Desalination and Water Treatment
www.deswater.com
doi: 10.5004/dwt.2021.27177

224 (2021) 83–94
June

Improving drinking water reliability from water purification facilities through appropriate technology, in the case of Binh Dinh, Vietnam

Jonglip Kim[a], Younghwan Moon[b], Jeyong Yoon[c], Junseok Hwang[d,*]

[a]*Technology Management, Economics and Policy Program, Seoul National University, Seoul 08826, Korea, email: prome00@hotmail.com*
[b]*Korea Institute of S&T Evaluation and Planning, Chungcheongbuk-do 27740, Korea, email: ket17@naver.com*
[c]*Korea Environment Institute, Sejong 30147, Korea, email: jeyong@snu.ac.kr*
[d]*Technology Management, Economics and Policy Program, Seoul National University, Seoul 08826, Korea, Tel. +82 2 880 8679, email: junhwang@snu.ac.kr*

Received 30 August 2020; Accepted 22 February 2021

ABSTRACT

The issues regarding reliability must be resolved for drinking water purification facilities. To solve reliability issues, it is necessary to investigate factors that impact drinking water perception among residents. According to surveys, this study verified each group's satisfaction and differences in sustainable reception intention through factor analysis and multiple regression analysis. The results showed that the reliability of the installed equipment and technology and the people who installed is essential and that sufficient information on usage, maintenance and repairs, and technology must be provided or understood by the user.

Keywords: Water purification facilities; Appropriate technology; Reliability; Public perception; Factor analysis

1. Introduction

According to the World Resources Institute (WRI), based on a metropolitan area with a population of 3 million or more, 33 cities and 255 million people are suffering from severe water shortages, and the scale is expected to increase to 470 million people in 45 cities by 2030 10 y later [1]. As extreme precipitation phenomena such as drought and floods increase due to recent climate change, the amount of water we can use is further decreasing, and areas that are suffering from water shortages are gradually expanding worldwide. This water problem is more severe in developing countries than in developed countries with relatively well-equipped infrastructure.

These developing countries are implementing various policies to solve the water problem. However, they have limitations due to financial problems, and in particular, many people still suffer from water problems in areas where the government and other agencies cannot supply water. Appropriate technology is appropriate for local culture and economic status and aims to solve social problems and innovation [2]. Appropriate technology has been attracting attention for a long time as a technology for water purification facilities in areas where existing water treatment facilities cannot be introduced for economic reasons or rural and remote areas where the government's administrative power is not reachable.

Previous studies have focused on finding business models of appropriate technologies, but empirical studies on how to reliably introduce and operate appropriate technologies in the actual field are insufficient [2,3]. We thought, however, that a technical approach alone could not solve the problem [4,5]. The socio-cultural context and the attitudes of users can affect the acceptance of appropriate

* Corresponding author.

technologies. In this study, an empirical analysis was conducted on Vietnam cases, focusing on water purification appropriate technology.

This study aims to verify each group's satisfaction and differences in sustainable reception intention according to surveys, training on appropriate technology, and level of reliability through factor analysis and multiple regression analysis targeting teachers in five schools. Over the last 3 y, water purification facilities were installed in the Binh Dinh region of Vietnam by the Institute for Global Social Responsibility (GSR) at Seoul National University (SNU). Moreover, this study highlights the different factors that can improve facilities' reliability, promote effective use, and increase sustainability.

2. Previous studies

2.1. Definition of appropriate technology

The concept of appropriate technology is originated from intermediate technology, which means it is located in the middle of high-tech and low-tech technology [6]. Schumacher defined intermediate technology as the technology that satisfies the immediate needs of those who use it or the technology that can be used easily, even without experts [6]. Thus, Bakker [7] defined appropriate technology as all kinds of technologies that could positively affect the work needed in human life. However, although appropriate technology does not exist as a single definition, it can be defined as a set of technologies or activities of these technologies with characteristics such as affordability, sound technology, flexibility technology, sustainability, local material use, and encouraging local participation [4]. Since the appropriate varies from region to region, it is necessary to consider the technology and the broad context of a society where technology is transferred [5].

A water purification system using appropriate technology can help many people who cannot get clean water [8]. Although many water purification technologies are commercialized, the technologies available in rural areas in underdeveloped countries are limited [9]. Each society has different conditions for accepting each technology, so they install affordable facilities considering capital costs, operating costs, effectiveness, energy consumption, environmental impact, and by-products.

Technology alone cannot solve local water problems [6]. When the appropriate technology was approached only engineeringly, engineers often judged and designed it regardless of the context of the user's demand and provided inappropriate solutions. The UN World Water Development Report pointed out that water problems should be interrelated with political, social, and economic contexts, not just technology, and thus should lead to responsible behavior at all levels of society [10].

In this study, we investigate the distribution of small-scale water purification facilities using appropriate technology as an alternative to water resource problems in developing countries. However, recognition of the appropriate technology is not yet popular, and the trust in the intermediate technology used for products using the appropriate technology is not high for potential users. Therefore, for more effective technology dissemination, trust in water purification facilities and technologies is essential, and if these requirements are not secured, it is difficult to ensure that water purification facilities using appropriate technologies will actually be used in local communities [3]. This study aims to analyzes factors that affecting the use of water purification facilities which using appropriate technologies through case analysis in Vietnam, and try to suggest insights on the promotion and utilization of technology.

