ELSEVIER

Desalination 251 (2010) 233–240

DESALINATION

www.elsevier.com/locate/desal

Rainwater harvesting as a sustainable water supply option in Banda Aceh

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Received 31 January 2008; revised accepted 15 May 2008

Abstract

In this case study, we investigate the applicability of rainwater harvesting as a sustainable water supply option in Banda Aceh, Indonesia, an area severely hit by the tsunami in 2004. Due to technical and geographical factors, the local residents spend approximately 16% of their incomes on the purchase of water. For this reason, a new, economical, and sustainable way of obtaining water is a most important and urgent concern. A team from Seoul National University recently developed and installed several rainwater harvesting systems in the area in January 2007 and 2008, focusing particularly on increasing public awareness of rainwater harvesting and capacity building in Banda Aceh. This paper discusses the general public perceptions, installation methods, and viability of the system. We found that rainwater harvesting, accompanied by an increase in public awareness and appropriate education, can best serve the needs of the community.

Keywords: Rainwater harvesting; Sustainable water supply; Tsunami-devastated area

1. Introduction

Safe water supply is the main concern in development assistance projects in developing countries because it is the fundamental and most essential requirement for establishing and maintaining a healthy life.

For technical, geographical, and economic reasons, many of the local residents in Banda Aceh did not have access to a safe water supply even before the tsunami struck in 2004. Since the tsunami the situation has become far worse. Problems exist with the area's current water supply options, such as the central water supply system, wells, and a desalination plant. The local people do not enjoy access to a reliable and safe water supply. For example, in case of the central water supply system, prior to the tsunami the coverage was never broad enough to provide water to the all local residents, but today even fewer people have access to tap water because the pipes were damaged during the

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Presented at the Water and Sanitation in International Development and Disaster Relief (WSIDDR) International Workshop Edinburgh, Scotland, UK, 28–30 May 2008.

doi:10.1016/j.desal.0000.00.000

Table 1
Interview result about the water status in Gano Village

	Age	Number of family members	Water source	Monthly Water costs (in rupiah[a])	Water costs as a percentage of household income (%)
1	32	6	W	0	0
2	37	3	T, B	144,000	24
3	50	9	B	600,000	25
4	39	7	B	500,000	20
5	36	5	W, B	50,000	10
6	23	5	T, B	n.a.	20
7	39	9	T, B	30,000	5
8	32	8	B	400,000	20
9	44	5	W, B	120,000	10
10	34	4	W, B	n.a.	n.a.
11	41	7	B	n.a.	20
12	40	3	W, B	30,000	n.a.
13	42	6	B	500,000	20

W, well; T, tap water; B, bottled water.
[a] The exchange rate of Indonesia rupiahs to US dollars is 0.0001091 as of 1 February 2008.

tsunami. Wells either were contaminated or became highly saline because of the tsunami.

There is, therefore, an urgent need to promote alternative water supply options to the traditional water sources, taking into account the current status of the water supply, and technical, geographical, and economic conditions in Banda Aceh.

We found that a rainwater harvesting option is a very suitable method for providing water to the local residents in the area, for the following two reasons. First, Indonesia has good meteorological and geographical characteristics for rainwater harvesting. The annual rainfall is 2263 mm and it tends to be distributed evenly throughout the year, without distinct differences between the dry and wet seasons. Since the tsunami, the difference appears to be even less significant. Second, the experience we gained during a rainwater harvesting demonstration project there in 2007 supported the idea of promoting rainwater as an alternative water supply option. During that project, we, a team of students from Seoul National University, installed three rainwater harvesting systems in the area for the first time, one at a private house, one at a kindergarten, and one at a health center. At the time of the installation, the owners of each of the facilities were very satisfied with the performance of the systems. More details on this can be found in the cover article of the IWA magazine, Water 21 [1].

In January 2008, we undertook a second visit to Gano Village in Banda Aceh and made checkup of the systems installed in 2007 and installed three more rainwater harvesting systems. The main objective of this second visit/project was not to build more rainwater harvesting systems but rather to investigate more fully the viability of rainwater harvesting as an alternative option for water supply. To this end, we focused on how to disseminate the idea of rainwater harvesting effectively. This paper describes the general status and public perceptions concerning various water supply options as well as our practice of installing rainwater harvesting systems and the installation process of these systems in Banda Aceh, Indonesia.

2. The status of water sources and costs

To investigate the current status of water usage in the area, 13 local residents were interviewed about their water sources and how much they spend on water. The interviewees were selected randomly and asked the same questions relating to these issues.

