Rethinking Site Selection Approaches for Geological Disposal of High-Level Radioactive Waste from a Social Psychological Viewpoint

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ABSTRACT

With growing concern about global warming and the increasing demand for energy, the use of nuclear power is expected to increase in both developed and developing countries. However, the safe disposal of radioactive waste, especially high-level radioactive waste (HLW), generated by nuclear power plants, remains an urgent and challenging issue that may affect sustainable development and utilization of nuclear energy in the future. Many countries, including the USA, Germany, France, Canada, Switzerland, Belgium, Japan, Sweden, and Finland, have had radioactive waste management programs for many years, but the plans and schedules in many countries have changed or even been suspended. Only Finland and Sweden have recently decided on sites for final disposal of HLW.

Here, we first present a brief overview of nuclear energy around the world, and introduce the situations related to energy, nuclear power, and management of HLW in Japan. Then, we discuss the processes and progress made related to waste management programs in several countries. Difficulties associated with geological disposal of HLW in Japan have been analyzed from a variety of aspects, including geological and hydrogeological conditions, historical, social, and cultural backgrounds. Discussion of the advantages and disadvantages of the two site selection approaches, i.e., the so-called “volunteer approach” and “invitation approach,” are presented from a social psychological viewpoint. Some considerations for reaching agreements and public acceptance are provided.

INTRODUCTION

The first commercial nuclear power station began operation in the 1950s, and there are now more than 430 commercial nuclear power reactors operating in more than 30 countries around the world. Their total capacity exceeds 387,000 MWe, supplying about 16% of global electricity needs. Nuclear power has become the third largest source of electricity in the world after coal (39%) and hydroelectricity (19%) [1].

With growing concern about global warming, effective countermeasures must be taken to reduce greenhouse gas emissions. In July 2009, the leaders of the G8 summit committed to reduction of global emissions by at least 50%, with developed countries agreeing to reduction of 80% or more by 2050 compared to 1990 [2]. In his speech at the United Nations Summit on Climate Change in September 2009, the Japanese Prime Minister Yukio Hatoyama pledged that Japan would seek to reduce greenhouse gas emissions by 25% compared to the 1990 levels by 2020. It will not be easy to achieve these goals, and concerted efforts and countermeasures will be required if progress is to be made [3].

As environmentally friendly renewable energy is conditionally available and limited, and nuclear power plants have no greenhouse gas emissions during the operation stage, many countries are planning to increase the use of nuclear power. In the fall of 2008, OECE/NEA (The Nuclear Energy Agency within the Organization for Economic Co-operation and Development) forecast that nuclear power will increase by 1.5-3.8 times the current capacity level around the world. At the Nuclear Construction Summit, USA 2009, the Electric Power Research Institute reported that the USA requires 64 GWe of new nuclear generation capacity by 2030, and 24 GWe by 2020. In China, 13 reactors with a total capacity of 13335 MW are under construction, and 13 others with a total capacity of 13609 MW are currently in the planning stages. In Japan, 2 reactors with a total capacity of 2285 MW are under construction, and 11 reactors with a total capacity of 14945 MW are planned for the near future [4].

Although nuclear power has advantages with regard to avoiding the environmental problems arising from thermal power generation through burning fossil fuels, such as coal and oil, the safe disposal of radioactive waste, especially HLW, generated by nuclear power plants remains an urgent and challenging problem to resolve. Many countries, including the USA, Germany, France, Canada, Switzerland, Belgium, Japan, Sweden, and Finland, have had radioactive waste management programs for many years, but the plans and schedules in many countries have changed over time or in some instances have even been suspended. Only Finland and Sweden have recently decided on sites for final disposal of HLW.

In view of these international and national trends associated with nuclear energy, a brief overview of the situation related to energy, nuclear power, and management of HLW in Japan is presented. The processes and progress made related to waste management programs in a number of countries were compared and analyzed. Difficulties associated with geological disposal of HLW in Japan are discussed with regard to various aspects, including geological and hydrogeological conditions, historical, social, and cultural factors. The advantages and disadvantages of two site selection approaches, i.e., the "volunteer approach" and the "invitation approach," were analyzed from a social psychological viewpoint, and some considerations for agreement formation and public acceptance are presented.

