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ARTICLE

Monitoring and Measurement Plan at the Rokkasho Low-Level Radioactive Waste Disposal Center

Tomoya YOSHIDA*, Takashi KOZAWA and Hisao SATOH

Japan Nuclear Fuel Limited, 504-22 Nozuki, Obuchi, Rokkasho-mura, Kamikata-gun, Aomori-ken 039-3212, Japan

The systematic monitoring and measurement (M&M) activities are planned at the Rokkasho low-level radioactive waste (LLW) disposal center of Japan Nuclear Fuel Limited (JNFL) for verification and validation of the LLW repository before and after its decommissioning. These M&M activities are conducted from the operational phase through decommissioning, in accordance with the requirements in the Regulations on Permit Standards for waste disposal facility[1]. Currently, JNFL's sites continue to operate stably with no significant levels of radionuclides detected. The aim of M&M and the current status of the facility are introduced below, along with proposed future approaches to validate the repository system such as in-situ testing.

KEYWORDS: waste disposal facility, monitoring, measurement, radioactive materials, coversoil, groundwater

I. Introduction

JNFL has been received low-level wastes, and has been disposing of them in the disposal site at Rokkasho village, Aomori prefecture, with a license to operate three waste disposal areas, No. 1, 2 and 3. The location of the disposal area is shown in **Fig. 1**. Previously, IAEA documented[2] specific monitoring and measurement requirements for low-level radioactive waste disposal sites. In Japan, there is a legal regulation set by the Nuclear Regulation Authority (NRA) that requires the establishment of facilities to monitor and measure radionuclides leaking from the disposal system with engineered barriers, etc. Therefore, JNFL has constructed M&M in accordance with the law.[3] In the regulations, following three items need to be validated: (1) leakage from disposal area; (2) radioactivity concentration and dose near the site boundary; (3) groundwater levels and other conditions near disposal area and its surroundings, for the period from the waste receipt to the beginning of decommissioning step (about 300 years). Since expected functions of the engineered barrier are sorptivity and low permeability, a number of previous studied on distribution coefficients of constructive and barrier materials involving bed rocks [e.g., 4)] and on hydraulic conductivity of bentonite coversoil [e.g., 5)]. Based on these results, dose simulations verified that the repository system could be controlled to be within safety condition. However, there is unverified issue that the system may suffer from chemical alteration with time because of the facility constructed below the groundwater level.

Here, we introduce the future plan to conduct M&M that detect chemical (e.g., pH) and radiochemical (e.g., Bq/L) signals from the facility, along with innovative in-situ test, in addition to existing M&M methods, for validation of the repository system.

*Corresponding author, E-mail: tomoya.yoshida@jnfl.co.jp

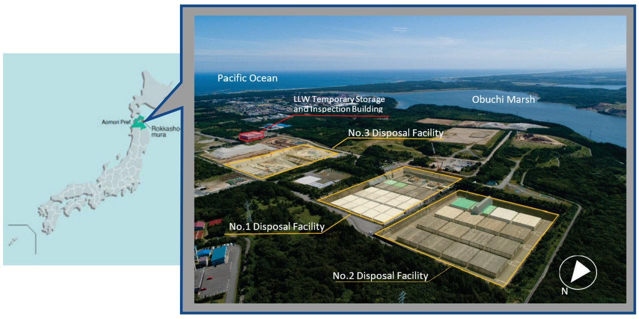


Fig. 1 Rokkasho low-level radioactive waste disposal areas

II. Business Timeline of the Operations at JNFL

Since establishment of JNFL in 1985 and business approval in 1990, we are proceeding the operations at the disposal site. Now our current status is in the phase of preparation for the coversoil construction at the No. 1 disposal area, and No. 3 disposal facility has begun operation in March 2025. Our disposal business proceeds in three step process, start from (1) design and getting approval, (2) operation and (3) management including monitoring (**Fig. 2**). Current phase is just before beginning of coversoil construction at the No. 1 disposal area. After completion of coversoil is performed, process proceeds from operation to management phase. The disposal business at JNFL continues 300 years until decommissioning in accordance with the law[6], though we hardly estimate what will be happening in the facility underground. Therefore, based on past events and technical knowledge, safety evaluation is conducted at design stage to simulation by analysis the future status of disposal area at the time. **Figure 3** shows a result of dose analysis for a living area above disposal area. Since this analysis will allow us to assess impact of radioactive materials to people living there after 300 years, the facilities need to be built and managed based on the results of the dose analysis. To ensure these assess when the business license was issued, monitoring and measurement are performed in operations and management phase as described in the following chapter.

