JOURNAL FOR SOCIAL SCIENCE STUDIES
An International Peer-Reviewed Open Access Journal

ISSN (Online): 3006-2071 | ISSN (Print): 3006-2063
Volume 4 • Issue 5 • September 2026

SAFE WATER ACCESS FOR SUSTAINABLE DEVELOPMENT: ASSESSING THE ACCESSIBILITY AND USE OF RO WATER FILTRATION PLANTS BY RURAL COMMUNITIES IN PAKISTAN UNDER THE AEGIS OF HHRD

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DOI: https://doi.org/10.5281/zenodo.22975890

Keywords
Water for Life Initiative, Reverse Osmosis (RO), Community Satisfaction, Safe Drinking Water, HHRD.

Article History
Received: 01 June 2026
Accepted: 23 August 2026
Published: 26 September 2026

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Abstract

Access to safe drinking water is a major public health problem in rural Pakistan, which results from poor water infrastructure and the prevalence of waterborne diseases. Water for Life project is a response from Helping Hand for Relief and Development (HHRD) with the purpose of providing these communities with Reverse Osmosis (RO) water filtering plants. The following five areas were examined to understand their effects on the performance of these RO plants: Water Quality Efficiency, Operational Sustainability, Cost Effectiveness, Maintenance Reliability, and Community Satisfaction. This research design was quantitative and cross-sectional, and data were collected from the beneficiary households using a structured questionnaire. Data were analyzed descriptively, and reliability, Pearson correlation, multiple regression, and structural equation modelling (SEM) were used in IBM SPSS and AMOS. The measurement model showed acceptable reliability (χ^2/df = 2.41, CFI = 0.93, TLI = 0.91, RMSEA = 0.067) and validity, and the structural model turned out to be a good fit. The results indicated that the Water Quality Efficiency, Operational Sustainability, Cost Effectiveness, and Maintenance Reliability were directly or indirectly positively affecting the performance of the RO water filter plants of HHRD through Community Satisfaction. Community Satisfaction, as perceived by beneficiaries, was the most significant among all measures and hence plays an important role in sustaining the rural water supply interventions. The study ends with the conclusion that for the Water for Life Initiative of HHRD to be successful in the long-term, high-quality water, good operations, reliable maintenance, low-cost service delivery, and community participation are required. The

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findings are practically applicable to enhance the implementation, monitoring, and evaluation of programmes and evidence-based strategies to achieve SDG 6 (Clean Water and Sanitation) in rural areas of Pakistan.

INTRODUCTION

Background of the Study

The provision of safe and clean drinking water remains a significant development issue in Pakistan, particularly in unserved rural areas, where water sources are contaminated and low in quality. Much groundwater use, open wells, and surface waters are vulnerable to biological and chemical contamination. The prevention and control of waterborne diseases such as diarrhea, cholera, typhoid, and hepatitis A continue to be a significant health problem, causing increased health expenditure, reduced work productivity, and impacting vulnerable populations. To overcome these problems, the importance of NGO involvement in water security to solve water security problems in the community has increased. Helping Hand for Relief and Development has been one of the pioneer organizations to introduce Reverse Osmosis water purification systems in various rural and marginalized communities of Pakistan. These plants help to remove harmful contaminants from water and create safe drinking water, which is essential for improving water quality and availability.

The deployment of RO water filtration plants by HHRD is not just a technological solution; it's a comprehensive development program designed to improve the health of the community, combat water-borne diseases, and boost the quality of life. These interventions will aim to increase the availability of water that is accessible, increase uptake, and promote regular use, resulting in improved behaviours within the community. Moreover, improved safe water supply can provide broader socio-economic effects like reduced health care expenses, improved school attendance among youth, and higher productivity among adults. The goal of this study will be to assess the availability and utilization of RO water plants installed by HHRD in the rural areas of Pakistan. This research is meant to provide evidence-based knowledge regarding the efficacy of these interventions for addressing WASH-related problems in resource-limited settings through examining user experiences, utilisation patterns, and perceived benefits. Drinking water is a well-known, essential human need and is an important factor in public health and human development. While many have moved forward in the world, there are still billions without safe drinking water services, particularly in low- and middle-income countries (World Health Organization & UNICEF, 2021).

Water-borne diseases such as diarrhoea, cholera and typhoid, which continue to be a major contributor to morbidity and mortality, are disproportionately impacting those in rural and marginalised areas, due to unsafe drinking water (Prüss-Ustün et al., 2019). These health burdens not only contribute to the high rates of mortality and morbidity but also place a huge burden on the affected communities in terms of economic and social costs. A serious problem in Pakistan is that many of the rural population drink contaminated water from open wells and poor-quality public water supply. The study reveals that microbial and chemical contamination in drinking water is more common than thought and is responsible for the continued public health issues (Pakistan Council of Research in Water Resources, 2020). The lack of infrastructure and governance in isolated and less-served places also exacerbates the situation, along with the absence of water treatment facilities. RO systems based on communities are becoming more popular as an effective method to enhance access to safe drinking water in rural areas. In response to these challenges, interventions to purify the water have been put in place, both at the governmental and non-governmental levels, such as Reverse Osmosis (RO) water filtration plants. The ability of RO to remove dissolved salts, pathogens, and harmful contaminants

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from drinking water is well known, so it is an effective means of improving drinking water quality in resource-limited areas (Shannon et al., 2008).