Table 1 briefly identifies the interviewees in terms of their age and the number of family members and tabulates the status of their water usage. As shown in the table, all interviewees except one are heavily dependent on bottled water either for drinking only or for drinking and other purposes. According to the respondents, the main purpose of bottled water is for drinking. However, because the quantity of water from taps or wells does not meet their demands, many also have to purchase water for other purposes such as taking a shower and washing clothes, tasks that do not require high quality water. According to the interviewees, whenever the water pumps do not function properly because of frequent electrical shortages, obtaining tap water is often unreliable two or three days a week (almost half of the time). Therefore, they tend to collect and store water from taps or wells in containers whenever water is available, and then use this stored water.

Based on the results of the interviews, approximate calculations were made to estimate the economic costs per household of purchasing bottled water. As expected, those without both tap water and wells face higher water costs, which accounts for a considerable part of their incomes; it ranges from 20% to 25% of their incomes. Those who have access to either tap water or wells tend to spend relatively less, but the water costs are still high considering the level of their incomes. A remarkable finding to emerge from this study is that it appears that these people are so used to spending that much money on water that they take the high water costs for granted, and do not actively try to find ways to reduce the costs or find another source of water supply, such as rainwater harvesting. Therefore, if the performance of the rainwater harvesting systems is successful and efficient, and the local community becomes truly aware of its financial benefits, the concept and use of rainwater harvesting will spread rapidly, even without any external forces.

3. Public perception of various water sources

Before we promote rainwater harvesting in the area, it is important to know how the local residents feel about this concept, i.e., whether they are aware of the opportunity of utilizing rainwater, and, if they are, whether or not they feel positive about it. Depending on the level of their understanding, we need to take appropriate actions such as offering seminars to increase public awareness, and education or training to disseminate rainwater harvesting in a more effective way. The following is a brief summary of the interviews carried out to determine public perceptions of different water sources in the area. Generally, people expressed the most faith in bottled water, followed by wells, tap water and rainwater, in that order.

3.1. Bottled water

Bottled water is the major source of water used for drinking in the area. If they can afford it, most of the interviewees use only bottled water for drinking purposes, even when other water sources such as wells and tap water are available. In particular, they tend to prefer brand-named bottled water for drinking, even though it is more expensive than others.

Another popular type of water similar to bottled water in the area is *refilled water*. It is a plastic container refilled with water and sold at water shops. It is cheaper than regular bottled water; it sells at approximately 4000 rupiah per gallon. Some people purchase the water at the shops, and others buy it when a truck with refillable water containers comes to the town to deliver it. We found that many of the people who do not have access to wells or tap water prefer refilled water to regular brand-named bottled water because of the lower price. The problem with the refilled water is that the source of the water is not well known. However, people who use the refilled water displayed high trust in its quality.

3.2. Tap water

People in developed countries tend to have greater trust in the quality of tap water than in other natural water sources such as wells or groundwater, because tap water is physically and chemically treated to be safe for human health. However, local residents in the area are skeptical about the quality of their tap water, for the following three reasons. First, this skepticism stems from a distrust of the government; people believe that the government is corrupt and does not fulfill its responsibilities properly; hence they think tap water is not good enough to be used for drinking or cooking. The second reason arises from their misunderstanding (or ignorance) of water treatment processes. Some of the interviewees displayed an aversion to the use of chemicals. They think that adding chemicals to water is unsafe for their health and that natural water from wells is much safer and cleaner—which is a great misconception. Lastly, the tap water service in this area is unreliable. As explained above, frequent electrical shortages result in the water pumps, which are needed to deliver water to the taps, not operating from time to time. This unreliable service contributes to the impression that the general quality of the tap water is also inferior.

3.3. Well water

Wells are the most popular source of water in Banda Aceh, but, due to its geographical characteristics, this is not the case in Gano Village where we installed the rainwater harvesting systems. Gano Village is by the seaside, thus traditional shallow wells are vulnerable to salinity issues. In fact, only a couple of wells are used in the area. Depending on the capacity of the wells, the well owners allow only three to five neighboring households to use water from the wells, and charge them a certain fee. The villagers are generally satisfied with the quality and even use it for drinking after boiling it.