ENERGY SITUATION IN JAPAN

Japan is an island country with limited energy resources, with an energy resource self-support or self-sufficiency rate as low as 4%. Even after taking account of imported uranium ore, the self-sufficiency rate of energy resources is still only about 20%. The first electricity from nuclear energy in Japan was generated at an experimental reactor in Tokai Village, Ibaraki Prefecture, in October 1963. There are now 55 reactors in 17 power stations throughout Japan, as shown in Fig. 1. The total capacity of these reactors reaches 49467 MW, and they produced 258.1 TWh of electricity, constituting about 30% of the total power generation in Japan in FY2008. In addition, 2 reactors with capacities of 2285 MW are currently under construction and a further 11 reactors with a total capacity of 14945 MW are planned, including the construction of four new power plants (Fig. 1). These basic data illustrate that nuclear power is an important source of electrical energy, supporting both civic life and industrial activity in Japan. To ensure energy security and to reduce greenhouse gas emissions in accordance with the Kyoto Protocol and the recent G8 summit declaration, nuclear power will continue to be used and will grow as a key source of energy in Japan in the future. By 2013, nuclear power is expected to have increased to about 40% of the total power generated in Japan, as shown in Fig. 2, which illustrates the proportion of nuclear energy in Japan's electricity supply and its changes over the past 40 years [4].

SITUATIONS RELATED TO MANAGEMENT OF HLW IN JAPAN

Generation of HLW

As in any other industry, waste and/or byproducts are also generated from nuclear power plants. However, the waste generated from nuclear power plants is radioactive and requires appropriate disposal. Among the different types of waste, HLW is made up of very dangerous highly radioactive materials, which must be isolated for several tens of thousands of years.

In general, HLWs are spent reactor fuel, and waste materials remaining after spent fuel is reprocessed. The latter is liquid waste with a high level of radioactivity. This high-level radioactive liquid waste is vitrified with a glass matrix and sealed in stainless steel canisters (HLW is heated to dryness resulting in a fine powder, mixed with crushed glass then melted in a furnace to be poured into the stainless steel canister whereupon the lid is welded shut.) generally measuring 0.4 m in diameter by 1.3 m in height.