2.2. Research on the reliability of water purification facilities and frequency of drinking

The volunteer group from SNU installed water purification facilities, but the reliability of drinking water had to be secured first in order for the water purification facilities to operate effectively for an extended period. Securing reliability regarding drinking water involves scientific verifications regarding water quality; instead, various social factors and personal factors interact and impact reliability [11]. Moreover, since the water purification facilities are relatively small, there may be a fair amount of mistrust compared to existing large-scale water purification facilities. In a study on public understanding of small-scale water supply facilities in Ontario, Canada, water supply facilities often did not undergo water quality inspections than the government's facilities, which led to public distrust [12].

Therefore, the literature on factors that impact public perception of drinking water was examined to verify factors that influence water usage frequency from water purification facilities. Canter et al. [11] concluded that the public perception of water quality risk is deduced through various social and personal factors. The author has defined impact on water quality perception from a broad sense and assessed various factors including visibility of water pollution, personal use of water resources, concern for toxic chemical substances according to emphasis on bacteriological quality, education level, age, pollution source, and proximity, familiarity with pollution sources, trust for relevant facilities and staff members, voluntary usage, familiarity, degree of self-control, degree of external control, unnaturalness. De França Doria [13] reviewed several variables that influence public perception. This study stated that the public's perception of water quality stemmed from a complex interaction of various factors and listed the main variables. First, the public's perception of drinking water was influenced by organoleptic properties as well as risk perception, attitude toward chemical substances that are used in water purification equipment, signals that are provided by supply systems, familiarity with certain substances, reliability of the supplier, and information provided by the water quality and information provider.

Bain et al. [14] surveyed the perception of drinking water safety among low-income and medium-income countries in South Africa. In developing countries, perceived drinking water safety had a greater connection with the taste, smell, or clarity of water than socioeconomic or demographic characteristics; these results are similar to those of studies in developed nations. DuChanois [15] identified factors for the discontinuous of water supply in developing countries or low-income counties: insufficient cost recovery, seasonal service, low maintenance, and using multiple sources.

Jones et al. examined the public perception of drinking water from a private water supply facility in Ontario, Canada [12]. Water quality inspections were not being frequently performed on these water supply facilities since the central government ran them. The water quality inspection process was inconvenient, there was a lack of knowledge on water quality inspections, and the inspection results were often unsatisfactory. All groups wanted all information on water quality inspections and discussed the importance of diverse information channels to spread such information. Turgeon et al. confirmed the importance of the consumers' socioeconomic characteristics regarding drinking water quality [16].

3. Research focus

This study focused on installing water purification facilities using appropriate technology by the GSR five times from 2015 to August 2017 in the Binh Dinh Province of central Vietnam with the SNU's support. The volunteer activities included the application of appropriate technology for installing water purification facilities in wells. Despite being short-term volunteer activities, efforts were made to utilize the region's materials and energy sources, considering the cultural, economic, and geographical conditions, and perform technical volunteer activities harmonious with local community organizations. The GSR conducted discussions with the foreign affairs office and education office in the Binh Dinh region and selected one school among elementary and middle schools to install water purification facilities and the necessary solar panels.

Two types of water purification facilities were installed for well water and rainwater at all five schools. The technology used was developed through cooperation between technicians at SNU and students who participated in the GSR's activities. The exact specifications differed slightly to match the circumstances of each school. Sand filters, reverse osmosis (RO) filters, or other filters were used based on the required amount of water and the school's water source. The volunteer group purchased RO filters and other components needed to build facilities in the local market as commonly used products in the area. A RO filter facility has been installed for drinking, and a sand filter facility has been installed for other use for each school. When water purified by the sand filter is used as drinking water, it is filtered once more with the RO filter. If a usual power source could not be safely supplied or it was beneficial to add an independent power source, solar panels were installed to support the water purification facilities' operation. A water tank was also installed to store rainwater and temporarily reserve purified water. The sinks that would enable this water and the necessary pipes were also built and provided. Through these efforts, the local schools could secure a small, independent, purified drinking water facility.

Construction typically occurred during SNU's vacation periods in January and August. During the construction period, which lasted around 10 d, water purification facilities, tanks, pipes, and sinks were installed. The required training and cultural exchange activities were also performed simultaneously at the local schools.

When the need for ongoing management was recognized over multiple rounds of short-term volunteer activities, training was conducted for the school supervisors and managers, and a maintenance manual was created for the management of the facilities in the future. Materials and filters that would continue to be used were provided in advance, which would last for a given time, and the school had to replace these on their own. Local companies provided guarantees for fixing damaged water tanks and solar panels, which were difficult for the schools to fix independently. In the next round of volunteer activities, volunteers visited schools where they were previously installed to assess facilities' state and perform maintenance and repairs.

