Alternative Drinking Water Source in a Coastal District of Bangladesh: The Case of Pond Sand Filter

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Abstract

An alternative drinking water source is a burning issue for the coastal regions of Bangladesh. Available water bodies are becoming increasingly saline due to the incessant intrusion of saline water into the surface water. It is a direct effect of global climate change and human-induced illegal activities. During the 1990s, the UNDP suggested PSF as one of the best alternatives for drinking water sources in the saline-prone coastal regions of Bangladesh. To this day, the program continues in various coastal areas of Bangladesh. This study focused on the people's perception of PSF as an alternative safe water source in the Khulna district. To do so, initial information was collected from Research Gate, Google Scholar, PubMed, and Wiley Online Library. To conduct the research, a mixed-methods approach was employed. To collect the required quantitative data, a stratified sampling technique was applied to reach various categories of respondents. The minimum sample size obtained following the sample chart given by Sekaran and Bougie (2016). Additionally, qualitative data were collected through Key Informant Interviews (KII). The data collection period spanned from November 2023 to January 2024. The mixed data support the study's rationale vividly through statistical evidence, which also supports the KII results. The results of the research will contribute to understanding the ground reality of installing PSF, as per feedback from the beneficiary group. The results also support the partial ground data to inform the development of a national policy ensuring safe water for coastal populations.

Keywords: *PSF, Alternative Water Source, Perception of the Beneficiary Group*

1. Introduction

Day-to-day drinking water crises are worsening in the coastal regions of Bangladesh due to rapid contamination of surface water sources with saline water. The alarming threat caught the attention of policymakers and several development agencies.

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To address the alarming threat, various alternative drinking water supply systems have already been implemented by government agencies, non-governmental organizations, and development organizations in the study areas. This study focused on a specific water treatment plant, namely the pond sand filter (PSF), which was installed by both government and non-government organizations in the study area. The main focus of the study is to explore the perception of the beneficiary groups from the PSF. To meet the study's objectives, the researcher primarily focused on a quantitative approach, and a sufficient number of respondents were reached. Moreover, the researcher conducted several key informant interviews (KIIs) to validate the results further. Overall, the researcher aimed to highlight the effectiveness of the Pond Sand Filter as an alternative water supply system for the salinity-prone coastal district.

2. Objectives

The following objectives were set to meet the study requirements:

i) To investigate the multi-dimensional sustainability of the water supply innovation.
ii) To explore the community members' perception to boost PSF.

3. Problem Statement

The alternative drinking water crisis in coastal regions of Bangladesh is an emerging and pressing issue. Millions of people reside in 19 coastal districts of Bangladesh, out of its 64 districts. Evidence shows that due to incessant climatic disasters, drinking water sources are being contaminated with saline water. As a result, freshwater sources are shrinking daily in those regions. Several studies have shown that the Pond Sand Filter is chosen as the best alternative drinking water source for disaster-affected coastal areas. This study focused on the reliability and validity of this alternative drinking water source, as well as its sustainability.

4. Literature Review

Pond Sand Filters (PSFs) have been identified as a crucial water treatment solution in Bangladesh's coastal region, where access to safe drinking water is significantly reduced due to salinity intrusion, arsenic contamination, and climate-related hazards (Hossain et al., 2022; Khan and Paul, 2024). These regions, which host millions of at-risk residents, are disproportionately affected by sea-level rise, cyclonic storms, and tidal flooding, resulting in polluted traditional water supplies such as ponds and shallow tube wells (Ashrafuzzaman,

Gomes, and Guerra, 2023; Tsai et al., 2024). The effectiveness of PSFs in inhibiting microbial and physico-chemical contamination has made them a popular alternative for water treatment within rural coastal settlements (Alam et al., 2017; Islam et al., 2011). The PSF system operates to filter pond water through sand and gravel layers, which physically and biologically filter suspended solids, pathogens, and other impurities. This low-input, low-cost technology is well suited for rural poor because it does not require electricity or highly developed operating skills (Kamruzzaman and Ahmed, 2006). Thus, PSFs have been widely applied in the southwestern coastal region, particularly in districts such as Khulna, Satkhira, Bagerhat, and Barisal (Rahman et al., 2021). Researchers have revealed that PSFs are effective in reducing pH, ammonium, total hardness, and turbidity (Hossain et al., 2015). Researchers demonstrated that PSFs reduced the fecal coliform counts from dangerous to acceptable levels (Alam et al., 2017; Shishir et al. 2018). Seasonal variability, biofilm obstruction, and poor user knowledge also contribute to ineffectiveness and abandonment in others (Hossain et al., 2015; Jubayer, 2015). Study results reaffirmed that PSFs removed up to 83% of E. coli during the dry season but only 76% of E. coli during the rainy season, which is inconsistent with effectiveness (Islam et al. 2011). Additionally, it is noted that poor-quality filter media and irregular backwashing significantly compromise PSF performance (Hasan et al., 2013). Turbidity was reported in household water during the study (Kamruzzaman and Ahmed, 2006; Harun and Kabir, 2012). Inaccessibility from far distances posed further usage hindrances, especially for women and children who are primarily responsible for water collection (Mallick and Roldan-Rojas, 2015). Saltwater intrusion by cyclones makes PSF water undrinkable, even after filtration. PSFs cannot remove dissolved impurities such as sodium, chloride, and arsenic (Tsai et al., 2024; Shammi et al., 2019). Arsenic contamination is also a serious issue because PSFs cannot remove this contaminant, and long-term health effects are a cause of concern (Hossain et al., 2015; Akhter et al., 2023). These gaps indicate the need for further treatment technologies such as chlorination, solar disinfection (SODIS), or connection with rainwater harvesting systems (Akter, Islam, and Gnauk A, 2010; Khan and Paul, 2023). It is recognized that incorporating PSFs with MAR and RWH can play a significant role in resisting salinity and seasonal water scarcity (Jahan et al., 2022; Ahsan et al. 2022). Secondary interventions, including the utilization of wetlands and riverbank filtration, have also been proposed (Haque and Nahar, 2023). In addition to the technical and operational issues, the sustainability of PSF is inherently linked to socio-economic and institutional drivers. Institutional governance models, such as the Community Management Plus (CM+) model, have been advocated to enhance levels of local ownership and operational resilience (Hasan et al., 2020;