3.4. Rainwater

Only a couple of the interviewees had used rainwater, not in an active way but passively: they used to place a small container below the eaves of their houses and collect rainwater. Because they did not have a regular and systematic rainwater harvesting system, the volume of collected rainwater was insignificant. Meanwhile, some of them have a positive perception of rainwater as clean water falling from the sky. On the other hand, many of them voiced some concerns related to health when asked whether they would use rainwater for drinking; they pointed out the possibility of pollutants from the atmosphere and the absence of minerals in rainwater. These concerns are, however, based on inadequate knowledge. First, as most of Banda Aceh is used for agriculture, there are few airborne pollutants in the air, unlike in other industrialized and developed cities. Therefore, the quality of rainwater will be much cleaner compared to other cities in the world where rainwater is widely used. Second, the amount of minerals required for daily consumption can be easily obtained through regular meals. For these reasons, drinking rainwater after boiling it is not harmful to health.

Table 2
Quality of water determined using The World Water Monitoring Day Test Kit

	Bottle water (refilled water)	Tap	Well	Rainwater storage tank
Turbidity (NTU)	0.86	0.56	2.03	3.5
pH	8.7	8	7	7.5
DO	Fair	Good	Fair	Fair

4. Quality of various water sources

The water quality from various sources was compared to determine how the actual quality differed from the public perception. Samples were taken from a bottled water container, tap, well and rainwater storage tank. For the test, a World Water Monitoring Day Test Kit from LaMotte [2] was used to measure pH and dissolved oxygen (DO) and a 2100P Portable Turbidimeter by HACH was used to test turbidity. The World Water Monitoring Day Test Kit (LaMotte Co.) is a simple kit specially manufactured to encourage laypersons to measure the quality of water around them and to build public awareness and involvement in protecting water resources. Therefore, the test results are generally accurate but not as precise as would be obtained using other more sophisticated and expensive test equipment. In the case of DO measurements, the test gives ballpark indications of poor, fair, and good water quality. Results are shown in Table 2.

The test results obtained from the different water sources were somewhat different to the local residents' expectations. Tap water had the best quality in terms of turbidity and DO, while water from the wells, in which people have the highest trust, proved to be the worst among the conventional water sources. In the case of rainwater from a storage tank, the sample was taken a couple of hours after rain. Because of time constraints, we did not manage to test the water after a certain settling period, which is the usual case for rainwater. We believe that the water quality, especially the turbidity, would have been much improved if we had allowed a certain amount of time for particulate matter in the rainwater to settle. From the results, we can nonetheless argue that the quality of rainwater is not far below that of well water.

Table 3
Heavy metal concentration (ppb) of water samples and drinking water guidelines

Metal	Rainwater at the widow's house	Tap water at kindergarten	Rainwater tank at kindergarten	River water	Guidelines for drinking water in Indonesia	Guidelines for drinking water in WHO
Al	26	89.4	168	7150	200	200
Cr	1.8	0.377	1.33	0.737	50	50
As	ND	0.356	1.08	0.273	10	10
Mn	ND	2.4	2.14	3.59	100	400
Cu	0.9	5.88	17.3	1.75	1000	2000
Cd	ND	ND	0.871	0.179	3	3
Zn	350.1	15.1	40.9	34.4	3000	3000
Pb	0.8	0.29	2.42	ND	10	10

On 2007, four samples are taken and heavy metal concentration is analyzed as in Table 3. In terms of heavy metal, the rainwater is far less than that is listed in WHO drinking water guideline [3]. High Zinc concentration observed at rainwater sample is due to the roof material.

The most important microbial test for the rainwater system has not been made. However, recent report from Australia shows that rainwater can be used for drinking purpose without any other treatment if the catchment and rainwater tank is managed well [4].

5. Checkup of rainwater harvesting systems built on January 2007

On January 2007, when we made the first visit with 12 students from Seoul National University, we installed three Rainwater Harvesting systems; at a widow's house, at a kindergarten, and at a UNICEF health care center. On January 2008, we visited the site for a checkup. First, the widow's house and rainwater system as well disappeared because the family has to move into a refuge village. The kindergarten RWH seemed to work extremely well because the teachers and students welcomed us with a thankful mind. Although there have been minor problems, the teachers fixed the problem very easily, because they knew the system very well from the construction period.

The third rainwater system at the UNICEF health care center (Fig. 1a) was not in function, instead, the owner was using the rainwater tank as a storage tank for purchased water. The main problem was from the roof water conveyor. Because of the breakage at one of the joints of PVC gutters, and slope of gutter is reversed outward from the tank side, rainwater is not collected into the rainwater tank. The solution was simple; we tied the gutter to the roof and made a slope toward the rainwater tank. Other minor problems were raised, such as the breakage of foundation and small filter connection pipe. These problems were solved easily using local people.

