Update on the Consideration of the Possibility of Deep Borehole Disposal in Japan

The NAPSNet Policy Forum provides expert analysis of contemporary peace and security issues in Northeast Asia. As always, we invite your responses to this report and hope you will take the opportunity to participate in discussion of the analysis.

Recommended Citation

Tomochika Tokunaga, "Update on the Consideration of the Possibility of Deep Borehole Disposal in Japan", Policy Forum, July 11, 2014, https://nautilus.org/napsnet/napsnet-policy-forum/update-on-the-consideration-of-the-possibility-of-deep-borehole-disposal-in-japan/

by Tomochika Tokunaga

11 July 2014

Originally published 29 March 2014, Department of Environment Systems University of Tokyo.

I. Update on the Current Status of Japan's High-level Waste Disposal Program

This report provides an update on the consideration of the possibility of deep borehole disposal in Japan, revising the report submitted to Nautilus Institute by the author last year (Tokunaga, 2013). As in the previous report, an update on the current status related to high-level waste disposal program in Japan is presented first below, followed by an update on information related to deep borehole disposal in Japan. In the final section of this report, several issues related to the possible application of deep borehole disposal are discussed.

As already presented in Tokunaga (2013), the Japanese implementing organization for high-level waste and the transuranic waste disposal, that is, the Nuclear Waste Management Organization of Japan (NUMO), was established in October 2000, and an open solicitation for accepting literature surveys for evaluating the suitability for radioactive waste disposal was initiated in December 2002. The documents distributed by NUMO for the open solicitation stated that all municipalities have a right to apply to the open solicitation, for which no application deadline was set at the time. The solicitation is still open and a final deadline has not yet been set even to this day. Please see Tokunaga (2013) for the events with respect to the open solicitation in between year 2002 to early 2007. The major activities related to the siting process that occurred from 2007 to the present (2014) in Japan are summarized below.

In the year 2007, since the official response to the initial solicitation by municipalities was extremely limited, a new option for initiating discussions was added, which focused on asking communities to accept a literature survey as a first step in the siting process. The open solicitation offer remained in place as well. The proposal acceptance scheme was explained as follows: "The opinions of the people in the regions will be fully respected and the government can take the step of proposing to municipalities that a literature survey be carried out". This essentially means that rather than waiting for municipalities to volunteer, the government could ask municipalities to be the focus of a literature survey to explore the suitability of the area for hosting disposal facilities if the municipalities are willing to accept the activities. See Figure 1 for the current process for repository site selection in Japan.

In addition, in year 2007, NUMO was identified as the implementing organization for the disposal of transuranic wastes, with the Japan Atomic Energy Agency (JAEA) declared to be the organization responsible for the disposal of radioactive wastes produced through research activities.

In year 2010, the Japan Atomic Energy Commission (JAEC) sent a request to the Science Council of Japan (SCJ) to consider recommendations for activities to disclose literature and information on the disposal of high-level radioactive wastes to the public. While this topic was under discussion in the SCJ, the Tohoku Earthquake and tsunami hit the Pacific coast of the northeast Japan, on March 11, 2011, and the disaster of the Fukushima Daiichi nuclear plant occurred following the inundation of the power plant site by the huge tsunami.

On September 11, 2012, SCJ sent a document entitled "Issues concerning high-level radioactive waste disposal (Reply)" back to JAEC (SCJ, 2012). The main messages conveyed in this document were summarized by JAEC (2012) as follows:

"The Reply from SCJ pointed out that seeking a consensus on an individual issue of selecting the final HLW disposal site before reaching a consensus on broader policies concerning nuclear power generation was procedurally inverted and thus inappropriate. Moreover, it suggested the requirements for a fundamental review of policies concerning HLW disposal, restructuring of the policy framework focusing on identifying the limits of scientific and technical viability, ensuring scientific autonomy, temporal storage and total volume control, and streamlining of procedures for determining reasonable policies in terms of fair burden sharing, and making multistage agreements by providing a venue for discussion. It recommended continuing tenacious negotiations from a long-term perspective to solve the problem."

Responding to the document from SCJ, JAEC reconsidered and issued the necessary approaches for the high-level nuclear waste disposal program (JAEC, 2012). JAEC (2012) summarized their resulting findings and direction as follows:

1: Clarify the amount and nature of the high-level radioactive waste for disposal in association with nuclear energy and fuel cycle policies, 2: Apply the latest earth science knowledge to a viability study of geological disposal, and share the result with the public, 3: Improve the operation according to the discussions on the need and significance of interim storage, 4: Provide a system of sharing disposal techniques and the site selection process with the public, and 5: The government leads policy reconstructing.