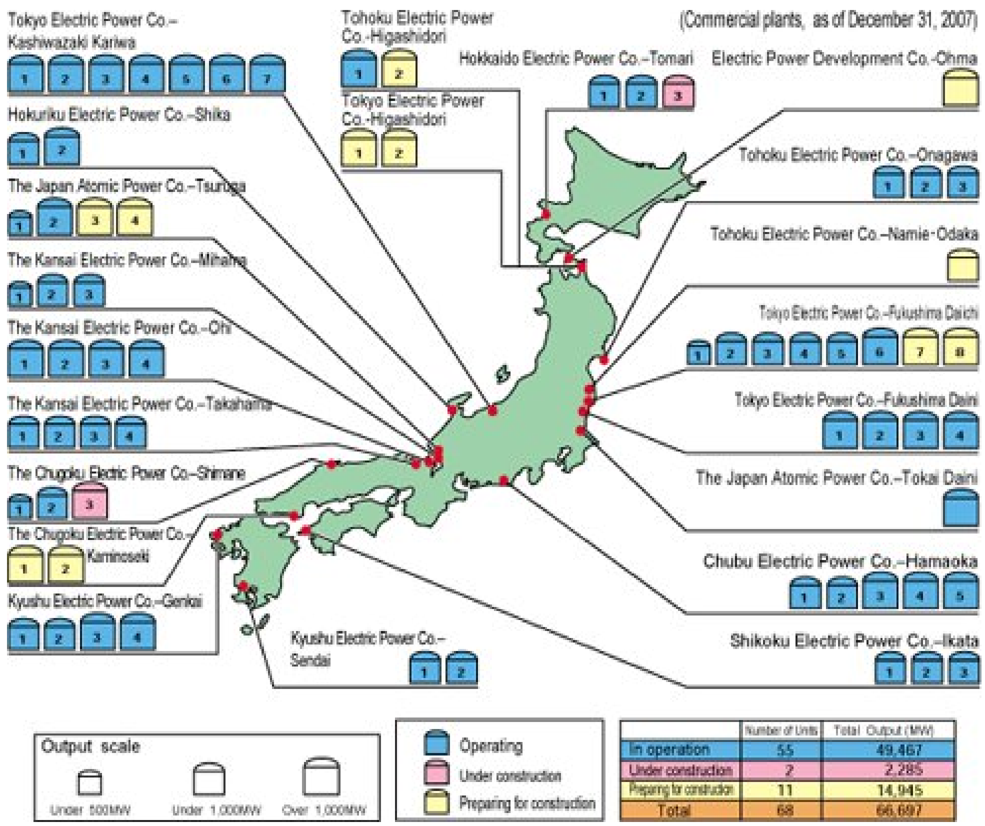

Fig. 1 Distribution of nuclear power plants in Japan

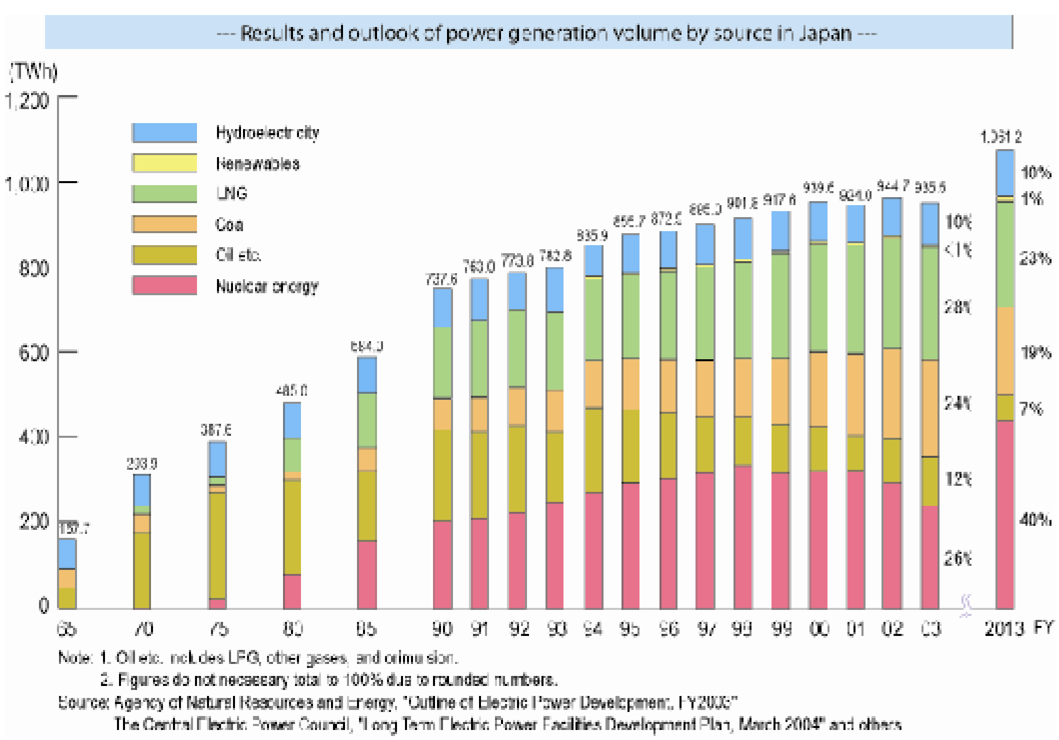

Fig. 2 Proportion of nuclear energy in Japan's energy supply

In Japan, both liquid and vitrified wastes are referred to as HLW. In other countries, such as the USA and Sweden where spent fuel is not reprocessed, the spent fuel itself is referred to as HLW.

By the end of 2008, thousands of tons of spent fuel, equivalent to 22,200 canisters, had been generated by nuclear power plants in Japan. Part of this spent fuel has been reprocessed, but the majority is still stored in facilities at individual nuclear power plants. Currently, the amount of spent fuel generated by nuclear power plants across the whole country is about 900-1000 t U per year. The amount of spent fuel is expected to increase corresponding with future increase in nuclear power generation. One large and urgent problem is that there are no commercial reprocessing plants currently in operation in Japan, though one reprocessing plant with a maximum capacity of about 800 t U has been newly constructed and is currently undergoing testing and adjustment. As the reprocessing capacity in Japan is less than the rate at which spent fuel is generated, an interim storage facility with a storage capacity of 5000 t is also under construction and will begin operation in the near future [5].