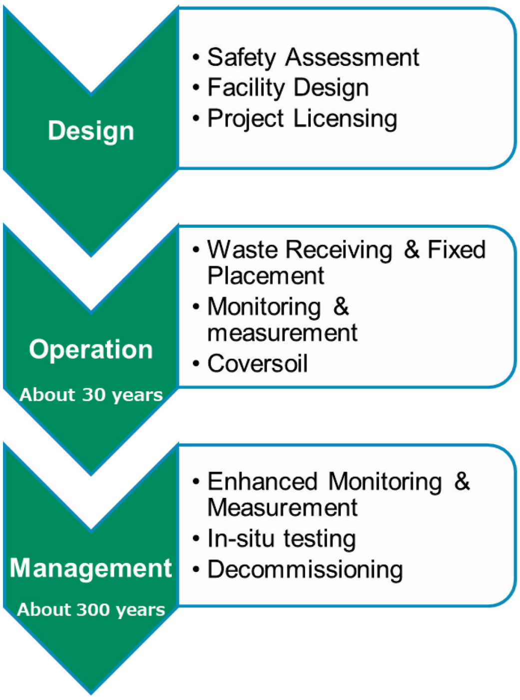


Fig. 2 Business timeline of the Rokkasho LLW repository

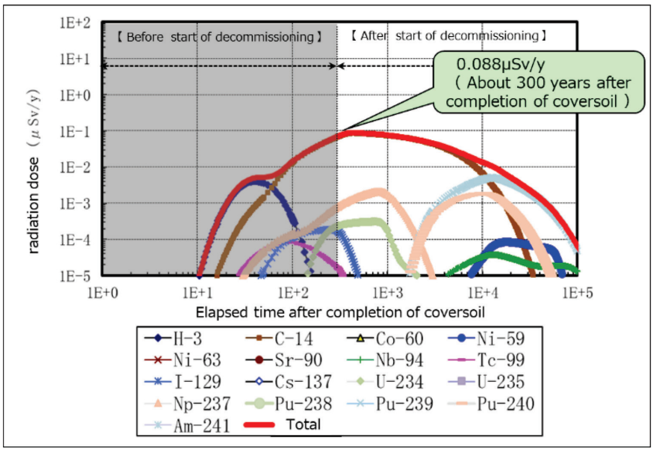


Fig. 3 Dose analysis for a living area above disposal area

III. Main Concept of Monitoring and Measurement

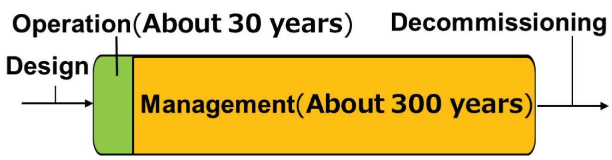
1. Outlines of the M&M and testing

Radioactive materials migrated from the waste disposal facility must be monitored throughout the entire period from the start of waste reception through decommissioning. Main concept of monitoring and measurement consists of two-phase requirements in order to

(1) confirm integrity before completion of coversoil,
(2) confirm integrity and long-term safety prediction after completion of coversoil.

Unexpected events in the facility can be detected by direct confirmation of disposal facility and these monitoring and measurement. However, after coversoil construction, disposal facility cannot be accessed directly but its status by these monitoring and measurement indirectly. When monitoring and measurement detect unexpected event, investigation into cause and review of safety assessment will be conducted. In monitoring and measurement, we check the items listed in **Fig. 4**. Before completion of coversoil, we check firstly concentration of radioactive materials which could have been leaked from disposal pit, secondly air dose inside and outside site, and finally groundwater level near boundary of perimeter monitoring area. In contrast, after completion of coversoil, we will check firstly concentration of radioactive materials leaked from waste disposal area, secondly groundwater level in and around waste disposal area and integrity of barrier function confirmed as chemical conditions of groundwater, and finally the transition of barrier functions such as enough sorptivity (Kd, ml/g) and low permeability (Kw, m/s) by in-situ testing.

In addition to conventional M&M methods, after completion of the coversoil, JNFL have a plan of in-situ tests with facility mockups which are placed at the similar depth to the disposal facility for 300 years, thought these tests will provide more robust evidence for predicting the future status of the facility in which the barrier function would be preserved.



