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Water Quality of Rainwater Harvesting Systems and Acceptance of Their Reuse in Young Users: An Exploratory Approach

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Abstract: The main objective of this study is to evaluate the water quality of different rainwater harvesting (RWH) systems and the social acceptance of their reuse in young users as an exploratory approach. Three RWH systems were implemented, and the quality of harvested rainwater was evaluated focusing on physicochemical and in situ parameters. Social acceptance was studied in one of the RWH systems using an adapted technology acceptance model. An informative talk about the operation of RWH was given to the users, who were students from a rural primary school. Surveys were conducted before and after the talk to evaluate the impact of providing information to users. The social acceptance was studied in one of the RWH systems. The results indicated that the harvested rainwater from RWH systems was suitable for reuse in agriculture despite the increase in turbidity and chloride concentrations in the outlet tap. The concentration of turbidity, phosphate as phosphorus, chloride and nitrate ranged between 0.8 and 1.9 NTU, 0.01–0.2 mg/L, 2.8–5.0 mg/L and 0.3–0.9 mg/L, respectively. In the acceptance study, the survey results and correlation analyses showed that providing information to users is crucial for increasing the acceptance of RWH systems. Moreover, this study demonstrated that RWH systems are a viable alternative technology for reusing and supplying water in arid and semiarid areas.

Keywords: rainwater harvesting systems; water quality; social acceptance

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1. Introduction

Water scarcity is a critical global challenge, especially in arid and semiarid zones where improve water management and the implementation of new technological and innovative solutions are mandatory [1]. Although rainwater is naturally used to irrigate various types of crops in areas that experience periods of water scarcity, it is necessary to store it to have an alternative source of water. Moreover, this water must be treated due to the contamination generated by the roofing materials [2]. Under this context, rainwater harvesting (RWH) systems are a viable alternative water technology that collect and store rainwater from buildings, rock catchments and land or road surfaces [3,4]. These systems are implemented in arid and semiarid countries to mitigate water scarcity due to their technical, economic, environmental and sustainability advantages. The harvested water obtained by RWH systems represents a new source for supplying water for domestic, sanitary and irrigation uses [5].

Despite the diverse benefits of RWH systems, their optimal implementation depends on several factors, such as the quality of harvested water and the acceptance of the technology by users [3,6]. Regarding water quality, the harvested water must be safe and pose no risks to human health or the environment when reused for domestic and irrigation purposes. In this line, the quality of harvested rainwater is affected by the roofing material. Several studies revealed that the accumulation of deposition (dirt, debris, tree litter, particulate and fecal matter from animals) and the chemical composition of runoff are the principal contributors to deteriorating water quality [2,7,8]. Therefore, monitoring water quality is essential to avoid contamination by microorganisms and other pollutants [9].

Acceptance is identified as a determinant variable in the successful implementation of RWH systems [10]. It may influence users' willingness to maintain and operate these technologies and to adopt practices that promote the long-term efficiency and durability of the RWH systems [11]. Various models have emerged to predict the social acceptance of a technology. One of these is the technology acceptance model (TAM), which explores the causal relationship between beliefs, attitudes and intentions by evaluating the perceived usefulness and attitudes influencing the intention to use a new technology [12]. Similarly, the extended TAM includes six psychological factors: (1) subjective knowledge, which is the personal understanding of the technology; (2) social trust, which is the relationship of dependency between users and the group interested in applying the technology; (3) technological environment, which relates to the community's trust in the technological environment requiring scientific and technological support; (4) social influence, which refers to the ability of a group to change individual thoughts, attitude and behaviors; (5) perceived risk, which is related to an individual's subjective evaluation of a particular risk severity; and (6) perceived cost, which consists of the cost involved in using a particular technology [13].

In general, there are already several published studies related to harvested rainwater quality and the public's perception [3,4,9,10,13–17]. These studies have focused on the perception of RWH users regarding the operation, design and hydraulic factors of RWH systems. However, of what is known, only the study of González-Patrón et al. [11] addresses these two issues simultaneously, having concluded that RWH systems had an impact on the water quality and reduced the incidence of diarrhea cases in the community. However, the perception of users did not link technology to the health impacts. The authors considered that the implementation of new treatment technologies must consider the local and cultural context. On the other hand, most studies on technology acceptance are focused on decision-makers and adult users (mainly farmers), and there is a gap in identifying factors that influence the levels of acceptance presented by the younger population [17–19]. Ignacio et al. [10] studied the social acceptance of these technologies by combining the TAM and the theory of planned behavior. Their results indicated that the user's attitude towards use can promote behavioral intention towards the use of the RWH systems. Moreover, increasing the perception and acceptance of this technology is fundamental to educating users through technical and operational knowledge [13].

Under the context that the TAM model for predicting social acceptance and the study of water quality is rarely used in RWH systems, the main objective of this study was to evaluate the water quality of different RWH systems and the social acceptance of their reuse in young users as an exploratory approach. To accomplish this, three RWH systems located in three different Chilean regions were implemented and studied. The quality of harvested water and the performances of the three RWH systems were evaluated while the social acceptance was studied in one of the RWH systems. In this study of acceptance, the value of education about the operation and functionality of RWHs was also demonstrated through an explanatory talk about this type of technology to users. This agrees with Lestari et al. [20], who point out the need for the education sector to incorporate innovative approaches, preparing students to face uncertainty and predict and evaluate consequences. In this sense, the approach of students to RWH systems promotes the incorporation of new practices; in turn, it allows these to be incorporated as part of the educational material, promoting awareness regarding the need for adaptation and transformation in the face of the impacts of climate change and current global changes. It is important to mention that this is one of the first studies on RWH implemented in Chile. Moreover, this work employs a non-probabilistic exploratory approach to understand the reuse of harvested rainwater. This work lays the foundation for future reports on RWH systems in Chile and Latin America.