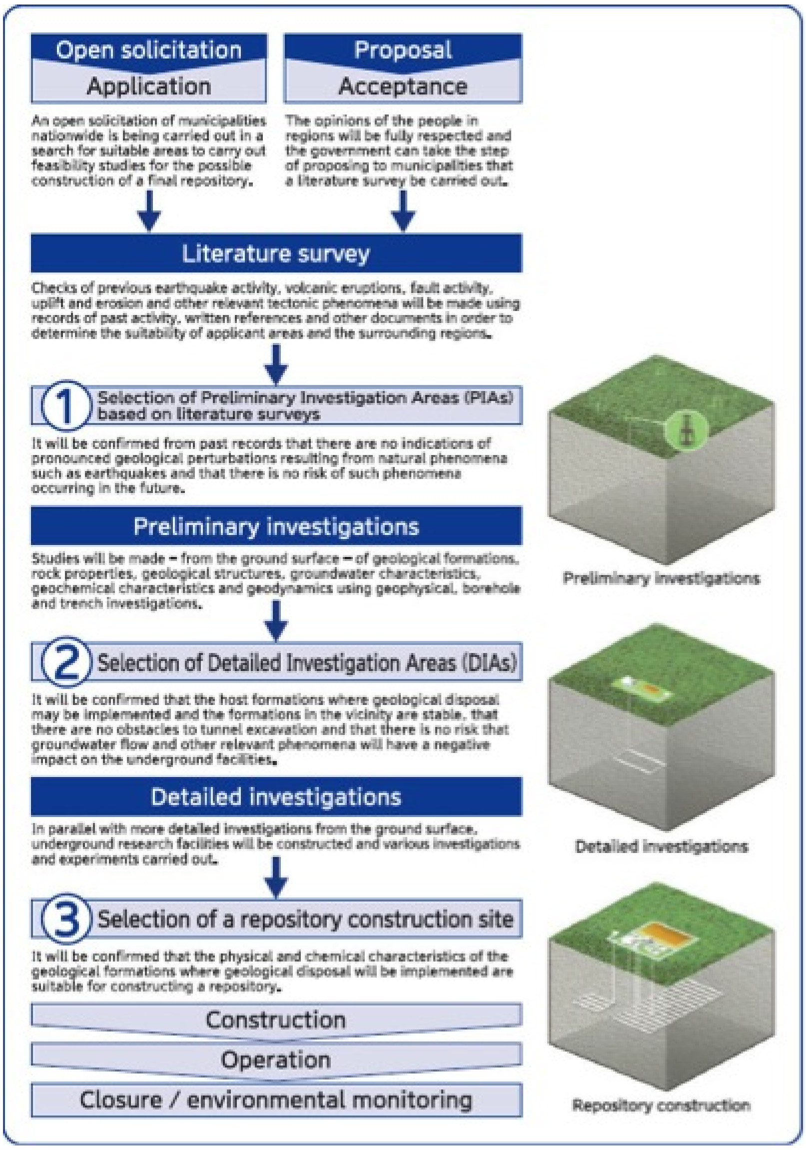


Figure 1. Process Proposed for Repository Site Selection in Japan (after NUMO homepage, http://www.numo.or.jp/en/jigyou/new_eng_tab03.html).

The Agency for Natural Resources and Energy, in the Ministry of Economy, Trade and Industry (METI), has been convening meetings of two subcommittees (working groups) related to the nuclear waste disposal since 2013. One committee (working group) has focused on summarizing the current status and issues related to the final disposal of high-level radioactive waste, discussing how the current generation should tackle issues related to final disposal, proposing possible improvements for the site selection process, and proposing improvements in the implementation structures for handling the high-level radioactive waste disposal program. The other subcommittee (working group) has re-evaluated the geological disposal of high-level radioactive waste from the viewpoint of the up-to-date scientific knowledge, and has focused mainly on the long-term stability of the geological environment. Both subcommittees (working groups) are now in the process of soliciting public comments on their draft mid-term reports, and the mid-term reports will be finalized after receiving public comments and discussing the possible revision of the present versions of the reports. Details of the discussion undertaken by both subcommittees (working groups) can be found on the METI website at http://www.meti.go.jp/committee/gizi_8/21.html.