Requirements for the M&M	
before completion of coversoil	
1	radioactive materials (e.g., Bq/L)
2	air dose rate (e.g., Sv/h)
3	groundwater levels (e.g., m)
after completion of coversoil	
1	radioactive materials and associated doses
2	groundwater levels and chemical condition
3	barrier function (Kw & Kd)

Fig. 4 Requirements for the M&M of the LLW repository

Ⅳ. Monitoring and Measurement Equipment

1. Overview

The location of monitoring boreholes is shown in **Fig. 5**. Currently, equipment for monitoring and measuring is installed near the site boundary with taking into account of general groundwater flow direction. We monitor and measure the concentration of leaked radionuclides at groundwater sampling wells, the groundwater levels at groundwater level measurement wells, and the air dose at monitoring points.

In addition, these boreholes are drilled to the depths ranging from several to several tens of meters based on the following considerations:

- The depth of the boreholes must be sufficient to collect groundwater from both the Quaternary soil and Miocene bedrock.
- The depth must cover the potential migration path of groundwater through the disposal facility.
- The depth must be enough ensure to collect a sufficient volume of water for analyzing the concentration of radioactive materials in the groundwater.

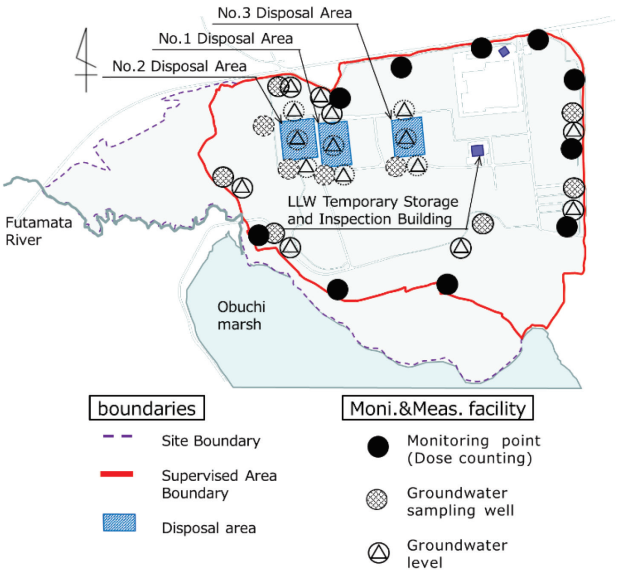


Fig. 5 Location map showing monitoring boreholes (for sampling and water-level measurement) and monitoring points (dose counting)

2. Drainage from Disposal pit

There is another possible method to detect the radionuclides from the waste. We can directly collect drain water that could be passing through the porous concrete behind the pit-wall in **Fig. 6**. This porous concrete is aimed to suppress water-encountering with waste packages. Drainage water can be collected into the connected plastic tank (Fig. 6). Every drainage samples are analyzed for radionuclides, although no significant detection has been recognized.

Fig. 6 Photographs of a pit-wall (left) and the inside of the tank housing (right)

3. Groundwater Sampling Wells

The map of groundwater sampling wells is shown in **Fig. 7**. These facilities collect groundwater near the site boundary and monitor and measure the radionuclides in the groundwater. There has been no detection of radionuclides. Along with pre-existing wells (blue meshed circles) near are areal boundary, we will additionally drill more holes (green ones) that are near facilities after completion of coversoil constructions.

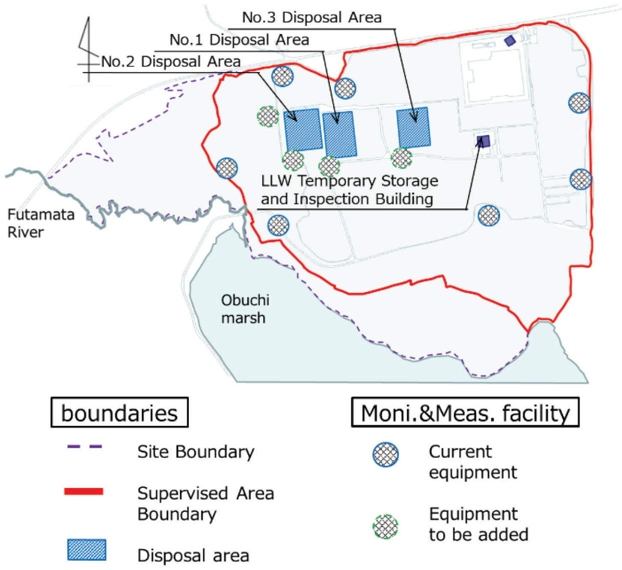


Fig. 7 Location map of groundwater sampling wells. (Green meshed is circle additional monitoring boreholes near disposal facilities.)