Volunteer activities occurred around Quy Nhon, the capital city of the Binh Dinh province. Quy Nhon is a travel destination in Vietnam and an important trade port in the central region Quy Nhon has a tropical climate divided into rainy and dry seasons; the annual number of rainy days is about 90 d with about 1,650 mm of precipitation. Although the overall precipitation is sufficient because the rainy season lasts from September to December and the dry season is between January and August, there is a significant gap in precipitation according to the season. No water supply facilities are installed in the suburbs. Consequently, in towns near schools benefiting from these activities that utilize appropriate technology, individual wells are dug up for every household, and water is purified using sand filters or small-scale purification filters to gain drinking water. While there is no direct cause of water pollution from industrialization, there are cases where the water coming from wells was found unsuitable for drinking owing to its high iron content. As is characteristic of regions located near the coast, where the river meets the ocean, seawater flows backward to the groundwater zone during the dry season, thereby increasing groundwater salt content.

Therefore, there was a lack of drinking water for students owing to insufficient drinking water facilities at the target schools. While there were schools that dug up wells and used sand filters, there was still insufficient supply during the dry season. They carried their water bottles and were unable to use residential water aside from drinking water. Therefore, there was a need to provide water purification facilities using appropriate technology.

4. Study method and survey analysis

From October 22–26, 2017, an interview was conducted with the school principals and managers at the respective schools to evaluate the previous activities and perform a preliminary survey on the next activities of the GSR. A questionnaire survey was also administered to the school teachers. A total of 92 teachers from five established schools responded to the survey. Since the number of teachers at each school was only about 30, including branch schools, the actual number of teachers that the surveys could be administered to at each school was only about 20. We selected teachers as a survey target because we expected that it would not be easy to obtain objective survey results for young students. The teachers were also trained by the institution on how to use and manage water purification facilities after installation and understood the principles and management methods of water purification facilities. Among the teachers, the teacher in charge of management was in charge of maintaining and operating the facility.

The in-depth interviews included questions regarding ① the local drinking water supply status before installation and the reason why the installation was requested, ② building reliability during the installation process and relevant issues, ③ frequency of use and satisfaction after installation, ④ management after installation, and ⑤ reaction from surrounding schools and the region.

The survey conducted on school teachers was developed based on the factors that were selected about previous studies on drinking water perception and critical questions in the World Health Organization's (WHO) "Core questions on drinking water and sanitation for household surveys" [17]. To survey the basic structure of drinking water usage, the WHO recommends surveying how each local community obtains water and the amount of labor used for this purpose. In this study's survey, the water acquisition method was divided into public wells, household well, local waterworks, household pumps, drinking water bottles, and rainwater. Also, it questioned how far outside the home consumers must travel to obtain water and how much labor is required. Moreover, the survey was divided into the general method for the survey respondent's region and the survey respondent and their family. It questioned how students drink water at school. However, unlike the dry regions considered in the WHO's recommendations, the survey on the amount of labor required to obtain water was excluded since Vietnam is not a dry region. Hence the water source was not too far from each household, and obtaining water did not require a significant amount of work. This study analyzed the literature referenced above to assess factors that impact the reliability of drinking water obtained using appropriate technology. Assuming that drinking water reliability could be determined based on the frequency of use (drinking), the study surveyed this statistic. Factors influencing the frequency of drinking water use were divided into quality factors, installation and maintenance factors, installation and maintenance durability factors, reliability factors regarding the appropriate technology and people who installed the facilities, perception of information on technology related to water purification facilities, and perceived quality of existing drinking water.

For the above research object, this study conducted an empirical analysis using survey data, as shown in Fig. 1. First, variables were constructed through previous studies, and factor scores of each variable were obtained through factor analysis from data. Moreover, the correlation between variables was finally analyzed through regression analysis of the research model using factor score from the factor analysis. Furthermore, in this study, SPSS 23.0 was used for these statistical analyses. The survey definition and description of variables are presented in Table 1.

The questionnaire was measured on a 5-point Likert scale, considering the characteristics of Vietnamese respondents who are unfamiliar with surveys. The reliability of each survey question is shown in Table 2, and the Cronbach's alpha, which represents the internal consistency of survey questions that implement the variables, was over 0.6, implying that each survey question's internal consistency was reliable [18].

Next, factor analysis was performed to check whether each survey question was grouped with homogeneous factors. The factor analysis results revealed that the survey questions were reduced to six factors, as shown in Table 3. Tables 4 and 5 present that the factor analysis results are at similar levels in terms of communalities and the KMO (Kaiser-Meyer-Olkin measure of sampling adequacy) and Bartlett's test. Communalities mean the proportion of each variable's variance that can be explained by the factors. KMO test is a measure of the proportion of variance among variables that might be common variance. Furthermore, Bartlett's test means fitness of factor analysis model.

As shown in Table 6, the survey questions were categorized into six factors of existing drinking water quality (EQW), quality of drinking water from using appropriate technology (QW), local installation and maintenance skills (M), reliability of appropriate technology (T), learning information on appropriate technology (IA), and degree of participation in installation and maintenance (MP).