II. Update on Information Related to Deep Borehole Disposal Gathered in Japan

Since the submission of the previous report (Tokunaga, 2013), further literature surveys were conducted to try to find additional information related to the deep borehole disposal concept in Japan. In the following, a summary of a report by NUMO (2004) and an update on deep borehole drilling experience in Japan are presented.

NUMO (2004) summarized possible variants to nuclear spent fuel and high level waste repository concepts, and in the appendix of the report, the concept of “vertical deep boreholes” was presented (Figure 2). The appendix noted, however, that the option involved some fundamental changes in the basic safety philosophy that has so far guided the development of nuclear materials disposal facilities in Japan, and that the deep borehole concept was included for the sake of completeness. As far as the author knows, this is the only document authored by Japanese authorities that includes a discussion of the deep borehole disposal concept in Japan.

As for deep drilling experience in Japan, as reported in Tokunaga (2013), the Ministry of Economy, Trade and Industry has conducted exploratory drilling for petroleum resources. Among these, the METI Shin-Takenomachi well, drilled in year 1993, and the METI Mishima well, drilled in year 1992, are the two deepest wells. The total depths of these wells are 6,310 m and 6,300 m, respectively, and the bottom hole temperatures of the wells were 197 degree Celsius and 226 degree Celsius, respectively. The hole diameter of the METI Shin-Takenomachi well at the deepest interval was 8-1/2” (ca. 21.5 cm) and the casing used for that interval was 7” (ca. 17.8 cm) outer diameter.

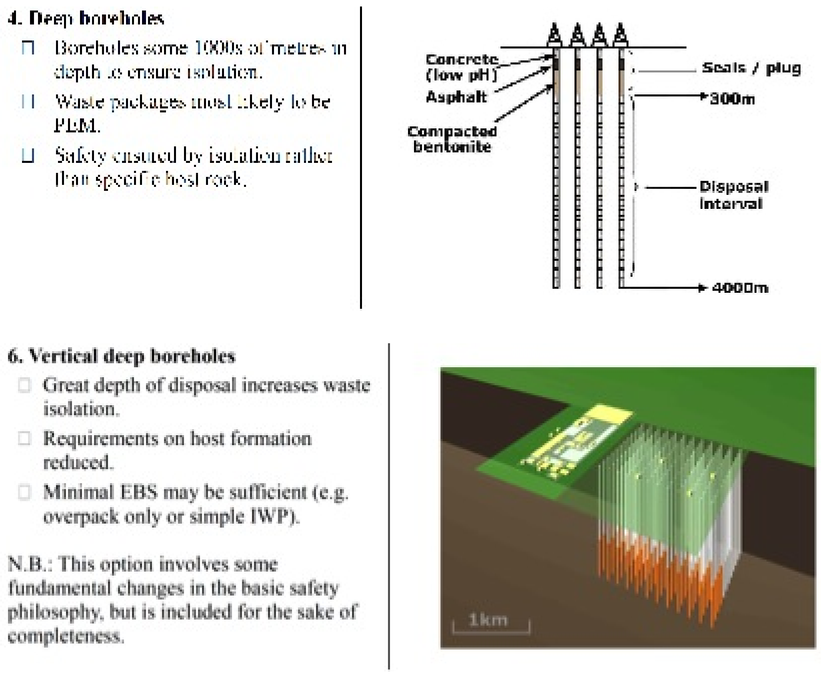


Figure 2. Vertical Deep Borehole Concept as Shown in the NUMO Rreport (NUMO, 2004)

Table 1 shows an example of the casing plan used for the METI Higashi-kubiki exploratory well (Morita et al., 1997). Note that the diameter of vitrified wastes produced to contain high-level wastes from reprocessing of nuclear spent fuel in Japan is 43 cm. Thus, in the case where deep borehole disposal of vitrified wastes is considered, technology development will be necessary to drill larger diameter, deeper holes in order to accommodate the size of the vitrified wastes. In this case, the consideration of the casing program becomes an issue, meaning that some compromise will be required among diameter of the hole, the strength of the casing, and the weight of the casing. For example, to make the diameter of the borehole larger, the required strength of the casing becomes higher, and it is then necessary to introduce thicker casings. Current limitations exist, however, on the ability of drilling systems to hold and handle the heavier casings. In the case where thinner casings are introduced, there may be higher risk that the borehole could collapse and/or the casing could be damaged, resulting in an increase in the possibility that canisters of wastes could become stuck part way down the borehole during waste disposal operations.

