

Article

Reasons of Acceptance and Barriers of House Onsite Greywater Treatment and Reuse in Palestinian Rural Areas

Rehab A. Thaher ¹, Nidal Mahmoud ², Issam A. Al-Khatib ^{2,*}  and Yung-Tse Hung ³

¹ Faculty of Graduate Studies, Birzeit University, P.O. Box 14, Birzeit, West Bank, Palestine; rehabthaher@gmail.com

² Institute of Environmental and Water Studies, Birzeit University, P.O. Box 14, Birzeit, West Bank, Palestine; nmahmoud@birzeit.edu

³ Department of Civil and Environmental Engineering, Cleveland State University, Cleveland, OH 44115, USA; y.hung@csuohio.edu

* Correspondence: ikhatib@birzeit.edu

Received: 18 May 2020; Accepted: 9 June 2020; Published: 11 June 2020



Abstract: In the last twenty years, house onsite wastewater management systems have been increasing in the West Bank's rural areas. The aim of this research was to reveal, in the context of providing onsite Grey Water Treatment Plants (GWTPs) for wastewater management in the rural communities in Palestine, the local population's perceptions, in the sense of acceptance of and barriers towards such a type of wastewater management, so as to figure out successes, failures and lessons. The data collection tool was a questionnaire that targeted the households served with GWTPs. The findings show that 13% of the total constructed treatment plants were not operative. The most important barrier as mentioned by 66.5% is odor emission and insect infestation. Then, 25.1% of the implementing agencies never monitor or check the treatment plants, and 59.3% of them monitor and check the plants only during the first 2–3 months. The next barrier is inadequate beneficiary experience in operation and maintenance. Health concerns regarding quality of crops irrigated by treated grey water were another barrier. The results revealed that the reuse of treated grey water in irrigation was the main incentive for GWTPs as stated by 88.0% of beneficiaries. The second incentive was the saving of cesspit discharge frequency and its financial consequences, as stated by 71.3%. Finally, 72.5% of the beneficiaries stated that they had a water shortage before implementing GWTPs, and the GWTPs contributed to solving it. The highest percentage (82.6%) of beneficiaries accepted the treatment units because of their willingness to reuse treated water for irrigation and agricultural purposes. Education level has an impact on GWTP acceptance, with 73% of not educated beneficiaries being satisfied and 58.8% of educated people being satisfied. Islamic religion is considered a driver for accepting reuse of treated grey water in irrigation, according to the majority of people (70%). Women play a major role on GWTP management; 68.9% of the treatment systems are run by men side-by-side with women (fathers and mothers), and 24% are run completely by women. The majority of GWTP beneficiaries (70.4%) are satisfied with GWTPs. Little effort is required for operation and maintenance, with only an average of 0.4 working hours per week. Therefore, house onsite grey water management systems are acceptable in rural communities, but attention should be given to the reasons of acceptance and barriers highlighted in this research.

Keywords: greywater treatment; house onsite; reuse; irrigation; acceptance; barriers

1. Introduction

1.1. General Information

Palestinian territories face significant and growing shortfalls in the water supply available for domestic use. The World Health Organization (WHO) considers 100 liters per capita per day (L/c.d) as the benchmark minimum for domestic consumption to achieve full health and hygiene benefits. In contrast, available water resources for domestic consumption in the West Bank are only 62 L/c.d [1].

The results of the Palestinian Central Bureau of Statistics [2] showed that 93% of the households in the Palestinian Territory live in housing units connected to a water network [2]. During 2015, data indicated that 53.9% of households in Palestine used wastewater networks to dispose their wastewater, while 31.8% of households used porous cesspits [2]. The estimated quantity of wastewater generated in the West Bank for the year 2015 was estimated at 65.82 million cubic meters (MCM) [3].

In the last twenty years, house onsite grey water management systems have been implemented in the rural communities of the West Bank, justified by lack of adequate wastewater services and driven by business opportunities for the implementing Non-Governmental Organizations (NGOs) funded by donors. Some of those projects were not successful, but some others are still operating very successfully. The reasons for acceptance and barriers of providing onsite grey water treatment plants from the beneficiaries' points of view have not yet been investigated.

A decentralized wastewater management system may consist of individual onsite systems and/or cluster systems, either singly or in combination with more highly collectivized facilities [4]. The degree of collectivization at any stage of the treatment and reuse or dispersal processes will be determined by a variety of local circumstances, including topography, site and soil characteristics, development density, type of development, community desires with regard to land use issues and sites of potential reuse and/or sites where discharge would be allowable. Decentralized wastewater systems in particularly arid regions promote wastewater uptake by plants [5].

The composition of grey water varies greatly and reflects the lifestyle of the residents and the choice of household chemicals for washing up, laundry etc. [6]. Characteristic of grey water is that it often contains high concentrations of easily degradable organic material, i.e., fat, oil and other organic substances from cooking, as well as residues from soap and detergents [7–9].

The generated amount of grey water greatly varies as a function of the dynamics of the household. It is influenced by factors such as existing water supply systems, number of household members, age distribution, life style characteristics, typical water usage patterns, etc. Reuse of treated grey water in irrigation can significantly contribute to reducing water bills and increasing food security [10–13], at the same time leading to saving of drinking water for domestic consumption.

Grey water, in contrast to common perception, may be quite polluted, and thus may pose health risks and negative aesthetics (i.e., offensive odor and color) and environmental effects [14–16].