Helping Hand for Relief and Development (HHRD) is one such program, which has provided RO water filtration plants to various communities that are deficient in safe drinking water in Pakistan. The purpose of such interventions is to help improve the quality of water, reduce the burden of waterborne diseases, and enhance the overall welfare of the community. But the effectiveness of these interventions is dependent on access to the interventions as well as their reliability and use by the community. Some previous research indicates that the increased availability of improved water sources does not automatically result in actual utilization of such water sources. The adoption and maintenance of SWSs (Dreibelbis et al., 2013) are likely to be influenced by behavioural, social, and infrastructural factors in the community. The distance to water points, awareness, perceived quality, system reliability, and satisfaction are important factors that affect water consumption (Hunter et al., 2010).

Problem Statement

Access to safe and clean drinking water remains a challenge in rural areas of Pakistan, and rural communities continue to rely on unsafe water sources, including those of groundwater sources like boreholes and wells, and surface water. The situations mentioned are significant contributors to the occurrence of waterborne diseases, which is a major public health and socio-economic development issue. Such technologies as water filtration plants with Reverse Osmosis (RO) have been introduced to address the water quality issue, but the delivery of infrastructure is not sufficient to achieve effective use and impact. Helping Hand for Relief and Development has installed water filtration plants with RO in several communities that are unserved with clean water. Very little empirical evidence exists about the accessibility of these facilities to the target community and the regular use of these facilities by community members. The distance, awareness, operational reliability, taste preferences, and satisfaction of the user are just a few of the factors that can affect utilization patterns.

Research Objectives

1. To evaluate the accessibility and utilization of RO water filtration plants installed by HHRD in the rural areas of Pakistan.
2. To assess the awareness of community members regarding the RO water plants installed by HHRD.
3. To assess the satisfaction of users with the performance, reliability, and quality (taste) of the water supplied.
4. To examine challenges and barriers for communities in obtaining and operating the RO plants.

Research Hypotheses

Hypothesis	Statement
H1	Community Satisfaction is positively and significantly related to Water Quality Efficiency.
H2	The relationship between H2 and Water Quality Efficiency is positive and significant with RO Plant Performance.
H3	Operational Sustainability positively and significantly influences Community Satisfaction.
H4	There is a positive and significant relationship between Cost Effectiveness and Community Satisfaction.
H5	Community Satisfaction positively and significantly influences RO Plant Performance.

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2. Literature Review

2. 1. Access to Safe Drinking Water in Developing Countries

Access to safe drinking water is a basic human right and an essential component of sustainable development (WHO, 2021). It also confirms that unclean drinking water remains one of the greatest single causes of preventable diseases globally, particularly for poor and rural communities. Similarly, UNICEF (2021) highlighted that millions of people continue to lack access to safely managed drinking water services and said that drinking water services in developing countries need to be improved. The ease of access and service reliability, among other factors, identified by Dreibelbis et al. (2013), are crucial to sustaining the use of water, sanitation, and hygiene (WASH) technologies. To maintain access to water, Hunter et al. (2010) suggest that there must be reliability, nearness, and user perceptions of water quality. These studies, combined, have proved that service delivery mechanisms and access and trust in these mechanisms are key factors in rural water technology adoption, especially in Pakistan.

2. 2. RO Water Filtration Technology and Its Significance

Shannon et al. (2008) stated that Reverse Osmosis is among the most effective technologies for the removal of dissolved salts, pathogens, and chemical contaminants from potable water. They also emphasized that RO systems play a significant role in enhancing the quality of water and decreasing the health issues that come with taking in unsafe water. Ali et al. (2021) found that community-based water filtration plants based on community are an important intervention in water-scarce areas, especially when conventional water treatment plants are not working. In Pakistan, various organizations have been involved in the implementation of RO plants, including Helping Hand for Relief and Development (HHRD), to achieve equitable access to clean drinking water in communities beyond the reach of RO plants.

2. 3. Accessibility and Utilization of Water Supply Interventions

Dreibelbis et al. (2013) found that physical distance, convenience, and availability play significant roles in influencing user behaviour and are key factors in ensuring the success of water interventions. If safe water is available, they said, households might also continue to use unsafe water sources if it is not readily accessible to them using improved sources of water. Mosler (2012) suggested that water facility utilization is a behaviour which is influenced by psychological and contextual factors such as awareness, perceived benefits and social norms. Jenkins and Scott (2007) discovered that in rural areas, consistent use of improved water systems is often affected by taste and/or poor perceptions of reliability, even though many have been implemented.