Hasan and Laila, 2024). The CM+ model incorporates user committees, scheduled maintenance, and liaison with local government agencies. Inequalities in access based on social stratification, gender roles, and regional stratification continue to leave specific groups excluded, compromising the equitable availability of clean water (Mallick and Roldan-Rojas, 2015; Naus et al., 2020). Some communities continue to use unsafe sources due to habit, convenience, or social norms (Inauen et al. 2013). It is documented how small private water providers incorporate PSFs in their supply chain but are hit by seasonal evaporation from ponds and poor maintenance (Hoque 2021). While PSFs have gained notable popularity among Bangladesh's water supply policy, scientists advocate incorporating them with other adaptive technologies such as Managed Aquifer Recharge (MAR), Rainwater Harvesting (RWH), and even solar desalination power plants to meet long-term water security goals (Jahan et al., 2022; Islam et al., 2023; Akter, Islam and Gnauk A, 2010). Studies such as those confirm multi-technology solutions tailored to community needs (Islam et al., 2023; Haque and Nahar 2023). Spatial and environmental information must guide the integration of technology. GIS-based models and sustainability assessment tools such as ternary diagrams have also been developed to optimize the location and performance of PSFs under different socio-ecological conditions (Khan, 2020; Mondal, Bari and Shafiquzzaman, 2023). Policymakers can identify where to prioritize interventions in areas of high-water scarcity, poor-quality groundwater, and high population pressures using such tools (Mondal and Bari, 2023; Roman et al.; 2021). It reaffirms the importance of persistent financial and administrative support for the maintenance of PSFs. User willingness to pay (Khan and Paul 2023). It reflects value and ownership, but is incomplete without government or NGO assistance (Alam et al., 2017). Small private water providers often depend on PSFs but are seasonally constrained and unregulated, with service quality being the casualty (Hoque, 2021). Epidemiological research is used to determine whether PSF-treated water reduces the prevalence of waterborne disease. These earlier studies have primarily employed short-term water quality analysis rather than health outcome metrics, thereby leaving a gap in determining the actual health effects of PSFs (Islam et al., 2011; Khan and Paul, 2023). PSF system strengthening directly contributes to Sustainable Development Goal 6 (Clean Water and Sanitation) by expanding access to safe drinking water. It also intersects with Goal 13 (Climate Action), as PSFs are a climate-adaptive, low-carbon technology that may assist vulnerable groups in adapting to water insecurity. However, such contributions need to be identified, appreciated, and supported through national policy and climate adaptation measures (Haque and Nahar, 2023; Ashik-Ur-Rahman and Gain, 2023). Despite the numerous research works on this topic, the literature remains

lacking in certain areas. The long-term health implications of water treated with PSF, comparisons with other water purification systems, and socioeconomic challenges associated with adoption require further examination (Inauen et al., 2013; Khan and Paul, 2023). Studies typically highlight the technical efficacy of the systems without sufficiently addressing the policy, behavioral, and institutional reforms that must occur to upscale and sustain them. (Mondal and Bari, 2023).

Several studies focused on different drinking water crises but from the above literatures it is clearly seen that none of the studies focused on the PSF. So, in this paper the researcher explored a new scenario regarding sustainability of water supply system in a coastal district of Bangladesh. The result of the study may significantly contribute in decision making on sustainable water supply system.

5. Conceptual Framework

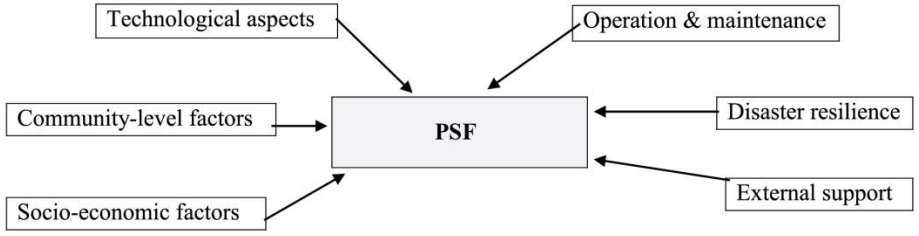

Figure 1: Conceptual framework of PSF as a dependent variable and its associated threats

Above conceptual framework shows the dependent variable PSF are associated with several independent variables which are linked with the objectives of the study. The independent variables are selected from various published study results such as Uddin et al. (2024) mentioned that study reveals that the poor quality of river water and rising levels of salinity increase reliance on alternative technologies, such as PSFs. It is a community level factor. Here, the dependent variable PSF is surrounded by six different independent variables which are ascribed in several literatures. Each of the independent variables has potential strength to influence the dependent variable PSF. The conceptual framework may let people understand possible variables which may affect the functionality of pond sand filter.

