

Groundwater Use in Earthquake Emergency: A Case Study in Japan

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Abstract: The results indicated that groundwater is very useful water source in the earthquake emergency as the domestic water for toilet cleaning, which is one of big water use problems in the emergency. Groundwater is also useful water source for the fire fighting in the earthquake emergency than river or pond waters. For the purpose of drinking and cooking, quality check of groundwater must be necessary at the ordinary time. Hand pumps or diesel or petrol-driven pumps have to be prepared for using groundwater in the emergency because the required electricity supply may not be available after the earthquake. It also made clear that the registration system of citizen's well, which is launching by many Japanese local governments, is effective and mapping of springs and wells is also helpful for using groundwater in the emergency. Some hospitals have introduced a deep well facility with a membrane filtration system obtaining high water quality and a private power plant system. Moreover, in recently, storage system of rainwater on the roof of households has been spread in the Tokyo Metropolis for using it in the disaster. In conclusion, the paper emphasized the importance of establishment a continuous monitoring system of groundwater including its water quality for using it effectively as one of countermeasures for the secure of water in the earthquake emergency.

Key words: earthquake emergency, secure of water, groundwater use, countermeasures, registration system of well, monitoring system, Mega City

Introduction

Many big earthquakes have occurred in the tectonic regions of the world. Usually, earthquakes cause damages of lifelines such as water, gas and electricity supply systems and even sewage systems in urban and rural areas. Most important problem of suffered people is how to get water for their drinking, cooking and toilet cleaning in the emergency. In some cases, water for the fire fighting is the most urgently necessary one because often the hydrant does not work well at the earthquake emergency. Medical activities are also damaged largely by destroying water supply systems. Securing water for daily life in the earthquake emergency as well as in the case of drought caused by the extreme climate must be a crucial problem and the establishment of countermeasures for those is one of our concerned issues, especially in a Mega City located in the tectonic regions. The purpose of the paper is to describe

an example of groundwater use as one of countermeasures for the secure of water in the earthquake emergency, which is launching by Japanese local governments after the huge Hanshin-Awaji (Kobe) earthquake occurred in 1995.

The Hanshin-Awaji Huge Earthquake

The Hanshin-Awaji huge earthquake of M 7.3 was occurred on January 17, 1995, which was the worst natural disaster in Japan after the World War II. Around 6,400 lives were lost, 40,000 lives were injured and 200,000 households were collapsed. This huge earthquake was happened on the Niigata-Kobe strain concentrated belt. On this strain concentrated belt, many other big earthquakes attacked Japan Island in recently as shown in Fig. 1.

In the Hanshin-Awaji earthquake, around 1,270,000 households were cut off the municipal water supply at the immediately after the earthquake and 490,000 households were cut off it even after one week passed. Maximum length of cut off the municipal water supply was reached 3 months, 90 days after the earthquake in some severe disaster districts. Water use problems in the earthquake emergency have been closed up in Japan as a trigger of this huge earthquake.