4. Groundwater-level Measurement Wells

The map of groundwater-level measurement wells is shown in **Fig. 8**. These are the facility monitoring and measuring, intended to determine the groundwater flow rates and direction at the site. The results of the groundwater flow analysis based on the previous groundwater level data display the dense contour lines of equal pressure in purple, which indicate three valleys around the disposal site. The groundwater at the disposal site flows along the three valleys to the Obuchi marsh, as indicated by the blue arrows. In addition to the groundwater sampling wells near the areal boundary, we will install more holes (green ones) after completion of coversoil.

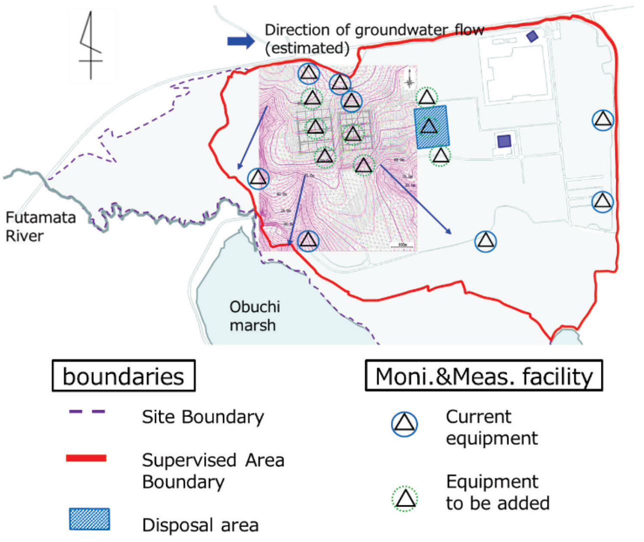


Fig. 8 Location map of groundwater-level measurement wells. (Superimposed with a calculated water-head surface near disposal facilities.)

5. Monitoring Points

The map of monitoring points is shown in **Fig. 9**. These are the monitoring points which are distributed to detect gamma ray emitted directly or as skyshine from the inspection building and disposal areas. Radiations are counted by gamma-ray spectrometry there.

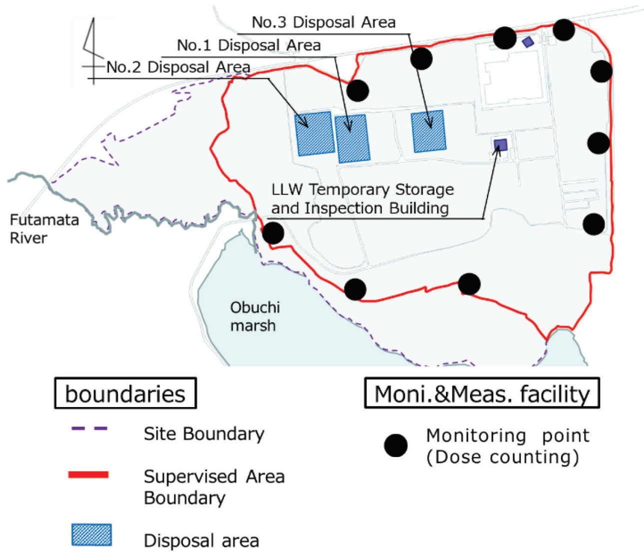


Fig. 9 Location map of monitoring points

V. Future Monitoring and Measurement Equipment

As above mentioned, we displayed the whole process from designing through operational to monitoring phases. The monitoring phase further involves in-situ test as another powerful monitoring option after completion of coversoil construction. We plan to advance the monitoring with the in-situ test as well as installation of M&M wells. **Figure 10** shows an example of the in-situ test facility in which mockup specimens simulating facility involving coversoil are emplaced at a depth equivalent to that of the actual disposal facilities. We periodically recover the mockup specimens and analyse the amounts of sorptive and clay materials to evaluate their degradation in Kd (ml/g) and Kw (m/s) values along with surrounding groundwater. This will allow us to monitor variations in barrier function under similar environments. Long-term chemical degradation can be observed in the periodic analysis, and useful information can be collected from this small "simulator" for application to actual facility. In-situ testing is frequently implemented as an experimental investigation to ascertain how the site-specific properties of the terrain and the performance of materials are suitable for repository.[7-9] However, at JNFL, it will be conducted concurrently with use of test pieces as small-scaled actual facilities and their analyses. Since there is no previous examples of monitoring and measuring barrier function of actual facility as an institutional control, this in-situ test is a challenging project to be innovated in methodology. Currently we are in the status of planning.