Grey water contains pollutants and microorganisms stemming from household and personal cleaning activities. Laundry and shower water are slightly polluted, but kitchen water is highly polluted with organic matter from food wastes, and so requires special attention [17]. Indeed, grey water contains by far fewer pathogens than total sewage [18]. Therefore, grey water should not be considered as a waste, but a beneficial resource. It is increasingly agreed that grey water can alleviate water shortages [19,20]. Grey water is a valuable water resource that can be utilized for irrigating home gardens or agricultural land [10].

The willingness of households to adopt a grey water treatment and reuse system depends on many factors such as sociocultural acceptance, public awareness, economic situation and institutional capacity in the field of the onsite treatment [21]. The public perception of wastewater reuse is still suspicious although generally grey wastewater reuse is more acceptable than black water reuse [22].

The aim of this research was to investigate the reasons of GWTPs' acceptance by the beneficiaries and the barriers of implementing these systems in the Palestinian rural communities.

1.2. Grey Water Practices in Palestine

Great efforts have been undertaken by Palestinian institutions, governmental and non-governmental, to advance the wastewater infrastructure centralized and onsite systems. Nevertheless, low population densities in rural and suburban areas and limited funding are major obstacles for the development of wastewater services. The Palestinian institutions promote implementation of house and community onsite treatments and agricultural reuse of treated effluents. However, sociocultural acceptance and public awareness should be addressed, as well as the institutional capacity to administer the decentralized wastewater management systems. Figure 1 shows an example of onsite grey water treatment plant, and Figure 2 shows a reuse scheme by treated grey water in Palestine.



Figure 1. Onsite grey water treatment plant, Duara Al Qare'-Ramallah.



Figure 2. Reuse scheme by treated grey water in Palestine, Al Qubeba-Jerusalem.

1.3. Description of House Onsite Grey Water Treatment Plant

The house wastewater piping systems are modified to separate the grey and black wastewaters. The (black) toilet wastewater is disposed into an available cesspit. The grey wastewater (wastewater sources except toilet wastewater) is transported to the household grey water treatment plant (GWTP).

The onsite GWTP is comprised of a septic tank (first compartment) ahead of two up-flow gravel filters (second and third compartments) as presented in Figure 1. Grease is tapped in the septic tank using an outlet T-shaped pipe as shown in Figure 3. The fourth compartment is a pumping wet well tank where the anaerobically pre-treated wastewater is lifted to a multi-layer coal–sand filter. Afterwards, the treated wastewater is stored in an irrigation tank connected to the garden irrigation network. More details about the system can be found in Burnat and Shtayye [23].

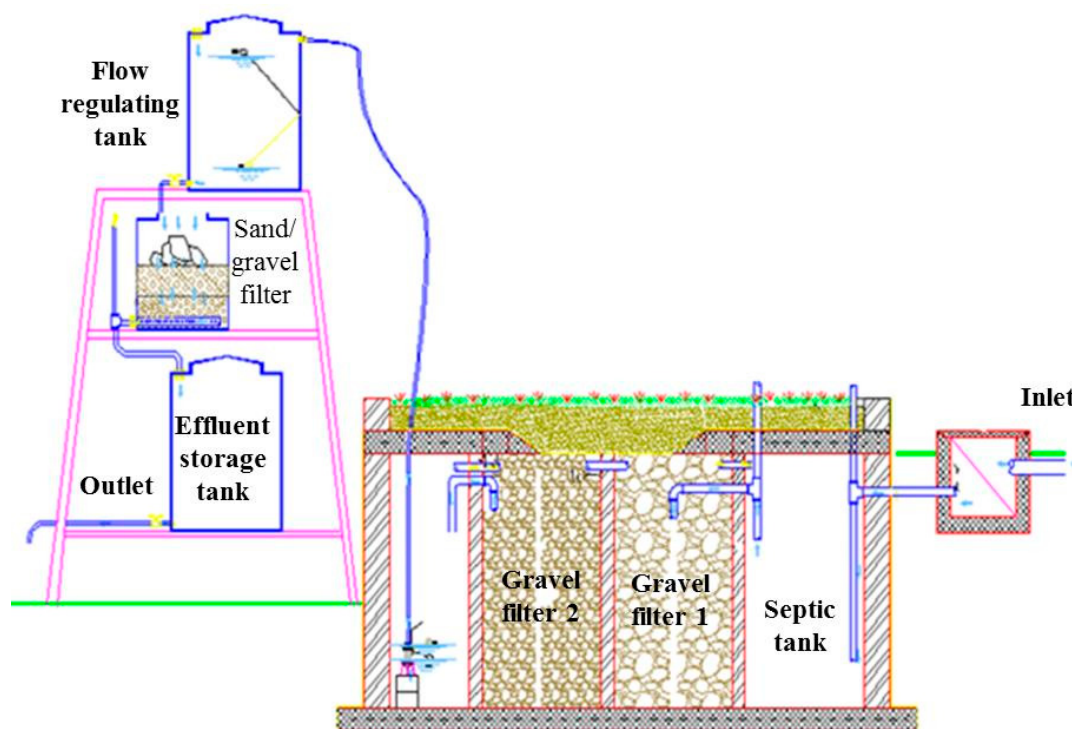


Figure 3. Onsite grey water treatment plant [23].

2. Methodology

The study area included 18 different rural communities in eight governorates of the West Bank: Ramallah, Jerusalem, Bethlehem, Hebron, Jenin, Tubas, Tulkarem, Nablus. The study area was selected according to the availability of onsite GWTPs distributed mostly in all governorates of the West Bank as illustrated in Figure 4.