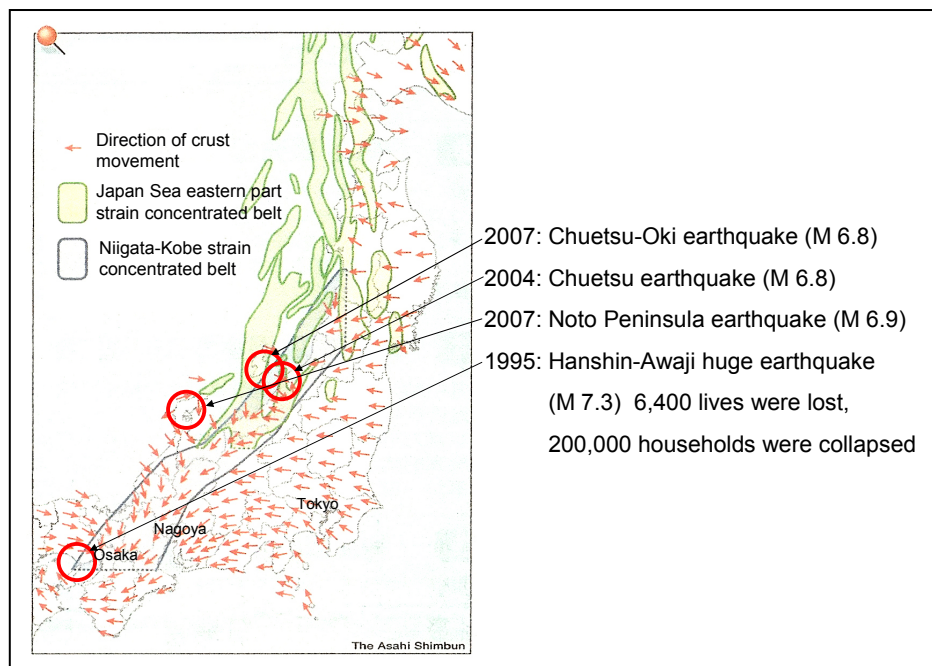


Fig. 1 Recent occurred big earthquakes in Japan (Add to Asahi NP, 2007).

Water use problems reported in the Hanshin-Awaji earthquake are as follows (Research Committee on Secure of Water in Huge Earthquake, 1999; Project Committee of MLIT, Japan, 2007):

- Fire fighting: could not use a hydrant, causing a big obstruction for fire fighting
- Medical activity: transportation of special water with high quality was needed to

hospitals

- Drinking and Cooking: citizens secured sold water for drinking and cooking
- Toilet cleaning: huge amounts of water were needed and it was difficult for secure and transportation it

Secure of water for the fire fighting and medical activities is the most urgently necessary one in the earthquake disaster. In the Hanshin-Awaji earthquake, 73.6 % of hospitals answered to the questionnaire that the main cause which declined the hospital function was cut off the municipal water supply (Yoshioka, 2007).

Water Demand Phase, Necessary Amount and Quality in Earthquake Emergency

Water demand phase in the earthquake disaster may be divided as shown in Fig. 2. Phase 1 corresponds to the immediately after to 3 days after the earthquake and its water demand is concentrated for the fire fighting, the medical activities and the drinking. In phase 2, water demand for drinking, cooking, toilet cleaning, bathing and washing and restore the municipal function is necessary. From 4 days after to till restore the city area is categorized as phase 3. In this phase, water for expansion of life water and restore the construction and the industry is needed. Figure 3 shows a target amount of water demand in the emergency water supply planed by the Administration Office of Kobe City, Japan after the huge earthquake. The figure indicates an expected amount of water demand per person per day depending on the passing time after the earthquake. This target amount has been planed based on the concept that restore the

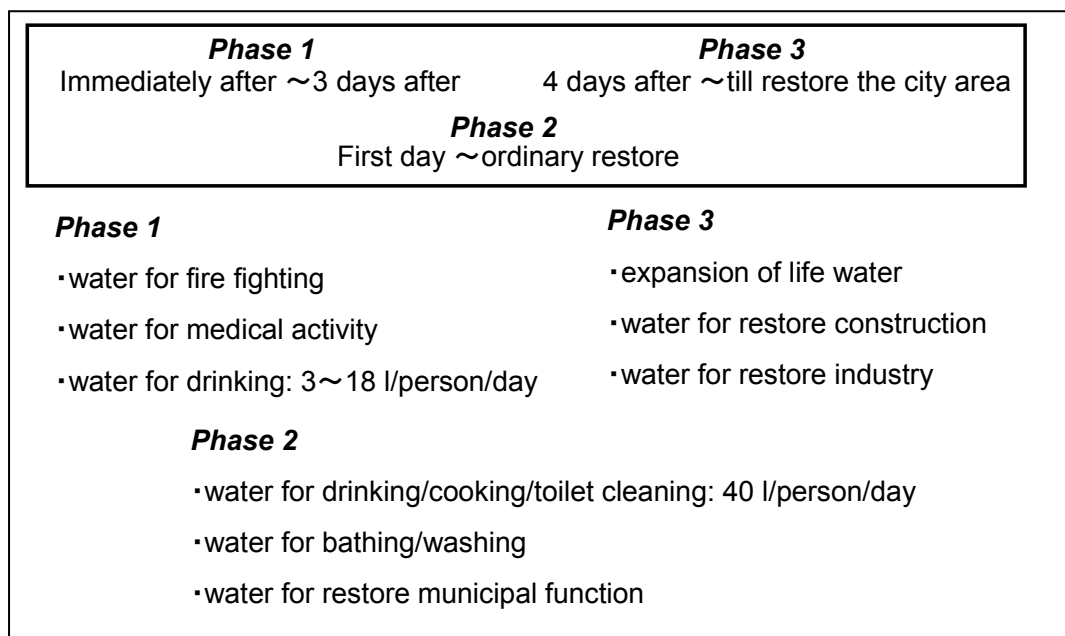


Fig. 2 Water demand phase in earthquake disaster (Research Committee on Secure of Water in Huge Earthquake Disaster, 1999; Project Committee of the MLIT, Japan, 2007).