Volunteer activities were divided into three time periods, and the factors that impacted the frequency of use were assessed for each period. There were several rounds of volunteer activities related to installing water purification facilities in the region, but they were merely one-time events

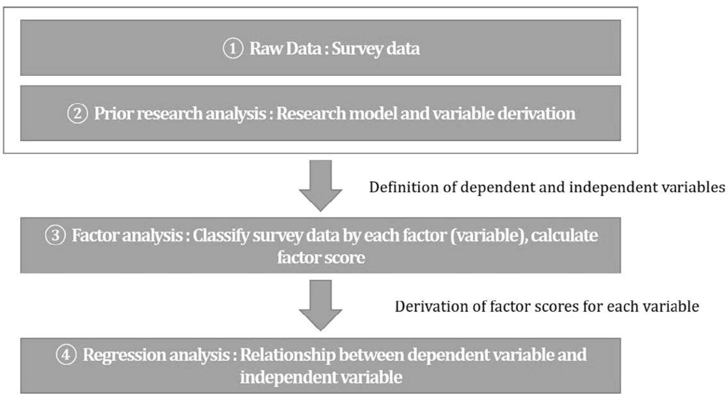

Fig. 1. Research methodology process.

Table 1
Definition and description of variables

Variables	Definition of variables	N	Min.	Max.	M	SD
Frequency of use (UF)	Frequency of drinking water	84	1.0	5.0	3.46	0.90
Quality of existing drinking water (EQW)	Incense of water	84	1.0	5.0	2.88	0.99
	Taste of water	84	1.0	5.0	3.11	0.93
Quality of drinking water using appropriate technology (QW)	Cleanliness	84	3.0	5.0	4.29	0.48
	Safety	84	3.0	5.0	4.26	0.49
	Taste of water	84	3.0	5.0	4.20	0.58
	Incense of water	84	2.0	5.0	4.17	0.71
Local installation and maintenance skills (M)	Easy to install locally	84	1.0	5.0	2.65	1.04
	Ease of local maintenance	84	1.0	5.0	3.01	1.07
	Easy to acquire local maintenance materials	84	1.0	5.0	3.29	1.01
Reliability of appropriate technology (T)	Installation group reliability	84	3.0	5.0	4.19	0.59
	Installation equipment reliability	84	3.0	5.0	4.18	0.58
	Maintenance reliability	84	3.0	5.0	4.25	0.60
	Installation technology reliability	84	2.0	5.0	4.17	0.58
	Filter reliability	84	3.0	5.0	4.14	0.60
Learning information on appropriate technology (IA)	Getting enough explanation	84	2.0	5.0	3.81	0.84
	Fully understanding an explanation	84	2.0	5.0	3.58	0.82
	Utilizing explanation on the maintenance activities	84	2.0	5.0	3.67	0.83
Degree of participation in installation and maintenance (MP)	Participate installation	84	1.0	5.0	3.08	1.23
	Participate in maintenance	84	1.0	5.0	3.51	1.19
	Self-installation capability	84	1.0	5.0	2.55	0.94
	Self-maintenance ability	84	1.0	5.0	2.56	0.92

Table 2
Questionnaire reliability

Variables	Cronbach's alpha	Items
Quality of existing drinking water (EQW)	0.752	2
Quality of drinking water using appropriate technology (QW)	0.873	4
Local installation and maintenance skills (M)	0.820	3
Reliability of appropriate technology (T)	0.958	5
Learning information on appropriate technology (IA)	0.884	3
Degree of participation in installation and maintenance (MP)	0.782	4

limited to the region where the facilities were installed. Therefore, this study also surveyed how long the reliability built through short-term activities lasted and how long the impact of using these facilities would last. Since each sample size was relatively small, the minimum sample size was obtained by dividing five rounds of volunteer activities into three time periods, and each sample group was analyzed through the above method.

5. Results

Each factor was verified through factor analysis on the survey questions. To verify the impact of factors on the use of water purification facilities that applied appropriate technology, factor scores were utilized for a multiple regression analysis as follows.

Frequency of use = Factor 1 (Reliability of appropriate technology, T) × Factor 2 (Quality of drinking water using appropriate technology, QW) × Factor 3 (Quality of existing drinking water, EQW) × Factor 4 (Learning information on appropriate technology, IA) × Factor 5 (Local installation and maintenance skills, M) × Factor 6 (Degree of participation in installation and maintenance, MP) (1)

The coefficient of determination for the regression analysis model was 0.321 (Table 7), which implies that the regression model provided a sufficient explanation of the relationship between frequency of use (dependent variable) and each independent variable. The Durbin-Watson test value, which represents the autocorrelation of error terms, was 1.643, verifying that each variable is

Table 3
Total variance explained of factor analysis

Factor	Initial Eigenvalue			Extraction sum of squared loading			Rotation sum of squared loading
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	7.239	34.473	34.473	7.239	34.473	34.473	6.040
2	3.441	16.386	50.860	3.441	16.386	50.860	3.943
3	1.897	9.035	59.895	1.897	9.035	59.895	2.089
4	1.593	7.584	67.479	1.593	7.584	67.479	3.906
5	1.356	6.457	73.936	1.356	6.457	73.936	3.206
6	1.026	4.886	78.822	1.026	4.886	78.822	2.805
7	0.665	3.168	81.990				
8	0.636	3.029	85.019				
9	0.526	2.505	87.524				
10	0.475	2.261	89.785				