In this study, a survey by questionnaire was conducted. A sample of 185 owner “beneficiaries” of onsite GWTPs at the household level was randomly selected and the questionnaire was distributed at the household level. The recovery rate was 89.2%, as 166 questionnaires were filled. The questionnaire was finalized after consulting several experts from different institutions and key people who work in the water and sanitation fields. The questionnaire was written in Arabic and included questions about family size, job, income, general information regarding the treatment plant, monitoring of the treatment plant, satisfaction regarding the GWTP, current status of the sanitation system, aesthetic concerns and the treatment plant’s impact, the impact of the sanitation system on health, reasons of acceptance and barriers, social and managerial aspects, financial aspects, confidence in the applied systems, etc.



Figure 4. Study area in eight governorates of the West Bank.

The surveyors were educated about the GWTP, its operation and maintenance methods and the environmental, economic and agriculture values that grey water provides. The questionnaire also included inquiries regarding inspection of the treatment systems and testing of the quality of treated water. The obtained data were analyzed using the Statistical Science Software Program (SPSS) software version 20 [24]. Acceptance of providing onsite GWTPs was statistically tested using logistic regression analysis.

3. Results and Discussion

3.1. General Information on Households

The survey results revealed that the average family size in the study area was 9.3 people, which is considered a large family size as the average family size in the West Bank is 5 persons [25]. Out of the total implemented GWTPs, 76.5% served one household, 14.2% served two households and 9.2% served three to four households. The average monthly income of the onsite GWTP owners ranged from 280 up to 830 US\$ as illustrated in Figure 5; the latest official Palestinian statistics reveal that 13.9% of the West Bank population is below the national poorness standard, as their average income is less than 580 US\$ [26].

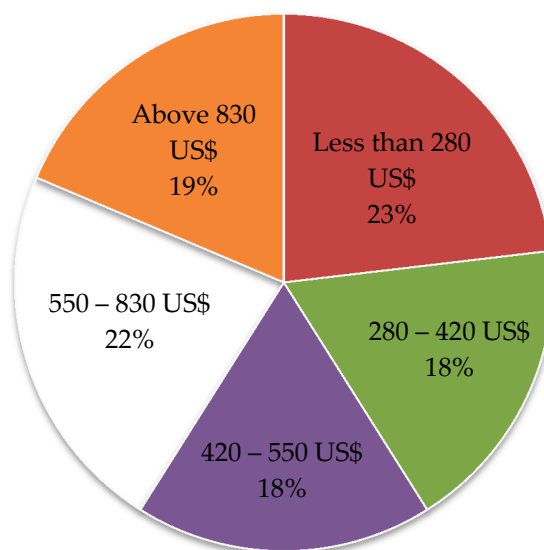


Figure 5. Percentage distribution of families based on family monthly income in US\$.

3.2. General Information on Onsite GWTPs

The treatment plants which are distributed in the rural communities have been constructed over the last twenty years, with 99.3% of them constructed over the last fifteen years. All of them were constructed by local or international NGOs supported by external donors.

The findings of this study showed that 13% of the total implemented GWTPs do not currently operate. The reasons include: (1) production of strong odors and their impact on the owners and neighbors; (2) not being effective in the treatment process, as stated by beneficiaries; (3) changing of the function of the plant to a rainwater harvesting cistern by some of the beneficiaries since construction; and (4) not being adequately trained on operation and maintenance.

The data revealed that 25.1% of the executing agencies had not ever monitored or checked the treatment plants. Furthermore, 59.3% of these agencies had followed the plants only during the early phase (2–3 months as per beneficiaries) after completion of construction; only 11.4% of them had monitored and operated the plants through regular visits and giving support to ensure the performance of the plants. Similarly, Ahmad et al. [22] reported that most onsite GWTPs did not operate after the funded projects had been terminated, a sequence of no identifications for ownership. No monitoring systems were available for the treatment plants, although those systems were used for irrigation. Moreover, Sandec [10] found that the main system malfunctions resulted from improper operation and maintenance attributable to the owners' poor understanding of the systems. Consequently, beneficiaries should be trained in proper management of the system, and as such their involvement during the planning and implementation stages is decisive.

The results showed that 61.7% of the implementing agencies had never inspected or monitored the quality of treated water, 26.9% of them had monitored the quality and process performance of the plants during the first period after implementation and only 7.2% had monitored the plants on a regular basis ranging between 1–2 times per month. This reveals that there was no reliable or continuous monitoring system of the plants by the implementing agencies. In fact, the monitoring tasks were shifted directly to the owners without adequate knowledge and experience of the system's monitoring and evaluation. The results showed that 48.8% of the system owners were not satisfied with the implementing agencies' behavior upon completion of the construction phase of the project. This high percentage of dissatisfaction shows the limited role and responsibility of the implementing agency which negatively affected the sustainability of these onsite wastewater treatment systems.

The beneficiaries stated that the implementing agencies made many mistakes throughout the planning and construction phases of the projects. During the planning phase, mistakes included inappropriate site selection of the treatment plant, improper technical design and capacity, lack of

consultation with community representatives such as community-based organizations (CBOs) and not conducting feasibility studies for the projects. During the construction phase, mistakes included leakage from the treatment plant, low quality of the main construction works and poor finish due to poor monitoring and supervision of construction.