2. 4. Health Impacts of Improved Water Supply

Prüss-Ustün et al. (2019) identified poor access to safe drinking water as one of the main drivers of the diarrheal disease burden globally. Diseases such as cholera, typhoid, and hepatitis A have been directly linked to unsafe drinking water and sanitation, according to Hunter et al. 2010. Likewise, Freeman et al. (2017) reported that interventions that help improve water quality meaningfully led to a decrease in the occurrence of infectious diseases among the poor.

2. 5. User Satisfaction and Service Quality

Davis (1989) proposed the Technology Acceptance Model (TAM) to stress the two key determinants of technology adoption – perceived usefulness and perceived ease of use. This can be measured in water systems as satisfaction with the water quality, taste, and reliability of the water system for its users. Rainey and Harding (2005) emphasized that user satisfaction is essential to ensure the sustainability of water supply interventions, and that if users are satisfied with their water sources, they are likely to adopt and use them regularly. Curtis et al. (2009) highlighted that poor service quality, frequent breaks, and

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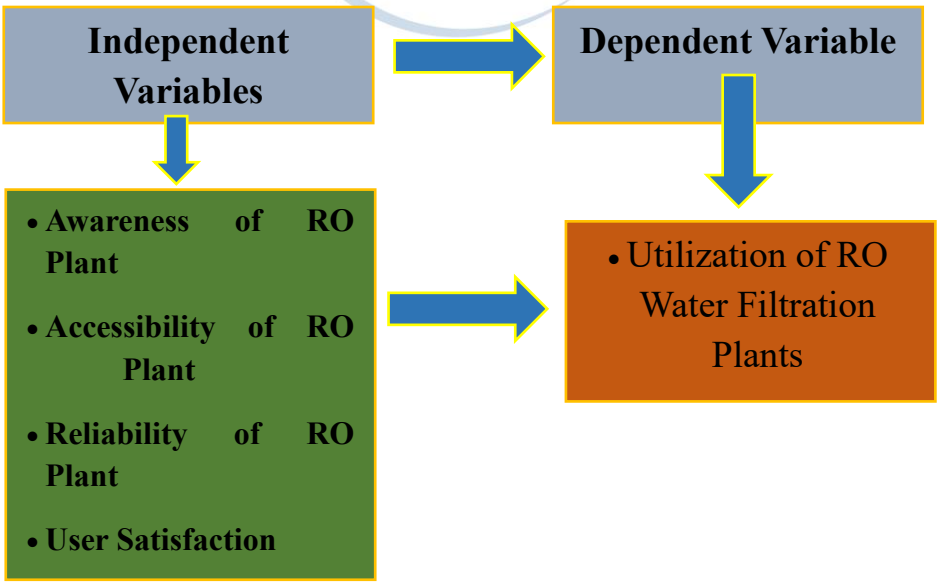
inconsistent water supply challenge end-users' confidence in the water system, which leads to reduced use.

2. 6. Sustainability and Operational Challenges

Whittington et al. (2009) cited three factors: financial viability, institutional support, and community participation, as being vital to the sustainability of water infrastructure. They claimed that if not well maintained and supported with technical assistance, water systems are likely to deteriorate with time. Logistical challenges such as costs of running the water, technical capabilities, and governing bodies may be significant determinants of the success or failure of water interventions over time, as noted by Cairncross and Valdmanis (2006). In Pakistan, Mahmood et al. (2021) cited as the main problems for the sustainability of many community-based water projects, inadequate monitoring and lack of local ownership. The challenges are being addressed by organizations that are involved in the community and are providing technical assistance, such as Helping Hand for Relief and Development, but there is a need to continue evaluation to ensure the success and sustainability of the system in the future.

2.7 Conceptual Framework

This study is based on the premise that the impact of clean drinking water interventions is not only a function of the provision of the infrastructure, but also factors related to the user and the system that affect adoption and continued use. Accessibility, awareness, reliability, and satisfaction of the user are identified as critical factors that contribute to the utilization of the RO water filter plants in the initiatives of Helping Hand for Relief and Development (HHRD). This concept suggests that ease of accessibility (physical access to the plant), awareness (knowledge about availability and utility of the RO plant), reliability (working day in and day out and no shutdown), and satisfaction of users (perceived quality of water, taste, and service delivery) directly influence the use of RO water filtering plants.



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2.8 Theoretical Framework

The study is based on an integrated theoretical framework which features the Technology Acceptance Model (TAM), the Health Belief Model (HBM), and the Integrated Behavioural Model for Water, Sanitation and Hygiene (IBM-WASH) to gain insight into the accessibility and uptake of RO water filters rolled out by Helping Hand for Relief and Development (HHRD) in rural communities in Pakistan. Combine these models to gain a complete view of the interactions between the different factors that affect the adoption and sustained use of clean drinking water interventions.