6. Methodology

The study is descriptive and analytical in nature. A mixed-methods approach is employed to explain the study's results. More specifically, the explanatory sequential method was applied to describe the mixed data. The target population of the study consists of coastal residents who are already under threat due to the water crisis. Two Upazilas of Khulna district have been selected as the study area, namely Paikgacha and Koyra. Banglapedia (2023) shows the total population size of the study regions is approximately 4,41,914 (Paikgacha 2,47,983 and Koyra 1,93,931). Following the formula given by Sekaran and Bougie (2016), the sample size of the quantitative data is set at 386 (The sample determination chart of the book shows that for a population of 400000 to 500000, the sample size is 381). Data were collected following stratified sampling so that different cluster of people can be reached as the target populations are diversified in nature. For example, respondents are diversified in respect of gender, religion and occupation. The researcher followed a semi-structured questionnaire to collect quantitative data. A checklist was prepared to collect qualitative data. Four undergraduate students were well-trained to collect data from the field of the study. Additionally, the BBS criteria were met to encompass diverse socioeconomic groups. After collecting the data, the researcher refined the dataset and adjusted necessary variables to meet the study's objectives. After thorough scrutiny, the data were input into SPSS software and then subjected to the necessary statistical calculations such as percentage distribution and several significant tests such as chi-square test, linear regression analysis and one-sample test to meet the study objectives. In addition, qualitative data were collected by conducting KII. The KII reports were scrutinized several times before final submission.

7. Results

The study objectives are logically met through rational analysis of the mixed data. A convergent parallel design was employed to analyze the mixed data.

Table 1: Frequently used drinking water sources

Source of water	Frequency	Percent
Rainwater Harvesting Tank	161	41.7
Deep Tube-well Supply	225	58.3
Total	386	100.0

Source: *Field Study, 2024*

The above table shows that the respondents mainly depend on the deep tube-well water supply system, which accounts for approximately 58%, whereas the rest rely on rainwater harvesting tank units as their primary drinking water source. Remarkably, the respondents did not mention PSF as a source of drinking water, as those units are not in suitable conditions.

7.1 Key Informant Interview (KII-1)

Mr. Mydul Islam, manager, Nobolok, Paikgacha, Khulna

Narrative of the Key Informant Interview (KII)

Nobolok is an NGO working to ensure safe water for the masses of people, and WaterAid, Netherlands, funded this project. During the initial part of this interview, the researcher tried to learn about their activities so that the focus could be put on the relevant areas of investigation. From the initial conversation, it was understood that they are supporting the municipal community in various ways to ensure safe drinking water. To differentiate income groups, they categorized them in the following way: A = Middle Class, B = Lower Middle Class, C = Poor, D = Hard Core Poor, and E = Rich people to access their fiduciary support. Nobolok supports up to 95 percent of the total installation cost of the reservoir, depending on the economic solvency of the beneficiary group. They also have an expert team for quick response in case any emergency maintenance arises. They have already started a test-based project at the Shibbari area on the basis of the Tubewell Sand Filter (TSF) process and distributing the water among families through a pipeline.

After understanding their basic procedures, the researcher focused on the objective and initially asked him about the availability of fresh water sources at Paikgacha municipality. He replied that although saline water reservation in municipal areas is restricted, this area is surrounded by saline water resources, such as shrimp-cultivated ghers, the Shibsha River, and, as a coastal area, it is very close to the Bay of Bengal. As a result, its underground water is also contaminated by saline water, and it is no longer potable. According to his information, surface water is available only during the rainy season and remains for only about three months. Despite the scarcity of potable water, people are reluctant to pay for it. Furthermore, in different shops and markets, potable water bottles are very rare and expensive for most inhabitants, as they are struggling to maintain their lives in a hand-to-mouth condition.

When the researcher asked him about the prevailing system of drinking water, he replied that the quantity of water in the reservoir is minimal and is used by only some wealthy families. Even though in most cases the reservoirs can support at

best for six months due to the scarcity of rainwater. He also mentioned that the water reservoirs are not maintained properly in most cases. For example, the owner merely cleans the reservoir. When asked about the durability of the reservoir, he replied that the reservoirs are either brick-built or big plastic containers. If the owners maintain them carefully, then they will last for ten to fifteen years. He also mentioned that the plastic container will pose a threat to the environment in the near future.

In response to another query regarding operation and maintenance, he stated that, as these reservoirs are developed personally, in most cases, people are avoiding the minimum maintenance costs to keep them clean and safe. From a community perspective, there is not a single reservoir installed in this municipal area. According to his knowledge regarding safe drinking water, the inhabitants of this municipality did not receive any external support from NGOs, Donor agencies, or government bodies.

Table 2: Duration of PSF

Duration	**Frequency**	**Percent**
1 - 5 Years	224	58.0
6 - 10 Years	142	36.8
11 Years and above	20	5.2
Total	386	100.0

Source: *Field Study, 2024*

Above table shows that the highest number of respondents mentioned the duration of a PSF unit is about 1 to 5 years which stands at 58%, The second highest group of respondents mentioned it is about 6 to 10 years which stands at about 37% and rest others mentioned that the plant lasts for above 11 years which stands about 5%.