Major Milestones in Geological Disposal of HLW

In June 2000, the Specified Radioactive Waste Final Disposal Act (the Act) was passed and implemented in Japan (Law No. 177). The Act specifies the establishment of a disposal implementing organization, financial arrangements for disposal costs, and stepwise processes for site selection. The Act also specifies that HLW will be disposed of underground, in a geological repository deeper than 300 m. Following enactment of the Act, a series of ordinances and notifications were issued by the Ministry of Economy, Trade, and Industry (METI) on implementing organizations, financing of and accounting for implementing organizations, the costs necessary for final disposal, organizations for management of the funds, and other detailed issues.

In accordance with the law, regulations, and notifications, the Nuclear Waste Management Organization of Japan (NUMO) was established in October 2000 as the implementing organization. NUMO's responsibilities cover site selection, preparing relevant license applications and overseeing the construction, operation, and closure of the repository, as well as collecting fees from the owners of nuclear power plants. The role of NUMO in Japan is similar to that of the Department of Energy (DOE) in the USA in the field of managing HLW. The total cost of disposal is estimated to be approximately 2.9 trillion yen (0.2 yen/kWh from electricity utilities and hence electricity users) for a repository with 40,000 canisters of vitrified HLW, the total amount of HLW that is expected to be generated by Japanese nuclear plants by 2020.

Together with the establishment of implementing organizations, an organizational framework or system that covers the implementation, regulation, management of funds, research, and decision making processes for the management of HLW has also been developed in Japan, as summarized in Fig. 3.

As specified by the Act, the process of determining a site for disposal of HLW shall consist of three stages: 1) selection of potential candidate sites as Preliminary Investigation Areas (PIAs), 2) selection of candidate sites as Detailed Investigation Areas (DIAs), and 3) selection of a site for repository construction. Corresponding to these three stages, the anticipated schedule proposed by the METI was as follows: 1) from November 2000 to about 2010: undertake a literature survey, select PIAs and conduct borehole programs, etc., 2) around 2010's: select DIAs and perform test programs in underground exploration facilities, etc., 3) around 2020's: select a site, construct a repository and perform safety examinations, etc., 4) about 2090: perform backfilling and closure of the repository [6].

In accordance with the Act, NUMO has already embarked on the first stage. In October 2001, NUMO announced an overall procedure for selection of PIAs for potential candidate sites. In addition, in December 2002, NUMO began "open solicitation" by publishing a set of four documents as an information package: Instructions for Application; Siting Factors for the Selection of Preliminary Investigation Areas; Repository Concepts; and the Site Investigation Community Outreach Scheme. The

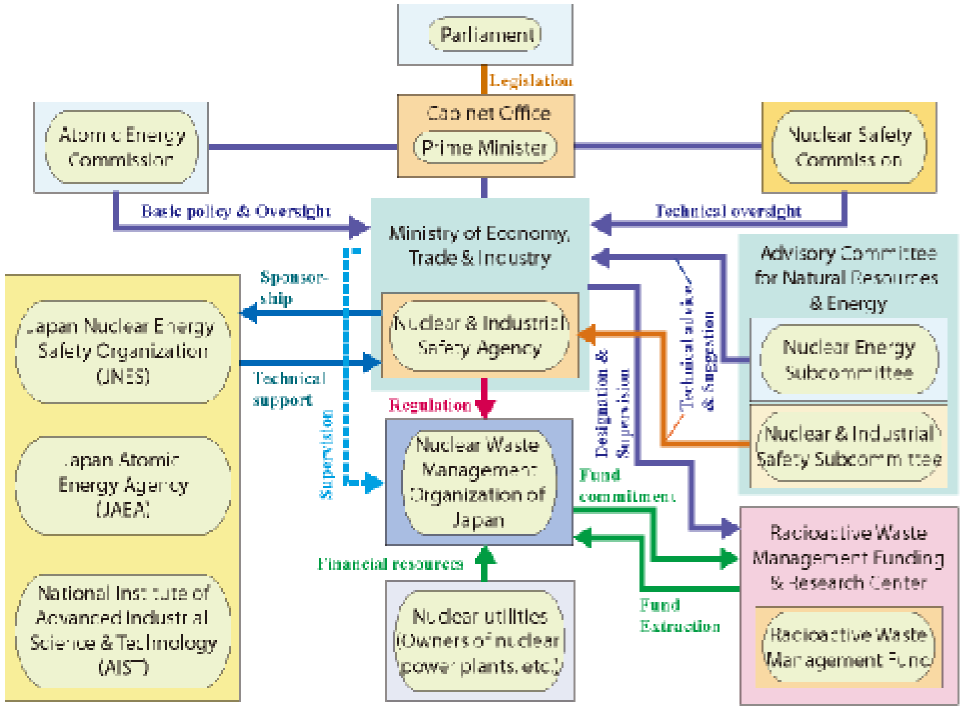

Fig. 3 Organizational framework for the management of HLW in Japan

information package was sent to all 3239 municipalities in Japan. By the end of 2006, about ten local municipalities including Saga Town in Kochi Prefecture and Kasasa Town in Kagoshima Prefecture and Goshoura Town in Kumamoto Prefecture showed interest, and the topics were reported by some news media, but none have led to actual implementation [7].

