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Public Acceptance of Water Reuse: Barriers and Facilitators in Yazd, Iran, in 2020

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ABSTRACT

Introduction: Droughts and precipitation imbalances in various parts of the world have underscored the significance of alternative water resources. In recent years, recycled water has emerged as a viable alternative, with wastewater being treated to a safe level for diverse purposes. However, the public acceptance of water reuse plays a pivotal role in determining the success of recycling initiatives. This study aims to identify the barriers and facilitators influencing public acceptance of water reuse in Yazd, Iran, during 2020.

Material and Methods: A cross-sectional study involving 384 individuals in Yazd city during 2020 was conducted. Participants were selected using the stratified sampling method. The data collection tool was a researcher-made questionnaire. Data were analyzed using descriptive statistics and the Pearson correlation test in SPSS software version 23.

Results: The most crucial facilitator for acceptance was the concept of segregating drinking water and recycled water networks. The primary barrier to acceptance was the perceived risk of recycled water contamination and potential health hazards. Water reuse was most widely accepted for construction purposes, followed by toilet flush tanks and irrigation of green spaces in parks and sports fields. A positive correlation (r = 0.416) existed between facilitators and acceptance of water reuse, indicating that enhancing facilitators positively affected acceptance.

Conclusion: To successfully implement water reuse projects, it is essential to consider key facilitators such as segregated water systems for different household uses, raising public awareness about the benefits of water reuse, and building public trust in recycled water safety.

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Introduction

In recent decades, increasing water demand, drought, and precipitation imbalances in different parts of the world have highlighted the importance of alternative water sources [1]. Recycled water is potential source of water and research studies have demonstrated that wastewater can be treated to a level that is safe even for human consumption [2]. However, in many jurisdictions public acceptance represents an obstacle to the introduction of these schemes [3].

Today, water shortage in Iran is considered a

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significant problem. According to the Falcon Mark classification, 1700 cubic meters per year per person is the limit of water stress, and levels less than 1000 cubic meters are contemplated as a critical condition; however, many of the central and eastern catchments of Iran are observed to be in this condition. Falcon Mark has presented another index called Water Crowding Index (WCI), which represents the number of inhabitants per million cubic meters of renewable water resources [4]. The index values between 600 and 1000 indicate water stress, between 1000 and 2000 show absolute water scarcity, and above 2000 indicate water as a barrier to growth and development. Considering the average renewable water resources (89 billion cubic meters per year) of the country in the last 15 years and the population of the census in 2016 (80 million people), the WCI index was about 900 for Iran in 2016, which is at the limit of water stress. Considering the population projection of 148 million people by 2041 (Ministry of Energy, 2015) and assuming no reduction in renewable water resources in the future, despite the negative effects of climate change on water resources, this index would reach 1200 by that year, which is considered an absolute water scarcity. Also, the values are higher than the average in the arid regions of the country [5].

Yazd province is one of the arid, semi-arid, and desert regions of the country, in terms of water resources; therefore, this region is facing water quality and quantity limitations and critical conditions. The annual precipitation in this province is reported to be 50 to 60 mm, which is almost a quarter of the average levels in the country. Therefore, providing water resources is vital for this province, and in such circumstances, water reuse is one of the helpful methods to overcome the problem of water scarcity [6]. Previous studies have shown that public acceptance of water reuse is a key factor in determining the success of water reuse projects, and regardless of the scientific and engineering considerations, public opposition has the potential of failing water reuse projects, before, during, or after their implementation [7, 8]. Public acceptance of recycled water is currently the most important success factor for any water reuse project. In fact, water reuse projects usually require the cooperation of engineers and sociologists in order to analyze the social aspects and possible cultural barriers to project implementation, and to propose solutions while studying technical parameters [9]. Water reuse projects may face public opposition due to various reasons, including prejudice, fear, attitudes, lack of knowledge, and public distrust [1,8,10]. Understanding the benefits of reuse, satisfaction with the physical quality of the effluent, knowledge regarding the system, perceived trust and control, knowledge of water scarcity, and previous experiences in using alternative water resources are among the important criteria in accepting water reuse [11, 12]. Different studies have shown that promoting public understanding is critical to improve the success of water reuse projects [13].

Yazd province is one of the desert regions of Iran with limited water resources, and water reuse is one of the methods to overcome the problem of water scarcity. Moreover, public acceptance of water reuse in different regions, with distinct cultural and climatic differences, is of great importance, and limited studies have been conducted on the barriers and facilitators of public acceptance of water reuse in Yazd.