3.3. Water and Sanitation Household Conditions

Treatment plants require available space surrounding the home; 95% of the household respondents had gardens. The average area of the gardens was between 100–500 m². Furthermore, 79% of the houses had rainwater harvesting systems. Treatment plants affect irrigation and saving of fresh water, as 51.5% of the interviewers used the fresh water from water network in irrigation before construction of GWTP. However, this percent considerably decreased after construction of the treatment plants: 15% of the beneficiaries still used a network water source in irrigation after construction of an onsite GWTP and 30% of them used a water network from time to time. Indeed, most of the investigated rural communities face chronic water shortages, with 72.5% of the beneficiaries reporting that before implementation of the treatment plants, they had a water shortage and the onsite GWTPs helped in alleviating this problem. A total of 35.3% of beneficiaries stated that the GWTPs contributed to solving the water shortage and 44.3% stated that GWTPs contribute partially to solving water shortages, since as they used treated water for irrigation, consequently they save fresh water. The average household planted area before and after establishment of a GWTP was 153 m², while the average planted area after establishing a GWTP was 156 m². Though the difference in the planted area is not significant, the agriculture practices became more efficient and productive. Likewise, Sandec [10] stated that treated grey water reuse in irrigation might considerably influence in lessening water bills and contributing to food security.

Findings revealed that there are two types of agriculture. The majority of the interviewees (77.8%) stated that they use treated water in open agriculture and 15.6% of them use treated water in a green house. The percentages of beneficiaries who use treated grey water in irrigating fruit trees, vegetables, flowers and fodder are 71.9, 44.3, 4.8 and 1.2%, respectively. The fruits are mostly consumed by the system owners' families (77.4%); around 10% are gifted to relatives, neighbors and friends and 7.5% are usually sold in the market. Therefore, the availability of a house onsite GWTP leads to utilizing treated effluent in irrigation, contributing to food security. Acceptance of implementing GWTPs for the purpose of treated effluent reuse in irrigation is varied according to the many reasons mentioned in Table 1.

- **Governorate:** From the results of Table 2, it appears that the percentages of acceptance have close values between all governorates, which shows that onsite GWTPs in the West Bank are acceptable for the purpose of reuse in irrigation. However, acceptance was not at the same level in all governorates.
- **Family Size:** From Figure 6 it is noticeable that the acceptance of a GWTP for reuse in irrigation is influenced by the number of family members, where the percentage increases with increasing family size.
- **Job:** Acceptance of GWTPs was different for people with different jobs as per Table 3, where a high percentage was found for workers and farmers (who have less income), while employees or wholesalers have relatively less interest in GWTPs.
- **Education Level:** 87.7% of less educated people accept GWTPs for reuse in agriculture, but a lower percent (81.2%) of educated people accept GWTPs. This emphasizes that educated people have more concerns regarding the quality of treated water.
- **Suffering from Water Shortage before Construction of GWTPs:** 85.6% of people who were suffering from water shortages accept construction of GWTPs for reuse in irrigation, while a lower percent (75.6%) is found for people who had no problems with water shortages.

- Garden Availability: 86.1% of people who have a home garden would be willing to reuse treated grey water in irrigation, however 22% of those who do not have a home garden were not able to reuse for irrigation.
- Frequency of Cesspit's Emptying before Providing GWTP: Acceptance of reuse in irrigation depends on discharge of cesspits per year: 76.2% of people who empty cesspits 1–3 times per year accept reuse in agriculture, while 88.3% of people who discharge their cesspits more than 4 times per year accept reuse in agriculture.
- Owner's Satisfaction of Cesspits: 73.9% of people who are satisfied in applying cesspits accept reuse in irrigation, while a larger percent (87.4%) of people who are not satisfied accept providing onsite GWTPs for the purpose of reuse in irrigation.

Table 1. Acceptance of providing GWTPs (grey water treatment plants) for reuse in irrigation.

Independent Value	Acceptance of GWTPs Asymp. Sig. (2-sided) Value *	Status
Age	0.526	Not significant
Governorate	0.002	Significant
Number of households	0.433	Not significant
Family size	0.0135	Significant
Job	0.00	Significant
Age of responsible person for managing GWTP	0.501	Not significant
Education level of those responsible of GWTP	0.00	Significant
Suffering of water shortage before construction of GWTPs	0.003	Significant
frequency of cesspit's emptying before providing GWTP	0.002	Significant
Level of noise	0.32	Not significant
Garden availability	0.00	Significant
Owner's satisfaction of cesspit's	0.001	Significant

*: Significant value, if Asymp. Sig. (2-sided) value is less than or equal 0.05.

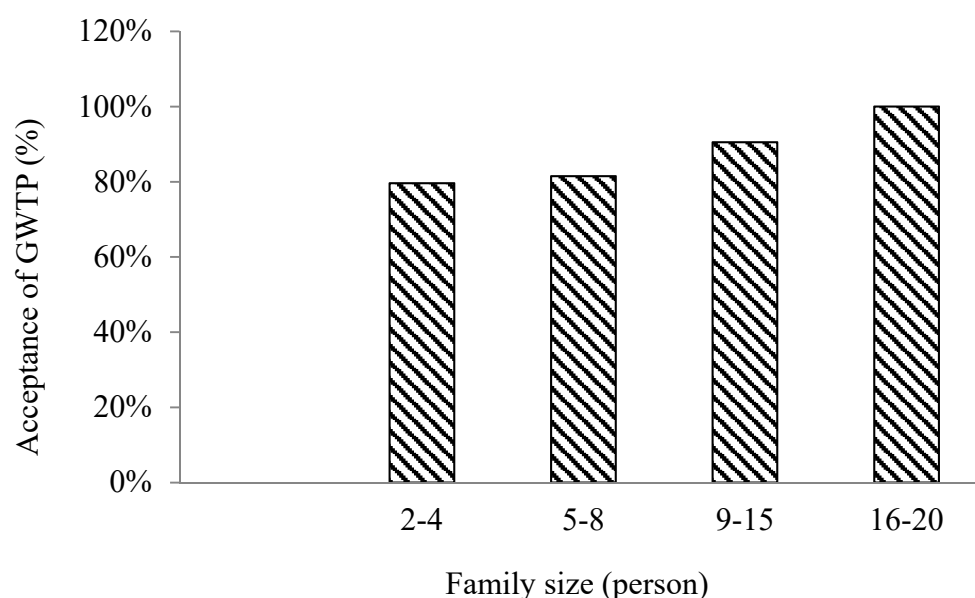


Figure 6. Acceptance of GWTPs for reuse in irrigation vs. family size.