In January 2007, Toyo Town in Kochi Prefecture became the first municipality to apply as a potential area to be listed as a PIA beginning with a literature survey, but escalation of opposition activities led to the resignation of the mayor and his loss of the subsequent election. The newly elected mayor withdrew the application and the literature survey for this town was abandoned in May 2007.

Reflecting on the lessons learnt, the Radioactive Waste Sub-Committee in METI recommended enhancement measures for the HLW disposal program in November 2007. Major enhancement measures included: 1) enhanced public acceptance activities to improve public confidence and to encourage municipalities to participate in the literature survey; 2) enhancement of R&D and international cooperation to promote public confidence; and 3) reinforcement of a cooperative framework among government, NUMO, and utility companies. A modification of the process of determining sites was also included wherein the government could invite candidate municipalities for literature survey, as a supplemental measure to NUMO's voluntary approach.

Although nationwide programs including energy caravans (mobile public information awareness raising projects), workshops, roundtable discussions, and newspaper and TV advertisements, have been continuously organized by the METI and NUMO, no municipality has yet applied as a potential area to be listed as a PIA. Progress is running far behind the anticipated time schedule, and Japan is currently facing the hurdle of finding suitable PIAs.

DIFFICULTIES ASSOCIATED WITH GEOLOGICAL DISPOSAL OF HLW IN JAPAN

Geological disposal of HLW in Japan is not a simple matter. In addition to existing scientific and technical issues, many other factors, such as geographic and geological conditions, historical, social, and cultural factors, also significantly affect agreement formation and public acceptance of geological disposal of HLW in Japan.

Geographical and Geological Conditions

The key issue of geological disposal of HLW is how to ensure the long-term safety of a disposal facility. As the radionuclides included in HLW are long lived, and it takes about 10,000 years for radioactivity to decay to a level corresponding to that of the original ore from which the nuclear fuel was produced, the time period that is considered necessary for the long-term performance assessment of a HLW geological disposal facility is generally in the order of several tens of thousands of years.

Japan is located in a geologically unstable zone. Earthquakes and volcanic eruptions occur very often, and some large-scale earthquakes, such as the Western Tottori Prefecture Earthquake (Mj7.3, October 6, 2000), have occurred recently in unpredicted areas. The geological and hydrogeological conditions in Japan are very complicated due to the repeated occurrence of seismological events. The complexities of structural geological, and hydrogeological conditions in Japan increase the difficulties of scenario analysis, model development, and prediction of parameter changes over a long time scale. The uncertainties associated with long-term performance assessment for a disposal facility also increase due to these reasons. All of these conditions will lead to difficulties in interpretation and/or description of long-term performance assessments, which are the key factors for agreement formation and public acceptance.

Historical Factors

Japan is the only country that has suffered from atomic bombings. Although nuclear power in Japan has increased over the last 40 years, and it has become an important source of electricity today, nuclear issues are still highly sensitive in Japan. Many people believe that nuclear energy is very dangerous, and from a psychological viewpoint, a long time will likely be necessary to alleviate such fears.

Social Factors

Nuclear technology is advanced, but complicated. In some cases, even small technical errors and/or human errors may cause serious accidents. Some accidents, such as the Three Mile Island Nuclear Power Plant Accident (March 28, 1979, USA), the Chernobyl Nuclear Power Plant Accident (April 26, 1986, Russia), the Mihama Nuclear Power Plant Accident (August 9, 2004, Japan; 5 people died), and the JCO Criticality Accident (September 30, 1999, Tokai Village, Japan; 2 people died), are often reported when discussing nuclear affairs in Japan. This reinforces the belief in some people that nuclear facilities are very dangerous.

In addition to these accidents, a number of scandals, such as falsification of data related to safety, and cover-ups of accidents by the electricity companies, have also led to public distrust with regard to the safety of nuclear facilities.

