CURRENT STATUS AND RECLAMATION PLAN OF FORMER URANIUM MINING AND MILLING FACILITIES AT NINGYO-TOGE IN JAPAN

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ABSTRACT

The Japan Nuclear Cycle Development Institute (JNC) conducted research and development projects on uranium exploration in Japan from 1956 to 1987. Several mine facilities, such as waste rock yards and a mill tailing pond, were retained around Ningyo-toge after the projects ended. Although there is no legal issue in the mine in accordance with related law and agreements at present, JNC has a notion that it is important to reduce the burden of waste management on future generations. Thus, the Ningyo-toge Environmental Engineering Center of JNC proposed a reclamation plan for these facilities with fundamental policy, an example of safety analysis and timetables. The plan has mainly three phases: Phase I is the planning stage, and this paper corresponds to this: Phase II is the stage to perform various tests for safety analysis and site designing: Phase III is the stage to accomplish measures. Preliminary safety analyses suggested that our supposed cover designs for both waste rock and mill tailing are enough to keep dose limit of 1 mSv/y at site boundaries. The plan is primarily based on the Japanese Mine Safety Law, also refers to ICRP recommendations, IAEA reports, measures implemented overseas, etc. because this is the first case in Japan. For the accomplishment of this plan, it is important to establish a close relationship with local communities and governments, and to maintain a policy of open-to-public.

INTRODUCTION

The waste management policy for uranium waste, which is one category of low level radioactive waste (LLW) generated from nuclear fuel facilities, was prepared by the Atomic Energy Commission (AEC) of Japan in December 2000 (1). This policy excludes the discussion on mining and milling wastes, such as waste rock, mill tailing and so on, because mining and milling activities are controlled by another regulatory system, i.e., the Mine Safety Law (MSL). Thus, reclamation of uranium mining and milling facilities is under consideration in Japan to reduce the burden of the waste management on future generations although there is no legal issue on the environmental preservation. The primary purpose of this paper is to describe some features of these mining and milling wastes in Japan and the strategy of reclamation plan which is now under discussion for the facilities in Ningyo-toge.

CURRENT STATUS OF JAPANESE MINE SITES

The activities for uranium mining and milling in Japan were carried out from 1956 to 1987, mainly in the Ningyo-toge area and the Tono area, by the Atomic Fuel Corporation and its successor, the Power Reactor and Nuclear Fuel Development Corporation (PNC), as a part of the domestic uranium exploration and exploitation (test mining and uranium refining). As the result, it was confirmed that the total ore reserve is about 7,000 tU3O8 with average grade of 0.054 %U3O8 in two developed uranium mines in Japan, that is, the Ningyo-toge mine and the Tono mine (Fig. 1.). Although there are two divisions named the Ningyo-toge mine and the Togo mine in the Ningyo-toge area, for simplification, both of them are referred to as the Ningyo-toge mine in this
By the end of the activities, about 86tU of uranium was recovered from about 80,000 t of ore in total. Although the mining and milling activities were completely ended in Japan when the PNC was superseded by the JNC in October 2000, the Tono mine has been designated to be a site for the geo-scientific basis research relating to the geological disposal of high-level radioactive wastes. On the other hand, the Ningyo-toge mine has been expected as the Ningyo-toge Environmental Engineering Center of the JNC (JNC Ningyo-toge) to develop decommissioning engineering for the front-end facilities from mines to uranium enrichment plants because of its history of projects. Both mines still have retained mine wastes and facilities, which are listed in Table I and Table II. Whereas waste rock contains natural uranium and its progenies, mill tailing is depleted in uranium and relatively rich in $^{226}$Ra, because it is residue of ore extracted by sulfuric acid. In any case, mining and milling wastes require long-term waste management, because these nuclides are belonging to uranium series and have long half-lives.