The novelty of this work was focused on the simultaneous study of two areas that are well documented separately in the literature but have rarely been explored together: social acceptance and water quality in RWH systems. Additionally, incorporating the perspective of young users in acceptance studies is innovative and contributes to the advancement of this research field, as young people play a key role in the implementation of sustainable solutions.

2. Materials and Methods

2.1. Study Area

This study was carried out on three RWH systems located in different regions of Chile: Maule (RWH 1), Ñuble (RWH 2) and Biobío (RWH 3), as shown in Figure 1. In the case of RWH 1 and RWH 2, these systems were installed in rural educational establishments called "Ana Luisa Espina Rivero School" and "Agricultural High School of Chillán", respectively. The two RWH systems were located in the rural areas of Chilean central zone called "Curepto" and "Cato", respectively, where the primary economic activities are agriculture and livestock farming (Figure 1A). On the other hand, RWH 3 was implemented in the Research Center of Water Research Center for Agriculture and Mining (CRHIAM) at the University of Concepción. This system was located in an urban area of Concepción, where the primary economic activities include services such as education and retail commerce. Figure 1B. shows the rainfall patterns of locations where RWH systems are installed. The accumulated precipitation in the area where RWH systems were located fluctuated between 800 and 1000 mm during 2023. From 2010 to 2022, the accumulated precipitations remained relatively stable in the areas of RWH 1 and RWH 2, and in 2023, it was rainier than the previous year. In the area of RWH 3, this parameter remained relatively stable except for the year 2021. In these systems, the harvested water was used for irrigation (RWH 2 and RWH 3) and to supply water for toilets (RWH 1).

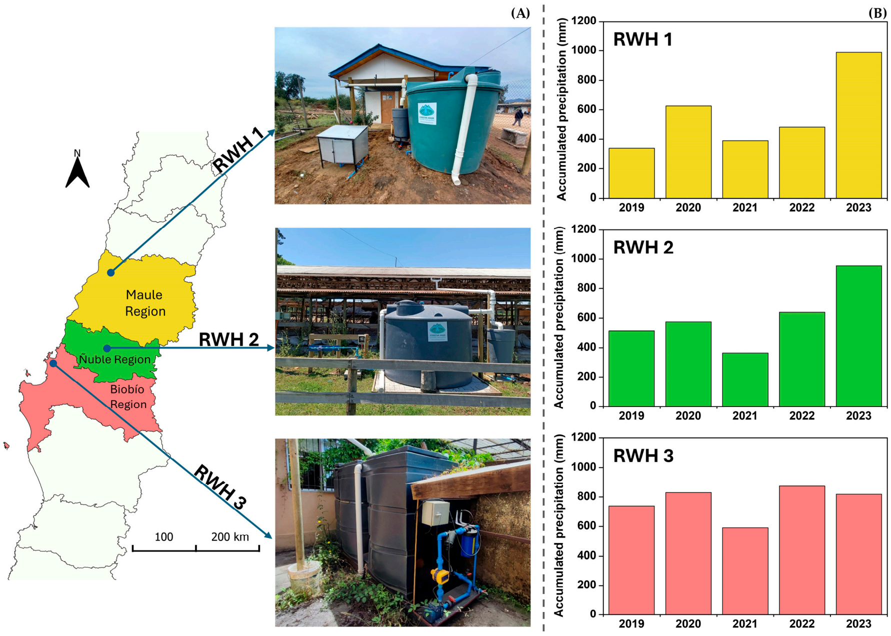

Figure 1. (**A**) Study area of the evaluated RHW systems; (**B**) accumulated precipitations at different locations where RHW systems are installed.

2.2. RWH Systems

Figure 2 shows a schematic diagram of RWH system used in this study. In general, this system consists of (1) the collection system consisting of the roof area and the drainage system. The roof types and areas varied depending on the RWH systems. For the roof of RWH 1, it had an area of 130 m^2 and it was constructed with zinc sheets. In the case of RWH2, the roof area was 100 m^2 using zinc sheets as constructed material. Finally, RWH 3 had an area of 50 m^2 with a material of gravel tile; (2) the primary filter, which separated huge solids (tree leaves, branches and other solids) from rainwater; (3) the flush diverter, where the sedimentation process took placed; (4) the storage tank, where the rainwater was storage and the disinfection with chlorine tablets was applied (0.2–2 mg/L); (5) a pump of 0.5 horsepower (HP), where harvested water was impulse for achieving (6) the filter systems composed by sequential filters of 130 µm and 5 µm; and finally (7) the outlet tap. It is important to mention that in RWH 1 and RWH 2, the storage tank had a circular geometry and a volume capacity of 5400 L, while RWH 3 was a rectangular tank with a volume of 5000 L. In RWH 1 only, the outlet tap was connected to the school bathroom to supply water for the toilets [8].