Table 4
Communalities

	Initial	Extraction
EQW2R	1.000	0.825
EQW3R	1.000	0.732
QW1	1.000	0.742
QW2	1.000	0.811
QW3	1.000	0.711
QW4	1.000	0.714
M1	1.000	0.740
M2	1.000	0.810
M3	1.000	0.707
T1	1.000	0.882
T2	1.000	0.930
T3	1.000	0.879
T4	1.000	0.819
T5	1.000	0.878
IA1	1.000	0.834
IA2	1.000	0.866
IA3	1.000	0.703
MP1	1.000	0.813
MP2	1.000	0.731
MP3	1.000	0.732
MP4	1.000	0.695

sufficiently independent and that regression analysis can be performed. Further, the significance probability regarding the analysis of variance (ANOVA) (Table 8) was less than 0.05, indicating that the regression model is suitable.

Table 9 shows the multiple regression analysis results performed through backward elimination to verify factors impacting the frequency of use regarding water purification facilities that apply the appropriate technology. As a result of the analysis, all variables except 'Local installation and maintenance skills (M)' were significant in the regression analysis. After removing insignificant variables,

Table 5
KMO and Bartlett's test

Kaiser-Meyer-Olkin measure of sampling adequacy		0.776
Bartlett's test of sphericity	Approx. chi-square	1,367.680
	df	210
	Sig.	0.000

reliability of appropriate technology (T), quality of existing drinking water (EQW), and learning information on appropriate technology (IA) were found to have a significant influence on the frequency of use.

The standardized coefficient of reliability of appropriate technology (T) and learning information on appropriate technology (IA) was 0.387 and 0.280, respectively, showing a positive correlation, while there was a negative correlation with the quality of existing drinking water at –0.197. Thus, reliability regarding water purification facilities that apply appropriate technology (installation technology, water purification technology, group reliability) and learning and understanding enough information on using and managing these facilities positively influence actual utilization. On the other hand, if the perceived quality of the existing drinking water source was high, the frequency of use of the new appropriate technology decreased. These results suggest that implementing appropriate technology must strongly reflect dissatisfaction regarding the existing drinking water source and the need for a new source.

5.1. Post-installation analysis by time period

In addition to the basic model analysis, a post-analysis was performed on factors that impacted the frequency of drinking water use, based on the amount of time that passed after installing water purification facilities in the Binh Dinh region. Three groups were made according to the term of volunteer activities: Less than 1 y of installation (14th), 1 y to less than 2 y (12th, 13th), 2 y or more (10th, 11th), and a regression analysis was performed for each group.

Table 6
Structure matrix of factor analysis

		Factors					
		1	2	3	4	5	6
Quality of existing drinking water (EQW)	EQW2R	–0.051	0.176	0.903	–0.010	–0.046	–0.057
	EQW3R	–0.181	0.387	0.785	0.140	0.055	–0.010
Quality of drinking water using appropriate technology (QW)	QW1	0.428	–0.854	–0.192	0.139	–0.031	–0.036
	QW2	0.373	–0.869	–0.243	0.262	–0.052	0.049
	QW3	0.538	–0.771	–0.297	0.213	0.034	0.105
	QW4	0.587	–0.775	–0.281	0.115	–0.112	0.070
Local installation and maintenance skills (M)	M1	0.244	–0.010	0.074	0.335	–0.837	0.340
	M2	0.315	0.041	0.031	0.377	–0.885	0.266
	M3	0.218	0.004	–0.176	0.218	–0.824	0.175
Reliability of appropriate technology (T)	T1	0.932	–0.373	–0.083	0.226	–0.308	0.214
	T2	0.953	–0.317	–0.034	0.252	–0.335	0.170
	T3	0.936	–0.388	–0.105	0.267	–0.279	0.218
	T4	0.878	–0.439	–0.099	0.426	–0.181	0.141
	T5	0.914	–0.469	–0.230	0.359	–0.154	0.198
Learning information on appropriate technology (IA)	IA1	0.374	–0.310	–0.081	0.862	–0.356	0.117
	IA2	0.327	–0.167	0.011	0.918	–0.324	0.282
	IA3	0.420	–0.105	0.105	0.791	–0.378	0.218
Degree of participation in installation and maintenance (MP)	MP1	0.238	–0.017	0.009	0.107	–0.187	0.868
	MP2	0.167	0.018	–0.195	0.323	–0.367	0.827
	MP3	0.198	0.268	–0.246	0.611	–0.247	0.647
	MP4	0.189	0.262	–0.400	0.492	–0.274	0.622
Extraction Method: Principal Components Analysis							
Rotated Method: Oblimin with Kaiser normalization							

Table 7
Model summary

Model	*R*	*R*-square	Adjusted *R*-square	Std. error of the estimate	Durbin-Watson
Baseline Model	0.567	0.321	0.287	0.7581	1.643

Table 8
ANOVA test

Model		Sum of squares	df	Mean square	*F*	Sig.
Baseline Model	Regression	21.488	4	5.372	9.346	0.000
	Residual	45.405	79	0.575		
	Total	66.893	83			

The coefficients of determination for the group's regression analysis model were 0.378, 0.437, and 0.693, respectively (Table 11), suggesting that the regression model provided a sufficient explanation of the relationship between frequency of use (dependent variable) and each independent variable. The Durbin-Watson test values, representing the autocorrelation of error terms, were 1.689, 2.192, and 1.243, respectively, verifying that each variable is sufficiently independent and that regression analysis can be performed [19]. Further, the ANOVA's significance probability (Table 12) was less than 0.05, indicating that the regression model is suitable.