Table I. Wastes generated from uranium mining activities in Tono

<table>
<thead>
<tr>
<th>Waste</th>
<th>Volume / Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste Rock</td>
<td>ca 18,000 m$^3$</td>
</tr>
<tr>
<td>Residue from Effluent Treatment</td>
<td>ca 22,500 kg</td>
</tr>
</tbody>
</table>

Table II. Wastes generated from uranium mining and milling activities in Ningyo-Toge

<table>
<thead>
<tr>
<th>Waste</th>
<th>Volume</th>
<th>Average U Concentration (Bq/g)</th>
<th>Average $^{226}$Ra Concentration (Bq/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste Rock (22 sites)</td>
<td>ca 220,000 m$^3$</td>
<td>&lt; 0.09 - 0.42</td>
<td>-</td>
</tr>
<tr>
<td>Mill tailing</td>
<td>ca 34,000 m$^3$</td>
<td>ca 3</td>
<td>ca 16</td>
</tr>
<tr>
<td>Heap Leaching Facility$^a$ Tank, Valve, Ion Exchange Resin, Concrete, etc</td>
<td>ca 10,000 drums (estimated)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

$^a$ Demolition of heap leaching facility is now under consideration, therefore waste volume described here is based on estimation.

The current environmental management is carried out in accordance with the MSL principally, and with the agreements with local governments supplementary. As the MSL was amended in 1989 according to ICRP Publication 26, the evaluations of environmental impact of mine sites have been required from the point of view of radiation protection. This concept has been also succeeded
to in the latest amendment according to ICRP Publication 60. Requirements of current Japanese
laws and agreements are:

- Environmental protection.
- Entry control for public; for example, by "keep-off" sign and fence at the site boundary.
- Effluent Treatment.
- Environmental monitoring; environmental radiation dose, and radioactivity concentrations
  of $^{238}\text{U}$, $^{226}\text{Ra}$ and $^{222}\text{Rn}$ in air and water samples.
- Control with effective dose limit of 1mSv/y outside of the site.

According to our environmental monitoring, it has been confirmed that the effective doses caused
are less than the public dose limit of 1mSv/y outside of any sites. For example, although
comparatively high radon concentrations in atmosphere have been observed in the sites, the
environmental impacts of radon released from sites have been negligible considering the natural
background level of radon (2). Such small impacts have been also proven annually from several of
crosschecking of our environmental monitoring performed regularly by the authorities, of local
government, etc.

STRATEGY OF RECLAMATION PLAN OF NINGYO-TOGE URANIUM MINING AND
MILLING FACILITIES

As is mentioned above, there is no legal issue in both mines in accordance with related law and
agreements at present. However, a reclamation plan for the uranium mine facilities of the JNC
Ningyo-toge was drawn up to reduce the burden of the waste management on future generations,
because the last mine owner has liabilities for maintaining uranium mine sites safely according to
the MSL.

RECLAMATION POLICY

The reclamation policy should be based on the MSL primarily, but also refer to the following
related recommendations, reports, etc., because the MSL does not define a final condition of the
reclamation about uranium mine waste:

- ICRP recommendations (e.g. 3, 4, 5, 6, 7, 8, etc.).
- IAEA reports (8).
- Uranium waste management policy prepared by AEC (1).
- Measures implemented for uranium mines in foreign countries (US, France, Australia,
  Canada, Germany, etc).
- Measures implemented for domestic metal mines.

The objectives of the site measures included are as follows:

- Solids containment.
- Control of radiation exposure.
- Control of radon gas.
- Control of liquids.
- Stability and integrity of site structures.
From these points of view and facts that the mill tailing in Ningyo-toge contains relatively high concentration of $^{226}\text{Ra}$, as well as the major manner in foreign countries, measures for mill tailing pond of the JNC Ningyo-toge have to include the following (Fig. 2.);

- Encapsulation cover with soil and vegetation
- Additional radiation exposure less than 1 mSv/yr at any place
- Dewatering of mill tailing
- Encapsulation with multi-component cover and vegetation
- Radon barrier system

These measures might also be applied for waste rock yards, but it would be simpler than that.

**EXAMPLE OF SAFETY ANALYSIS**

Even though, in Japan, the risk assessment on future generations is not required according to MSL, safety analyses were preliminarily carried out for representative 2 waste rock sites and the mill tailing pond to assess feasibility of the measures. Fig. 3 shows an example of selected 7 scenarios for the analysis referring a report published by Nuclear Safety Commission of Japan which discusses the clearance level for decommissioning of reactors and examines safety of shallow ground disposal of such wastes (9). Members in the critical group for the analysis were assumed to be engaging in construction work or living at each site boundaries, and having a general lifestyle in Japan. The applied codes include ORIGEN-2 for estimation of radioactivity concentrations in sources, QAD-CGGP for that of radiation exposure, NESTOR developed by the JNC Tokai works for that of radionuclide migration in aquifer, etc. The input data required for calculations should be site specific in general, however, they are insufficient in both quality and quantity at present. Therefore, the calculation was done with both site specific and generic data. Moreover, the estimation of exposure caused by radon was excluded because cover for waste rock and mill tailing
sites is assumed to be about 2 and 3 m thick for waste rock and mill tailing sites respectively, which would be sufficient to neglect radon exhalation.