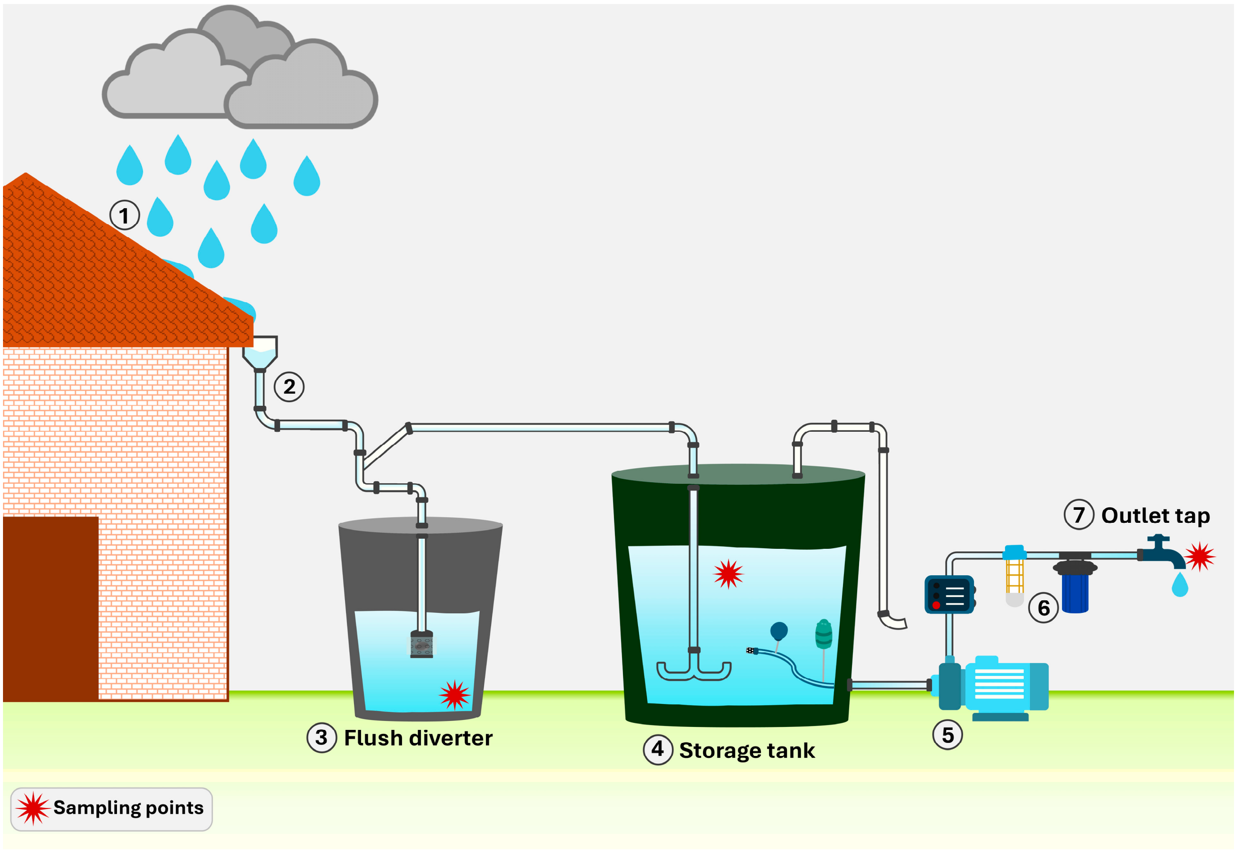

Figure 2. Schematic diagram of RWH system.

2.3. Sampling Points and Data Collections

Figure 2 also shows the sampling points (red color) used in this study for the three RWH systems (RWH 1, 2 and 3) that corresponded to (1) the flush diverter, (2) the storage tank and (3) the outlet tap. The water samples were collected and conducted at 3 points per RWH from August 2023 to December 2023. The water samples were taken after a rain episode. For this reason, meteorological conditions were consulted every day for organizing the monitoring as soon as possible. In the case of RWH 1, the samples were taken on 11 September 2023, 20 November 2023 and 11 December 2023. For RWH 2, the samples were taken on 4 October 2023, 30 October 2023 and 6 December 2023. Finally, the samples were taken on 29 August 2023, 5 September 2023 and 20 October 2023 for RWH 3. Due to the complexity of accessing samples and coordinating with rural schools, only three samples were taken for each RWH system. It is important to note that RWH 1 and RWH 2 are located in rural areas in Chile with times travel of 5 and 3 h, respectively. Samples were stored in amber bottles at 4 °C and processed within 48 h. The dry weather periods between monitoring days had a duration of 5 days and 22 days for RWH1; 23 days and 19 days for RWH 2; and 1 day and 23 days for RWH 3.

2.3.1. In Situ and Physicochemical Characterization of Water Samples

All water samples from RWH systems were previously filtered using Whatman filters with a pore of 0.45 µm. The measured parameters were selected based on the reuse guidelines from the Environmental Protection Agency (EPA), Food and Agriculture Organization (FAO) and International Organization for Standardization (ISO) [21–23]. In situ parameters such as pH, temperature, reduction–oxidation potential (redox) and electrical conductivity (EC) were measured using OAKTON portable equipment (PC650-480485, OAKTON, Benoi Sector, Pioneer, Singapore). Additionally, dissolved oxygen (DO) and turbidity were also determined using portable oxygen sensor (HANNA OXI 330i/set HI 9146-04, HANNA Instruments Inc., Weilheim, Germany) and a portable waterproof turbidimeter (OAKTON T-100, OAKTON, Benoi Sector, Pioneer, Singapore), respectively. The concentrations of chemical oxygen demand (COD, colorimetric method), ammonium nitrogen (NH_4^+-N, colorimetric method at 640 nm), phosphate as phosphorus (PO_4^{-3}-P, colorimetric method at 890 nm), total nitrogen (TN, Spectroquant-Nova 60, kits Merck, Darmstadt, Germany) and total phosphorus (TP, Spectroquant-Nova 60, kits Merck, Darmstadt, Germany) were also measured based on the Standard Methods protocols [24]. Moreover, the determinations of anions (fluorine, chloride (Cl^-), nitrate (NO_3^-), nitrite (NO_2^-), phosphate (PO_4^{-3}), sulfate (SO_4^{-2}) and bromide) and cations (lithium (Li^+), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+})) were carried out using ionic chromatography (930 Compact IC Flex, Metrohm, Herisau, Switzerland). For this, the water samples were previously filtered through a 0.22 µm membrane filter. Moreover, the total and fecal coliform in water samples mentioned in Section 2.3 were also measured using multiple-tube fermentation technique (9221-E) in each RWH system.

