding environment, additional research will be conducted to adopt and develop a scenario that satisfies the confirmation of DPRK nuclear activity.

The scenario established in this study has the potential to be used as data for collecting environmental samples to verify the denuclearization of nuclear facilities. It is also expected to contribute to the establishment of procedures for DPRK's denuclearization verification and inspection of undeclared facilities.

REFERENCES

- [1] KAERI, "Radiation Environment Assessment for Nuclear Inspection", 1995.
- [2] International Atomic Energy Agency, "Application of Safeguards in the Democratic People's Republic of Korea", 2020.
- [3] Nuclear Safety and Security Commission, "2021 Nuclear Safety R&D Project Plan", 2021.