Flash Distillation

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Abstract

Japan has had an abundant amount of water and its advanced water system allows the citizens to have hot and cold water 24/7. However, it is said that these water systems, which is a major lifeline in daily life, will stop running after a catastrophic earthquake. Until roads can be cleared for help to arrive, it is up to these citizens to get safe water supplies for themselves. However, this is not such an easy case. It was proven in the 3/11 Eastern Japan Earthquake of how difficult it can be just to get the needed amount of water for each family. Thus, we promote this plan.
In our plan to build a water purification instrument for temporary evacuation shelters, we will apply the chemical engineering property of vacuum flashing to the resources available after a cataclysmic earthquake. Vacuum flashing is the heating of a liquid that, upon release to a lower pressure generated by a vacuum pump, undergoes considerable vaporization (flashing). Manual means of creating a vacuum environment will be a significant aspect of our plan and our primary objective is to simultaneously productively accumulate condensed water and preserve the heat necessary for flash vaporization.

Keywords

Flash distillation, earthquake, solar panel, evacuation shelter, water supply

Introduction

“You don’t know what you have until it’s gone”. We, the people in japan, are gifted with running tap water and sufficient sterile water for medical purposes, all thanks to Japan’s climate and good governance that improves water management. Therefore, Japanese civilians tend to take water for granted. They only come face to face with the absolute essentiality of water when they are denied access to it whether it is due to natural or synthetically generated obstructions. For this investigation, we focused on the lack of water, both for consuming and for medical purposes, in agricultural communes prone to isolation at times of natural disasters. We also took the super-aging society into consideration in the process of our investigation. We aim to ameliorate the status quo by introducing our plan proposal. The objective of this investigation is to ensure all residents of isolated agricultural communes are able to access safe, consumable water for minimum survival until help arrives.

1 The purpose of this investigation

The purpose of this investigation is to highlight the lack of variety in the methods of providing abundant water supply to all civilians after natural disasters, focusing especially on the delay of water arrival in isolated agricultural communes. While we were searching for the aftermaths of previous earthquakes in Japan, we were outraged to see that some people did not receive consumable water for weeks after the town or village’s isolation. We aim to utilize this investigation as an opportunity to reemphasize the necessity of water to those who take running water for granted. Furthermore, we desire to propose our plan to prefectures with high concentration of agricultural communes prone to isolation and with high probabilities of experiencing a cataclysmic earthquake within the next five decades. At last, our core objective is to introduce our plan to temporary evacuation shelters that will safeguard the health-related wellbeing of earthquake victims in the near future.

2 The method of this investigation

We researched, analyzed and interpreted data regarding agricultural communes, isolation, earthquakes, methods of water purification and methods of generating electricity. We then elucidated the issues behind Japan’s current strategy for supplying water to every citizen at times of natural disasters. Thoroughly comprehending the status quo of water distribution post-natural disasters, we propose to install flash distillation water purification systems in temporary evacuation shelter in such communes. After the Water is Life 2016 conference, we plan to visit actual agricultural communes that are at risk of becoming isolated to promote the execution of our water purification system.

3 Background research and analysis

3.1 Isolated Agricultural Communes

3.1.1 Prevalence

There are thousands of agricultural communes that are prone to becoming isolated due to natural disasters distributed all throughout Japan. A study shows that 29.3% of all agricultural communes are prone to isolation and thus, presents issues regarding the complex methods in which citizens can gain access to survival necessities post-isolation.

The following is a table, provided by a survey carried out by the Japanese Cabinet Office in 2009, which identifies the number of agricultural communes that are prone to isolation per province (Ministry of Agriculture, Forestry and Fisheries).

Table 1: The Prevalence of Isolated Agricultural Communes (per province; 2009)
(Ministry of Agriculture, Forestry and Fisheries)

Prefectures/Year	2005		2009		2013	
	Susceptible of isolation	Safe from isolation	Susceptible of isolation	Safe from isolation	Susceptible of isolation	Safe from isolation
Hokkaido	350	2730	336	2775	292	2777
Aomori	150	170	155	168	168	155
Iwate	230	1750	254	1767	294	1732
Miyagi	150	400	145	394	133	406
Akita	150	940	130	566	138	953
Yamagata	460	1600	443	1578	441	1617
Fukushima	350	1460	339	2474	230	2579
Ibaraki	50	280	81	294	67	308
Tochigi	250	770	257	786	249	806
Gunma	660	310	633	333	595	350
Saitama	150	330	173	342	204	311
Chiba	40	40	35	38	34	39
Tokyo	100	70	97	65	109	57
Kanagawa	100	40	112	32	109	38
Niigata	680	1050	677	1164	675	1157
Toyama	280	130	341	94	346	98
Ishikawa	180	240	169	252	179	242
Fukui	150	810	209	789	228	770
Yamanashi	450	910	493	915	494	922
Nagano	1320	2710	1276	2740	1163	2816
Gifu	440	1050	503	1063	514	8
Shizuoka	360	840	356	852	363	853
Aichi	510	210	485	243	494	236
Mie	300	130	315	122	320	117
Shiga	130	240	119	248	146	233
Kyoto	450	630	444	640	399	677
Osaka	120	80	120	78	114	84
Hyogo	410	1150	378	1193	376	1201
Nara	370	680	425	691	403	731
Wakayama	570	230	520	275	535	276
Tottori	120	780	117	781	100	796
Shimane	670	1430	625	1507	634	1497
Okayama	640	1840	432	2062	469	2047
Hiroshima	520	2370	1114	2513	729	2908
Yamaguchi	570	1380	551	1388	539	1416
Tokushima	370	700	442	623	449	616
Kagawa	160	640	157	641	174	824
Ehime	400	1300	425	1280	621	1120
Kouchi	830	390	887	339	948	317
Fukuoka	290	640	261	666	325	602
Saga	190	400	188	398	173	413
Nagasaki	250	1000	236	1016	210	1042
Kumamoto	850	1760	405	1693	417	1679
Oita	950	1320	854	1451	880	1434
Miyazaki	550	600	524	616	537	620
Kagoshima	120	1830	156	1798	204	1774
Okinawa	0	10	1	9	1	9
National number	17451	41318	17406	42141	17212	41532