2.3.2. Statistical Analysis

In this study, the in situ and physicochemical parameters in RWH1, RWH2 and RWH3 were compared using RStudio version 4.3.1, with a significance level of $p = 0.05$. The normality of data was tested using the Shapiro–Wilks test. Then, an ANOVA test for the data with a normal distribution and a Kruskal–Wallis test for the data without a normal distribution were performed. It is important to mention that the data used for these analyses included the triplicates from each water sample to increase the sample size.

2.4. Acceptance Study of Harvested Rainwater Use

2.4.1. Characteristics of Study Area and Participants of the Survey

The survey was conducted at Ana Luisa Espina Rivero School, located in the rural community of Curepto, Maule region where RWH 1 was implemented. Curepto has a warm temperate climate with winter rains and high atmospheric humidity, and the average precipitation in the last 10 years has been 1194 mm. This rural school was selected for applying the survey due to better maintenance of the technology and a more favorable attitude of the school community toward being part of this study. In the case of RWH 2, the school environment was not optimum for organizing and carrying out the surveys. Finally, RWH 3 was implemented in an administrative office from the University of Concepción and the users were not in line with the educational orientation of this study.

The participants are students from Ana Luisa Espina Rivero school, located in Curepto, Maule region, with an approximate enrollment of 50 students. The surveyed courses corresponded to seventh and eighth grade (students aged 12 to 14 years old), with a total of 12 students participating in the research. The selection of these courses students is related to their capacity to understand RWH operation, design and maintenance. Moreover, teachers and administrators were not considered in this study. In this case, the sample size was small to be incorporated into survey analyses. The sample size represented 100% of the total population considered.

2.4.2. Preparation of Informed Consent

Prior to administering the surveys, an informed consent form was prepared for the parents. This document outlined the study's objective, introduced the team responsible for its application, and ensured the anonymity and confidentiality of the data obtained. The preparation of the document was supported by the teacher in charge of the course.

2.4.3. Questionnaire Design

The instrument was based on the survey conducted by Liu et al. [13] in the population of Shanghai, China, which determined the acceptance of RWH systems using the TAM. For this study, the survey by Liu et al. [13] was modified and employed a Likert scale, a 5-point psychometric scale ranging from 1 (totally disagree) to 5 (totally agree). The instrument consisted of 17 statements divided into the aspects of perceived usefulness (PU), acceptance of systems (AS), subjective knowledge (SK), social trust (ST), technological environment (TE), social influence (SI), perceived risk (PR) and perceived cost (PC). In addition, a final open question section was added that aimed to obtain more information on how to address issues related to rainwater use and suggestions on how to present information in a dynamic way.

2.4.4. Adaptation and Validation of the Survey

The survey, adapted from Liu et al. [13], was modified to meet the educational levels of the community in which it was applied and the research objectives. Additionally, it underwent a validation process by experts related to the research topics to evaluate the developed instrument. The survey is available in the Supplementary Materials (see Supplement S1).

2.4.5. Application of the Survey

The survey was administered at two different points during the research, with the aim of assessing how seasonal variations and the progressive delivery of information regarding the RWHs could influence the responses obtained. Consequently, the data collection instrument was applied at the beginning and at the end of the second semester of 2023, specifically on 11 September for the first survey and 11 December for the second survey. An in-person talk on RWH system was conducted. This talk was focused on providing information about the origin and nature of RWH systems, their operation, benefits compared to a traditional piping system and potential uses. The talk was designed to address the concerns raised by the students in the first survey and it was conducted in a way that allowed students to participate and interact with the installed system.

2.4.6. Data Analysis

A data analysis was carried out, which included a descriptive analysis to summarize, analyze and identify trends in the applied surveys. Additionally, the results of the first survey were used to obtain additional information that served as a basis for preparing the informative talk. Furthermore, a correlation analysis was conducted, where a correlation coefficient was used to measure and describe the relationship between the aspects of each set of surveys. This allowed for the evaluation of how the different aspects relate to each other, expressed through the correlation coefficient, which ranges from -1 to 1. Both analyses were performed using Python version 3.10.12.

3. Results and Discussion

3.1. Water Quality of RWH Systems

Table 1 shows the in situ parameters in different RWH systems. During the treatment, the pH values ranged between 5.5 and 7.6, showing a tendency towards neutrality. For the

EC, there was a trend of more than a 30% decrease when comparing the water samples from the flush diverter and outlet tap in RWH systems. These results demonstrated that these systems could enhance water quality. In this line, the quality of harvested rainwater, in terms of the pH and EC, was similar to those reported in the literature [15,25–27] and was within the range of reuse guidelines that recommended values between 6.0 and 9.0 [21] and between 700 and 3000 µS/cm [22], respectively. Regarding redox and DO, these concentrations remained within the ranges of 100–300 mV and 6–9 mg/L, respectively. These positive values indicated an aerobic environment in RWH systems due to DO levels being above 2.0 mg/L [16].

Table 1. In situ parameters in different RWH systems.