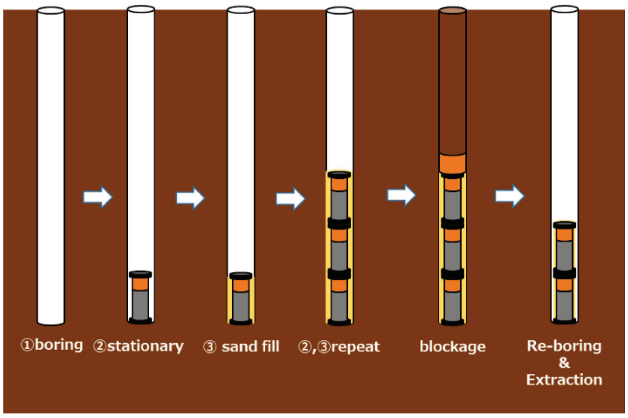


Fig. 10 An illustrated image of the in-situ test facility

Here is an example of a method study. Although the method has not been well-established yet, we are considering the reasonable way to situate the numerous specimens simulating disposal facilities on the borehole bottoms and recovering them at an interval period to evaluate their changes by solid analyses. It is expect that regular analysis of the solid phase by this method will allow for observation of changes in Kd and Kw over time under real-world conditions. Therefore, we believe that events transpiring in subterranean facilities can be simulated in a concurrent manner. Also, we parallelly simulate and compare this degradation within the actual and mockup facilities in different scales. Data obtained from conventional M&M and in-situ test provides more reliable evidence for predicting future condition of facility where barrier functions are likely to be maintained.

VI. Summary

Our mission is to maintain and manage the LLW repository safety for over 300 years in order to ensure that the people and environment are not affected by radionuclides. The our M&M methods are crucial not only for detecting and understanding the current status of disposal facilities, but also for assessing of future safety. Monitoring in boreholes, in-situ testing, and accumulation of assessment with simulations will be towards better understanding the future condition of each disposal areas and enhance safety verification in the future. Most recently, periodic safety review integrating new technical knowledge and safety evaluation is supposed to be carried out.

References

1) At waste disposal facility conformity to permit standard regulations, Article 12 monitoring and measurement facility (Disposal Facility 1, 2 and 3), Japan Nuclear Fuel Limited. 2021, [In Japanese].
2) Surveillance and Monitoring of Near Surface Disposal Facilities for Radioactive Waste, Safety Reports Series No. 35, International Atomic Energy Agency. 2004.
3) Regulations Concerning Standards for Location, Structure and Equipment of Class II Waste Disposal Facilities, Nuclear Regulation Authority. 2021 [In Japanese]
4) Management of sorption distribution coefficients of radionuclides in low-level radioactive waste disposal facility, JNFL-LLW-TR, Japan Nuclear Fuel Limited. 2024. [In Japanese]
5) H, Komine, "Theoretical Equations on Hydraulic Conductivities of Bentonite-Based Buffer and Backfill for Underground Disposal of Radioactive Wastes," *Journal of Geotechnical and Geoenvironmental Engineering*, American Society of Civil Engineers. 2008.
6) Interpretation of the Regulations Concerning Standards for Location, Structure and Equipment of Class II Waste Disposal Facilities, Nuclear Regulation Authority. 2021. [In Japanese]
7) L. Ove, et al., "In situ experiments on nuclide migration in fractured crystalline rocks," KBS Teknisk Rapport, Svensk Kärnbränslehantering AB. 1978.
8) IAEA, "In situ Experiments for Disposal of Radioactive Wastes in Deep Geological Formations," *IAEA Technical Document*, International Atomic Energy Agency. 1987.
9) IAEA, "Technologies for in situ immobilization and isolation of radioactive wastes at disposal and contaminated sites," *IAEA Technical Document*, International Atomic Energy Agency. 1997.