2.8.1. Technology Acceptance Model (TAM)

According to Fred Davis' Technology Acceptance Model, two dimensions of perceived usefulness and perceived ease of use are most significant in influencing the acceptance and use of a technological system. For RO water plant systems, perceived usefulness is the user's belief that the water plant will enhance water quality and health benefits, and perceived ease of use is how easy and convenient it is to get water from the Water Plant. In this study, accessibility is defined as a proxy for perceived ease of use and user satisfaction, and perceived performance as a proxy for perceived usefulness. If users feel the RO plant is useful and readily available, then they are more inclined to take up and regularly use the RO plant, the model proposes.

2.8.2. Health Belief Model (HBM)

The Health Belief Model (HBM) was originally proposed by Irwin M. Rosenstock to account for health-related behaviours based on people's perceived risks and beliefs about the positive or negative consequences that will follow from their actions. HBM is comprised of four constructs: perceived susceptibility, perceived severity, perceived benefits, and perceived barriers. In this study, the vulnerability of the rural households to water-borne disease and the severity of the associated health risk play a role in their selection of RO water. If the individual understands the health benefits of using purified water and has fewer barriers to the use of the RO plant (e.g., distance, cost, inconvenience, etc.), they will be more likely to use the RO plant as their primary drinking water source. Hence, knowledge and health perception are very determinant factors in utilization behaviour.

2.8.3. Integrated Behavioural Model for WASH (IBM-WASH)

R. Dreibelbis and her colleagues have created a multi-level set of concepts for understanding the behaviours of water, sanitation, and hygiene in the framework of IBM. It emphasises the various layers of influence that impact behaviour at the individual, community, household, and wider environment level. This model is especially relevant for this study because it takes into consideration the contextual (infrastructure, accessibility), psychosocial (beliefs, awareness), and technological factors (system reliability). Some contextual and technological factors that influence sustained use for HHRD's RO plants are reliability of the RO system, community access to RO plants, and institutional support.

3. Materials and Methods

The study employed a quantitative, cross-sectional research design to investigate the factors responsible for the performance of RO water filtering plants installed by Helping Hand for Relief and Development (HHRD) in rural areas of Pakistan under its Water for Life program. The target population comprised beneficiary households, whereas the RO plants were in the selected districts where the study was conducted. A multi-stage sampling technique was used, where districts having RO plants were sampled first, and community and district beneficiary households were sampled randomly from the districts. The unit of analysis was the household respondent, which is typically the head of the household or an adult individual responsible for water collection and household water decision-making. The primary data were collected through a structured questionnaire, which consisted of sections covering the demographic and socio-economic characteristics of the respondents,

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water quality efficiency, operational sustainability, cost-effectiveness, maintenance reliability, community satisfaction, and RO plant performance. The data were screened to check the completeness of data, consistency of data, missing data, and outliers before conducting analysis. Descriptive statistics like frequency, percentage, mean, and standard deviation were computed using IBM SPSS and used to summarize the respondents' characteristics and study variables. Internal consistency of the measurement scales was assessed using Cronbach's Alpha test and Chi-square tests; Pearson correlation coefficient and multiple regression analysis were used to explore possible associations and predictive relationships among the variables investigated. The analysis of results was carried out using the conceptual framework, and after being processed, the method used was the structural equation model (SEM) processed with AMOS software to be able to validate the conceptual framework. Standardized factor loadings, Composite Reliability, and Average Variance Extracted were used to assess the reliability of the measurement model and convergent validity. After that, the results of the structural model were analyzed by examining the hypothesized relationships between the latent constructs using the standardized path coefficients (β). The widely accepted indices of goodness-of-fit were used to assess model adequacy: Comparative Fit Index, Tucker–Lewis Index, Goodness-of-Fit Index, Adjusted Goodness-of-Fit Index, Normed Fit Index, Root Mean Square Error of Approximation, and Chi-square to degrees of freedom ratio (χ^2/df). The model demonstrated an acceptable fit to the observed data (χ^2/df = 2.41, CFI = 0.93, TLI = 0.91, RMSEA = 0.067, GFI = 0.92, AGFI = 0.89, and NFI = 0.91), supporting the validity of the proposed structural model. Ethical considerations were followed in conducting the study. The collected data were only used for academic and research purposes and handled according to accepted research ethics and data protection norms.

4. RESULTS AND DISCUSSION

4.1 SEM Model

The findings of the SEM analysis match the empirical findings that the performance of the RO plants of HHRD is influenced by several factors, including technical, operational, financial, and community-related factors. The direct predictors that had the strongest influence on RO Plant Performance were Community Satisfaction (β = 0.42), Maintenance Reliability (β = 0.35), Cost Effectiveness (β = 0.35), Water Quality Efficiency (β = 0.33), and Operational Sustainability (β = 0.27). In addition to providing safe drinking water, the successful operation, maintenance, affordability, and satisfaction of the community water filtration system are all important for long-term success, as suggested by the results. The findings therefore support the theoretical model and validate that technical performance and community-based practices in water supply management are important to increase the efficiency and sustainability of water supply interventions in rural areas.