Table 13 presents the multiple regression analysis results between groups based on the point of installation. For Group 3, which corresponds to a relatively short amount of time after installation (less than 1 y), the quality of existing drinking water, learning information on appropriate technology (IA), and degree of participation in installation and maintenance (MP) had a significant influence on the frequency of use. Groups 1 and 2, which correspond to at least 1 y after installation, the reliability of appropriate technology (T) significantly influenced the frequency of use for Group 2. In contrast, the quality of existing drinking water and appropriate technology reliability

Table 9
Result of model

Model		Unstandardized coefficients		Standardized coefficients	T	Sig.
		B	Std. error	Beta		
Baseline Model	Constant	3.464	0.083		41.881	0.000
	Reliability of appropriate technology (T)	0.348	0.089	0.387	3.895	0.000
	Quality of existing drinking water (EQW)	–0.177	0.084	–0.197	–2.111	0.038
	Learning information on appropriate technology (IA)	0.251	0.090	0.280	2.799	0.006
	Local installation and maintenance skills (M)	0.167	0.089	0.186	1.880	0.064
Dependent variable: UF						

Table 10
Group classification by period

Group	Term	Questionnaire	Installation	Elapsed period after installation
Group 1 (2 y or more)	10th	12 person	Summer 2015	30 months
	11th	18 person	Winter 2015	24 months
Group 2 (1 y to less than 2 y)	12th	18 person	Summer 2016	18 months
	13th	14 person	Winter 2016	12 months
Group 3 (less than 1 y)	14th	22 person	Summer 2017	6 months

Table 11
Model summary by group

Model	*R*	*R*-Square	Adjusted *R*-square	Std. error of the estimate	Durbin-Watson
Group 1	0.615	0.378	0.332	0.7645	1.689
Group 2	0.661	0.437	0.398	0.6534	2.192
Group 3	0.832	0.693	0.642	0.5075	1.243

significantly influenced Group 1. However, the quality of existing drinking water had an important impact in the beginning stages after installation (less than 1 y), as time passed to the middle (1 y to less than 2 y) and later periods (2 or more years), the reliability of appropriate technology was found to have a more significant influence.

6. Discussion and conclusion

These results showed that the installed equipment and technology's reliability and the people who install this equipment are vital for the frequency of drinking water use from small-scale water purification facilities. That is, sufficient information on usage, maintenance and repairs, and technology must be provided or understood by users.

SNU's volunteer activities may have been short-term, but the small-scale water purification facilities they built within this short period are being operated over a long period. For these facilities to be operated for a long time and continue to be used, it is essential to provide clean water and gain users' trust in this water. Unlike large-scale water purification facilities, these small-scale facilities must be run by school personnel because no one can fully manage and take charge. Further, the people who initially installed the facilities during their volunteering time cannot stay behind to provide constant maintenance services.

Therefore, it is inevitable for reliability to be an essential factor for small-scale water purification facilities built quickly. Scientific guarantees regarding drinking water quality may foster this reliability, but this must be based on a foundation of trust regarding the people who installed these water purification facilities and the technology used to install them, as Canter et al. [11]. The smaller the facility, the more difficult it is to build this reliability [12], and this was verified through the surveys conducted in the Binh Dinh region of Vietnam.

This study also found that sufficient information on the water purification facility must be provided to the person managing the facility and the people who will use them. This finding is the same as the argument made by Melby et al. [20], who emphasized four principles that must be adhered to during short-term activities, including respect for

Table 12
ANOVA test by group

Model		Sum of squares	df	Mean square	*F*	Sig.
Group 1	Regression	9.586	2	4.793	8.200	0.002
	Residual	15.781	27	0.584		
	Total	25.367	29			
Group 2	Regression	9.618	2	4.809	11.263	0.000
	Residual	12.382	29	0.427		
	Total	22.000	31			
Group 3	Regression	10.455	3	3.485	13.530	0.000
	Residual	4.636	18	0.258		
	Total	15.091	21			

Table 13
Result by group

Model		Unstandardized coefficients		Standardized coefficients	T	Sig.
		B	Std. error	Beta		
Group 1	Constant	3.162	0.143		22.148	0.000
	Reliability of appropriate technology (T)	0.419	0.157	0.426	2.664	0.013
	Learning information on appropriate technology (IA)	0.313	0.152	0.328	2.054	0.050
Group 2	Constant	3.631	0.120		30.189	0.000
	Reliability of appropriate technology (T)	0.720	0.166	0.607	4.343	0.000
	Quality of existing drinking water (EQW)	–0.336	0.147	–0.320	–2.287	0.030
Group 3	Constant	3.278	0.121		27.153	0.000
	Quality of existing drinking water (EQW)	–0.424	0.118	–0.511	–3.605	0.002
	Learning information on appropriate technology (IA)	0.646	0.136	0.656	4.735	0.000
	Degree of participation in installation and maintenance (MP)	–0.348	0.141	–0.359	–2.473	0.024

the local culture, promoting bilateral participation, strengthening local competence, and providing long-term training opportunities. The study by Melby et al. [20] argued that there must be more participation from both parties from selecting a location to installation so that the residents can continue to manage the facilities even after the short-term volunteers who built the facilities leave. Therefore, the results of the present study serve as a reminder that local competence must be strengthened while installing these water purification facilities built by appropriate technology to foster the ability to manage the facilities continuously, and training opportunities must be offered so that the residents can resolve problems that may occur in the future.