Since the table does not give a visual representation of the concentration and disparity of isolated agricultural communes, the Cabinet Office has also provided a color-coded map of Japan (Ministry of Agriculture, Forestry and Fisheries).

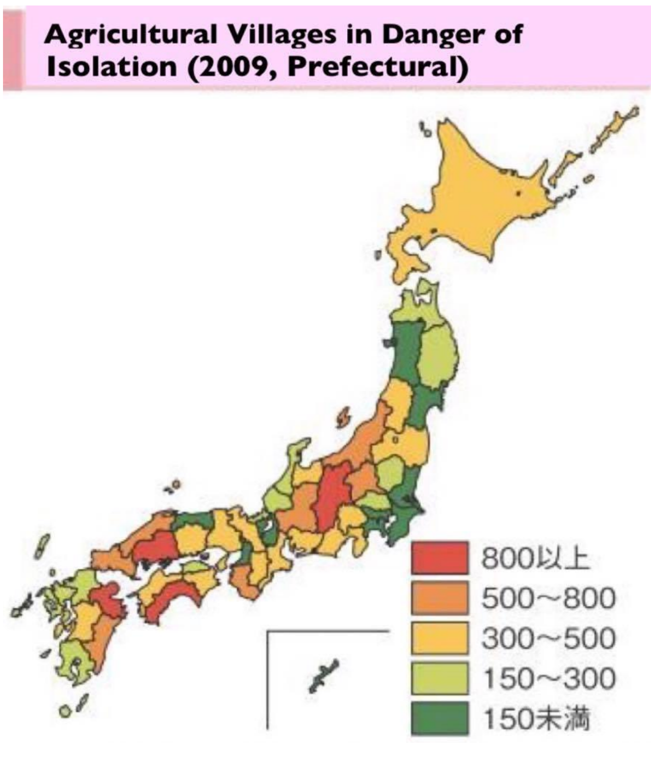

Figure 1: A map of Japan indicating the concentration of agricultural communes prone to isolation
(Per province; 2009)
(Ministry of Agriculture, Forestry and Fisheries)

The color-coded map provided by the Cabinet Office reveals that agricultural communes prone to isolation are concentrated in rural to suburban areas, specifically Nagano, Kochi, Oita, and Kumamoto provinces. In addition, agricultural communed prone to isolation are more prevalent in inland and southern coastal provinces facing the Philippines Sea.

3.1.2 Causes of Isolation

First and foremost, the Japanese government defines isolated communes as;

"Communes that suffer from difficulties or impossibilities of human mobility and distribution of materials due to the inability of four-wheeled automobiles to access by roads or marine traffic caused by the following reasons:

- blockages and damages to roads caused by earthquake or water damage-related landslides;
- road damage caused by earthquake or water damage-related liquefaction;
- roads flooded due to tsunamis;
- earthquake or tsunami damages to anchorages."

(Ministry of Agriculture, Forestry and Fisheries)

Therefore, this investigation will continue on the basis of this definition.

As is evident, the majority of the causes of isolation are direct consequences of large earthquakes. Furthermore, the following is a survey held in 17,212 agricultural communes that are prone to isolation, which was conducted by the Director-General for Policy Planning (Disaster Prevention) in 2005, 2009, and 2013, accordingly. The survey investigates which of the reasons listed in the definition above are the most common factors that cause the isolation of agricultural communes throughout the country.

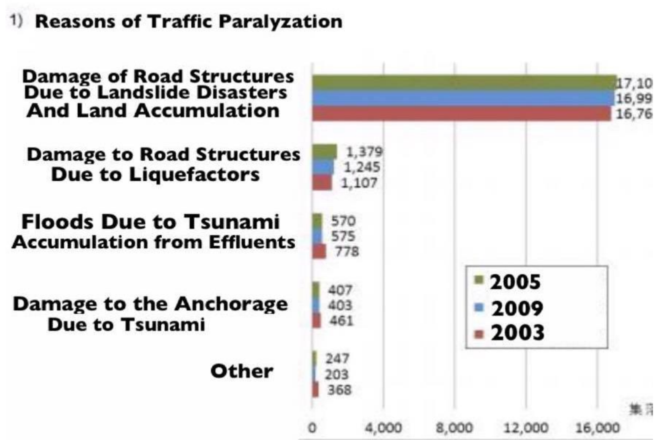

Figure 2: Common factors of isolation in agricultural communes
(2005 results green; 2009 results blue; 2013 results red)
(Ministry of Agriculture, Forestry and Fisheries)

3.1.3 Status Quo of Evacuation Shelters in Agricultural Communes

In order to shed light on the stretch supply lines of evacuation shelters and the lack thereof in the first place, we must first investigate, compare and contrast the status quo of the agricultural communes' population size and the issues that they face at times of natural disasters.