Table 1. Example of Casing Plan Applied to the METI Higashi-kubiki Exploratory Well (after Morita et al., 1997). The well was constructed in year 1989 to 1990 and the total depth of the well was 6,001 m.

Depth interval	Outer diameter of the casing
0 to 401 m	30” (ca. 76.2 cm)
401 to 1,491 m	20” (ca. 50.8 cm)
1,491 to 3,583 m	13-3/8” (ca. 34.0 cm)
3,583 to 5,000 m	9-5/8” (ca. 24.4 cm)
5,000 to 6,001 m	8-1/2” (ca. 21.6 cm)*

*: This interval was not cased.

III. Discussion on the Possibility of Deep Borehole Disposal in Japan

3.1 Number and size of vitrified wastes in Japan

In order to inform the further discussion on the possibilities for deep borehole disposal in Japan, the current plan for and size of vitrified wastes from reprocessing, as they have been and will be produced in Japan are summarized below.

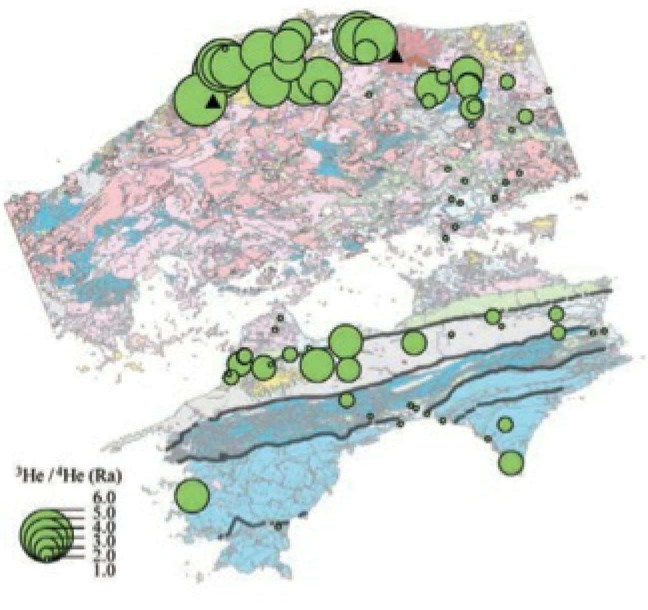
According to the current plan for high-level radioactive waste disposal as prepared by NUMO, the number of vitrified waste canisters to be disposed of will be on the order of 40,000 or more. This number may change in response to changes in Japan’s nuclear power policy (see Takase, 2013). The outer diameter of the vitrified wastes currently produced is 43 cm, as described in the previous section of this report.

The difficulties in applying the deep borehole disposal concept to the current Japanese high-level radioactive waste disposal plan are as follows. First, the number of ultra-deep borehole needed may become large. For example, in the case in which 400 waste canisters are disposed per borehole, more than 100 ultra-deep boreholes would be needed to dispose of the vitrified wastes Japan will produce. Also, the outer diameter of the current vitrified waste is much larger than our current ability to make larger ultra-deep borehole, and it is currently technically challenging to drill ultra-deep borehole with larger diameter. According to an interview with a drilling expert in the oil industry, it will be possible to set a casing with an outer diameter of 18-5/8” (ca. 47.3 cm) at a depth of 3,000 m if geological conditions are quite stable and appropriate for drilling. The inner diameter of the casing mentioned above can be ca. 45.1 cm if one uses low strength, thin casing. With this approach, it is theoretically possible to store the vitrified wastes with an outer diameter of 43 cm at a depth of 3,000 m. The number of waste canisters that can be stored in a single borehole, however, becomes significantly smaller in this scenario, because of the shallower total depth of the borehole. Of course, we can think of changing the diameter of the high-level radioactive wastes, i.e., the vitrified wastes, to fit into the diameter of the ultra-deep borehole. In this case, the number of vitrified waste containers would be larger, and the necessary number of ultra-deep boreholes also becomes larger. The coming decades may bring technological advances in ultra-deep drilling that may make accommodating vitrified wastes in the current 43 cm diameter easier, but these technologies remain to be developed and commercialized.

The other topic that must be taken into consideration is retrievability. As already discussed during the Security of Spent Nuclear Fuel Working Group meeting convened by Nautilus Institute in Seoul in April of 2012,[1] it will be very difficult to retrieve wastes from ultra-deep borehole if multiple wastes are lowered into a borehole. Based on recent discussions in Japan, for example, discussions in the subcommittee (working group) mentioned above, maintaining an option of reversibility and retaining the possibility to retrieve high-level radioactive waste is considered to be quite important, and these concepts need to be taken into account very seriously until the disposal site is finally closed. Thus, it is not so straightforward to introduce the deep borehole disposal option into the current Japanese plan for the disposal of high-level radioactive wastes.