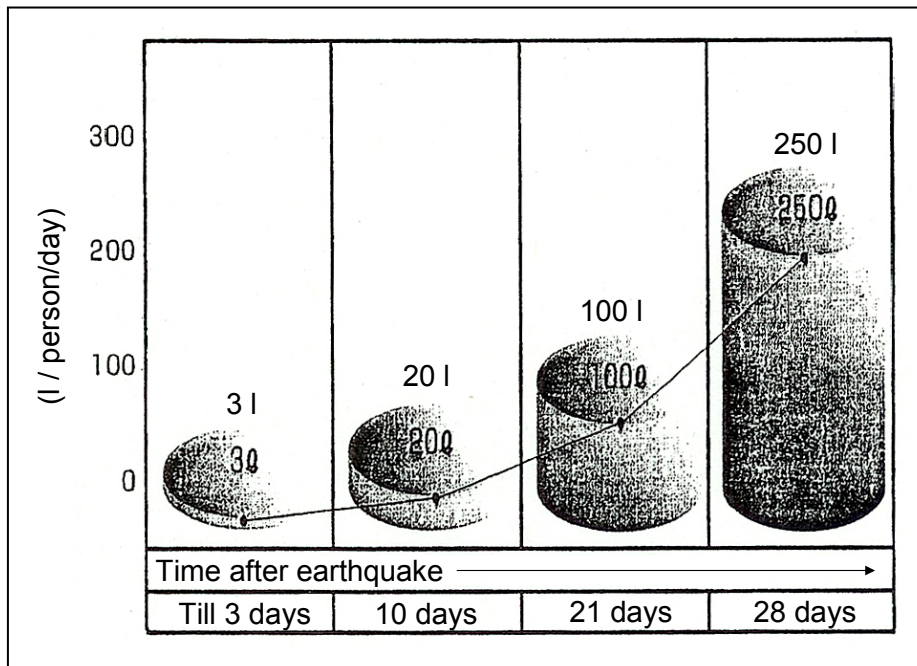


Fig. 3 Target amount of water demand in the emergency water supply planned by the Administration Office of Kobe City, Japan (Research Committee on Secure of Water in Huge Earthquake Disaster, 1991).

city area should be accomplished within 4 weeks after an earthquake. It seems that the amounts of water demand indicated in this figure are the minimum requirements in the earthquake emergency in a Mega City like Kobe.

In the earthquake emergency, not only the amount of water but also the quality of water is required for some purposes. Table 1 summarizes the water needs for each utilization category in the earthquake disaster considering the time and place and the required amount and quality. For the medical activities, high quality of water and a lot of amount is necessary from the immediately after and is needed for continuous supply. This is one of big water use problems in the earthquake emergency because the transportation of such kind special water is needed to the hospital, but this transportation of water is usually difficult in the earthquake emergency. For the life water such as drinking, cooking, bathing and washing also needs a clean water. On the contrary, for the fire fighting and the toilet cleaning, although a huge amount of water is necessary but no need the strictly requirement of water quality as indicated in Table 1. In the case of Hanshin-Awaji earthquake mentioned above, for the initial stage of the firefighting, groundwater source was ranked similar one as the hydrant usage and exceeded the usage of river and pond waters as mentioned later.

Figure 4 shows the getting route of drinking water of Kobe citizens in the huge earthquake. It is clear that most of people get water from water wagon and sold water at stores for their drinking and the use of well water, shallow groundwater, is very rear

Table 1 Water needs for each utilization category in earthquake disaster (Research Committee on Secure of Water in Huge Earthquake Disaster, 1999; Project Committee of the MLIT, Japan, 2007).