The following is the result of an investigation conducted by the Director-General for Policy Planning (Disaster Prevention) that aimed to gain accurate data regarding population size in agricultural communes all across Japan (Ministry of Agriculture, Forestry and Fisheries). When the investigation was carried out in 2007, 13.3% out of the 17,212 communes that provided data claimed to have had less than 25 residents, 14.6% had 26 to 50 residents, 19.0% had 51 to 100 residents, 16.8% had 101 to 250 residents, 4.8% had 251 to 500 residents, 1.7% had more than 501 residents and the rest (29.7%) answered uncertain. The same investigation was carried out in 2013 accordingly and the results consisted of 17.4% out of the 17,212 agricultural communes subjects answered to have had less than 25 residents, 16.6% had 26 to 50 residents, 18.3% had 51 to 100 residents, 16.0% had 101 to 250 residents, 4.1% had 251 to 500 residents, 1.6% had more than 501 residents and the population of the remaining communes (26.0%) remained uncertain.

3.1.3.1 Prevalence of Evacuation Shelters

The following graph shows the number of evacuation shelters in agricultural communes.

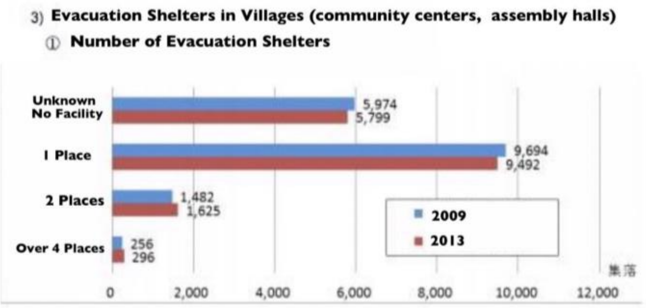

Figure 3: The prevalence of evacuation shelters in agricultural communes
(2007 results in blue, 2013 results in red)
(Ministry of Agriculture, Forestry and Fisheries)

This survey was last conducted in 2013 and it reveals how most agricultural communes are oftentimes not efficiently prepared for a catastrophic natural disaster. Out of the 17,212 commune subjects, 33.7% claimed to not have any evacuation shelters in their agricultural commune, 55.1% claimed to have 1, 9.4% claimed to have 2~3, and the remaining 1.7% claimed to have four or more.
The following scientific method proves that the number of evacuation shelters in agricultural communes is not enough to assure the safety of all of its residents in times of natural disasters.

Hypothesis:

The number of evacuation shelters is not enough to safeguard the entire population.

Definitions:

We will assume that the middle of the range in the data for the populations of agricultural communes is equivalent to the average within that range.
We will assume that a single evacuation shelter can efficiently shelter up to 50 people.

Data:

Table 2: The percentage of the population that will find refuge in evacuation shelters

	None (33.7%)	1 Shelter (55.1%)	2-3 Shelters (9.4%)	4< Shelters (1.7%)
13 Residents (23.5%)	0.0%	100.0%	100.0%	100.0%
38 Residents (22.4%)	0.0%	100.0%	100.0%	100.0%
75 Residents (24.7%)	0.0%	66.7%	100.0%	100.0%
175 Residents (21.6%)	0.0%	28.6%	57.1%~ 85.7%	100.0%
375 Residents (5.5%)	0.0%	13.3%	26.7%~ 40.0%	53.3%<
750 Residents (2.2%)	0.0%	6.7%	13.3%~ 20.0%	26.7%<
<Average> 78 Residents (100.0%)	0.0%	64.1%	100.0%	100.0%

*The data from agricultural communes that answered the population size as uncertain has been removed.

This data shows that agricultural communes prone to isolation with a population size larger than 75 people are not able to guarantee the safety of all of their residents.

Therefore, the hypothesis stands.

3.1.3.2 Water Supply in Evacuation Shelters

Water is necessary for survival. Thus, it ought to be mandatory for all evacuation shelters to constantly have a stock of bottled water or install a water purifier that can create water that is safe to drink. However, an investigation executed in 2013 revealed that only 5.0% of all agricultural communes claimed to have an evacuation shelter within its borders that have abundant supplies of bottled water, as shown in the graph below (Ministry of Agriculture, Forestry and Fisheries).

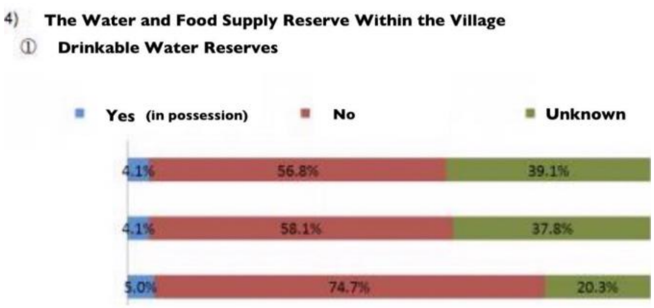

Figure 4: Bottles water in evacuation shelters
(Ministry of Agriculture, Forestry and Fisheries)

Furthermore, 62.7% of the communes with water supplies estimate that the supply of bottled water will not last a day if

there’s a demand from more than 50 people (Ministry of Agriculture, Forestry and Fisheries).
The results of the same survey also showed that in 2013, only 361 agricultural communes out of 17212 (2.1%) had installed water purification systems (Ministry of Agriculture, Forestry and Fisheries). Even if an evacuation shelter claimed to have installed water purification systems, 62.9% only have one machine installed, which for most cases cannot purify water with impurities larger than 1.0mm in diameter (Ministry of Agriculture, Forestry and Fisheries).