Parameters	**Unit**	**RWH1**			**RWH2**			**RWH3**			**Regulatory Limits [21–23]**
		Flush Diverter	**Storage Tank**	**Outlet Tap**	**Flush Diverter**	**Storage Tank**	**Outlet Tap**	**Flush Diverter**	**Storage Tank**	**Outlet Tap**	
pH	-	7.6 ± 1.3	5.9 ± 2.9	6.7 ± 0.5	7.1 ± 0.9	7.6 ± 0.5	7.0 ± 0.3	6.8 ± 1.3	7.2 ± 0.5	6.6 ± 0.5	6.0–9.0
T	°C	14.3 ± 5.3	12 ± 3.4	10.3 ± 1.3	14.2 ± 4.7	13.7 ± 4.7	14.6 ± 4.0	12.6 ± 3.3	13.0 ± 3.9	13.4 ± 3.6	NC
EC	µS/cm	87.7 ± 7.7	61.8 ± 7.6	60.4 ± 19.6	78.2 ± 39.0	27.5 ± 5.6	21.2 ± 0.3	70.6 ± 46.4	39.1 ± 24.1	50.9 ± 23.1	700–3000
redox	mV	149.8 ± 27.9	143.6 ± 67.7	156.2 ± 34.2	257.2 ± 127.0	274.8 ± 186.8	189.9 ± 79.1	262.3 ± 59.5	306.2 ± 66.4	297.0 ± 57.4	NC
DO	mg/L	8.7 ± 0.2	9.1 ± 0.1	8.9 ± 0.2	7.8 ± 1.1	7.5 ± 1.4	8.1 ± 1.5	5.9 ± 2.1	6.3 ± 2.6	5.6 ± 2.9	NC

Notes: T: temperature; EC: electrical conductivity; Redox: oxidation–reduction potential; DO: dissolved oxygen; NC: not considered; N = 3. References in the table correspond to the regulatory limits.

On the other hand, Figure 3 shows the concentrations of different contaminants detected in the three compartments of RWH systems (flush diverter, storage tank and outlet tap). It is important to mention that four out of the nineteen evaluated parameters were selected because some contaminants were not detected in the measurement, and the average values of other parameters had a variability greater than 70% (see Table S1). Moreover, non-significant differences between RWH systems were observed ($p > 0.05$). In general, the performance of RWH systems concerning the studied parameters showed negative values of removal efficiencies (below -10%). This behavior was expected due to the technology's operation with high storage times, which decreased the water quality [4]. Gao et al. [16] studied the evolution of water quality in RWH systems during a period of 60 days. The results revealed that nutrients and sediments accumulated during the storage, with concentrations for turbidity and nitrate being twice as high. Regarding the quality of harvested rainwater from the three RWH systems, the concentrations of turbidity, phosphate as phosphorus, chloride and nitrate in the outlet tap varied between 0.8 and 1.9 NTU, 0.01–0.2 mg/L, 2.8–5.0 mg/L and 0.3–0.9 mg/L, respectively. These obtained values were below the limits established by various water reuse guidelines for agricultural proposes. In the case of turbidity, the USEPA and ISO guidelines propose a maximum limit of 2 NTU [23,26]. For phosphate, nitrate and chloride, the maximum allowed concentrations are 10 mg/L, 10 mg/L and 300 mg/L, respectively [28]. Regarding chloride concentrations (Figure 3C), values were higher in the flush diverter than in the storage tank in RWH 1 and RWH 2. This trend can be related to the rainwater characteristics and roof types. The roofs of both systems are composed of zinc sheets that, according to literature, have the highest impact on water quality leaching ions and heavy metals [29]. In terms of microbial contamination, the total fecal coliform abundances were measured in the different water samples, and they were under the detection limits of the technique (<1 most probable number (MPN)/100 mL), showing no occurrence of fecal contamination (see Table S1).