Category	Time/Place	Required amount and quality
Fire fighting	• Till around 3 days	<ul style="list-style-type: none"> • No need for water quality • Huge amount • Constant amount
Medical activity	<ul style="list-style-type: none"> • Continuous supply • Immediately after 	<ul style="list-style-type: none"> • High quality • 5 l /person/day for visitors • 40~60 l/person/day for inpatient • 250 l/person/day for washing
Drinking/cooking	<ul style="list-style-type: none"> • Continuous supply • For all place 	<ul style="list-style-type: none"> • Clean water • Min. 3 l~max. 60 l/person/day
Toilet cleaning	<ul style="list-style-type: none"> • Immediately after • Continuous supply 	<ul style="list-style-type: none"> • No need for water quality unless including particles • Several 10 l for 2~3 days in ave.
Bathing/washing	• Several days~one week after	<ul style="list-style-type: none"> • Clean water • 60 l/person/day • Increase with time
Maintenance of municipal function	• Continuous supply for main facilities	• Necessary water quality is different depending on utilization purpose
Restore water	• After stable water supply	• Necessary water quality is different depending on utilization purpose

in case for drinking. This means that the purified water is required for drinking and cooking, and the management of water quality of groundwater at the ordinary time is necessary, especially in the urban area like Kobe.

Figure 5 shows the getting route of life water such as washing, bathing and toilet cleaning as same in Fig. 4. In this case, water quality is not so much required as for drinking, use of well water increases a little than for the case of drinking and sources for getting route are more varieties such as seepage water from the water supply pipe, public water plug on the road and river or sea waters as can be seen in Fig. 5.

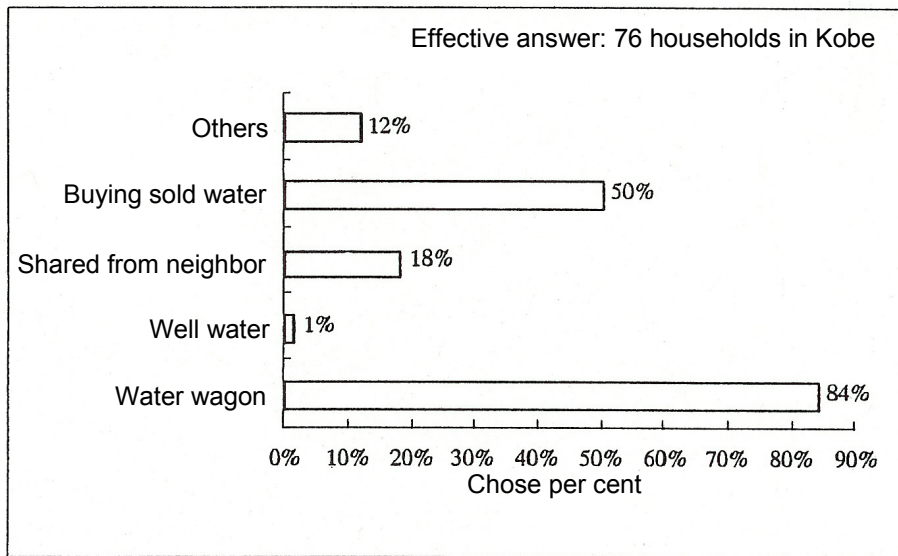


Fig. 4 Getting route of drinking water of Kobe citizens (Research Committee on Secure of Water in Huge Earthquake Disaster, 1999).