3.1.3.3 Emergency Electricity in Evacuation Shelters

Nowadays, most of the technologies accountable for our daily necessities are dependent on electricity. Methods of communication, safeguarding health, and getting proper access to the appropriate help are all necessary actions in times of natural disasters that rely heavily on the usage of electricity. Thus, to secure an emergency power source should be prioritized by evacuation shelters. However, the status quo begs to differ. The following table shows the results of a survey conducted by the Director-General for Policy Planning (Disaster Prevention) that aimed to investigate how many evacuation shelters in agricultural communes have access to an emergency power source (Ministry of Agriculture, Forestry and Fisheries).

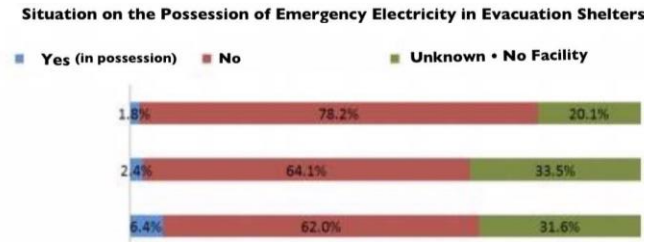

Figure 5: Emergency power supply in evacuation shelters (Ministry of Agriculture, Forestry and Fisheries)

In 2005, 1.8% (306 communes) of all evacuation shelters claimed to have access to an emergency power source and the percentage grew to become 2.4% (423 communes) by 2009. The percentage grew at a rapid pace from 2009 to 2013 and reached 6.4% (1096), the growth of which may have been perhaps influenced by the devastating consequences of the Great Tohoku Earthquake Tsunami that occurred in 2011.
The Director-General for Policy Planning (Disaster Prevention) further analyzed the lack of access to emergency power source in evacuation shelters by conducting a survey directed specifically towards the 2.4% (in 2009) and 6.4% (in 2013) of evacuation shelters that ensured a secondary power source. The survey asked each subject evacuation shelter how many consecutive hours the emergency power source could generate power for. Below is a graph showing the number of hours the emergency power source can generate power for.

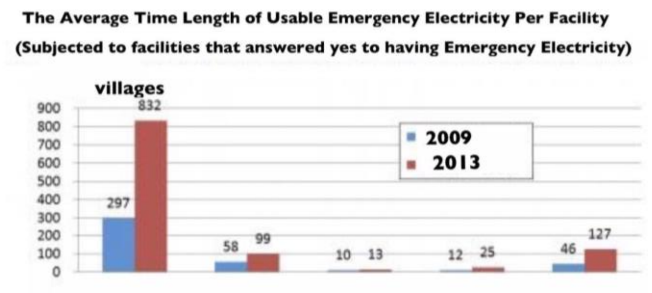

Figure 6: Usage length of emergency power sources (Unit: hours)
(Ministry of Agriculture, Forestry and Fisheries)

This graph shows that out of the 1096 communes that had evacuation shelters with access to emergency power sources, 832 communes (75.9%) only have power sources that can generate electricity for less than a consecutive 24-hour period. Furthermore, 99 communes (9.0%) answered 24~47 hours, 13 communes (1.2%) were 48~71 hours, and 25 communes (2.3%) claimed to be able to generated power for more than a consecutive 72-hour period. The remaining 127 communes (11.6) answered that they were not sure of how long the power source would be able to continuously generate electricity for (Ministry of Agriculture, Forestry and Fisheries).
The results of these surveys reveal that most evacuation shelters in agricultural communes do not ensure access to an emergency power source; or cannot rely on generated electricity for long even in the case that the shelters are equipped with secondary power generators. Therefore, our plan proposal comes with a method to generate power consecutively and efficiently.

3.2 Earthquakes

Five years ago, a catastrophic Magnitude 9.0 earthquake shook Eastern Japan on March 11, with an epicenter approximately 70 kilometers east of the Oshika Peninsula of Tohoku and the hypocenter at an underwater depth of approximately 30 kilometers. The earthquake unleashed a savage tsunami on the shores of Tohoku, leaving rubble and death in its wake. This event led to the level 7 nuclear meltdown of Fukushima Daiichi Nuclear Power Plant, which released radiation throughout the world. Presently it is reported that over 19,000 people lost their lives by the earthquake, and over 400,000 buildings were damaged. The picture below portrays the catastrophic results of the 2011 Great Tohoku Earthquake and Tsunami.