Based on the analysis results by period, learning information on appropriate technology had the most critical impact on the frequency of use in the beginning stages, while may suggest that as time passes after providing sufficient information, this may lead to trust in the technology. Therefore, for water purification facilities built by appropriate technology to be truly useful in installation and use, enough information must be provided starting from the very beginning.

However, there were limitations to the surveys. Anonymous surveys are rare in the Binh Dinh region. Therefore, people were unfamiliar with surveys and were averse to selecting two opposites on the Likert scale. Hence, their differentiation power was not very strong, and it was not easy to assess their inclinations. Also, there is a possibility that there is a recall bias in the answers through the questionnaire.

Also, since there were not many teachers in each school, a large-scale survey could not be conducted. Therefore, there is a possibility that a bias problem may occur due to a small number of samples. This limitation is a common issue that appears in most regions that are beneficiaries of appropriate technology. Because the beneficiary's size was small, the number of people who could experience the appropriate technology was limited; hence, a large-scale survey could not be conducted. Therefore, there must be a different method that can serve to supplement surveys in future studies.

Acknowledgments

This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2016S1A5A2A03926786).

References

[1] D. Mitlin, V.A. Beard, D. Satterthwaite, J. Du, Unaffordable and Undrinkable: Rethinking Urban Water Access in the Global South, World Resources Institute, 2019.
[2] Y.H. Moon, J.S. Hwang, Crowdfunding as an alternative means for funding sustainable appropriate technology: acceptance determinants of backers, Sustainability, 10 (2018) 1456, doi: 10.3390/su10051456.
[3] J.M. Lee, K.O. Kim, H.H. Shin, J.S. Hwang, Acceptance factors of appropriate technology: case of water purification systems in Binh Dinh, Vietnam, Sustainability, 10 (2018) 1–20.
[4] H.M. Murphy, E.A. McBean, K. Farahbakhsh, Appropriate technology – a comprehensive approach for water and sanitation in the developing world, Technol. Soc., 31 (2009) 158–167.
[5] D. Laufer, M. Schäfer, The implementation of Solar Home Systems as a poverty reduction strategy—a case study in Sri Lanka, Energy Sustainable Dev., 15 (2011) 330–336.
[6] S.E. Friedrich, Small Is Beautiful: Economics as if People Mattered, Abacus, London, 1973.
[7] J.I. (Hans) Bakker, The Gandhian approach to swadeshi or appropriate technology: a conceptualization in terms of basic needs and equity, J. Agric. Ethics, 3 (1990) 50–88.
[8] C. Ray, R. Jain, Drinking Water Treatment – Focusing on Appropriate Technology and Sustainability, Springer Science + Business Media B.V., Springer Netherlands, 2011.
[9] M. Thompson, A critical review of water purification technology appropriate for developing countries: Northern Ghana as a case study, Desal. Water Treat., 54 (2015) 3487–3493.
[10] World Water Assessment Programme, Water: A Shared Responsibility, Berghahn Books, 2006.
[11] L.W. Canter, D.I. Nelson, J.W. Everett, Public perception of water quality risks-influencing factors and enhancement opportunities, J. Environ. Syst., 22 (1992) 163–187.
[12] A.Q. Jones, C.E. Dewey, K. Doré, S.E. Majowicz, S.A. McEwen, D. Waltner-Toews, S.J. Henson, E. Mathews, Public perception of drinking water from private water supplies: focus group analyses, BMC Public Health, 5 (2005) 1–12, doi: 10.1186/1471-2458-5-129.
[13] M. de França Doria, Factors influencing public perception of drinking water quality, Water Policy, 12 (2010) 1–19.
[14] R.E.S. Bain, S.W. Gundry, J.A. Wright, H. Yang, S. Pedley, J.K. Bartram, Accounting for water quality in monitoring access to safe drinking-water as part of the Millennium Development Goals: lessons from five countries, Bull. World Health Organ., 90 (2012) 228–235.
[15] R.M. DuChanois, E.S. Liddle, R.A. Fenner, M. Jeuland, B. Evans, O. Cumming, R.U. Zaman, A.V. Mujica-Pereira, I. Ross, M.O. Gribble, J. Brown, Factors associated with water service continuity for the rural populations of Bangladesh, Pakistan, Ethiopia, and Mozambique, Environ. Sci. Technol., 53 (2019) 4355–4363.
[16] S. Turgeon, M.J. Rodriguez, M. Thériault, P. Levallois, Perception of drinking water in the Quebec City region (Canada): the influence of water quality and consumer location in the distribution system, J. Environ. Manage., 70 (2004) 363–373.
[17] WHO, Core Questions on Drinking Water and Sanitation for Household Surveys, World Health Organization, 2006.
[18] N. Schmitt, Uses and abuses of coefficient alpha, Psychol. Assess., 8 (1996) 350–353.
[19] N.E. Savin, K.J. White, The Durbin-Watson test for serial correlation with extreme sample sizes or many regressors, Econometrica: J. Econom. Soc., 45 (1977) 1989–1996.
[20] M.K. Melby, L.C. Loh, J. Evert, C. Prater, H. Lin, O.A. Khan, Beyond medical "missions" to impact-driven short-term experiences in global health (STEGHs): ethical principles to optimize community benefit and learner experience, Acad. Med., 91 (2016) 633–638.