7.2 Key Informant Interview (KII-2)

Mr. Md. Wahedur Rahman, Manager, BRAC WASH, Paikgacha, Khulna

Narrative of the Key Informant Interview (KII)

The respondent mentioned that BRAC WASH is a sister concern of the reputed NGO BRAC INTERNATIONAL. Through this project, they aim to address the drinking water issues in coastal regions. To ensure that the rural poor have access

to safe drinking water, they are motivating them to establish a PSF water filter at the community level. In Paikgacha Upazilla, BRAC WASH has already established over 50 PSF filters. To implement this initiative, the NGO is providing 90% of the total installment cost of each unit, which ranges from 90,000 to 110,000 taka. Initially, they create a community-based cooperative that includes all local facilitators. After reaching a primary agreement regarding the installation site, they began the project work.

Mr. Wahed mentioned that, due to income disparity, many common villagers fail to pay their share of the project cost or reach a consensus at the community level. For example, he said that in Khushkhali union, they are trying to set up a PSF project for the community, but they are quite reluctant to pay the initial amount, i.e., 10% of the total value.

When the researcher inquired about the technological and maintenance aspects of the project, Mr. Wahed stated that the main reservoir was constructed using local technology, as it is simply brick-built and guided by a local mason. However, for other necessary parts, such as the tap, we need to collect them from the market. He also mentioned that it is easy to function and maintain the project, and no expertise is required. However, in the event of theft, sudden disorder, or inadequate maintenance, it may disrupt regular performance. He also mentioned that from the perspective of durability, it can be said that with minimum maintenance, this project can sustain itself for at least twenty years. However, due to a scarcity of rainwater or an extreme drought, it may not function sufficiently.

According to Mr. Wahed, the PSF system is relatively safe from natural disasters, except for floods, as it relies on pond water for its initial water supply. When questions arose about the government or any other support, he stated that the government had taken various initiatives. Still, all efforts had gone in vain due to mismanagement and a lack of maintenance. He said that other NGOs and donor agencies are also working in this field, such as WaterAid, Nobolok, and others.

The P-value is .000, and the Pearson Chi-Square value is 237.551, as seen in Table 3. Thus, statistical evidence suggests that the drinking water source and the affordability of maintenance work are highly interdependent. In this case, it can be said that the maintenance heavily depends on financial solvency. Here, the researcher applied a chi-square test to show the significance of the relationship between water source and respondents' financial capacity.

Table 3: Chi-square test

Drinking Water Source * Affordability of maintenance work Cross-tabulation					
Count		Affordability of maintenance work			Total
		Somewhat costly	Not costly	Affordable	
Drinking Water	Rainwater Harvesting Tank	0	20	141	161
	Deep Tubewell Supply	41	163	21	225
Total		41	183	162	386

Chi-Square Tests			
	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	237.551[a]	2	.000
Likelihood Ratio	273.208	2	.000
Linear-by-Linear Association	203.689	1	.000
N of Valid Cases	386		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 17.10.

Source: *Field Study, 2024*

7.3 Key Informant Interview (KII-3)

Bipul Kumar Das, Public Health Engineer, Public Health Office, Koyra, Khulna

Narrative of the Key Informant Interview (KII)

According to the discussion with the Upazilla Public Health Officer, the researcher learned that more than one hundred PSF plants (brick-built, each costing approximately 30,000 taka) have been implemented in this coastal area to ensure pure drinking water for the delta community. But unfortunately, all of them went out of order due to a lack of proper maintenance. As per his knowledge, he mentioned that in this locality, the scarcity of pure drinking water is acute. Due to the limited availability of sources of pure water resulting from mass shrimp cultivation, and the area's proximity to the Bay of Bengal, which contributes to saline water intrusion.

When questioned about the project's failure, he said that local inhabitants are quite reluctant about the healthy livelihood, and they merely agree to pay for the installation of a water reservoir. He also mentioned that although not all are economically sound, most are ignorant regarding the effects of polluted water on health.

According to Mr. Bipul, another reason for the failure of this government project is that the local community does not take care of the PSF plant carefully after the handover of maintenance liability to the community stakeholders, who are

provided with basic instruments like pliers, range finders, and so on. He also mentioned that it was the failure of the community beneficiary group as they did not perform their minimum responsibility to carry the partial maintenance expenditure.

As per his information, besides the government, different NGOs have also come forward to install different safety measures to ensure safe drinking for this coastal community, but still the local people are suffering a lot. He also mentioned that the unconsciousness of the inhabitants triggers their health risk condition. But with the minimum awareness, the PSF project can easily be monitored and maintained, which can play a vital role in maintaining a healthy lifestyle.

Table 4: Linear regression analysis

Model Summary[b]					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.612[a]	.375	.367	.47327	1.429
a. Predictors: (Constant), Affordability of maintenance work, Availability of spare parts in the local market, Source of money					
b. Dependent Variable: Duration of PSF					

ANOVA[a]						
Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	51.072	5	10.214	45.603	.000[b]
	Residual	85.114	380	.224		
	Total	136.187	385			
a. Dependent Variable: Duration of PSF						
b. Predictors: (Constant), Affordability of maintenance work, Availability of spare parts in the local market, Source of money						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.701	.113		15.012	.000
	Source of money	.193	.033	.555	5.830	.000
	Availability of spare parts in the local market	.318	.067	.267	4.736	.000
	Affordability of maintenance work	.438	.063	.483	6.963	.000
a. Dependent Variable: Duration of PSF						

Source: *Field Study, 2024*

The above linear regression results (Table 4) illustrate that plant duration depends on three specific factors. In this case, the value of R square is .375 (the "R Square" column), indicating that the independent variable explains 37 per cent of the total variation in the dependent variable. Furthermore, the ANOVA table regression model significantly predicts the dependent variable, as the significant value here is .000 (the "Sig." column). Finally, the coefficients table shows that the B value of the type of source of money is .193 (the "B" column), and the P-value is .000 (the "Sig." column), also, B value for the type of availability of spare parts in the local market is .318(the "B" column), and the P-value is .000 (the "Sig." column), and B value for Affordability of maintenance work is .438 (the "B" column), and the P-value is .000 (the "Sig." column), indicating that PSF plant longevity highly depends on the above mentioned predictors which are generated aligned with the objectives of the study.