Table 2. Acceptance of GWTPs for reuse in irrigation per governorate.

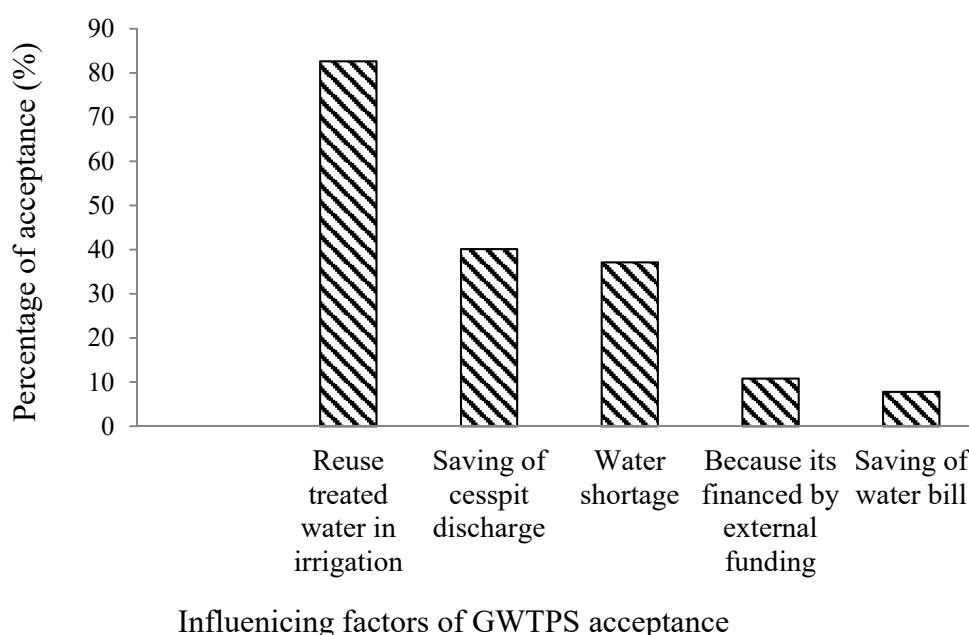
Governorate	Number of Respondents	Acceptance of GWTPs (%)
Bethlehem	4	83.3
Ramallah	55	68.1
Jerusalem	7	100
Hebron	38	85.7
Nablus	6	100
Tulkarem	7	85.7
Jenin	39	82.1
Tubas	10	100

Table 3. Acceptance of GWTPs for reuse in irrigation versus job.

Job	Acceptance of GWTPs (%)
Worker	85
Employee	78.6
Farmer	90
Wholesaler	80%

3.4. Reasons for Acceptance GWTPs

The reasons for acceptance of GWTPs to replace the previous sanitation system “cesspits” were different across many aspects. The highest percentage (82.6%) of beneficiaries who accepted having treatment units was due to their willingness to reuse treated water in irrigation and agricultural purposes, and the lowest percentage was in regards to saving on the water bill, as illustrated in Figure 7.

**Figure 7.** Percentage of beneficiaries' acceptance of GWTPs based on influencing factors.

Similarly, Adilah [27] reported that treated effluent reuse for irrigating fruit trees and flowers in the home garden has the highest potential to be accepted. Saving of cesspit discharge is another important reason for accepting GWTP, as only black wastewater goes to the cesspit. Water shortage is also a reason for accepting GWTP, as the majority experience water shortages, especially in the summer. The lowest percentage is for savings on the water bill because providing a GWTP does not have much effect on utilization of fresh water, as they were not used for irrigation before construction of the GWTPs.

3.5. The Barriers for Application of Onsite GWTPS

Many barriers were raised by interviewees for the application of GWTPs; the following barriers are arranged by priority, as illustrated in Figure 8. The first and biggest barriers are odor emission and insect infestation. This emphasizes the importance of further developing the systems to improve their performance. The second barrier is the lack of implementing agency (NGOs) follow-up, especially after the end of implementation. The NGOs do not implement evaluation and monitoring of system performance after the projects have ended. Accordingly, the beneficiaries do not have the required experience in operation and maintenance. Health risks and worries about water quality are other barriers since people are not confident about the quality of treated grey water. A lower percentage of beneficiaries stated other barriers such as operation and maintenance burden on the householder, lack of experience in operation and maintenance and the financial burden of operation and maintenance. Likewise, Ahmad et al. [22] reported that no monitoring systems were available for the treatment plants, although those systems were used for irrigation. This emphasizes the importance of considering the follow-up process and practical training in operation and maintenance as a part of project implementation.

