Research in the selection of Very Low Level Radioactive Waste Disposal site in southwest China

Tuo Xianguo[a*], Long Qiong[a], Zhong Hongmei[a], Xu Zhengqi[a], Mu Keliang[a], Gao Lan[a], Li Ju[b], Luo Deli[b], and Dou Tianjun[b]

[a]Chengdu University of Technology, College of Applied Nuclear Technology and Automation Engineering, Erxianqiao Dongsan Road1#, 610059, Sichuan, China
[b]China Academy of Engineering Physics, 621700, Mianyang, Sichuan, China

Abstract: The ultimate goal of Chinese Radioactive Nuclear Waste Management and Disposal Security is that must use proper and optimized ways to manage radioactive waste and make sure human beings and the environment either at the present or in the future can be free from any unacceptable risks. According to the goal, this paper presents an overview of comprehensive site characterization work that comprises investigations of physical geography, climatology, geology and hydrogeology, as well as geological hazard on two candidate Very Low Level Radioactive Waste (VLLW) disposal sites (Site Ⅰ and Site Ⅱ) which are both located in the south west of China. The results showed that there are many similarities in the regional extent of the two sites, but many distinct differences are found in terrain and topographic features, granule stratum, hydraulic gradient, and so on. On the whole, the two alternative sites are in line with the requirements for very low level radioactive waste disposal, and Site Ⅰ is superior to Site Ⅱ.

KEYWORDS: VLLW; site selection; suitability evaluation.

1. Introduction

Since 1898 radioactive materials have been found, nuclear science and technology and the nuclear industry have developed by leaps and bounds [1]. Meanwhile, radioactive wastes have been inevitably produced and a certain part of them are proved to be very low level radioactivity [2]. Using the low-level (LLW) or intermediate-level waste (ILW) disposal methods to dispose this kind of waste requires a large amount of disposal cost, while disposing them together with normal waste can not meet the increasing public demands to the environment [3-4]. In the context of the conflict, some developed countries raised the concept of “VLLW” which means very low level radioactive waste, and it is proposed to manage and dispose them separately [5].

According to the ultimate goal of Chinese Radioactive Nuclear Waste Management and Disposal Security [6], that is, must use proper and optimized ways to manage radioactive waste and make sure human beings and the environment either at the present or in the future can be free from any unacceptable risks, any designs and operations of radioactive nuclear waste management facilities or systems should meet the requirements of radiation and environmental protection and should implement the principle of protecting future generations. In addition, the long-term geological stability and suitable geological, geochemical, and hydrogeological conditions of the venues should also be taken into consideration [7]. In this paper, two candidate sites of VLLW disposal in southwest China are selected, and in accordance with the strict disposal site suitability requirements, investigations undertaken at the two sites comprise economy and geography conditions (population, transportation, climate, etc.), topography conditions, geological structure situations, as well as hydrogeological conditions. Through a comprehensive study of analysis and comparison, conclusions are gathered to serve the needs of repositories engineering with respect to layout and construction and safety and long-term performance assessment for VLLW disposal.

2. Status of site investigations: overview

2.1 General

[*] Presenting author, E-mail: txg@cdut.edu.cn

The two alternative disposal sites (Site Ⅰ and Site Ⅱ) are both located in the southwest of China about 3km far away from each other. In the regional extent area of the two sites, residential areas are located in near cities and counties as well as large or medium-sized enterprises townships. In the mountain area, the population density is very small and people live scattered that many parts of the mountains are uninhabited. Due to the high mountains and the inconvenient traffic, the economy is relatively underdeveloped. Residents in this area are living on agriculture and other sidelines. There are no great industries or mining enterprises there, just a few small plants.

Figure 1: The location of Site Ⅰ

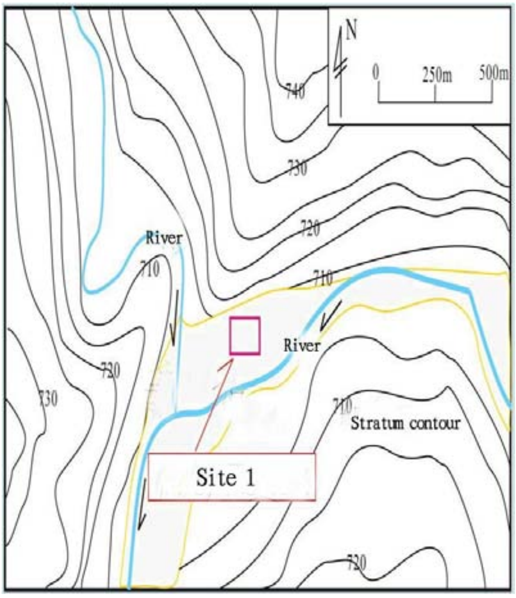
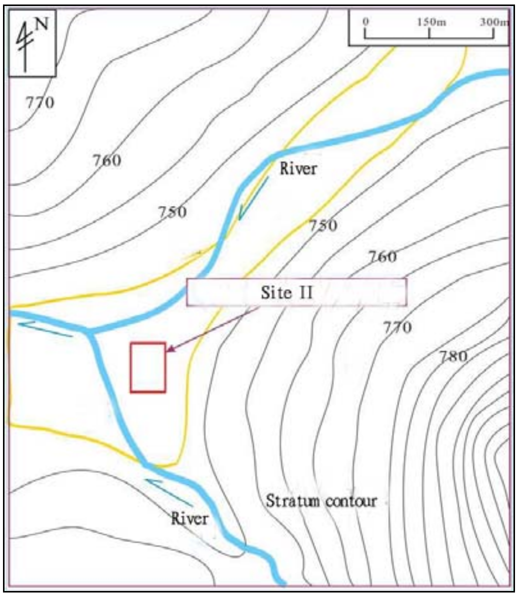