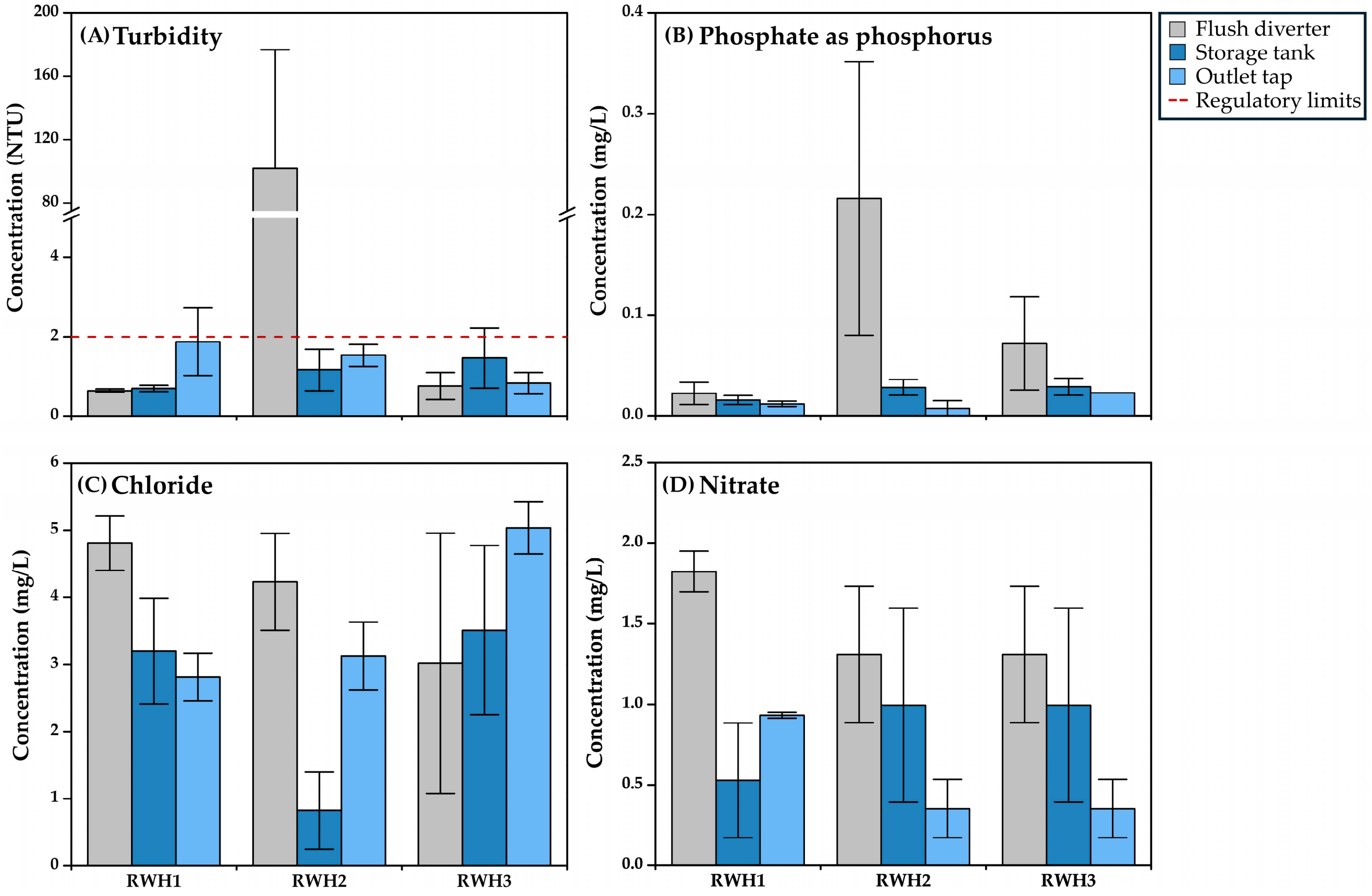

Figure 3. Concentrations of different contaminants in RWH systems. (**A**) Turbidity; (**B**) Phosphate as Phosphorus, (**C**) Chloride, (**D**) Nitrate. Notes: The regulatory limit was only considered for turbidity. Concentrations of phosphate as phosphorus, chloride and nitrate are high (10 mg/L, 10 mg/L and 300 mg/L, respectively) and they affect the quality of the figure.

Despite the limitations associated with the number of samples, these results demonstrated that the harvested rainwater from RWH systems was appropriate for reuse in agriculture in arid and semiarid zones despite the increase in contaminant concentrations during treatment (Figure 3). Rainwater is naturally reused for agricultural irrigation. However, the contact with roof and roofing material can affect the water quality. Moreover, in areas with scarcity periods, it is necessary to store water for long periods without affecting the quality of harvested rainwater [2]. Furthermore, the relevance of applying different physicochemical treatments in RWH systems, such as sedimentation, filtration and chlorination, can be seen in the maintenance of water quality despite the storage time. In this line, Dissanayake and Han [30] studied the effect of tank numbers on the RWH performances for enhancing the sedimentation process. They recommended that at least three sedimentation tanks in RWH systems should be a good alternative for assuring the quality of harvested rainwater. In the case of our RWH systems, they had two tanks followed by membrane filtration systems that allowed removing solids particles. To ensure the quality of water, it is necessary to combine different types of technologies such as physical, chemical and biological technologies.

Other important factors to consider in the performance of RWH systems are maintenance and the roof type. Although these parameters were not considered in this study, issues with the maintenance of valves, pumps and pipes were observed in RWH systems. In RWH 2, pumps, pipes and valves were blocked by rotting leaves and branches. In addition, some valves were broken and were not repaired. Lee et al. [27] evaluated the quality of collected rainwater at a downtown middle school RWH system and they considered that deteriorating water quality was caused by the absence of maintenance. Several studies have indicated that the roof type is an important parameter influencing water quality [26]. Moreover, the roof type is also linked to the air quality in the area where the RWH systems are installed [29]. Although RWH 3 was located in an urban area with more polluted air, the contaminant concentrations did not follow this trend.

3.2. Acceptance of Harvested Rainwater Use

3.2.1. Surveys' Results

Regarding the number of students who responded to the survey, it should be noted that it was 100% of the sample (seventh and eighth grade). This is because the enrollment of students in rural establishments is low. In Chile, approximately 280 thousand students receive education in 3247 rural establishments, which is equivalent to 7.7% of the total enrolled in the system, making it possible to find schools with less than 10 students grouped in a combined course [31].

Figure 4 shows the results from the first and second surveys conducted at the rural school according to the Likert scale. During the first survey, the aspects with the highest averages were related to the perceived usefulness (4.33), acceptance of the systems (4.16) and the technological environment (4.83). In this case, the students agreed that the use of the RWH system could be beneficial both for the environment and for the establishment. They showed interest in the idea of using rainwater within the establishment and considered that it was adequate space for its installation. Additionally, they trusted the technology used by these systems. On the contrary, subjective knowledge (3.41), social influence (2.66), and perceived risk (3.58) were the aspects with lowest average (see Figure 4A). This tendency suggested that the students neither agreed nor disagreed with the corresponding statements. Likewise, they somewhat disagreed that their social environment influenced their opinion on the use of RWH systems and they were neutral regarding the risks that RWH systems might generate. Moreover, these results can be related to the fact that students did not have an awareness of the risk associated with the improper maintenance of RWH systems. In this case, maintenance is an important factor to consider for the successful implementation of this type of technology.