- Replacement of GWTPs in Case of Providing Sewerage Networks: 52.1% of GWTPs owners would not replace the treatment plant in the case of providing sewerage networks, while 37.7% of them stated that they would replace the treatment plant in the case of providing sewerage networks. The mentioned results refer to many aspects that interfere with the replacement of GWTPs in the case of providing sewerage networks, as discussed below.
- Water shortage: 56.6% of GWTP beneficiaries who accepted GWTPs because of water shortages were not willing to replace the onsite GWTP in the case of providing sewerage network, while 43% of GWTP beneficiaries who did not face water shortages preferred replacing the onsite GWTP in the case of providing sewerage network. This result indicates that water shortage is a significant reason to maintain the onsite GWTP.
- Availability of Fund by External Donor: 66.6% of GWTP beneficiaries who accept GWTPs because they are supported by external funds were not willing to replace the onsite GWTPs in the case of providing sewerage network, while 52.1% of GWTP beneficiaries who accept GWTPs when they are not supported by external funds were not willing to replace the onsite GWTPs in case of providing sewerage network, which means that fund availability was not a significant reason for replacing the onsite GWTPs.
- Reduction of Cesspit Discharge Frequency: 53.9% of GWTP beneficiaries who accepted a GWTP for the reduction of cesspit discharge frequency were not willing to replace the onsite GWTP in the case of providing a sewerage network, while 37.4% of GWTP beneficiaries who accepted a GWTP for not saving cesspit discharge were willing to replace the onsite GWTP in case of providing sewerage network. From the mentioned results it is concluded that reduction of cesspit discharge frequency is a major reason for preference of GWTPs.
- Reuse in Irrigation: 54.4% of GWTP beneficiaries who accept a GWTP for the purpose of reuse in irrigation were not willing to replace the onsite GWTP in the case of providing a sewerage network, while 47.4% of GWTP beneficiaries who accept a GWTP not for reuse in irrigation were willing to replace the onsite GWTP in the case of providing sewerage network. From the mentioned results it is concluded that reuse in irrigation is an important reason for preference of GWTPs.
- Saving in Water Bill: 61.5% of GWTP beneficiaries who accept GWTPs for saving on their water bill were not willing to replace the onsite GWTP in the case of providing a sewerage network, while 40.0% of GWTP beneficiaries who accepted a GWTP not for saving on their water bill were willing to replace the onsite GWTP. This means that saving on their water bill is a very important reason for preference of GWTPs.

- **Satisfaction of Applied System:** 68.1% of GWTP beneficiaries who were satisfied with the unit's performance were not willing to replace the onsite GWTP in the case of providing a sewerage network, while 71.3% of GWTP beneficiaries who were not satisfied with the unit's performance were willing to replace the onsite GWTP. This indicates that the satisfaction of the existing sanitation system is a significant issue regarding the replacement of it with another one.
- **Contribution of GWTPs to Solve the Water Shortage:** 60.3% of GWTP beneficiaries who benefited from the treatment units by their contribution in solving water shortages were not willing to replace the onsite GWTP in the case of providing sewerage network, while 72.0% of GWTP beneficiaries who did not get benefits from the treatment units regarding their water shortages were willing to replace the onsite GWTP.
- **Monitoring, Operation and Maintenance of the GWTPs:** GWTPs are basically managed by women: the GWTPs are operated by men (fathers) and women (mothers) side-by-side (68.9%), while 24% are operated solely by women. Therefore, more focus should be placed on o women in terms of training and managing onsite sanitation systems, since they are more involved in household water management. The majority of the interviewees (73.1%) completed high school only or less, 20.4% had a university degree and higher education. Little effort is required for running the GWTPs, since the average yearly working time is 19.7 hours, corresponding to 0.4 hours per week. Operation and maintenance work include cleaning and checking the inlet manhole, removing scum from the first compartment (septic tank), pipe cleaning and cleaning of the whole treatment plant.

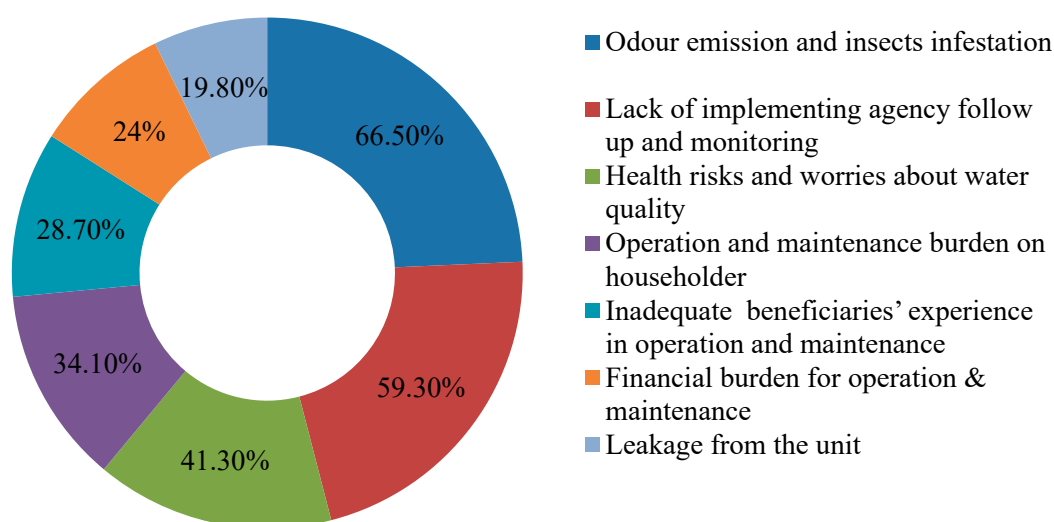


Figure 8. Barriers of providing onsite GWTPs.