3.2. Update on deep-seated fluid issues

The Research Core for Deep Geological Environments (2012) recently published its report on the spatial distribution of helium dissolved in groundwater and hot spring water (Figure 3). The $^3He/^4He$ ratio is considered to be useful to estimate the contribution of deep-seated fluid to the near-surface groundwater. As shown in Figure 3, the spatial distribution of $^3He/^4He$ is quite variable, and it is apparent that the groundwater and hot spring waters on the Pacific side of northern Japan generally show very low $^3He/^4He$ ratios, indicating that the upwelling of deep-seated fluid is not occurring there even under the quite active tectonic conditions in the area. Further study is expected to lead to a better understanding of the geological processes associated with the upwelling of deep-seated fluids, and to a better explanation of the spatial distribution of the occurrence of such upwelling.



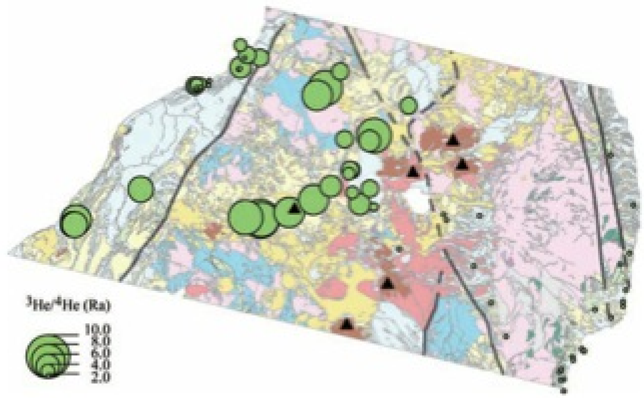


Figure 3. Spatial Distribution of $^{3}He/^{4}He$ in Southwest Japan (upper) and Northeast Japan (lower). Research Core for Deep Geological Environments (2012)

3.3. Discussion on the possible application of deep borehole disposal concept in Japan

A key advantage of the deep borehole disposal concept compared with mined repositories is that the former is much less affected by the type of the wastes to be emplaced because the deep borehole disposal concept principally isolates the wastes in deep subsurface settings where diffusion of heat and substances in the wastes is controlled by the long distance from the disposed wastes to the surface and by the limited interaction of deep groundwater with the biosphere. As such, the deep borehole concept can be applied to radioactive wastes with complex chemistry and/or those that are small in volume but highly radioactive, in addition, potentially, to high-level wastes from reprocessing, spent nuclear fuel (appropriately packaged), and potentially plutonium (in a diluted and vitrified form). Examples include the following wastes:

1. Debris from inside the partially-melted cores of three of the Fukushima-Daiichi nuclear power reactors;
2. Fuel and spent fuel from the pool at the Fukushima-Daiichi nuclear power plant;
3. Radioactive wastes from the research institutions; and
4. ^{129}I and ^{14}C in transuranic wastes.

To further explore prospects for deep borehole disposal of these special radioactive wastes, the amounts and volumes of these wastes were obtained from published information (Fukushima Prefecture website and NUMO, 2011). The number of fuel assemblies in the unit 1 to 3 of the Fukushima-Daiichi nuclear power plant reactor cores at the time of the tsunami accident was 1,496, that of the spent fuel assemblies in the unit 1 to 4 pools of the Fukushima-Daiichi nuclear power plant was 2,284, and that of the new fuel assemblies in the unit 1 to 4 pools of the Fukushima-Daiichi nuclear power plant was 360. As for the transuranic wastes, the volume of the ^{129}I-containing waste currently in storage in Japan is 319 m^3, and this volume can be significantly reduced by applying appropriate processing and packaging methods. The volume of ^{14}C-containing wastes is 5,792 m^3, and thus it may be a bit difficult to think these materials as “small volume” wastes because of their larger volume.