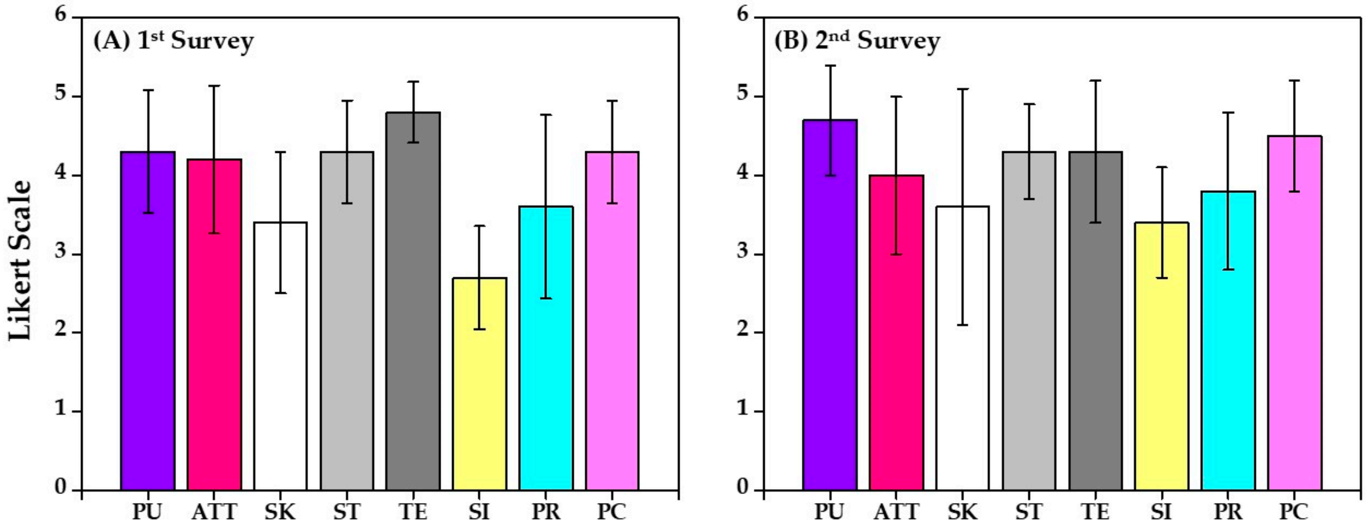

Figure 4. Results of (**A**) 1st survey and (**B**) 2nd survey. PU: perceived usefulness; ATT: attitude related to RWHs; SK: subjective knowledge; ST: social trust; TE: technological environment; SI: social influence; PR: perceived risk; PC: perceived cost.

After the talk, the second survey was applied and the results indicated that the lowest averages were observed in the aspects of social influence (3.41) and perceived risk (3.83). Despite the delivery of information, there were no changes in the trends for these aspects. However, the averages for perceived usefulness (4.66) and subjective knowledge (4) increased, demonstrating that the talk had a positive impact on these aspects (see Figure 4B). These results highlighted the importance of adapting information to the needs and concerns of users when implementing new technologies, such as RWH systems. By directly addressing the students' concerns, the talk improved the perceived usefulness and subjective knowledge about these systems. This ultimately influenced the acceptance and adoption of new technologies. Ahmad et al. [32] indicated that providing adequate and relevant information is crucial for the implementation of sustainable technology.

3.2.2. Correlation Analyses from Surveys

Figure 5 shows the correlation matrices of evaluating aspects during the first (Figure 5A) and the second surveys (Figure 5B). Regarding the perceived usefulness, a positive correlation of 0.37 with perceived risk was observed before the talk (Figure 5A). This result suggested that as the perception of usefulness increased, the perceived risk associated with these systems also increased. However, after the talk, a negative correlation of −0.23 was observed (Figure 5B), indicating an expected trend with the delivery of information, where an increase in the perception of usefulness leads to a decrease in perceived risk. In relation to the acceptance of the systems, a positive correlation of 0.79 was observed before the talk (Figure 5A), indicating a good attitude towards the use of RWH systems. After the talk, this correlation slightly increased to 0.80, suggesting that a higher perceived usefulness was associated with a more positive attitude towards the use of RWH systems (Figure 5B). In the case of acceptance of the systems with subjective knowledge, a positive correlation of 0.66 was observed before the talk (Figure 5A), suggesting that a relationship between these aspects already existed. Moreover, after the talk, this correlation slightly increased to 0.69, reaffirming that the delivery of information enhanced the positive attitude towards the use of these technologies (Figure 5B).

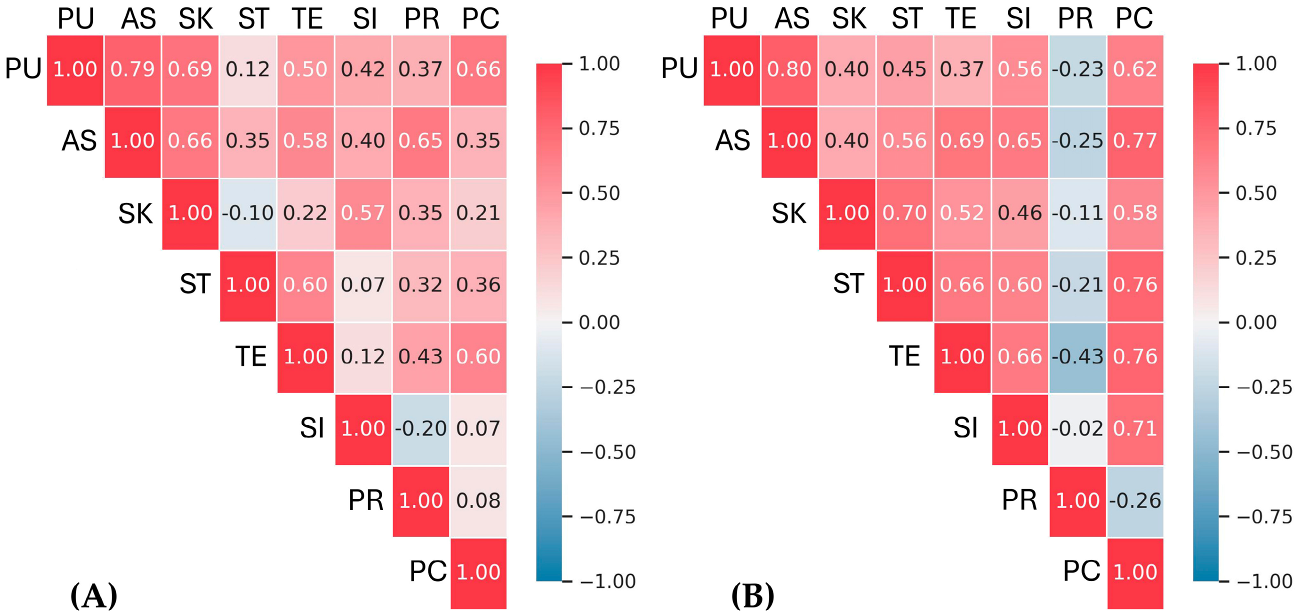

Figure 5. Correlation matrices of evaluated aspects during (**A**) first survey and (**B**) second survey (PU: perceived usefulness; AS: acceptance of the system; SK: subjective knowledge; ST: social trust; TE: technological environment; SI: social influence; PR: perceived risk; PC: perceived cost).