Figure 7: 2011 Great Tohoku Earthquake and Tsunami

As a result of the nuclear power plant accident, the government issued certain areas that prohibit people from returning home. Although five years has passed, there are still many places that are still in the “difficult-to-return” zone, in which people are discouraged from staying for long periods of time for health reasons. The 470,000 survivors were forced to live in small, unsatisfactory temporary shelters, and to this day, there are still hundreds of families that are unable to live in a proper home.
Moreover, in smaller villages, roads were blocked due to landslides, and many were damaged from the earthquake. This caused many villages to become isolated, and it took several days to a whole week for the government to send rescue teams and bottled water to the citizens seeking refuge. Unfortunately, those several days were crucial for these citizens, as they need to find a source of water that clears the minimum requirements for consumable water in order to safeguard their health. Although humans can survive two weeks without food, they can only live for an average of three days without water. We must also emphasize how evacuation shelters oftentimes do not have enough water supplies for all citizens to survive until the roads are cleared for water supplies to come through. Water from natural resources isn’t purified, and thus the lack of sanitation of water quality can be detrimental to the health of survivors.
It is predicted that in there is a 70% chance that an earthquake over Magnitude 8.6 will occur in the Kanto area within the next 30 years. The map below shows the percentage of encountering an earthquake larger than Magnitude 8.6 in the next 28 years, classified by geographical locations (The Headquarters for Earthquake Research Promotion).

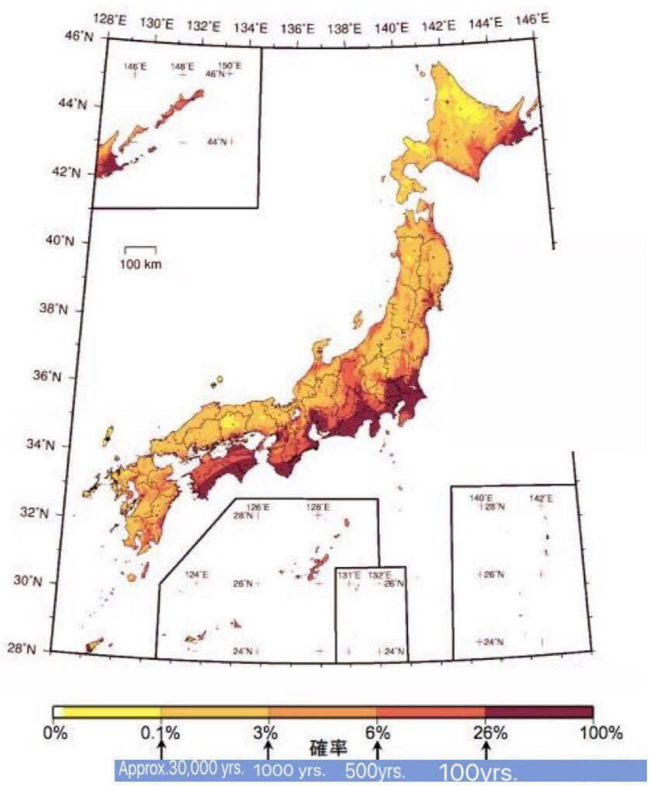

Figure 8: Percentage of encountering an earthquake larger than Magnitude 8.6 in the next 30 years, by location (2014) (The Headquarters for Earthquake Research Promotion)

In preparation for large-scale damages, citizens, especially those in smaller villages, need to prepare in order to survive (Veolia Water Technologies)the next few days until the government can send help if isolation occurs. According to government reports, it is assumed that the earthquake will occur by the movement between the Philippine Sea Plate and the North American Plate. The expected economic damage by the earthquake is 112 trillion yen. This earthquake will cause major losses and it is the government’s role to protect its citizens. In order to do so, there is a need to set the flash distillation system to these agricultural villages in danger of isolation.

3.3 Water Quality

3.3.1 Safe Water Standards

3.3.1.1 Normal Circumstances

In developed countries, citizens use the public water supply system every day, and life without it is almost impossible to imagine. Japan is especially known for its high standards of clean water, and water can be drunk straight from the faucet. However, after a catastrophic earthquake, it is almost inevitable that the public water system will be razed and unusable. Thus, the survivors will have to be the judge of which water is drinkable and which is not.
Normally, the Japanese water systems have certain conditions in which the water has to meet in order to be sent throughout the country. The definition for water quality standards based on the methods the WHO uses for the water quality standards in terms of drinking water, and even if humans consume multiple doses of water from the same source it will not negatively affect the human body. Those conditions are extremely detailed, ranging to substances from factories such as mercury, to natural substances such as calcium and magnesium. The following table is an extract of some of the conditions the Bureau of Waterworks Tokyo Metropolitan Government has set for the water supply that is distributed around the prefecture.

Table 3: Conditions of safe water (Tokyo Prefecture) (Bureau of Waterworks Tokyo Metropolitan Government)

Conditions	Standard Amount
1. General Bacteria	under 100 colonies in 100mL of sampled water
2. Escherichia coli	none
3. Cadmium and its compounds	less than 0.01mg/L
4. Mercury and its compounds	less than 0.0005 mg/L
10. Nitrate-state nitrogen, as well as nitrite nitrogen	less than 10mg/L
32. Zinc and its compounds	less than 1.0mg/L
33. Aluminum and its compounds	0.2mg/L
34. Iron and its compounds	less than 0.3mg /L
35. Copper and its compounds	less than 1.0mg/L
36. Sodium and its compounds	less than 200mg/L
37. Manganese and its compounds	less than 0.05 mg/L
38. Chloride ion	less than 200 mg/L
39. Calcium, Magnesium, cause of hardness	less than 300mg/L
45. Phenols	0.005mg/L converted to the amount of phenol
46. Organic matter (TOC)	less than 5mg/L
47. pH	over 5.8 under 8.5
48. Taste	no abnormalities
49. Odor	no abnormalities
50. Color	under 5 degrees
51. Transparancy	under 2 degrees

From these conditions it can be said that there are a lot of substances that are pernicious to the human body, and in order to protect the citizens from these threats the government is thoroughly purifying the water. For an example, the amount of cadmium that is allowed in water is 0.003mg/L (Bureau of Waterworks Tokyo Metropolitan Government). This substance comes from industrial wastewater and mines, and has caused pollution-related diseases such as the “Itai-Itai disease” which became a national public health issue in the late 20th century in Japan. Water is something that people cannot go without in their lives and in order to keep the citizens healthy it needs to be as clean as possible.