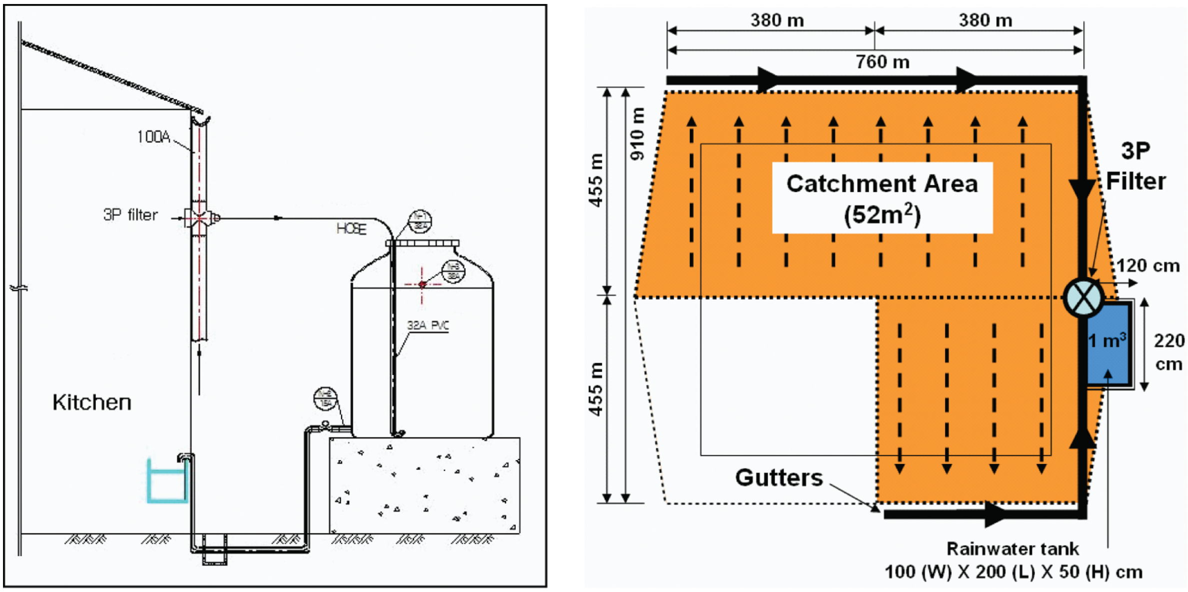
Some lessons are learned from this checkup process. Although the problem may be very simple because of the inherent simplicity of rainwater system, people seldom try to fix it. The main reason is because the owners does not fully understand the system and they rely too much on the doners, and they do not have money for the maintenance. So it is vital that the owners should understand the Rainwater Harvesting system and should be ready to correct minor problems by themselves.

6. Installation of rainwater harvesting systems

6.1. Technical aspects

We installed rainwater harvesting systems of similar design and size at three houses in Gano Village. For the purpose of this paper, and to avoid redundancy, we will study only one of the three cases.

A rainwater harvesting system is simple in principle: rainwater is channeled from roofs to tanks. Generally the system consists of the following four



(a) (b)

Fig. 1. Schematic diagram of the rainwater harvesting systems (a) at UNICEF health care center (2007) and (b) at Gano Village (2008).

components: catchment surface, conveyors, filter, and storage tanks. Fig. 1 illustrates the basic dimensions of the system (a) and includes a schematic diagram of how the rainwater is collected in the tank (b). Collected rainwater from the roofs is channeled to the filter and the filtered water is stored in the tank.

A brief overview of the materials used and the installation procedure for each component is given.

Catchment surface: Because we built the rainwater harvesting system at an existing house the original roof was used for catchment, without any alterations. The roof was made of galvanized iron with a smooth surface that is ideal for rainwater harvesting. The catchment area is 52 m^2 and the expected annual volume of rainwater collected is 105,908 L, taking into account a runoff coefficient (0.9) and the annual rainfall in the area.

Conveyors: Plastic gutters were installed to capture rainwater running from the eaves of the house. They were fitted on pre-installed metal brackets that were customized to complement the slope of the roof in order to minimize possible overrunning and to improve catchment efficiency. To prevent water leakage, silicon was used to seal the connected parts of the gutters. Finally, the gutters were connected to the filter and tank using PVC pipes, and were sloped toward the pipes to facilitate good drainage.

Filter: A filter is necessary in rainwater harvesting to remove debris that gathers in the catchment area and to ensure high quality water. We installed a 3P Filter Collector [5] made by 3P Technik Gmbh, Germany before the storage tank. A characteristic of this type of filter is its simple installation and maintenance, which is an important criterion when considering suitable filters because the system will subsequently be used by laypersons who do not have strong technical knowledge. In particular, the filter can be easily removed and cleaned without needing to dismount the filter body from the downpipe.