Figure 2: The location of Site Ⅱ



2.2 Site Ⅰ

Site Ⅰ is located in the river valley of an unnamed river and one of its tributary streams. The main ditch of the valley extends from the two estuaries up stream to the upper reaches of the river. The area is flat and low-lying, about 101,635 m^2 in size with 822 m the south river border, 734 m the north mountain border and 211 m the west side of the river border. The detail information about Site Ⅰ is showed in Fig.1, and set 10,000 m^2 as the disposal site.

2.3 Site Ⅱ

Site Ⅱ is also located in a narrow valley formed by the river confluence of two unnamed rivers. The area is about 127,015 m^2 with 367 m the mountain border, and 1,002 m the northwest river border. Details of its location are showed in Fig. 2: the valley extents from northeast toward southwest with 100 to 300 m the wide; two mountains are located around the valley and the relative altitude is 300 to 1000 m. Set 10,000 m^2 for the disposal site as well.

3. Investigation methods and objectives

The selection work for a radioactive waste disposal site is a complex and multidisciplinary study which includes geophysical investigation, field and laboratory geological survey, geological mapping, geochemistry mapping, hydrogeology drilling and other means of investigation.

3.1 Physical geography investigation

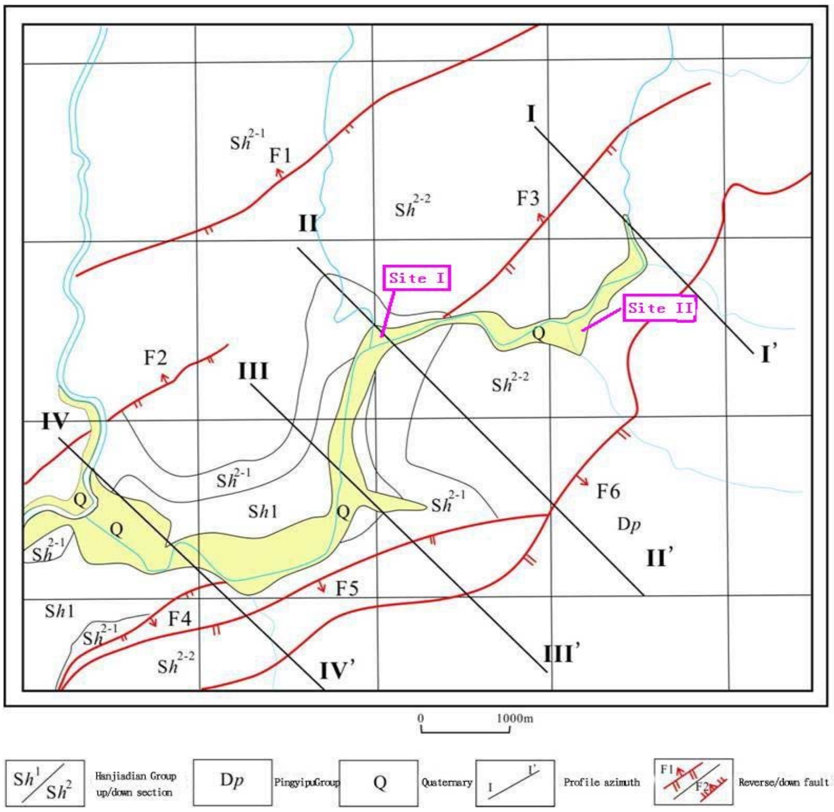
Through field measurement and data collection, make clear the physical geographical conditions of the two alternative sites, include:
(a) The location situations;

(b) Terrain and topographic features;
(c) Climate and weather features include temperature, humidity, rainfall, wind and wind directions and so on.