Under these conditions, not only some civil groups, but also some political parties, such as the Social Democratic Party and Japanese Communist Party, have declared themselves to be opposed to nuclear power.

Cultural Factors

Risk analysis is an emerging discipline. In general, risk analysis is broadly defined as including risk assessment, risk characterization, risk communication, risk management, and policy relating to risk. Risk analysis is a relatively young science compared to other scientific and/or technical disciplines. Although many risks ordinarily accompany daily life, Japanese people generally prefer the word “safety” to “risk.”

Therefore, it would be very difficult to discuss safety assessments including uncertainties with the general public in Japan.

Safety culture refers to "…..the characteristics of the work environment, such as the values, rules and common understandings that influence employees' perceptions and attitudes about the importance that the organization places on safety." according to the Director-General of the OECD/NEA in 2006.

It appears that Japanese nuclear professionals were overconfident and complacent regarding safety related to nuclear activities until the mid-1990s. A Japanese White Paper on Nuclear Safety (1994) stated that "Nuclear safety performances in Japan are recognized as excellent worldwide. It is strongly expected that Japan provides its accumulated know-how of nuclear safety as the international asset for every country." The JCO Criticality Accident that killed two people could be regarded as a typical case that has occurred due to such complacency.

As the message given by Japanese nuclear professionals to Japanese civilians was that nuclear activities in Japan are 100% safe, any problems related to nuclear activities have led to overreactions from the public and distrust of any reassurances about nuclear safety.

As indicated by the Chairman of the Nuclear Safety Commission of Japan at the Symposium on Nuclear Safety Culture in 2006, shortcomings, or weak points, in Japan's culture of nuclear safety include the fact that the culture has not been developed systematically and is not based on objective factors. Its weak points were hidden by a "can-do" atmosphere in the pioneer days of nuclear energy and by over reliance on success and excellent performance over a long period. Similar to the safety culture, a social climate associated with risk assessment and risk communication has not been formed in Japan.

RETHINKING APPROACHES TO SITE SELECTION

In addition to the scientific and technical issues, sociopolitical concerns are also involved in the process of site selection, because public agreement and support are of fundamental importance for the success of a project.

Although the volunteer or open solicitation approach appears democratic, this approach is not necessarily feasible. From a social psychological viewpoint, decision making can be divided into two patterns: personal decision making and social consensus building. The former applies basically to personal consumption, donation, and other activities where individuals have autonomy. The latter applies to advanced sciences, high-technologies, and environmental problems that ordinarily undergo public dispute, agreement formation, and public acceptance. As no volunteers have come forward since Toyo Town withdrew its application in May 2007, an invitation approach has been incorporated into the site selection process, as a supplemental measure to NUMO's voluntary approach in Japan.

The most important prerequisite for social consensus building is public awareness. METI and MUMO have addressed this point. Nationwide projects, such as energy caravans, workshops, roundtable discussions, and newspaper and TV advertisements, have been organized continuously by the METI and NUMO in recent years. These activities have increased the public's awareness of the necessity of nuclear power and the importance of geological disposal, but most people are still wary about safety related to the geological disposal of HLW due to historical, social, and cultural factors, and the nature of geological and hydrogeological conditions in Japan. The formation of cultures related to risk communication and risk governance is necessary in Japan, and this process will likely take a long time.

To reach social agreement on geological disposal of HLW in Japan, the involvement of the whole of society is of fundamental importance. A process and framework considering a variety of different aspects and factors incorporating historical, social, and cultural factors should be established. Figure 4 illustrates the process and framework recently proposed by the authors [8]. There is still a long way to go before site selection can be realized. The formation of positive cultures related to risk communication and risk