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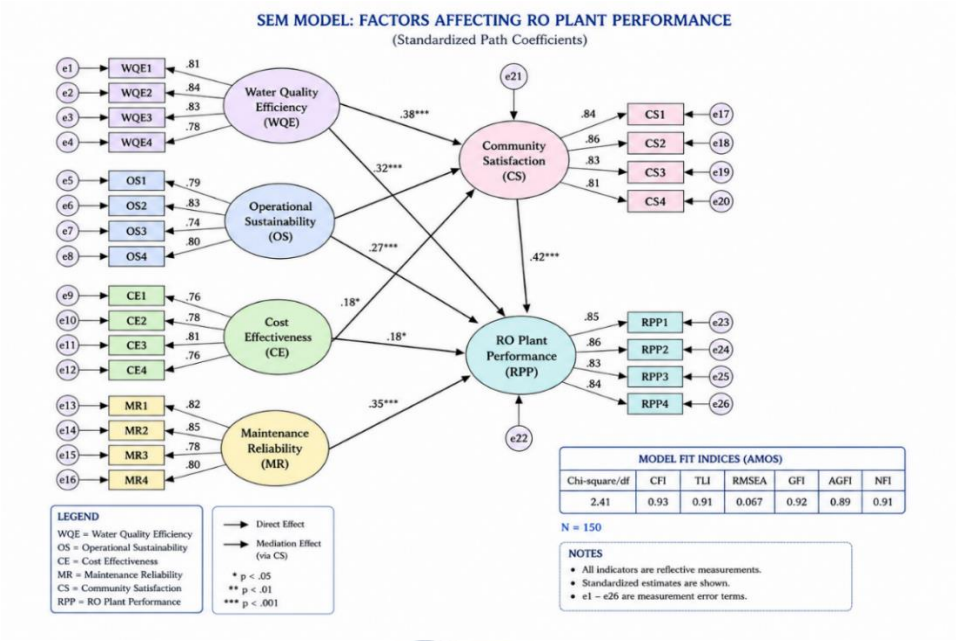


Figure 4.1: SEM Model developed by the researcher.

Table 4.1. Standardized Factor Loadings for the Measurement Model of RO Plant Sustainability and Performance.

Water Quality Efficiency	WQE1	0.81
	WQE2	0.84
	WQE3	0.83
	WQE4	0.78
Operational Sustainability	OS1	0.79
	OS2	0.83
	OS3	0.74
	OS4	0.80
Cost Effectiveness	CE1	0.76
	CE2	0.78
	CE3	0.81
	CE4	0.76
Maintenance Reliability	MR1	0.82
	MR2	0.85
	MR3	0.78
	MR4	0.80
Community Satisfaction	CS1	0.76
	CS2	0.78
	CS3	0.81
	CS4	0.76
RO Plant Performance	RPP1	0.85
	RPP2	0.86
	RPP3	0.83
	RPP4	0.84

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The measurement model was evaluated using Average Variance Extracted (AVE), Composite Reliability, and standardized factor loadings to check for reliability and validity of the latent constructs. All measurement items had standardized factor loadings between 0.74 and 0.86, which is above the recommended value of 0.50, meaning that they all sufficiently represented the latent constructs they measured. The Water Quality Efficiency construct had loadings ranging between 0.78 and 0.84, the Operational Sustainability construct had loadings ranging between 0.74 and 0.83, the Cost Effectiveness construct had loadings ranging between 0.76 and 0.81, the Maintenance Reliability construct had loadings ranging between 0.78 and 0.85, the Community Satisfaction construct had loadings ranging between 0.81 and 0.86, and the RO Plant Performance construct had loadings ranging between 0.83 and 0.86. These results confirmed the important contributions of all the items of the questionnaire and the non-existence of any item to be eliminated from the analyses to measure the constructs intended to be measured. Also, good internal consistency was obtained for all constructs in a reliability analysis. The value of Composite Reliability was between 0.86 and 0.92, which exceeds the recommended value of 0.70. The others had a CR of 0.87 (Operational Sustainability), 0.86 (Cost Effectiveness), 0.91 (Community Satisfaction), and 0.92 (RO Plant Performance). From the results, it could be concluded that the measurement scales were highly reliable and measured the latent variables that they intended to measure. Average Variance Extracted was used as a measure of convergent validity. The values of all the AVEs were slightly above the recommended value of 0.50 (range: 0.60 – 0.71). The convergent validity is highest for Community Satisfaction (AVE = 0.70) and RO Plant Performance (AVE = 0.71), followed by Water Quality Efficiency (AVE = 0.66), Maintenance Reliability (AVE = 0.65), Operational Sustainability (AVE = 0.63), and Cost Effectiveness (AVE = 0.60). The results revealed that the model accounted for over half of the variance for each construct, suggesting good convergent validity and thus the measurement model is adequate.