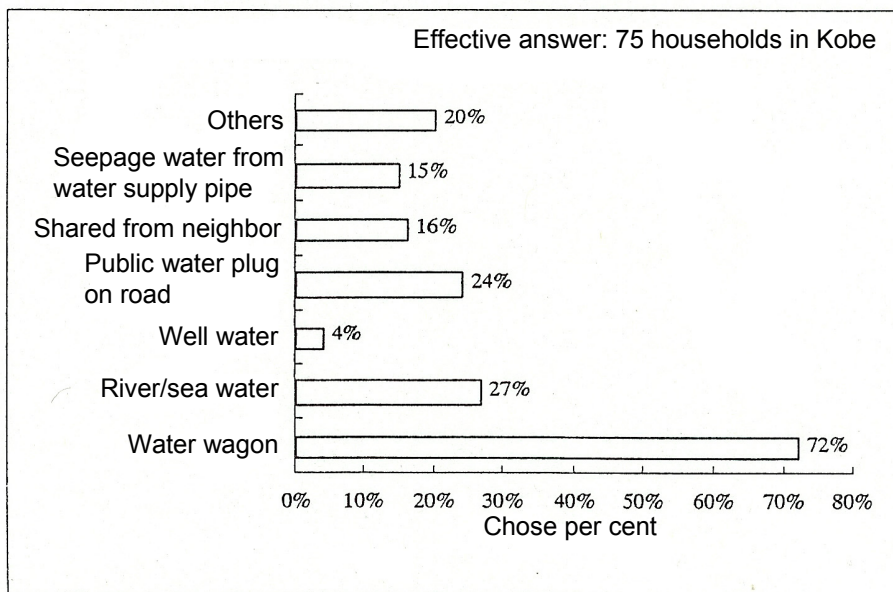


Fig. 5 Getting route of life water of Kobe citizens (Research Committee on Secure of Water in Huge Earthquake Disaster, 1999).

Groundwater Use in Earthquake Emergency

In case of the Hanshin-Awaji earthquake, the recovery of water supply in the Awaji Island was prompt because most of residents have wells at their grounds and could pumped up shallow groundwater successfully using hand pump or electricity which already recovered within the same day of the earthquake (Yoshioka, 2006).

Groundwater use in the Kobe City was also reported as follows (Kamiya et al,

1998):

- 17 Jan. (immediately after): used well water for fire fighting by bucket relay with 500 citizens
- 18 Jan. (one day after): 100 m line was appeared for getting well water
- 20 Jan. (3 days after): 200 citizens used groundwater by pumping from 7 m depth well
- 24 Jan. (7 days after): “Kikumasamune”, famous Sake (Japanese rice wine) brewing company, opened utilization of “Miya-mizu”, brewing groundwater, for citizens from 9 AM to 3 PM in every day
- 28 Jan. (11 days after): used well water which was constructed before World War II (around 55 years old one)

Table 2 shows water sources for the fire fighting by citizens in the Kobe City at the earthquake. It can be seen that comparing with the hydrant, groundwater source is also effectively used for the fire fighting among other water sources.

Table 2 Water sources for fire fighting by citizens in Kobe City (Research Committee on Secure of Water in Huge Earthquake Disaster, 1999).

Water source	Utilization number
Hydrant	17
Well water (GW)	14
River water	11
Bath stored water	9
Tank water of company	5
Public bath water	4
Pond water	4

Table 3 shows the characteristics of water sources for the earthquake disaster. This Table may be useful for the risk assessment of water sources in the earthquake emergency. River and sea waters have a large amount in quantity but those waters must be transported to required places, of which transportation is not easy in usual in the earthquake emergency. Moreover, sea water should be necessary the treatment for fresh water before the using. On the other hand, groundwater has an advantage of coincidence with need and supply places, although the amount of water will be affected by the earthquake. This advantage of groundwater source will be useful for the domestic water use such as the initial fire fighting as mentioned above and the toilet cleaning which is listed as one of crucial water use problems in the earthquake emergency, especially in a Mega City.

Table 3 Characteristics of each water source for earthquake disaster (Research Committee on Secure of Water in Huge Earthquake Disaster 1999; Project Committee of the MLIT, Japan, 2007)

Water source	Quantity	Quality	Remarks
River, lake and pond waters	•Large amount	• Different depending on source	•Transportation is necessary
Sea water	•Large amount	•Treatment for fresh water	•Transportation is necessary
Groundwater	•Amount will be affected by earthquake	•Pollution of shallow GW •Clean in deep GW	•Coincide with need and supply places •Water table decline •Water pollution •Set of pumping power
Rain water	•Set of water tank 200 l~2,000 m ³	•Possibly clean, but treatment is necessary in some times	•Coincide with need and supply places

For the purpose of drinking and cooking, quality check of groundwater must be necessary at the ordinary time. Hand pumps or diesel or petrol-driven pumps have to be prepared for using groundwater in the emergency because the required electricity supply may not be available after an earthquake.