Appendix

A1. Survey questionnaire

Hello. This survey is to research to secure the reliability of appropriate technology related to drinking water at the Technology Management, Economics, and Policy Program (TEMEP) at Seoul National University. I'd like to ask you a question about drinking water obtained from existing drinking water and installed water purification facilities using appropriate technology. It will be used for research to utilize appropriate technology development in the future. Thank you

A2. General question about drinking water

1. How do the villagers (your neighborhood) usually drink water? (Multiple answers possible)
① Well at the home ② Local water supply* (Tap water) ③ Common well at the village ④ Home water supply* ⑤ Appropriate technology center facility ⑥ Others

*Local water supply refers to waterworks jointly operated by local governments or similar organizations for residents. Home water supply refers to a facility supplied through a pipe made by itself in the home.

2. How do students usually drink water at school? (Multiple answers are possible)
① Well at the home ② Local water supply (Tap water) ③ Common well at the village ④ Home water supply ⑤ Appropriate technology center facility ⑥ Others
3. How do you usually drink water? (Only one answer is possible)
① Well at the home ② Local water supply (Tap water) ③ Common well at the village ④ Home water supply ⑤ Appropriate technology center facility ⑥ Others
4. Are the villagers around the school usually satisfied with the quality of the water they drink?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree
5. Does the water that the villagers around the school usually drink smell?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree
6. Do you feel the taste in the water that the villagers around the school usually drink?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree
7. Does the water that the villagers around the school usually drink look clean?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree
8. Is there a way that villagers around the school take to make drinking water safer?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree

8-1. How do they make drinking water safer?
① Boiling ② Use water filter ③ Receive water and wait before drinking sunlight disinfection ⑤ Filtering with cloth ⑥ Others ⑦ I don't know
Questions about drinking water at a water purification facility using appropriate technology in the school

9. How much water do you use drinking water from the water purification facility provided by the school?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree

10. Does this water taste different from the water you usually drink at home?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree
(If you select No. ④ and ⑤, go to problem 10-1)

10-1. Did you stop drinking this water because it tastes and smells different?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree

10-2. If so, please briefly explain how this water tastes and smells different compare to drinking water at your home
Transparency, safety, quality about drinking water at a water purification facility using appropriate technology in the school

11. Do you think the water has become cleaner after going through the water purification facility?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree

12. Do you think the water became safer after going through the water purification facility?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree

13. Has the taste of water improved after going through the water purification facility?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree

14. Did the smell of water get better after going through the water purification facility?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree
Installation and maintenance of drinking water at a water purification facility using appropriate technology in the school

15. Can water purification facilities be installed in the village or school itself?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree

16. Can water purification facilities be maintained in the village or school itself?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree

17. Is it easy to get the materials needed to maintain the water purification facilities in the village or school itself?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree

18. Do you think it is expensive to maintain the water purification facility? (Tell me the cost burden you feel subjectively)
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree
Water quality after the maintenance of appropriate technology

19. Will the water through the water purification facility continue to be clean after a year?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree

20. Will the water through the water purification facility continue to be safe after a year?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree

21. Will the taste and smell of water through the water purification facility remain the same after a year?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree

22. Do you want to use the water purification facility after a year?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree
Reliability about water purification facility installation and its technology

23. How much do you trust the people who installed the water purification facility?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree

24. How much do you believe in a water purification facility?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree

25. Do you think the water purification facility will be maintained continuously?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree

26. Is the technology used in the water purification facility reliable??
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree

27. Is the filter used in the water purification facility reliable??
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree
Getting information on the appropriate technology

28. Have you heard enough about the technology and principles used in the water purification facility?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree

29. Did you fully understand the description of the technology and principles used in the water purification facility?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree

30. Did you fully utilize the technology and principles for the water purification facility and use it for maintenance?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree

Degree of participation in water purification facility installation and maintenance

31. Did you participate in installing water purification facilities?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree
32. Did you participate in maintaining the water purification facilities?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree
33. If enough materials are given to you, can you install a water purification facility without the assistance of a technician?
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree
34. If enough materials are given to you, can you fix and maintain a water purification facility without the assistance of a technician
① Strongly disagree ② Disagree ③ Neither agree nor disagree ④ Agree ⑤ Strongly agree