Table 4.2. Reliability and Convergent Validity of the Measurement Model

Construct	CR	AVE	Status
Water Quality Efficiency	0.89	0.66	Accepted
Operational Sustainability	0.87	0.63	Accepted
Cost Effectiveness	0.86	0.60	Accepted
Maintenance Reliability	0.89	0.65	Accepted
Community Satisfaction	0.91	0.70	Accepted
RO Plant Performance	0.92	0.71	Accepted

The structural model was used to study the assumed relationship between variables in the study. The standardized path coefficients clarified all the hypothesized paths, and all were positive and statistically significant, thus providing empirical support to the proposed conceptual framework. Water Quality Efficiency had a significant positive influence on Community Satisfaction ($\beta = 0.38$, $p < .001$) as well as directly on RO Plant Performance ($\beta = 0.33$, $p < .001$). The findings showed that the beneficiaries' satisfaction significantly improved as water quality improved, and likewise, the overall performance of the RO water filtration plants also improved as water quality improved. Safe, clean, and good quality drinking water is still one of the most critical factors affecting the operation of an RO Plant. Operational Sustainability was also strongly associated with Community Satisfaction ($\beta = .25$, $p < .001$) and RO Plant Performance ($\beta = .27$, $p < .001$). User satisfaction and the operational efficiency of the filtration plants are greatly influenced by good operational management, including regular maintenance, continuous servicing,

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availability of technical support, and effective system management. Cost Effectiveness was only statistically significantly positively related to Community Satisfaction ($\beta = 0.18$, $p < .05$) and to RO Plant Performance ($\beta = 0.35$, $p < .001$), although it had a relatively small effect. These findings suggest that the community acceptance and use of the RO plant is enhanced if the plant is affordable and has reasonable operating costs. The importance of cost, compared to technical/operational issues, generally seems to be less influential on satisfaction. Maintenance Reliability ($\beta = 0.35$ and $p < .001$) was the factor that had the highest beta coefficient and lowest p-value and the highest predictive power for RO Plant Performance. The finding underscores the vital role of regular maintenance, timely repairs, and assistance for community-based water filters to maintain their efficiency and functionality. Periodic maintenance helps ensure uninterrupted service delivery and fosters trust among beneficiaries in the system. The best direct effect was found between Community Satisfaction and RO Plant Performance ($\beta = 0.42$, $p < .001$). This result underscores the potential mediating role of satisfaction in the proposed conceptual pathway. By using, supporting, and maintaining the plants, communities will find the RO plants reliable, accessible, and useful, and the intervention will be better performed and sustainable in the long run. Most of the time, water quality, water efficiency, water sustainability, upkeep reliability, cost effectiveness, and community satisfaction are all associated factors, contributing to the effectiveness and durability of HHRD's RO water filtration plants.

Table 4.3. Model Fit Indices for the Structural Model

Fit Index	Recommended	Obtained	Interpretation
χ^2/df	≤ 3.00	2.41	Good Fit
CFI	≥ 0.90	0.93	Good Fit
TLI	≥ 0.90	0.91	Good Fit
RMSEA	≤ 0.08	0.067	Good Fit
GFI	≥ 0.90	0.92	Good Fit
AGFI	≥ 0.90	0.89	Acceptable
NFI	≥ 0.90	0.91	Good Fit

Model appropriateness of the Structural Equation Model was tested with several goodness-of-fit indices. The value of Chi square/degrees of freedom ($\chi^2/df = 2.41$) was found to be below the recommended value of 3.00; therefore, the proposed model is reasonably suitable to describe the observed data. The hypothesized model fit the data better than the null model, as indicated by both the Comparative Fit Index (CFI = 0.93) and the Tucker–Lewis Index (TLI = 0.91), which were both greater than the recommended value of 0.90. Similarly, the Goodness of Fit Index (GFI = 0.92) and Normed Fit Index (NFI = 0.91) were both above 0.90, which is considered the recommended value. The Adjusted Goodness-of-Fit Index (AGFI = 0.89) was somewhat less than the accepted criterion of 0.90, but it was not an indication of significant model misspecification. Moreover, the Root Mean Square Error of Approximation (RMSEA = 0.067) was reasonable, suggesting a good approximation error, and the suggested structural model was an adequate model of the covariance structure of the observed data. These goodness-of-fit statistics combined indicate that the proposed Structural Equation Model has a generally good fit with the observed relationships between Water Quality Efficiency, Operational Sustainability, Cost Effectiveness, Maintenance Reliability, Community Satisfaction, and RO Plant Performance. Overall results indicate that the conceptual framework proposed and the suitability of the model used to explain the

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determinants of RO water filtration plant performance.