3.3.1.2 In case of natural disasters

Regarding the issue of securing safe water in natural disasters, specifically earthquakes, the solution would be ideally simple if the public water system were safe after a large earthquake; however that is nearly impossible. Moreover, it became very clear in the 2011 Great Tohoku Earthquake that finding drinkable water resources was difficult in such situations, especially in communes prone to isolation. In order to survive the few days or weeks in which disaster aid organizations cannot reach the aforementioned communes prone to isolation, the survivors must know how to judge the conditions of consumable water without risking side effects or ingesting harmful substances found in unpurified water. The following table lists the minimum conditions of safe, drinkable water. For the purposes of simplifying this investigation and the implementation of our plan, the conditions listed here will act as the minimum requirements for our water distillation system.

Table 4: Minimum requirements for consumable water

Conditions	Inhibitory Factors
Colorless	Iron (Fe), Manganese (Mn), Copper (Cu), Zinc (Zn), Organic Matter, etc.
Transparency	Waste products, Iron (Fe), Manganese (Mn), Copper (Cu), Zinc (Zn), Clay particle, Organic Matter, etc.
Tasteless	Iron (Fe), Manganese (Mn), Copper (Cu), Zinc (Zn), Organic Matter, Sodium, Hard water, etc.
Odorless	Anaerobic bacteria, Hydrogen sulfide, Moss, Organic Matter, etc.

3.3.2 Methods of Purifying Water

In a catastrophic earthquake, water resources are crucial for survival. However, in isolated agricultural communes, there is a high probability of the water system being damaged, and becoming unusable. Because there is no working water system, there are no ways to cleanse water of its bacteria and waste that will be mixed in the water. As a result, judging whether the water is drinkable or not will be judged by the finder’s senses; sight, smell, and taste. However, it is not always the case that humans can find water that is safe enough to drink. Thus, there are several ways to clean the water people have obtained, such as distillation, filtration, and disinfection. However, even though each option has its advantages, there are still many problems that they face in terms of survival.

Table 5: Comparing methods of purifying water
(Hygienic Chemistry Division Human Life and Science Research Facility; Solar Power Generation's Ecological Reparation; The Headquarters for Earthquake Research Promotion)

表　浄水方法の比較

除去対象		蒸留	布/紙濾過	消毒		浄水器	
				煮沸	薬剤	中空糸膜	活性炭
微生物	原虫類	◎	△	◎	○	◎	×
	細菌	◎	×	◎	◎	◎	×
	ウイルス	◎	×	◎	◎	△	×
有害物質	重金属	◎	×	×	×	△	×
	農薬類	○	×	×	×	×	△
不快成分	濁り	◎	△	×	×	◎	×
	色	◎	×	×	×	×	○
	味	◎	×	×	×	×	○
	臭い	○	×	×	×	×	○
	消毒薬	◎	×	○	−	×	○

◎ ほぼ完全に除去又は不活性化できる　△ 一部が除去又は不活性化できる
○ 大部分が除去又は不活性化できる　× 全く除去又は不活性化できない

Filtration is a system where water is filtered through a sort of membrane in order to get rid of dirt, sand, and other foreign objects in the obtained water. While it is very easy to use and effective in cleaning water of its basic rubbish, it is completely ineffective in terms of bacteria and pesticides. Thus, the core reason for the inability to drink straight water cannot be resolved. When in need of purified water, filtration should be paired with another option in order to completely cleanse it.
There are two ways in which one can sterilize water; the first option is using sterilization pills, and the second is boiling water. Compared to the latter, which takes time and cannot sterilize a large amount of water at the same time, the former is cheap to buy and can sterilize large amounts of water efficiently. However, using these medical products can be difficult as not having enough cannot kill enough bacteria and using too much can be detrimental to the drinker’s health. Moreover, it cannot get rid of heavy metals or pesticides, which are harmful to the human body.
Compared to these two options that are mainstream nowadays, distillation can kill bacteria and can rid the water of heavy metals and pesticides. It does not affect the taste of water and can be used with any kind of water that can be found within isolated villages. Because the distillation apparatus is fairly large, it is fit for being placed at evacuation shelters, and since the water is completely safe, this can be used by people of all ages.

4 Our proposal

Given the lack of emergency water supplies in agricultural communes prone to isolation under the status quo, the high probability of Japan encountering an earthquake larger than Magnitude 8.6 in the coming 3 decades, and the inability for natural disaster aid forces to provide safe water for all persons within a few days, we propose to install our flash distillation water purification system in one evacuation shelter (or a public facility in the case that there are no evacuation shelters) for each agricultural commune that is a subject of our plan. Our plan was inspired by the mechanics behind the Multi-Stage Flash Distillation (MSFD), a cutting-edge seawater desalination technology that produces 60%of the world’s desalinated seawater.
Our water purification system also aims to produce safe water for medical use (Veolia Water Technologies).