3.2 Geology and geological hazard investigation

Through geological measurements, profiling (Fig. 2) and mapping, identified the conditions of geology and predict geological hazards in these two candidate sites as follows:
(a) Types, modes and distributions of occurrence;
(b) The main chemical composition and weathering characteristics of rock;
(c) Geological structure characteristics, especially the fault of the occurrence;
(d) The accumulation thicknesses and the stabilities of alluvial deposit, residual deposit, talus materials and cumulate materials of the Quaternary;
(e) The development of tectonic events;
(f) The mechanical properties of rock and soil;
(g) The potential geological hazards, and so on.

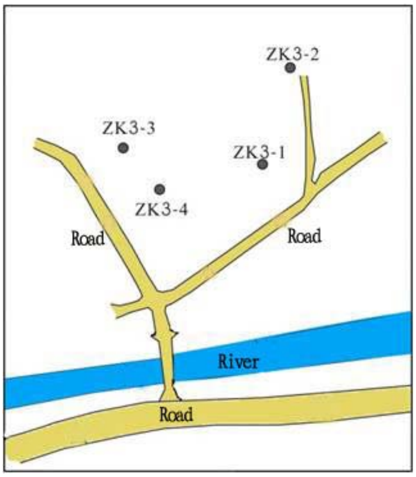
Figure 3: Geological investigations in the whole region of Site Ⅰ and Site Ⅱ

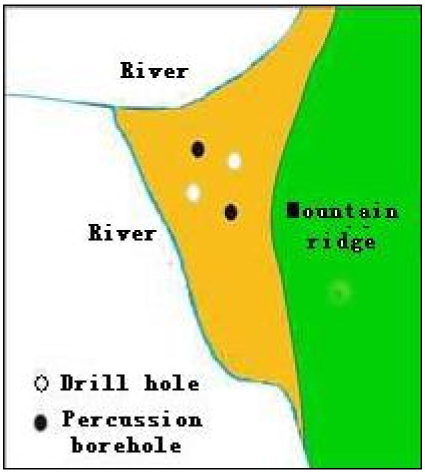


3.3 Hydrogeology investigation

Hydrogeological investigation includes surface and underground hydrological investigations. By the drilling activities (Fig.4 and Fig.5) and pumping tests, hydrological data are obtained and then figure out:
(a) Magnitude, storage and transmissivity of the aquifer, and water catchment conditions, as well as direction, slope and the possibility of reverse of ground water flow, etc.;
(b) Compensation, runoff and draining conditions of ground water;
(c) Chemical type of groundwater;
(d) Phreatic water surface, water level, streamflow, permeability and porosity, hydraulic gradient, particularly hydraulic conductivity of ground water, and so on.

Figure 4: Drilling activities in Site Ⅰ **Figure 5:** Drilling activities Site Ⅱ





4. Comparison

According to field surveys and site investigations, combined with activities such as drilling and a series of indoor and field experiments in the two candidate sites, some comparisons are carried out on physical geographical, geological and hydrogeological conditions:

4.1 Physical geography

4.1.1 Similarities

Both the two candidate disposal sites are located in mountains, so the regional terrain is complex. The valley takes mountains as barriers and due to the particular geological structure and surface hydrological net, the terrain and topographic features present as hills, valley and river terrace landscape; river flows with seasonal variation and groundwater (mostly underflows) is reserved in the aquifer layer of alluvium and diluvium in the first terrace. The depth of burial of groundwater is about 1.5 to 5.5 m and the chemical type is HCO_3-Ca. The whole region has typical valley meteorological characteristics: the average temperature is 14.7 ℃, with 35.0 ℃ the highest and minus 5.4 ℃ the lowest; the relative humidity is 77%; and the annual rainfall is about 532 to 1326 mm from June to September; and winds directly affected by the impact of the topography results in ESE (east to southeast) mountain wind and WNW (west to northwest) valley wind.

4.1.2 Differences

Since the locations are different, Site I and Site II present many differences in topographic features. Located in the valley platform, Site I is relatively flat. The north side is closes to the mountains while the east and the west sides are platforms. The relative elevation is about 30 to 40 m, and the mountain area is small which made the water catchment area small as well. But in Site II, there are two mountains located in its southwest and southeast sides, and therefore, the relative elevation is much higher, up to 100 m, and the water catchment area is larger than that of Site I.

4.2 Geology and geological hazards

4.2.1 Similarities

Due to the impact of a variety of tectonic forces, the tectonic movement in the regional extent area of the two sites is developed. There are one anticline and six faults in this region. The core formation is the Silurian Hanjiadian group up section, and the two wings are Hanjiadian group down section. The biggest fault is a boundary line of the Devonian and the Silurian formation, while other faults are small.

Both the two sites have the Silurian Hanjiadian Group, the Devonian Pingyipu group and the Quaternary formation. The Quaternary formation distributes along the river valley, and has two types: one is the clay and gravel layer formed by alluvial deposit and residual deposit, the other is slope materials of weathered bedrock. In addition, there are many other artificial gravel accumulations in it.