7.4 Key Informant Interview (KII-4)

Mr. Poritosh Gosh, Headmaster, Darun Mollic DHK Secondary School, Paikgacha, Khulna

Narrative of the Key Informant Interview (KII)

DHK Secondary School of Paikgacha Thana is situated in a remote area, away from the mainstream suburb, which resembles a delta surrounded by the River Shibsha and shrimp-cultivated ghers. After about one hour of motorbike journey, we reached there and finally met with the headmaster. Mr. Gosh is very amiable in nature and frankly shared his experience with the researcher. He mentioned that in his school, they installed a big Rain Water Harvest (RWH) underground plant with the help of BRAC. The newly installed sanitary system is also build by the help of the NGO BRAC.

When the researcher asked him about the water supply system of the community, he replied that pure water supply scarcity is a very common issue in this locality, but it is noticeable that inhabitants are quite reluctant regarding safe drinking water. One of the primary reasons for their ignorance is illiteracy. During the summer, this community suffers significantly from a lack of drinking water and domestic feed water due to the scarcity of rain. Moreover, the unavailability of sources and limited income prohibit them from accessing safe water, even from the market. He also mentioned that there are very few steps he noticed by the local leaders to solve the major issue, though it is possible to mitigate the water crisis with some community-level initiatives.

Regarding the Pond Sand Filter (PSF) project, he said that it is a feasible technology for water treatment, which is installed with the help of BRAC

WASH. It is easy to maintain to get safe water, but the community in charge is not carefully regulating the plan. As a result, the longevity of the PSF plant is facing threats. Another issue regarding the maintenance is that people mostly depend on the helping hand from the NGO rather than taking steps for minor renovation, such as damage to the water tap.

From his view, PSF is comparatively more disaster resilient as it is brick-built and covered safely. But it is not safe against floods. Because it primarily depends on the pond water source. As per his experience, government projects regarding PSF failed due to mismanagement and a lack of community involvement.

Table 5: One-sample test

One-Sample Statistics				
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
Source of money	386	4.0933	1.71369	.08722
Role in Water Supply Project	386	1.3109	.72559	.03693

One-Sample Test						
	Test Value = 1					
	T	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Source of money	35.463	385	.000	3.09326	2.9218	3.2648
Role in Water Supply Project	8.418	385	.000	.31088	.2383	.3835

Source: *Field Study, 2024*

Table 5 demonstrates that the t-value is 35.463 and the P-value is .000, both of which are highly significant. As a result, it can be inferred that the source of money significantly impacts the role in the water supply project. Here, the means of the two different groups were tested considerably.

7.5 Key Informant Interview (KII-5)

Mr. Robindra Das, Pharmacy Assistant, Maa Drug House, Sardar Mor, Koyra, Khulna

Narrative of the Key Informant Interview (KII)

Mr. Das has been in his current job for the last fifteen years. Their Drug shop is just beside the famous Sardar Pukur Park. This pond is historically valuable as, over the last few decades, local inhabitants have depended on this pond for

drinking water and other household purposes. From his long experience, he said that this pond is the only source of safe drinking water for the community, and people from about 1 mile away collect daily drinking water from here as it is the only source of fresh water in this locality.

According to his view, approximately half of the residents in this community live below the poverty level. So, it is quite impossible for them to pay for collecting fresh water, whereas they invest most of the income in managing daily food intake. He also mentioned that on the bank of Sarder Pukur, a government agency installed two Pond Sand Filters (PSF) for collecting drinking water. But due to lack of maintenance the project went out of service. As per his information initially local leader (Member of Union Parishad) takes the responsibility to look after it but after some months he becomes careless regarding the matter as there was no one for monitoring the project.

From the perspective of the project's sustainability, he said that with minimal maintenance, it could run for twenty to thirty years, as it is brick-built. He also said the water source is relatively safe from disaster because the high bank well protects the pond. He shared that people are not cautious about health safety due to polluted drinking water, and water-related diseases are very common among the inhabitants, especially children, who are the most vulnerable victims.

So far, he has claimed that several projects have been undertaken by GOs and NGOs to ensure fresh water for the locality, but all those initiatives have gone in vain due to a lack of awareness in the community.

8. Discussion

The study results vividly narrate the significance of the study. Five different KII reports support the five different tables. The significant value of statistical evidence clearly states the rationality and validity of the study. Though the PSF system is mentioned in other studies, those are not focused on it in detail. Let us take a look at the narration in other studies.