A few thoughts on the application of deep borehole disposal for “small volume” wastes present in Japan are as follows. First, for deep borehole disposal it may not be necessary to separate wastes based on their chemical characteristics. Avoiding this separation step could significantly reduce the required pre-disposal efforts need for the separation of wastes with complicated chemistries. Also, the “small volume” wastes can be accommodated in smaller-diameter boreholes, and hence current drilling methods can be directly applied. Side-tracking and multi-lateral drilling capabilities brought into commercial operation over the past decade for use in the oil industry make it possible to characterize deep geological formations surrounding a disposal site, and make it possible to monitor the temporal changes in the geosphere environment by using the side-tracked boreholes as monitoring sites. Further investigations towards the development of strategies for applying the deep borehole disposal concept to these “small volume” wastes in Japan will be necessary, and may well be of interest, as a possible alternative option for disposal and isolation of these wastes.

IV. SUMMARY

This paper presents updates on the current status of the high-level nuclear waste disposal program in Japan, and on information related to possible deep borehole disposal of nuclear materials in Japan, as well as providing a discussion of possible applications of the deep borehole disposal concept to “small volume” radioactive wastes.

No matter which materials are to be disposed of, it will be necessary to develop scenarios for safety analysis specific to the deep borehole disposal concept because the engineered barriers that would be used in deep borehole disposal (waste packaging, borehole linings, and the materials used to isolate waste packages from each other, for example) may not be effective in very deep environments, and concepts related to long-term safety can be considerably different from those relevant to the operation of mined repositories. To further explore safety issues related to deep borehole disposal, we need to improve our understanding of the ultra-deep geological environment. The side-tracking/multi-lateral drilling and monitoring techniques developed in oil industry can be important tools for deep borehole research because those technologies can help us to better understand the deep geological situation, and can provide us with opportunities for monitoring the rock surrounding deep boreholes. If the deep borehole disposal concept is to be applied in Japan, issues related to the upwelling of the deep-seated fluid should be further studied. Finally, cost estimation and other factors related to deep borehole construction and operation should be studied in much more detail if the deep borehole disposal concept is to become a possible alternative option for Japan’s nuclear waste disposal program.

V. references

Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry homepage, http://www.meti.go.jp/committee/gizi_8/21.html.

Fukushima Prefecture website, http://www.pref.fukushima.lg.jp/sec/16025c/genan10.html.

Japan Atomic Energy Commission (JAEC), 2012, *Renewing Approaches to Geological Disposal of High-Level Radioactive Waste (HLW) (Statement)*. http://www.aec.go.jp/jicst/NC/about/kettei/121218_e.pdf, 9p.

Morita, N., Siato, S., Sakuma, S., Takahashi, W., Yoshida, C., Sano, M., Jinzaki, Y., Nakayama, S. and Kakuma, H., 1997, “JUDGE Project: A continental scientific drilling into subduction zone (7) Technical development”. *Bull. Geol. Surv. Japan*, 48, 186-243. (in Japanese)

Nuclear Waste Management Organization of Japan (NUMO), 2004, *Development of Repository Concepts for Volunteer Siting Environments*. NUMO-TR-04-03, 54p.

Nuclear Waste Management Organization of Japan (NUMO), 2011, *Technology and Safety for Geological Disposal of Transuranic Wastes*. NUMO-TR-10-03 (in Japanese, title translated by TT)

Nuclear Waste Management Organization of Japan (NUMO) homepage, http://www.numo.or.jp/en/jigyou/new_eng_tab03.html.

Research Core for Deep Geological Environments, 2012, *Technical Report on the Review and Assessment Features, towards the Submission of the Preliminary Field Investigations of HLW Geological Disposals*. Geological Survey of Japan Open File Report, no. 560, Geological Survey of Japan, AIST. Available as http://www.gsj.jp/data/openfile/no0560/gsj_openfile_560.pdf.

Science Council of Japan (SCJ), 2012, *Issues concerning high-level radioactive waste disposal (Reply)*. http://www.scj.go.jp/ja/info/kohyo/pdf/kohyo-22-k159-1.pdf, 36p.

Takase, K., 2013, *The Japanese Energy Sector and Nuclear Spent Fuel Scenarios*. Nautilus Institute Special Report, dated December, 2013, and available on www.nautilus.org.

Tokunaga, T., 2013, *Consideration on the Possibility of Deep Borehole Disposal in Japan*. A report submitted to the Nautilus Institute for Security and Sustainability, 16p. Dated February 19. 2013, and available as https://nautilus.org/wp-content/uploads/2013/03/Tokunaga_DBD_paper_19-2-2013_final.pdf.

VI. NAUTILUS INVITES YOUR RESPONSES

The Nautilus Peace and Security Network invites your responses to this report. Please leave a comment below or send your response to: nautilus@nautilus.org. Comments will only be posted if they include the author's name and affiliation.