Geological hazards are few. As the main types of rock in the two sites are phyllite slate and sandstone, the stability of rock is good. And despite of the relatively steep slope gradient, the vegetation and trees are growing well which makes the loose accumulation surface layer consolidate. In a word, geological hazards have little impact on the two sites.

4.2.2 Differences

(a) Formation
The formation structure of the two sites is basically the same, but different processes and ways of dereliction have formed different characteristics. In Site I, as the relative elevation of mountains is small, the kinetic energy of mud-rock flow is small, and during the process of forming the clay and gravel layer, a clay layer is also formed over it. Although the clay layer is non-homogeneous, its small particle size is propitious to the disposal site. In Site II, because of the two steep mountains, the mud-rock flows might be discharged rapidly, so it is difficult to form a clay layer in the ground surface.

(b) Vadose zone
The vadose zone in Site I is thicker than that in Site II. It is 4 to 7 m in the wet period and 6 to 8 m in the dry season in Site I. While in Site II, it is 3 to 5 m in the wet period and 4 to 6 m in the dry season.

(c) Particle composition
According to the results of screening tests, the medium average levels of fine particles (diameter <1 mm) is about 20 %, and stable in Site I. While in Site II, the medium average levels of fine particles (diameter <1 mm) is about 10 % and unstable.

4.3 Hydrogeology

4.3.1 Similarities

Geographical and geological conditions created a groundwater compensation, runoff and draining system. Abundant rainfall and lush vegetation are good water sources, and the ancient rock, as well as the strong tectonic movements which formed a short and fast groundwater circulation are provide good conditions to the storage and movement of groundwater. The exposed bedrock fracture and its good permeability are conducive to the infiltration of rainfalls. Both the two sites take the mountain area as the compensation zone, the platform in front of the mountains as the runoff zone, and the rivers as the draining zone.

4.3.2 Differences

(a) Phreatic water surface
The phreatic water surface in Site I is 711 to 714 m, and the water level is 6 to 9 m. While in Site II, the phreatic water surface is 730 to 740 m, and the water level is 5 to 7 m. The depth of the phreatic water surface and the thickness of the vadose zone are two complementary factors, and the greater the depth of the phreatic water surface, the better for the disposal site.

(b) Hydraulic gradient
Hydraulic gradient is an important factor to impact radionuclide migration rate. As Site I and Site II have different topographic features, the hydraulic gradient is also different. According to the data got

from the drilling boreholes, the hydraulic gradient in Site I is 0.00129, and in Site II the hydrodynamic force is much stronger, it is 0.016.

(c) Compensation, runoff and draining conditions
Although both the two sites take the mountain area as the compensation zone, the platform in front of the mountains as the runoff zone, and the rivers as the draining zone, differences are still existed in:
① Compensation zone
As the water catchment area of Site I is small, the streamflow is only about 400 m^3/d, while in Site II is up to 800 m^3/d. In addition, under the same weather conditions and the same rainfall volume, Site I which covered by a 3 to 5 m layer of clay in the ground surface, can effectively block the infiltration of water by making rainfall run off directly into the river.
② Runoff zone
According to the different hydraulic gradient, the carrying capacity of groundwater in Site II is much stronger than that in Site I.
③ Draining zone
Water in the two sites is directly drains away to the rivers. And in Site I, the nearest river is about 150m far away from its southern boundary. In Site II, the nearest river is about 40 m far away from its western border.

Table 1: General comparison

Comparing items		Site I	Site II
Geographical conditions		flat	steep
		S(a)=0.1km^2	S(a)=0.13km^2
		water catchment area is small	water catchment area is large
Geological conditions	formation	surface layer is clay	surface layer is clay and gravel
	vadose zone thickness	5-8m	4-6m
	particle composition	20% (d<1mm)	10% (d<1mm)
Hydrogeological conditions	phreatic water surface depth	5-8m	4-6m
	hydraulic gradient	I(b)=0.00129	I(b)=0.016
	compensation zone	f(c)=400m^3/d	f(c)=800m^3/d
	runoff zone	carrying capacity of groundwater is low	carrying capacity of groundwater is strong
	draining zone	the nearest river is 150m away	the nearest river is 40m away

(a) site square
(b) hydraulic gradient
(c) streamflow

5. Conclusion

Based on the final data (Table 1) and comprehensive analysis and comparison on geographical conditions, geological conditions and hydrogeological conditions, the two candidate sites are in line with the requirements for VLLW disposal, and Site Ⅰ is superior to SiteⅡ. The results providing a regional reference to safety and environmental impact assessment work.

Acknowledgements

This paper is supported by National Natural Science Foundation of China (Grant No. 40574059 and No. 40673058).

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