The calculated results with above supposition suggested that our cover designs are enough to keep dose limit of 1 mSv/y at site boundaries. For example, the result for the waste rock yard with the soil cover of 2.0 m thick indicated that total of effective doses estimated in all scenarios was far less than 1 mSv/y; the highest effective dose estimated was given about $3 \times 10^{-3}$ mSv/y to construction workers on aquifer, or to resident people taking in groundwater as drinking water.

**Fig.3. Scenarios selected for preliminary safety analysis**

**Fig.4. Annual dose rate of each exposure pathways**
The result for mill tailing pond with soil cover of 3.0 m thick indicated that total of effective doses estimated in all scenarios was also far less than 1 mSv/y; the highest effective dose estimated was given about $4 \times 10^3$ mSv/y to construction workers on site boundary (Fig. 4.). Additionally, uranium concentrations in drinking water were estimated below the WHO’s provisional guideline value 2 micrograms per litter (10).

TIMETABLE

The comprehensive schedule of the reclamation plan of uranium mine facilities of the JNC Ningyo-toge consists mainly of three phases. Phase I is the planning stage to establish the conceptual and the detailed plans (11), and the present paper corresponds to this. Phase II is the stage to perform various field measurements, laboratory-scale tests and demonstration-scale tests in order to collect data for safety analysis and site designing including analysis to evaluate site stability. Phase III is the stage to accomplish measures including decision of site designing in detail and the implementation of monitoring and surveillance, in order to verify that sites would be maintained by the institutional control. Some aspects of Phase II are summarized in the next section.

DATA ACQUISITIONS

The most important purpose of Phase II is to asses and demonstrate the performance of site measures from the results of laboratory-scale tests and demonstration-scale tests carried out in order to collect data for site designing and safety analysis. Each scale of tests has three components as shown in Table III with some examples of data acquisition. The demonstration-scale tests are planning to be performed in vats of former heap leaching facility and its period would last for 3 to 5 years.

<table>
<thead>
<tr>
<th>TEST 1. Characterization on Radiation Shielding and Rn Exhalation</th>
<th>Laboratory-Scale Test</th>
<th>Demonstration-Scale Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurements of Exhalation Parameters of Cover Materials</td>
<td>Evaluation of Radiation Shielding by Cover Layer</td>
<td></td>
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<tr>
<td></td>
<td>Evaluation of Rn Exhalation Control by Cover Layer</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TEST 2. Characterization on Hydrology</th>
<th>Laboratory-Scale Test</th>
<th>Demonstration-Scale Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurements of Hydrologic Parameters of Cover Materials and Flow Analysis</td>
<td>Evaluation of Infiltration Control by Multi-Layered Cover</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TEST 3. Characterization on Migration of Radionuclides</th>
<th>Laboratory-Scale Test</th>
<th>Demonstration-Scale Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurements of Radionuclide Transport Parameters of Liner, Adsorbent, etc. and Solute-Transport Analysis</td>
<td>Evaluation of Effect of Liner, Adsorbent, etc.</td>
<td></td>
</tr>
</tbody>
</table>

Field researches on some features are also required for the purpose of long-term stability of the sites and structure integrity, including;
Some of equipment, such as encapsulation covers, liners, etc., will be designed and installed based on the results of Phase II. It is being required finally in Phase II to assess safety, stability and integrity of site structures as a whole taking data from field measurements into consideration.

CONCLUSION

Reclamation of uranium mining and milling facilities is necessary to reduce the burden of the waste management on future generations although there is no legal issue on the environmental preservation. Based on experimental safety analyses, a conceptual reclamation plan was therefore proposed for the mine facilities of the JNC Ningyo-toge, and this would be the first case in Japan. A detailed plan is being made with not only the requirements of MSL but also worldwide standards, domestic discussion of radioactive waste management, acceptance of local residents, etc., taken into consideration. Experiences based on this reclamation will provide useful information on the safety analysis of other radioactive wastes. For the accomplishment of this plan, it is important to establish a close relationship with local communities and governments, and to maintain a policy of open-to-public.

REFERENCES