The scattered results indicate that PSFs can reduce turbidity, total coliform, and fecal coliform content within permissible drinking water quality limits, even from remote and highly salt-damaged locations (Hossain et al., 2016). Several studies indicate that there are limitations to the removal of dissolved salts and pathogens, particularly during extreme climate events and drought periods when pond water supply is not a reliable option (Shaibur, 2022; Farhana, 2011). Microbial contamination resulting from improper maintenance practices and inadequate community management further diminishes their reliability (Harun and Kabir, 2012; Khan and Paul, 2024). The results highlighted the socio-

environmental impacts of salinity intrusion and underscored the need for research into PSF performance under various environmental conditions (Lam et al., 2018). It is observed that competition for access to PSF-treated water during drought periods is particularly high among marginalized communities. These observations demonstrate that social dynamics can support or undermine technical interventions, and hence must be considered in any long-term water security strategy (Huq and Easher, 2021). Community attitudes strongly influence the choice of water supply method, with PSFs being preferred in areas where awareness about alternative technologies is lacking (Islam et al., 2011). Evaluating PSFs against other technologies, such as reverse osmosis and deep tube wells, emphasized the role of PSFs during the period of Cyclone Amphan, when other sources were not operational (Jubayer, 2015; Hossain et al., 2015; Rafa et al., 2021).

Notably, the mixed results clearly demonstrate the relevance of the study; however, the findings may not apply to other coastal regions of Bangladesh due to geographical variations. The following arguments outline the reasons for the failure and offer hope for the Pond Sand Filter (PSF).

Study results show that poor governance and inadequate maintenance of operations undermine water security in southwestern Bangladesh (Hossain et al., 2021). Inclusive management systems and community monitoring can promote trust, reduce misuse, and enhance resilience. Community participation in filter maintenance and water testing is promoted in studies (Harun and Kabir, 2012; Khan and Paul, 2023). At last, it can be said that the study results explored a rational and logical ground to set a sustainable water supply system to the study area.

9. Conclusions and Recommendations

The study results vividly reflect the objectives. Mixed results rationally focused on the present scenario of PSF as per the respondents' feedback. Significance tests verified the quantitative data, which is further supported by the KII results. Overall, it is evident that PSF, as an alternative drinking source for the studied coastal regions, is a fiasco. In most cases, it is not the fault of the technology, but rather the increasing climatic threats and human-induced undue practices that pose threats to the freshwater surface resources. Remarkably, the study results may provide policymakers with pathways to make informed decisions about selecting the best alternative technology. Moreover, this inductive study's results clearly set a foundation based on the responses from the beneficiary groups regarding the validation of an alternative water source.

Based on the study findings, the following recommendations are suggested to ensure sustainable water retention systems for the coastal regions of Bangladesh.

- It is evident from the study findings that prior justification for the proper functioning of a water treatment plant is very effective for a specific coastal region.
- Enhancing the capacity of the target population is a priority for introducing a new system.
- Community residents' awareness regarding the policy and the introduced water supply system must be ensured.
- Multi-level sectors have to be incorporated to make such water supply initiatives a successful program.
- Local intuition should be appropriately addressed rather than imposed programs.
- A rigorous national water policy should address the needs of the peripheral regions.
- Community-based initiatives are more viable for the coastal regions.
- Structural barriers should be appropriately addressed before introducing a new water supply system.
- Finally, gender roles have to be diagnosed appropriately to ensure the long-term usefulness of any incorporated water supply systems.

References

Ahsan, Md.N., Khatun, F., Islam, Md.S., Hossain, Md.S., Mou, B.H. and Kumar, P. (2022). Assessment of household-level adaptation strategies to water stress in southwesterncoastal Bangladesh: a counter-factual analysis. *Water Policy*, *24*(9), pp.1516–1540. https://doi.org/10.2166/wp.2022.064

Akhter, T., Naz, M., Salehin, M., Arif, S.T., Hoque, S.F., Hope, R. and Rahman, M.R. (2023). Hydrogeologic Constraints for Drinking Water Security in Southwest Coastal Bangladesh: Implications for Sustainable Development Goal 6.1. *Water*, *15*(13), p.2333. https://doi.org/10.3390/w15132333

Akter, J., Islam, S.N. and Gnauk A (2010). *Water resources management in the coastal region of Bangladesh*. ResearchGate. https://www.researchgate.net/publication/263125815_Water_resources_management_in_the_coastal_region_of_Bangladesh

Alam, F.M.A., Islam, M.S., Ghosh, G.C. and Yeasmin, T. (2017). Assessing the drinking water quality and performance of pond sand filters (PSF) in coastal area of Bangladesh: a cross sectional study on dacop upazila of Khulna. *International Journal of Advanced Geosciences*, *5*(2), p.69. https://doi.org/10.14419/ijag.v5i2.7924

Ashik-Ur-Rahman, M. and Gain, A.K., 2023. *Water security in the coastal region of Bangladesh*. In: H. Ojha, N. Schofield and J. Camkin, eds. *Climate risks to water security*. Palgrave Studies in Climate Resilient Societies. Cham: Palgrave Macmillan. Available at: https://doi.org/10.1007/978-3-031-16648-8_7

Ashrafuzzaman, M., Gomes, C. and Guerra, J. (2023). The Changing Climate Is Changing Safe Drinking Water, Impacting Health: A Case in the Southwestern Coastal Region of Bangladesh (SWCRB). *Climate*, *11*(7), p.146. https://doi.org/10.3390/cli11070146

Farhana, S. (2011) *Suitability of pond sand dilters as safe drinking water solution in storm surge prone areas of Bangladesh: a case study of Post-Aila situation in Shyamnagar, Satkhira district, Khulna*. Master's thesis, BRAC University, *Dhaka*. https://www.semanticscholar.org/paper/Suitability-of-pond-sand-dilt er s-as-safe-drinking-a Farhana/eb729be64fe3f38b1451651d4f07cba 81a8a91cd