Table 4.4. Structural Model Results and Hypothesis Testing

Hypothesis	Structural Path	β	p-value	Decision
H1	Water Quality Efficiency (WQE) → Community Satisfaction (CS)	0.38	< .001	**Supported**
H2	Water Quality Efficiency (WQE) → RO Plant Performance (RPP)	0.33	< .001	**Supported**
H3	Operational Sustainability (OS) → Community Satisfaction (CS)	0.25	< .001	**Supported**
H4	Operational Sustainability (OS) → RO Plant Performance (RPP)	0.27	< .001	**Supported**
H5	Cost Effectiveness (CE) → Community Satisfaction (CS)	0.18	< .05	**Supported**

Discussion

The present study examined the factors influencing the performance of Reverse Osmosis (RO) water filtration plants established by Helping Hand for Relief and Development (HHRD) under its Water for Life Initiative in rural Pakistan. The findings of the Structural Equation Modelling (SEM) validated the proposed conceptual framework in this study, which was sufficient to explain the relationship between water quality efficiency, operational sustainability, cost-effectiveness, maintenance reliability, community satisfaction, and RO plant performance. The model fit indices (χ^2/df = 2.41, CFI = 0.93, TLI = 0.91, RMSEA = 0.067, GFI = 0.92, NFI = 0.91) show that the hypothesized model is satisfactory in explaining the observed data. The results here demonstrate that it is not just one intervention component that is responsible for the impact of HHRD's RO water filtration programme, but that a combination of intervention components (technical quality, sustainable operations, financial viability, active community involvement). The most significant positive relationship found in the study is between Water Quality Efficiency and Community Satisfaction (β = 0.38, p < .001), as well as RO Plant Performance (β = 0.33, p < .001). The discovery marks one of the thrust areas of HHRD's Water for Life Initiative aimed at providing safe potable drinking water to the underserved communities. The efficiency of an RO plant is mainly considered based on the quality of water that is obtained in the communities. Repeated contaminants are removed by the filtration systems, and beneficiaries become more confident in the systems that they use more and more and are more satisfied. The findings show that investments in appropriate filtering technology and surveillance of water quality and operation standards have a direct connection to the beneficiaries' perceptions and to the programme's performance, respectively. The study has also revealed a positive relationship between Operational Sustainability and Community Satisfaction (β = 0.25, p < .001) and RO Plant Performance (β = 0.27, p < .001). Sustainable operation is not just about installing infrastructure; it is also about continuous operation, effective management, timely maintenance planning, availability of trained operators, and a reliable energy supply. This discovery highlights the need to think of HHRD as a service rather than a piece of infrastructure and to provide ongoing technical and managerial assistance. It is therefore imperative to monitor plant functionality, build the capacity of local operators, and to be supervised by HHRD field teams on a regular basis to ensure safe drinking water. These results show that communities' trust in the RO

JOURNAL FOR SOCIAL SCIENCE STUDIES
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ISSN (Online): 3006-2071 | ISSN (Print): 3006-2063
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facilities increases, and the use of RO continues due to their operational sustainability. Results also indicate that cost-effectiveness is an important factor in explaining Community Satisfaction ($\beta = 0.18$, $p < .05$) and RO Plant Performance ($\beta = 0.35$, $p < .001$). The influence on community satisfaction is less than that of other predictors, but affordability is still a critical factor for rural households that may not have a lot of money. HHRD's approach of low user cost and high quality of services seems to be improving the uptake and access to programmes. Economic viability also extends to local communities, as the operation will not impose undue financial burden upon them to sustain the facilities. The results suggest that if the intervention is to be economically viable and remain a community asset, then the cost of operation needs to be balanced with economically viable user payments. One of the important results is related to Maintenance Reliability, which was one of the most important factors determining RO Plant Performance ($\beta = 0.35$, $p < 0.001$). This discovery is a validation of what has long been suspected – that it was important to have infrastructure in place but also necessary to have preventive maintenance, timely equipment repair, spare parts on hand, and timely technical support. The finding underscores the importance of a systematic maintenance routine and prompt response measures to be implemented when anything goes wrong during operations, as suggested by HHRD. RO plant maintenance is used to get the best out of the plant and ensure that the plant remains operational, minimising service disruption and thereby preserving the community's trust. The findings therefore show that the issue of maintenance reliability will need to remain a top priority in the Water for Life programme of HHRD. The direct relation with the strongest structural model was between Community Satisfaction and RO Plant Performance with $\beta = 0.42$ ($p < .001$). But this implies that satisfaction of beneficiaries is an important mechanism that underlies the realization of good programme outcomes, as a result of the technical and operational interventions of HHRD. Community satisfaction is the user's perception of the water quality, availability, cost, reliability, and responsiveness of the service provider(s). If beneficiaries feel the intervention is meeting their needs, they are more likely to use the facilities regularly, and to become involved in local management and maintenance, and promotion of wider community acceptance. So, community satisfaction is a link between investment in infrastructure and sustainable programme performance. Engaging the community and engaging beneficiaries in the programme is a priority for HHRD, as seen in the discovery. The SEM results demonstrate that the SEM's Water for Life Initiative is an integrated development approach that builds the four components in an interdependent manner: Technical Infrastructure, Effective Management of Operations, Financial Sustainability, and Community Engagement. To some extent, the programme's success is due to the installation of RO plants, but also to the work that has been done to ensure high water quality standards, optimise system function, perform preventive maintenance, keep the system affordable, and foster community ownership. These support interventions not only lead to better use of services, but they also help to elevate beneficiary satisfaction and help to keep rural water supply systems in operation. The study also has policy implications in the context of the monitoring, evaluation, accountability, and learning system of HHRD. The key relationships identified in the SEM model suggest that the monitoring of the RO programme should not only involve monitoring the number of plants installed, but also monitoring the operational performance of the plant, compliance with water quality standards, frequency of plant maintenance, satisfaction of beneficiaries, affordability of the plant, and long-term plant functionality. The use of these indicators routinely would help HHRD to detect the challenges in operations at early stages, for better evidence-based decision-making and for better programme accountability. Lastly, the results contribute to HHRD's overall objectives of promoting