Countermeasures for Secure of Water in Disaster Emergency

After the Hanshin-Awaji earthquake, countermeasures for the secure of water in the disaster emergency have been considered by many local governments in Japan. One of such countermeasures is the registration system of citizen's well for disasters. Figure 6 shows the panel indicating the citizen's cooperation well for disasters in the Kobe City. This register system of citizen's open well has been started from 1996 in the Kobe, just one year after the earthquake, and the registered well reached 517 wells by October 1998. The list of registered wells and its location map have been prepared by the Administration Office of the city and the check of well water quality has been carried out in periodically. Similar registration system has been launched by many other local governments, especially in a Mega City like Tokyo and Yokohama. For example, Tokyo Metropolitan Government has specified 2,769 wells in 23 Wards as for the disaster well by 1995. In the Yokohama City, the registered well has reached 3,517 wells by 1995 and for each well, water quality check has been charged by monthly with an analytical standard as same as the municipal supply water. The Kokubunji City in Tokyo Metropolis has constructed old style well facility constituting with a hand



Fig. 6 Panel indicating citizen's cooperation well for disasters in Kobe city (Research Committee on Secure of Water in Huge Earthquake Disaster, 1999).

pump, street furniture and infiltration measure system. In total, 8 sets have been constructed in around the city by 1990 and the maintenance of the facility has been charged by the City Administration and Citizen's Prevention Committee.

Mapping of springs and wells for using groundwater in disasters emergency has been proceeding not only by the local government but also by citizens. It seems that like this map is very useful in the disaster emergency at the place where is covered by concrete jungles due to the urbanization.

Utilization of rainwater on the roof of households, which is led to the street furniture (water tank) with a hand pump is also spread in recently in Ward districts of Tokyo Metropolis for the purpose of using stored rainwater in the emergency as shown in Fig. 7. This type of street furniture, which collects rainwater for life water using, had been used in Japan already in the Edo era, more than 150 years before, as shown in Fig. 8. This picture shows the rainwater pail (bucket) existing in front of the house. It also can be seen that the Kanji (Japanese) of "Mizu (water)" is described on the surface of the pail. The rainwater using system has been introducing again in recently as an important self water source as well as groundwater source in the disaster emergency.

For the medical activities, to avoid the difficulty of special water transportation in the earthquake emergency, some hospitals have introduced a deep well facility as one of countermeasures, which can supply 80 % of drinking water at an ordinary time, with a membrane filtration system and a private power plant system. In case of Japan, total of 353 facilities with like those systems have been introduced by April 2004 including 116 hospitals (Sugimoto, 2004).

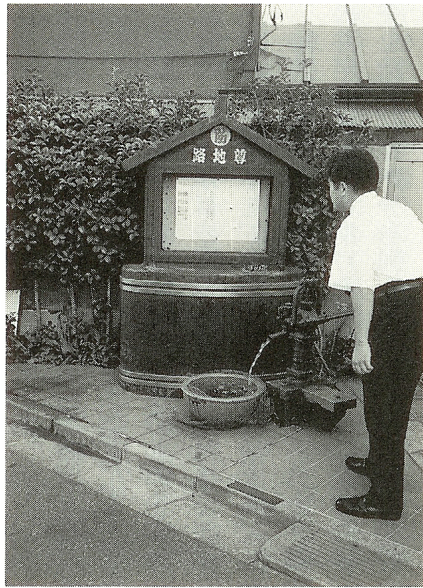


Fig. 7 Street furniture with a hand pump for using rainwater on roof in Sumida Ward, Tokyo (Kamiya et al., 1998).



Fig. 8 Rainwater pail (bucket) in Edo era (Kamiya et al., 1998).

Concluding Remarks

The results indicated that groundwater is very useful water source as the domestic water for toilet cleaning, which is one of big water use problems and needs a huge amount of water in the earthquake emergency. Groundwater is also useful water source than river or pond waters for the fire fighting as demonstrated in the case of Hanshin-Awaji earthquake. For the purpose of drinking and cooking, quality check of groundwater must be necessary at the ordinary time. Hand pumps or diesel or petrol-driven pumps have to be prepared for using groundwater in the emergency because the required electricity supply may not be available after the earthquake.

It makes clear that the registration system of citizen's well is launching by many Japanese local governments and mapping of springs and wells is also proceeding by local government or by citizens for using groundwater in emergency purposes. Some hospitals have introduced a deep well facility with a membrane filtration system and a private power plant system. Moreover, in recently, utilization of rainwater on the roof of households, which is led to a street furniture (water tank) with hand pump, is also spread in the Tokyo Metropolis for the purpose in emergency use.

Groundwater is a significant water source in an earthquake emergency. For this purpose, establishment of a continuous monitoring system of groundwater including its water quality is an urgently necessary matter, especially in the tectonic region in the world.

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