4.1 Assumptions

In order to calculate the effectiveness of our flash distillation water purification system, we have set concrete assumptions in order to elucidate the advantages and aftermaths of implementing our plan proposal in agricultural communes that are prone to isolation. Our calculations are based on the following assumptions:

1. That the plan will be implemented in an agricultural commune prone to isolation with a population size of 75,
2. That there will be an average of 7 hours of sunlight per day,
3. That the system will run for 7 hours every day,
4. That Drum A holds 120L of water,
5. That Drum B holds 110L of water,
6. That the provided agricultural water consists of 2.5215(mg/L) of foreign substances, excluding large substances such as dirt, and because the number is so infinitesimal we consider it insignificant,
7. That the room temperature is 25.0 degrees Celsius,
8. That the subject commune is not at risk of a tsunami,
9. That 1 individual needs around 0.89L (30 ounces) of water to sustain health,
10. That π equals 3.14,
11. That $1.0m^2$ of solar panels is equal to 1kWh,
12. That the average solar panel is capable of generating 15% of the energy,
13. That 90% of the energy of the water vapor from Drum A is transferred to Drum B through Pipe B.

We have investigated the rate of evaporation, the necessary kWh to power the device and many other specific calculations to substantiate the effectiveness and practicality of our flash distillation water purification system.

4.2 Subjects of our Plan Proposal

We have compared Figure 1 and Figure 8 in order to determine the subjects of our plan proposal. In short, we aim to implement our flash distillation water purification system in prefectures with high concentration of agricultural communes prone to isolations as well as a high risk of encountering an earthquake larger than magnitude 8.6 in the coming 30 years. The following is a map depicting the subjects of this plan, red areas to be prioritized over the orange areas.

Figure 9: Subjects of our flash distillation water purification system (prefectures)

The red consists of Miyazaki, Oita, Ehime, Kouchi, Kagawa, Tokushima, Wakayama, Mie, Aichi, Shizuoka, and Nagano prefectures. The prefectures identified in red are generally located on the southern border of Japan and faces the North Pacific Ocean, or the Philippine Sea to be precise. The orange consists of Tokyo, Kanagawa, Chiba, Ibaraki, and Hokkaido.

4.3 Blueprint

The following diagram is the blueprint for our water purification system.

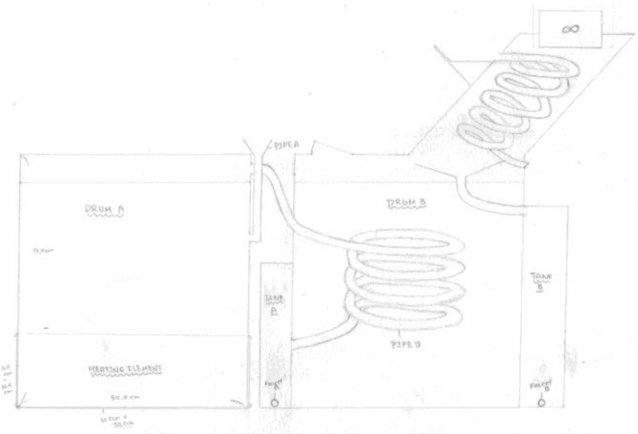

Figure 10: A blueprint of our flash distillation water purification system

The width, length and height are all measured in centimeters, water volume in liters, evaporation rate in liters per hour, air pressure in hPa, energy in kW, and temperature in degrees Celsius. Drum A is where the water will boil at the normal boiling point of 100 degrees Celsius and the product (the water vapor) will heat the water in Drum B. Drum B is the site of the flash distillation.

4.4 Calculations

4.4.1 Drum A

The measurements of Drum A are as follows;
Height=55.0cm, Length=50.0cm, Width=50.0cm
Since the volume of water in Drum A is 120 liters, as concreted by assumption 4, 48.0cm above Drum A's bottom will be the water surface level.
Therefore,

$$50.0(L) * 50.0(W) * 48.0(H) = 120{,}000cm^3 = 120L$$

Weight of consumable water:

$$120L = 120{,}000g$$

In our water purification system, Drum A will produce 18.0 liters of safe water per hour, which is equivalent to 18,000g/h.

Since the heat of vaporization for water at 100 degrees Celsius is 2254J/g, Drum A needs 2254J to transfer 1.0 gram of water at 100 degrees Celsius into water vapor. The temperature of the water vapor is also 100 degrees Celsius because the water and the water vapor are in direct contact.

Therefore, the energy needed to vaporize 18000 grams of water per hour can be calculated by the following equations.

$$2254\, J * 18{,}000\, g = 40{,}572{,}000\, J/h$$

$$40{,}572{,}000\, J/h\ /\ 3600 = 11270\, J/s$$

Thus, Drum A requires 11270J per second in order to effectively produce 18.0 liters of safe water per hour. 11270J/s is equivalent to 11270W.

The heating element that heats Drum A must transfer 11270W to the water inside Drum A.

However, the heating element must heat the water inside Drum A to reach its boiling point of 100 degrees Celsius before it can start to constantly produce 18 liters of safe water per hour.

The energy needed to bring the water inside Drum to the boiling point is 37800000J, as calculated by the following formula.

$$(100 - 25) * 120000\, g * 4.2 = 37800000\, J$$

Since the heating element transfers 11270W, water is Drum A will require 0.93 hours to reach 100 degrees Celsius.

$$37800000\, J\ /\ 11270\ (J/s) \approx 3354\, s = 0.93\, h$$

As stated in assumption 3, the system will run for 7 hours per day. However, Drum A will produce safe water for 6.07 hours since it requires 0.93 hours to setup.