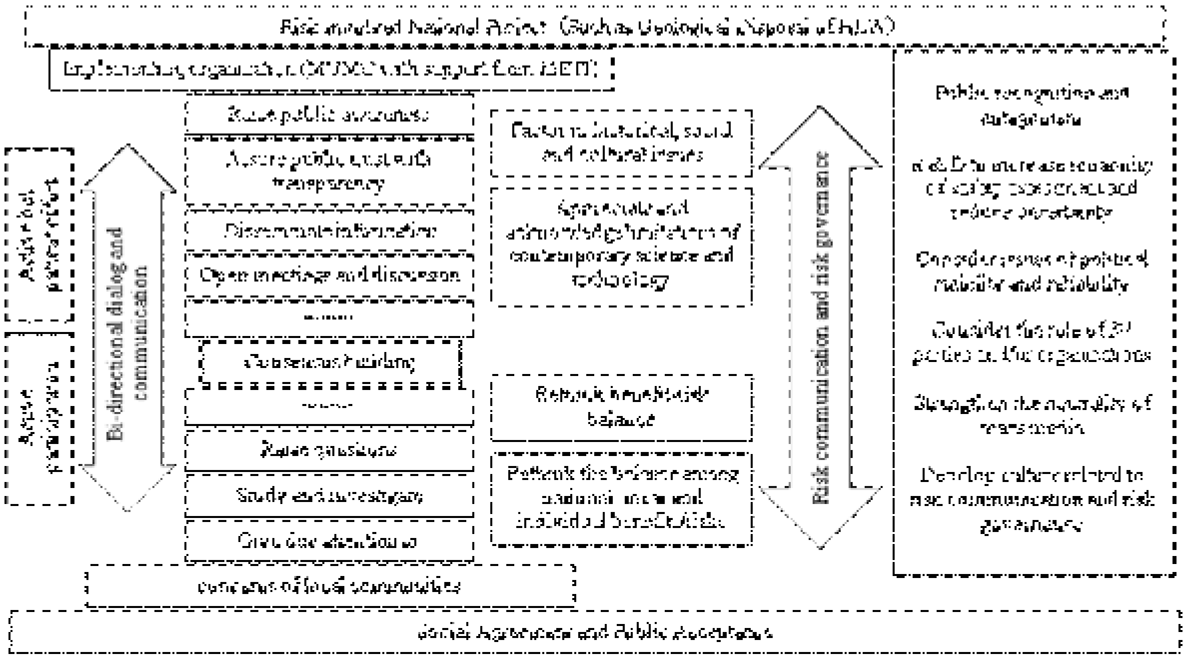

Fig. 4 Framework for consensus building associated with geological disposal of HLW

governance with respect to historical, social, and cultural factors may open the way to public acceptance of geological disposal of HLW in Japan.

CONCLUDING REMARKS

The safe disposal of radioactive waste, especially high-level radioactive waste, generated by nuclear power plants, remains an urgent and challenging issue around the world. It has become a key issue that may affect sustainable development and utilization of nuclear energy in the future.
Similar to other developed countries where nuclear power is used and it is necessary to dispose of nuclear waste, Japan is now facing the hurdle of selecting potential candidate sites as preliminary investigation areas. Due to the complexity of geological and hydrogeological conditions, and consequent complexity of safety assessments, plus unique Japanese historical, social, and cultural factors, there may be a long way to go before site selection can be realized. The following points should be enhanced and/or strengthened to facilitate this process:

1. Public awareness and recognition of the need to dispose of HLW is the first step in alleviating dispute and concern.

2. Assurance of scientific, political, and organizational reliability and trust related to nuclear activities.

3. Objective review by independent parties and/or organizations.

4. The formation of cultures related to risk communication and risk governance with respect to historical, social and cultural factors that may open the way to public acceptance of geological disposal of HLW in Japan.

REFERENCES

1. World Nuclear Association (2009). Nuclear Power in the World Today, < http://www.world-nuclear.org/info/inf01.html> (March 2009).
2. AFP BB News (2009). < http://www.afpbb.com/article/environment-science-it/environment/2619287/4343890> (July 9, 2009).
3. Ministry of Foreign Affairs of Japan (2009). < http://www.mofa.go.jp/policy/UN/assembly2009/pm0924-1.html> (October 29, 2009)
4. Japan Atomic Energy Relations Organization (2009). Graphical Flip-Chart of Nuclear and Energy Related Topics, 2008-2009.
5. Zhang et al. (2009). Nuclear Energy and the Management of High-Level Radioactive Waste in Japan, *Journal of Hydrologic Engineering*, 14(11), 1208-1213.
6. Ministry of Economy, Trade, and Industry (METI) (2000). Final Disposal Plan for Specified Radioactive Waste, Rep. No. 292 (In Japanese).
7. NUMO (2009). < http://www.numo.or.jp/>
8. Zhang et al. (2009). Geological Disposal of HLW and Risk Governance, Atomic Energy Society of Japan, 2009 Fall Meeting.