Haque, S.E. and Nahar, N. (2023). Bangladesh: Climate Change Issues, Mitigation, and Adaptation in the Water Sector. *ACS ES&T water*, *3*(6), pp.1484–1501. https://doi.org/10.1021/acsestwater.2c00450

Harun, M.A.Y.A. and Kabir, G.M.M. (2012). Evaluating pond sand filter as sustainable drinking water supplier in the Southwest coastal region of Bangladesh. *Applied Water Science*, *3*(1), pp.161–166. https://doi.org/10.1007/s13201-012-0069-7

Hasan, M.B. and Laila, G.A. (2024). Investigating the Potential of the Community Management Plus Model for Governing Community Drinking Water Systems in Barind Tract of Bangladesh: A Case Study of Deep Tube- Well Water SupplyInstallations. *Social Sciences Review*, *40*(2), pp.81–112. https://doi.org/10.3329/ssr.v40i2.72133

Hasan, M.B., Driessen, P.P.J., Majumder, S., Zoomers, A. and van Laerhoven, F. (2020). A Community Management Plus Model for the Governance of Rural Drinking Water Systems: A Comparative Case Study of Pond Sand Filter Systems in Bangladesh. *International Journal of the Commons*, *14*(1), pp.662–679. https://doi.org/10.5334/ijc.1006.

Hasan, M.H., Kader, M.A., Shaon, M.T.I., Alam, M.I. and Billah, M.M., 2013. Performance on existing Pond Sand Filter (PSF) located at southern region of Bangladesh: a case study. *International Journal of Engineering and Technolo gy*, *3*(6), pp.600-607.

Hoque, S.F. (2021). Socio-spatial and seasonal dynamics of small, private water service providers in Khulna district, Bangladesh. *International Journal of Water Resources Development*, pp.1–24. https://doi.org/10.1080/07900627. 2021. 1951179

Hossain, M., Rahman, S.N., Bhattacharya, P., Jacks, G., Saha, R. and Rahman, M. (2015). Sustainability of arsenic mitigation interventions—an evaluation of different alternative safe drinking water options provided in Matlab, an arsenic

hot spot in Bangladesh. *Frontiers in Environmental Science*, *3*. https://doi.org/10.3389/fenvs.2015.00030

Hossain, M.J., Chowdhury, Md.A., Jahan, S., Zzaman, R.U. and Islam, S.L.U. (2021). Drinking Water Insecurity in Southwest Coastal Bangladesh: How Far to SDG 6.1? *Water*, *13*(24), p.3571. https://doi.org/10.3390/w13243571

Hossain, M.R., Shahriyar, S., Rahman, M.A., Sabab, F.R., Nawshin, N. and Forhad, A.B.M. (2016). Suitability of pond sand filter as an alternative safe drinking water technology at the Sundarban Region, Bangladesh. *Journal of Biodiversity and Environmental Sciences*, *8*(2), pp.283–292. https://www. researchgate. net/publication/350734919_Suitability_of_pond_sand_filter_as_an_alternative_ safe_drinking_water_technology_at_the_Sundarban_Region_Bangladesh

Hossain, Md.R., Khan, Md.S., Islam, Md.A. and Hasan, M. (2022). Pond sand filter as an alternative system for purifying drinking water: climate change perspective in Mongla, Bangladesh. *International Journal of Energy and Water Resources*. https://doi.org/10.1007/s42108-021-00172-y

Huq, H. and Easher, T.H. (2021). Coastal Water: Wisdom, Destruction, Conflicts and Contestation – A Case of Southwest Coastal Region of Bangladesh. *Intech Open eBooks*. https://doi.org/10.5772/intechopen.95002

Inauen, J., Hossain, M.M., Johnston, R.B. and Mosler, H.-J. (2013). Acceptance and Use of Eight Arsenic-Safe Drinking Water Options in Bangladesh. *PLoS ONE*, *8*(1), p.e53640. https://doi.org/10.1371/journal.pone.0053640

Islam, M.S., Deb, B.K., Alam, S.R. and Nishat, A. (2023). Technology for adaptation: a case study of developing a detailed inventory of drinking water supply technologies along the salinity-affected coastal region of Bangladesh. *AQUA - Water Infrastructure Ecosystems and Society*, *72*(5), pp.673–689. https://doi.org/10.2166/aqua.2023.184

Islam, Md.A., Sakakibara, H., Karim, Md.R., Sekine, M. and Mahmud, Z.H. (2011). Bacteriological assessment of drinking water supply options in coastal areas of Bangladesh. *Journal of Water and Health*, *9*(2), pp.415–428. https://doi.org/10.2166/wh.2011.114

Jahan, K., Zahid, A., Bhuiyan, M.A.E. and Ali, I. (2022). A Resilient and Nature-Based Drinking Water Supply Source for Saline and Arsenic Prone Coastal Aquifers of the Bengal Delta. *Sustainability*, [online] *14*(11), p.6703.https://doi.org/10. 3390 /su14116703

Jubayer, A. (2015*). Evaluation of drinking water technologies used in South-Western coastal Bangladesh a case study*, [Postgraduate Thesis, BUET]. Available at:http://lib.buet.ac.bd:8080/xmlui/handle/123456789/4305

Kamruzzaman, A.K. and Ahmed, F. (2006). Study of performance of existing pond sand filters in different parts of Bangladesh. *Loughborough University*. https:// hdl.handle.net/2134/29649

Khan, M.A.K. (2020). *Development of a GIS based model to explore safe water options insouthern coastal region*. [Master's Thesis. Military Institute of Science and Technology]. https://dspace.mist.ac.bd/xmlui/handle/123456789/623