4. Conclusions and Recommendations

4.1. Conclusions

Reasons for acceptance of GWTPs. Reuse of treated grey water in irrigation was the main incentive for a GWTP as stated by 88.0% of respondents, followed by reduction in cesspit discharge frequency and its financial consequences as stated by 71.3%. A total of 35.3% of respondents mentioned water shortages, reduction of potential risks of ground water pollution, reduction of water bill and enhanced hygiene. Availability of funds was an important driver for the construction of GWTPs as stated by 70.7%. Islamic religion was considered a driver; the majority of people (70%) accepted reuse of treated grey water in irrigation. Women play a major role in GWTP management since they are more involved in household water and sanitation management; 68.9% of the treatment systems are run by men side-by-side with women (fathers and mothers), and 24% is run completely by women. The aesthetic

impact of the system is very positive, as mentioned by 74.9% of beneficiaries. The majority of GWTP beneficiaries (70.4%) are satisfied. Little effort is required for operation and maintenance, with only an average 0.4 working hours per week.

Barriers for Onsite GWTPs. The first barrier as mentioned by 66.5% is odor emission and insect infestation. A total of 59.3% stated that the systems lack follow-up and monitoring from the implementing agency's side. System failures were also caused by inadequate beneficiary experience in operation and maintenance and lack of system understanding was stated by 34.1% of beneficiaries. Health concerns and doubt surrounding the quality of crops irrigated by treated grey water was another barrier raised by beneficiaries.

Success and Failure Lessons. Water shortage is a main driver for providing an onsite grey water system, and farmers with experience in agriculture are more capable of managing the grey water system and reuse schemes than others. Failure of GWTPs happened as a result of inappropriate operation and maintenance and lack of system understanding, as well as lack of technical support from the implementing agency. Sometimes failures happened as a result of improper utilization of treated water and seepage of water into the surrounding area, lack of reuse schemes and agricultural plans and finally beneficiaries' limited experience in agricultural practices.

House onsite grey water management systems are acceptable in rural communities; therefore, a more proper system is required to handle the wastewater and replace cesspits and their harmful implications on environment, ground water and public health.

4.2. Recommendations

- There is an essential need to improve the performance of the treatment plants, to increase treatment efficiency and to introduce well-operated wastewater treatment facilities.
- Ensure treated water quality complies with applied local and international standards and its suitability for reuse purposes.
- At the policy level, the government should encourage and be more aware of the potential application of onsite GWTPs in rural communities, so the government should be more involved in wastewater management in rural areas to replace cesspits.
- The government should encourage the use of non-conventional water resources in agriculture, especially treated grey water.
- Implementing agencies should implement regular monitoring and maintenance of the onsite GWTPs, especially after the end of implementation and consider this phase as a part of the project implementation.
- Implementation of GWTPs should be applied according to social and technical feasibility studies, including involvement of people in the planning and implementation process to ensure understanding of the whole system.
- GWTP beneficiaries require the necessary training in operation and maintenance of the system management to maintain sustainability and to handle the system successfully.
- Development of public awareness programs, to better understand and improve public knowledge of wastewater systems and perception toward reuse schemes, in parallel with field visits of local people to other wastewater treatment and reuse facilities for sharing of knowledge and ideas.
- A more proper system is required to handle the wastewater to replace cesspits and their implications on the environment, ground water and health in rural communities.