In conclusion, Drum A is capable of producing 109.26 liters of safe water per day, as calculated in the following equation.

$$18\, L/h * 6.07\, h = 109.26\, L/day$$

4.4.2 Drum B

The measurements of Drum B are as follows;
Height=55.0cm, Length=50.0cm, Width=50.0cm
Since the volume of water in Drum B is 110 liters and Pipe B's volume is $10000cm^3$, 48.0cm above Drum B's bottom will be the water surface level.
Therefore,

$$50.0(L) * 50.0(W) * 48.0(H) - 10000cm^3 = 110{,}000cm^3 = 110L$$

Weight of consumable water:

$$110L = 110{,}000g$$

In our water purification system, Drum B will use heat from Drum A's water vapor in order to raise the temperature from 25 degrees Celsius to 60 degrees Celsius.

The energy required for water in Drum B to reach its boiling point at 60 degrees Celsius is 16170000J.

$$(60 - 25) * 110000\, g * 4.2 = 16170000\, J$$

For every gram of water vapor that passes through Pipe B, 2422J/g will be released.

$$2254\, J/g + 4.2 * (100 - 60) = 2254 + 168 = 2422\, J/g$$

As stated in assumption 13, 90% of that energy will be transferred directly to Drum B.

$$2422\, J/g * 0.9 = 2179.8\, J/g$$

Since 5 grams of water vapor releases energy in to Drum B per second, Drum B receives 10899J per second.

$$2179.8\, J/g * 5.0\, g = 10899\, J/s$$

The water in Drum B will use this energy to reach its boiling point at 60 degrees Celsius, lowered significantly by the vacuum pump.

Since the heat of vaporization for water at 60 degrees Celsius is 2356 J/g, Drum B needs 2356 J to transfer 1.0 gram of water at 60 degrees Celsius into water vapor. The temperature of the water vapor is also 60 degrees Celsius because the water and the water vapor are in direct contact.

Therefore, for every gram of water vapor from Drum A that releases energy into Drum B, 0.925g of water will vaporize.

$$2179.8\, J/g\ /\ 2356\, J = 0.925\, g$$

Since Drum A produces 18000 grams of water vapor per hour, Drum B will produce 16653 grams (around 16.7 liters) of safe water per hour.

$$18000\, g/h * 0.925 = 16653\, g/h \approx 16.7L/h$$

Now, we must calculate how many hours Drum B can produce 16.7 liters of safe water for.
In order to do so, first we must calculate the time needed for the water in Drum B to reach its boiling point.

$$16170000\, J\ /\ 10899\, J/s = 1483.65\, s = 0.41\, h$$

We must add the 0.93 hours needed by Drum A to reach boiling point to 0.41 hours in order to figure out the setup time for Drum B.

Therefore, Drum B can run for 5.66 hours since the water in Drum B requires 1.34 hours to reach the boiling point.

In conclusion, Drum B is capable of producing 94.3 liters of safe water per day, as calculated in the following equation.

$$16653\, g/h * 5.66\, h = 94255.98\, g/day \approx 94.3L/day$$

4.4.3 Drum A and Drum B Total

In total, Drum A and Drum B combined will produce around 204 liters of safe water per day.

$$94.3L/day + 109.26L/day = 203.56L/day \approx 204L/day$$

4.4.3 Heating Element

The heating element that surrounds the bottom half of Drum A is responsible for heating the water to its boiling point, which is 100 degrees Celsius.

The heating element must be capable of transferring 11270W to Drum A.

We will use a thin film heater that has the following specifications in our instrument (Ultra-thin Film Heater).
Heat Resistant Temperature=180 degrees Celsius
Maximum W Density=2.0W/cm^2
Heater Thickness=0.2mm

Since 11270W is needed to heat the water, the film must cover 5635cm^2 of Drum A. Therefore, the instrument will require four 16.0cm∗50.0cm films and one 50.0cm∗50.0cm film to heat Drum A.

4.4.4 Vacuum Pump

At the same time, the vacuum pump connected to Drum B requires electricity as well. The specifications of the vacuum pump used in our plan are as follows.
Ultimate Pressure=149.4mmHg
Electric Motor=100V, 200W

4.4.5 Solar Panel

The heating element requires 11270W and the vacuum pump uses 200W. Therefore, the solar panels in place must generate 11470W. According to assumptions 11 and 12, our instrument requires the placement of solar panels with the total surface area being 76.5m^2.

$$11270W \ / \ 150W = 76.5$$

5 Conclusion

The status quo of the government's methods of distribution drinking water to residents of isolated agricultural communes poses issues that may put a victimized civilian's health at risk. Therefore, we thought it was absolutely necessary for a new water purification system to be installed in temporary evacuation shelters in such communes. Our flash-distillation water purification system is efficient because running the instrument for a full day will produce enough consumable water for all residents for a period of two to three days while leaving extra water for medical use. Furthermore, it does not require menial labor because we have designed the instrument while answering to the physical challenges of the elderly. Through this investigation, our core objective was to ensure that all residents of isolated agricultural communes are able to access safe, consumable water for minimum survival until help arrives. We believe that our plan proposal to install the flash distillation water purification system can be the next step towards ensuring access to water in times of disasters for all.

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