Khan, M.S. and Paul, S.K. (2023). Fresh water management in coastal Bangladesh: preparedness and adaptation. *Discover Water*, *3*(1). https://doi.org/10. 1007/s43832-023-00052-y

Khan, M.S. and Paul, S.K. (2024). Quality and efficiency assessment, health issues and management practices of pond sand filter water in coastal Bangladesh. *International Journal of Energy and Water Resources*, *8*(3), pp.311–325. https://doi.org/10.1007/s42108-023-00264-x

Khan, Md.S. and Paul, S.K. (2023). Groundwater quality assessment and health issues in coastal zone of Bangladesh. *Journal of Hazardous Materials Advances*, [online] *10*, p.100278. https://doi.org/10.1016/j.hazadv.2023.100278

Lam, Y., Surkan, P.J., Winch, P.J. and Nizame, F.A. (2018). Freshwater access in high salinity regions: impacts and adaptation insights from the Ganges River Delta. *Journal of Global Health Reports*, *8*. https://doi.org/10.29392/ joghr.2.e2018007

Mallick, B. and Roldan-Rojas, F.L. (2015). Social Stratification in the Drinking Water Scarcity Context: Empirical Evidence of Coastal Bangladesh. *American Journal of Water Resources*, *3*(3), pp.92–99. https://doi.org/10.12691/ajwr-3-3-4

Mondal, B. and Bari, Q.H. (2023). Exploring sustainable water supply system of south-western coastal region of Bangladesh: A case study in Assasuni Upazila. *AIP Conference Proceedings*, 2713, p.060010. https://doi.org/10.1063/5.0130187

Mondal, B., Bari, Q.H. and Shafiquzzaman, Md. (2023). A ternary diagram approach to evaluate the sustainability of existing water supply systems in southwest coastal Bangladesh. *Sustainable Water Resources Management*, *9*(5). https://doi.org/10.1007/s40899-023-00925-z

Naus, F.L., Burer, K., van Laerhoven, F., Griffioen, J., Ahmed, K.M. and Schot, P. (2020). Why Do People Remain Attached to Unsafe Drinking Water Options? Quantitative Evidence from Southwestern Bangladesh. *Water*, *12*(2), pp.342. https://doi.org/10.3390/w12020342

Rafa, N., Jubayer, A. and Uddin, S.M.N. (2021). Impact of cyclone Amphan on the water, sanitation, hygiene, and health (WASH2) facilities of coastal Bangladesh. *Journal of Water, Sanitation and Hygiene for Development*. https://doi.org/10.2166/washdev.2021.170

Rahman, M., Ali, M., Ahmed, T., Habib, M. and Hossain, M. (2021). Drinking Water Supply Options in Arsenic and Salinity Affected Areas of Bangladesh: A Case Study. *Journal of Environmental Science and Natural Resources*, *12*(1-2*)*, pp.215–223. https://doi.org/10.3329/jesnr.v12i1-2.52039

Roman, O., Hoque, S.F., Ford, L., Salehin, M., Alam, M.M., Hope, R. and Hall, J.W. (2021). Optimizing Rural Drinking Water Supply Infrastructure to Account for Spatial Variations in Groundwater Quality and Household Welfare in Coastal Bangladesh. *Water Resources Research*, *57*(8). https://doi.org/10.1029/2021 wr029621

Sekaran, U. and Bougie, R. (2016). *Research Methods for Business: A Skill Building Approach*. John Wiley & Sons.

Shaibur, M.R. (2022). Salinity Levels in Pond, Deep Tube Well and Pond Sand Filter Waterin Two Unions of Southwestern Coastal District Satkhira, Bangladesh. *Advances in Science, Technology & Innovation*, pp.193–197. https: //doi. org/10.1007/978-3-031-00808-5_45

Shammi, M., Rahman, Md., Bondad, S. and Bodrud-Doza, Md. (2019). Impacts of Salinity Intrusion in Community Health: A Review of Experiences on Drinking Water Sodium from Coastal Areas of Bangladesh. *Healthcare*, [online] *7*(1), p.50. https://doi.org/10.3390/healthcare7010050

Shishir, Md.A., Mamun, Md.A., Mian, Md.M., Ferdous, U.T., Akter, N.J., Suravi, R.S., Datta, S. and Kabir, Md.E. (2018). Prevalence of Vibrio cholerae in Coastal Alternative Supplies of Drinking Water and Association with Bacillus-Like Spore Formers. *Frontiers in Public Health*, 6. https://doi.org/10. 3389/ fpubh. 2018.00050

Tsai, C., Hoque, M.A., Vineis, P., Ahmed, K.M. and Butler, A.P. (2024). Salinisation of drinking water ponds and groundwater in coastal Bangladesh linked to tropical cyclones. *Scientific Reports*, *14*(1), p.5211. https://doi.org/10.1038/s41598-024-54446-6

Uddin, M.R., Khandaker, M.U., Ahmed, S., Abedin, M.J., Hossain, S.M.M., Mansur, M.A.A, Akter, S., Akbor, M.A., Jamal, A.H.M.S.I.M., Rahman, M.M., Kazi, M., Siddique, M.A.B. and Idris, A.M. (2024). Assessment of coastal river water quality in Bangladesh: Implications for drinking and irrigation purposes. *PloS one*, *19*(4), pp.e0300878–e0300878. https://doi.org/10.1371/ journal.pone. 03 00878