Tank: A storage tank with a capacity of 1000 L was specially designed in Korea to be ideal for use in this area. The tank's most distinguishing characteristic is its material; it is fabricated from PVC tarpaulin, which is durable, weatherproof, and opaque. This fabric tank has the following features. First, the introduction of a fabric tank reduced the unit price of the tank to \$US60. A storage tank is generally the most expensive component of a rainwater harvesting system. By using a tank constructed from a more inexpensive material, fabric, we were able to reduce the unit cost of the total system. Second, being constructed from fabric improves this tank's portability, as the tank is relatively lightweight and flexible. After heavy rains, when the tank is full, people can easily store it for their future water use without any serious physical constraints related to storage space, because, unlike regular plastic tanks, it can take on any physical shape. Moreover, the empty tank is collapsible and can be folded and stored easily. Meanwhile, the concrete tank bed was constructed to be strong enough to hold one ton of water and high enough to provide the residents with easy access to the outlet.

6.2. Social aspects

The aim of this project was not confined to the installation of three rainwater harvesting systems. Rather, we consider this project as a starting point for increasing public awareness about rainwater harvesting and spreading the practice so that rainwater harvesting can become a popular alternative method for obtaining water in the Aceh area. To this end, we took further action beyond technically building the rainwater harvesting systems. First, we educated the local residents in using the system properly by distributing a simple instruction manual translated into Indonesian; we also gave demonstrations. In addition, through frequent communications, we tried to provide the locals with results of scientific analysis of the quality of the rainwater in efforts to reduce their negative perception of rainwater. Second, we tried to foster a good relationship with the local community to encourage their involvement in the installation process. This was done by organizing several special events to promote interaction with them. For example, an event called "Korean Day" was organized, at which approximately 100 children and adults in the area gathered and had good time with our team members. In addition, children were invited to paint the rainwater tanks together with us. These efforts helped to promote the concept of rainwater harvesting, and we were able to forge links with the community; several residents even voluntarily participated in the installation process. The involvement of the local residents can be considered as an implicit capacity building and technology transfer. Lastly, considering his influence in the area, we chose to install the system at a chief's house. We found that the chief's power is significant in the area and the neighbors tend to gather at his house on a regular basis. Therefore, if the system at his house performs well then the concept of rainwater harvesting would be disseminated more quickly.

7. Conclusions

This paper describes the general status of water usage, public perceptions, and actual water quality of various water sources in Gano Village in Banda Aceh, Indonesia, and our efforts to disseminate rainwater harvesting there.

Many of the residents there face high water costs and are looking for alternative methods of obtaining water that are more reliable and sustainable than the conventional water sources. Rainwater harvesting was proposed and studied as a new option for water supply in Aceh and its viability was explored from two perspectives: technical and social. From a technical perspective, the system is a very useful alternative in Banda Aceh for the following reasons: (1) the materials used can be obtained easily and cheaply in the area; (2) its design and installation is simple and replicable, using locally available technology; (3) maintenance is easy; (4) the expected volume of collected water is considerable; and (5) the introduction of a fabric tank reduced the unit cost significantly. Therefore, we can expect that the rainwater harvesting system will be widely adopted and used in the area, and will result in a significant reduction in the economic burden of purchasing water. However, when we investigated the viability of this system from a social perspective, we discovered some problems that need to be solved before we can attempt to disseminate the idea of rainwater harvesting in the area. We found that not many local people are aware of the benefits of utilizing rainwater and, as reflected in the results of the interviews, some of them even have a misunderstanding regarding the quality of rainwater. Therefore, increasing public awareness and offering relevant education should be attended to first in order to effectively expand the option of rainwater harvesting at a later time.

This study confirms that rainwater harvesting, accompanied by proper education, can be a competitive option for a safe water supply in terms of costs, simplicity of installation and maintenance, and water quality.

Besides Gano Village in Banda Aceh, there are many even poorer and more devastated areas in the world that do not have access to clean water. They do not need state-of-the-art technology to solve their problems; they require only appropriate and affordable technology, such as rainwater harvesting, to provide them with safe and clean water. We believe this case study can be used as a role model to be studied by international organizations and NGOs in their efforts to assist with development of other poor areas without safe water supplies.

Acknowledgement

This research was supported by Research Institute of Engineering Science, Seoul National University.

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