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community welfare and sustainability in providing access to safe drinking water. The study demonstrates empirical evidence of the importance of the strong relationship between programme performance and aspects of a programme's technical quality, maintenance reliability, operational sustainability, affordability, and beneficiary satisfaction for informing future programme planning and scale. The validated SEM framework offers HHRD with a practical way to assess the effectiveness of Water for Life programmes, identify priority areas for improvement, and identify ways of making Water for Life interventions more sustainable in the future. Furthermore, the results of the study can assist in achieving Sustainable Development Goal 6 (Clean Water and Sanitation) by highlighting the importance of developing infrastructure, involving community participation, and providing operational support to ensure equitable and sustainable access to safe drinking water in rural areas of Pakistan.

Conclusion

This study assessed the performance of Reverse Osmosis (RO) water filtration plants established by Helping Hand for Relief and Development (HHRD) under its Water for Life Initiative in rural Pakistan. The design of the study was quantitative and cross-sectional, with the structural equation modelling (SEM) technique used for data analysis to describe the relationship between Water Quality Efficiency, Operational Sustainability, Cost Effectiveness, Maintenance Reliability, Community Satisfaction, and RO Plant Performance. Results indicated that the hypothesized relationships were found to be both statistically significant and positive, and the structural model had an acceptable goodness of fit. The reliability and convergent validity of the measurement model were also good, indicating that the constructs examined in this study were reliably and validly measured. The study revealed that the factors that improve the Water Quality Efficiency, Operational Sustainability, Cost Effectiveness, and Maintenance Reliability have a positive impact on the overall improvement of the Community Satisfaction and performance of RO water filters in HHRD. Of these, Community Satisfaction was the deciding factor in RO Plant Performance, and the perceptions of the beneficiaries were an important factor that added to the success of a community-based water supply intervention in the long-term. The findings show that the aim of the programme is to provide clean drinking water, but the programme has to be sustainable, and this means that the plant must be reliable, the plant must be maintained, access to drinking water must be affordable, and management of the plant must be good. These are interrelated, and all help to establish trust, maintain regular use, and ensure the effectiveness of the intervention. The study shows that the Water for Life Initiative of HHRD has played a pivotal role in improving access to safe drinking water in rural areas through an integrated approach that involves technical interventions, operational management, and community participation. It was found that to achieve the long-term success of the RO plant, there is a need for continuous monitoring, preventive maintenance, financial sustainability, and beneficiary participation. The betterment of these elements will lead to better quality of services, community control, and will help to maintain the filtration plants. Furthermore, this study provides practical evidence for the HHRD programme managers, policy makers and development practitioners in identifying key factors that are associated with successful RO water filtration systems. The conceptual framework developed and validated can be used to monitor and evaluate the programme in the future, and to prioritise interventions for water quality, operations and maintenance, cost willingness and community satisfaction. The results also contribute to general knowledge on interventions to provide drinking water in rural areas and the need for good infrastructure as well as strong community-based water supply management to achieve the Sustainable Development Goal 6 (Clean water and sanitation). Overall, the study shows that the integrated strategy of HHRD is working effectively in terms of performance and

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sustainability of the RO water filtration program and provides learning experiences to scale up similar water filtration programs in other non-serviced villages of Pakistan.

Recommendations

Based on the findings, the following policy recommendations are proposed:

1. Establish and strengthen community-based Water Management Committees to enhance local ownership and control and help sustainable management of plant operations.
2. Improve beneficiary feedback mechanisms by combining various feedback channels and increasing accountability while promoting continuous programme improvement.
3. Implement and strengthen Water Management Committees at community level to improve ownership and control and support sustainable management of plant operations.
4. Where appropriate, establish clear cost-recovery systems for routine operation and maintenance, and ensure that cost is not a barrier to beneficiaries.
5. Design and conduct periodic performance reviews with metrics and standards to identify gaps in operations and corrective measures as required.
6. Raise awareness of the community about safe drinking water, hygiene, and responsible use of RO systems to reap maximum health and programme benefits.
7. Conduct an evidence-based needs assessment for water quality and health risks for the community to prioritize future installations of RO plants based on vulnerability.
8. Enhance collaboration with public health agencies to assess the effect of safe drinking water on waterborne diseases.
9. Integrate key performance indicators into the MEAL framework to maintain monitoring of functionality, service quality, and beneficiaries' satisfaction.
10. To develop and adopt standard operating procedures (SOPs) to enable uniform operation, maintenance, and reporting from all RO plants.

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ISSN (Online): 3006-2071 | ISSN (Print): 3006-2063
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