Liu et al. [13] supported their hypothesis that the perceived usefulness had a positive effect on the acceptance of the systems, presenting a value of 0.487. This result had a synergistic effect with the intention to use these systems. In this study, the results showed a positive correlation for these aspects with a value of 0.79 and 0.80 in the first and second surveys, respectively. This behavior confirmed that the perceived usefulness is a key predictor for the acceptance of the systems. Regarding social trust in relation to the perceived usefulness, the results of 0.12 in the first survey and 0.45 in the second survey were obtained, which differed from the values reported by Liu et al. [13], who presented a value of 0.36. The improvement in data correlation can be attributed to the talk, which likely increased the students' trust in the operation of RWH systems.

Social influence also showed a positive correlation with the perceived usefulness in the obtained results, with values of 0.42 and 0.56 for the first and second surveys, respectively. This indicated that the social environment for using the RWH system can enhance the perceived usefulness, in contrast to the values presented by Liu et al. [13], who reported a value of 0.16. This difference shows that the talk reinforced this influence by highlighting the perceived benefits and social acceptance of RWH systems. It is important to note that cultural variability in the perception of water reuse, as mentioned in the study by Zhu et al. [33], is also relevant. Cultural and contextual factors can significantly influence the perception and acceptance of RWH systems. Therefore, it is essential to consider these factors when interpreting the results and designing future interventions to promote the adoption of these technologies.

The obtained results highlighted the importance of subjective knowledge in the perceived usefulness, with values of 0.69 and 0.40 for the first and second surveys, respectively. This tendency indicated that the students with higher subjective knowledge tend to perceive the RWH system as more useful, in line with Liu et al. [13]. The decrease in correlation after the talk suggests that, although the talk increased the general knowledge of the students. The perceived usefulness of RWH systems began to depend on other factors introduced or discussed during the activity. The talk not only broadened knowledge but also presented new factors that influenced how students evaluated the usefulness of these technologies. Other studies, such as the one by Baawain et al. [14], indicated that subjective knowledge about water treatment and reuse affects the perception and attitude of the community. This suggests that knowledge and previous experiences can be enhanced through divulgation methods, helping to better understand the mentioned aspects. In this study, the informative talk on rainwater use through RWH systems showed a positive impact on the acceptance of these systems.

In line with the results of Ahmed et al. [32], education and public outreach are fundamental for improving the perception and acceptance of water reuse. The talk is an example of how educational efforts can impact the acceptance of RWH systems. The changes in survey results before and after the talk highlighted the importance of continuing to provide spaces for divulgating knowledge and educational initiatives to address concerns and increase the understanding of water treatment and reuse. This can promote the acceptance and adoption of such technologies within the community. Similar results also have been shown by Segura et al. [34]. Emerging technologies for RWH, as well as other sustainable technologies for transforming organic matter into energy, must be introduced to the community for its acceptance [35,36].

The relevance of education and public outreach in promoting sustainable water management practices is an important factor that had to be implemented during the evaluation of technology. In this line, the public policies of governments must promote and incentivize this type of technology to face the negative effects of climate change and water scarcity. In the case of the Chilean Government, the National Irrigation Commission creates a program called "Small Agriculture" that encourages small farmers and indigenous peoples to access bonuses to co-finance their irrigation projects with water efficiency where RWH is included.

4. Conclusions

Despite the limitations of this study, the results demonstrated that the quality of harvested rainwater from the RWH systems met the values proposed by EPA, FAO and ISO regulations and can be reused for agricultural purposes. In the outlet tap, the concentrations of turbidity, phosphate as phosphorus, chloride and nitrate fluctuated between 0.8 and

1.9 NTU, 0.01–0.2 mg/L, 2.8–5.0 mg/L and 0.3–0.9 mg/L, respectively, in RWH systems. Non-significant differences between RWH systems were observed ($p > 0.05$).

Regarding the social acceptance of this system, the results of surveys and correlation analysis demonstrated that the informative talk positively influenced the perceived usefulness and acceptance of the RWH system. In this case, the perceived usefulness increased by 7% from the first to the second survey. In this line, the correlation analyses showed that a positive correlation between acceptance and perceived usefulness was observed after (0.79) and before (0.80) the talk. This result indicates a good attitude toward the use of RWH systems. This study revealed the relevance and importance of delivering information to young users to increase knowledge about the technology and enhance the social acceptance of reusing harvested rainwater. Considering young users in this study is innovative and valuable because young people play an important role in generating significant changes for a sustainable future. This study will serve as a basis for future research related to the evaluation of both water quality and the acceptance of RWH systems.

On the other hand, these findings can help to promote and encourage governments to impulse public policies on this type of technology for facing water scarcity in arid and semiarid zones. In this line, these policies must include water quality guidelines and social acceptance assessments based on scientific evidence.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/resources13110159/s1 Supplement S1: Rainwater use acceptance survey; Table S1: Physicochemical parameters in RWH systems.

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