Author Contributions: Conceptualization, R.A.T.; Methodology, N.M. and R.A.T.; Validation, N.M. and R.A.T.; Formal Analysis, R.A.T.; Investigation, I.A.A.-K.; Data Curation, R.A.T.; Writing—Original Draft Preparation, R.A.T.; Writing—Review & Editing, I.A.A.-K.; Visualization, Y.-T.H.; Supervision, N.M.; Project Administration, R.A.T.; Funding Acquisition, N.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by the Palestinian Water Authority through the project of “Wastewater Need Assessment in the Palestinian Rural Communities” funded by the Austrian Development Agency (ADA)/Australian Government.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. WBG. *Securing Water for Development in West Bank and Gaza*; International Bank for Reconstruction and Development: Washington, DC, USA, 2018.
2. PCBS. *Results Household Environmental Survey*; Palestinian Central Bureau of Statistics: Ramallah, Palestine, 2015.
3. ARIJ. *Status of the environment in the state of Palestine*; Applied Research Institute—Jerusalem: Bethlehem, Palestine, 2015.
4. Lambert, L.A.; Jordan Lee, J. Nudging greywater acceptability in a Muslim country: Comparisons of different greywater reuse framings in Qatar. *Environ. Sci. Policy* **2018**, *89*, 93–99. [\[CrossRef\]](#)
5. Chirisa, I.; Bandaiko, E.; Matamanda, A.; Mandisvika, G. Decentralized domestic wastewater systems in developing countries: The case study of Harare (Zimbabwe). *Appl. Water Sci.* **2017**, *7*, 1069–1078. [\[CrossRef\]](#)
6. Boano, F.; Caruso, A.; Costamagna, E.; Ridolfi, L.; Masi, F.; Demichelis, F.; Galvão, A.; Pisoeiro, J.; Rizzo, A.; Masi, F. A review of nature-based solutions for greywater treatment: Applications, hydraulic design, and environmental benefits. *Sci. Total Environ.* **2020**, *711*, 134731. [\[CrossRef\]](#) [\[PubMed\]](#)
7. Ridderstolpe, P. *Introduction to Grey Water Management*; EcoSanRes Programme, Stockholm Environment Institute: Stockholm, Sweden, 2004.
8. Maimon, A.; Gross, A. Greywater: Limitations and perspective. *Curr. Opin. Environ. Sci. Health* **2018**, *2*, 1–6. [\[CrossRef\]](#)
9. Oh, K.S.; Leong, J.Y.C.; Poh, P.E.; Chong, M.N.; Lau, E.V. A review of greywater recycling related issues: Challenges and future prospects in Malaysia. *J. Clean. Prod.* **2018**, *171*, 17–29. [\[CrossRef\]](#)
10. Morel, A.; Diener, S. *Greywater Management in Low and Middle-Income Countries, Review of Different Treatment Systems for Households or Neighbourhoods*; Sandec Report No. 14/06; Sandec (Water and Sanitation in Developing Countries) at Eawag (Swiss Federal Institute of Aquatic Science and Technology): Dübendorf, Switzerland, 2006.
11. Zraunig, A.; Estelrich, M.; Gattringer, H.; Kissner, J.; Langergraber, G.; Radke, M.; Rodriguez-Roda, I.; Buttiglieri, G. Long term decentralized greywater treatment for water reuse purposes in a tourist facility by vertical ecosystem. *Ecol. Eng.* **2019**, *138*, 138–147. [\[CrossRef\]](#)
12. Leong, J.Y.C.; Balan, P.; Chong, M.N.; Poh, P.E. Life-cycle assessment and life-cycle cost analysis of decentralised rainwater harvesting, greywater recycling and hybrid rainwater-greywater systems. *J. Clean. Prod.* **2019**, *229*, 1211–1224. [\[CrossRef\]](#)
13. Gorgich, M.; Mata, T.M.; Martins, A.; Caetano, N.S.; Formigo, N. Application of domestic greywater for irrigating agricultural products: A brief study. *Energy Rep.* **2020**, *6*, 811–817. [\[CrossRef\]](#)
14. Diaper, C.; Dixon, A.; Butler, D.; Fewkes, A.; Persons, S.A.; Stephenson, T.; Strathern, M.; Strutt, J. Small scale water recycling systems—Risk assessment and modelling. *Water Sci. Technol.* **2001**, *43*, 83–90. [\[CrossRef\]](#) [\[PubMed\]](#)
15. Siggins, A.; Burton, V.; Ross, C.; Lowe, H.; Horswell, J. Effects of Long-Term Greywater Disposal on Soil: A Case Study. *Sci. Total Environ.* **2016**, *557–558*, 627–635. [\[CrossRef\]](#) [\[PubMed\]](#)
16. Oteng-Peprah, M.; de Vries, N.; Acheampong, M.A. Households’ willingness to adopt greywater treatment technologies in a developing country—Exploring a modified theory of planned behaviour (TPB) model including personal norm. *J. Environ. Manage.* **2020**, *254*, 109807. [\[CrossRef\]](#) [\[PubMed\]](#)
17. Redwood, M. Greywater use in the Middle East and North Africa region. In Proceedings of the Greywater Stock-taking Meeting, IDRC-CSBE, Aqaba, Jordan, 12–15 February 2007.
18. WHO. *Guidelines for the Safe Use of Waste-Water, Excreta and Grey Water—Volume 1–4—Excreta and Grey Water Use in Agriculture*; World Health Organization: Geneva, Switzerland, 2006.

19. Ashok, S.S.; Kumar, T.; Bhalla, K. Integrated Greywater Management Systems: A Design Proposal for Efficient and Decentralised Greywater Sewage Treatment. *Procedia CIRP* **2018**, *69*, 609–614. [CrossRef]
20. Oteng-Peprah, M.; Acheampong, M.A.; deVries, N.K. Greywater Characteristics, Treatment Systems, Reuse Strategies and User Perception—a Review. *Water Air Soil Pollut.* **2018**, *229*, 255. [CrossRef] [PubMed]
21. Radingoana, M.P.; Dube, T.; Mollel, M.H.; Letsoalo, J.M. Perceptions on greywater reuse for home gardening activities in two rural villages of Fetakgomo Local Municipality, South Africa. *Phys. Chem. Earth Parts A B C* **2019**, *112*, 21–27. [CrossRef]
22. Ahmad, A.; Lubbad, I.; Shaheen, A.; Mogheir, Y. *Small Scale Wastewater Treatment Plants in Palestinian Rural Areas: An Environmentally Sound Option*; Environment Quality Authority: Gaza, Palestine, 2009.
23. Burnat, J.; Shtayye, I. On-site grey water treatment in Qebia Village, Palestine, Greywater Use in the Middle East. Technical, Social, Economic and Policy Issues. 2009. Available online: <https://www.idrc.ca/sites/default/files/openebooks/466-6/index.html> (accessed on 14 December 2019).
24. *SPSS Statistics for Windows*; Version 20.0; IBM Corp.: Armonk, NY, USA, 2011.
25. Palestinian Central Bureau of Statistics (PCBS). On the Occasion of the International Population Day 11/7/2019. Ramallah, Palestine. 2019. Available online: <http://www.pcbs.gov.ps/post.aspx?lang=en&ItemID=3503#> (accessed on 20 February 2020).
26. PCBS. *Poverty Profile in Palestine*; Palestinian Central Bureau of Statistics: Ramallah, Palestine, 2017.
27. Adilah, O. Assessment of Wastewater Reuse Potential in Palestinian Rural Areas. Master's Thesis, Faculty of Graduate Studies, Program in Water and Environmental Engineering, Birzeit University, Palestine, Birzeit, 2011.



© 2020 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).