Accepting water reuse projects is associated with many barriers and facilitators, and recognizing them and planning to strengthen the facilitators or remove the barriers can lead to an increment of public acceptance. During the past few years, due to the limitation of water resources, various reuse projects have been started in the field of agriculture and industry, such as Karizboom project of Kausar Yazd Institute in the city of Yazd.

Therefore, considering the importance of water reuse projects, this study was conducted with the aim of identifying the barriers and facilitators of public acceptance of water reuse in Yazd city in 2020.

Materials and Methods

This cross-sectional study was carried out on

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384 people in Yazd city in 2020, which were selected using the stratified sampling method (Figure 1). The sample size was determined based on the assumption of 50% acceptance with water reuse (p = 0.5), (d = 0.1), (α = 0.05), and test power at the level of 20%.

Due to the prevalence of COVID-19 in the community, an online questionnaire was prepared. Then, the contact numbers of some water network consumers were randomly selected and the questionnaires were distributed among people of Yazd city through WhatsApp social network. The inclusion criteria were people aged over 18 years with a smartphone. Data collection tool was a five-part researcher-made questionnaire, including demographic information, knowledge regarding water and wastewater, acceptance, barriers, and facilitators of public acceptance of water reuse. The validity of the questionnaire was confirmed by the panel of experts and the reliability was confirmed by retesting and calculating Cronbach's alpha. Data were analyzed using descriptive statistics and the Pearson correlation test in SPSS software version 23.

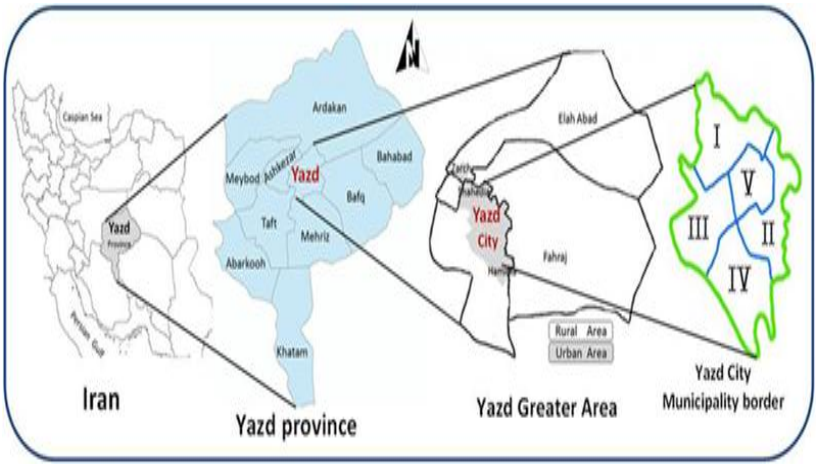

Figure 1: The map of Yazd city

Results

In this study, 52.6% of the participants were male, 71.4% were married, and 37% were office workers. Moreover, 59.9% of the participants had no information about recycled water, and radio and television, with 24.2% frequency, were the most important sources of information about recycled water (Table 1).

Figure 2 reveals that the highest acceptance of water reuse is related to construction (72.4%), toilet flash tanks (71.9%), and irrigation of green spaces of parks and sports fields (66.7%).

Regarding the facilitators, the most important facilitator (74%) was “segregation of drinking water and recycled water networks" at home (Figure 3).

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Table 1: Absolute and relative frequency distribution of demographic information

Variable	Options	Frequency (n=384)	Percentage
Gender	Male	202	52.6
	Female	182	47.4
Marital status	Single	110	28.6
	Married	274	71.4
Level of education	High school	35	9.1
	Diploma	89	23.2
	Bachelor	169	44
	M.A	73	19
	Ph.D.	18	4.7
Occupation	Worker	42	10.9
	Office worker	142	37
	Self-employed	73	19
	Housewife/househusband	71	18.5
	Unemployed	56	14.6
Residence status	Apartment	101	26.3
	Freestanding house	283	73.7
Have you ever received information about the use of recycled water?	Yes	154	40.1
	No	230	59.9
If yes, from what source? (You can choose up to 4 options)	Book	44	11.5
	Internet	88	22.9
	Radio/television	93	24.2
	Friends	50	13
	Other	79	20.6
Which wastewater subscriber are you?	Having a branch	130	33.9
	Pre-purchase	36	9.4
	No branch	218	56.8

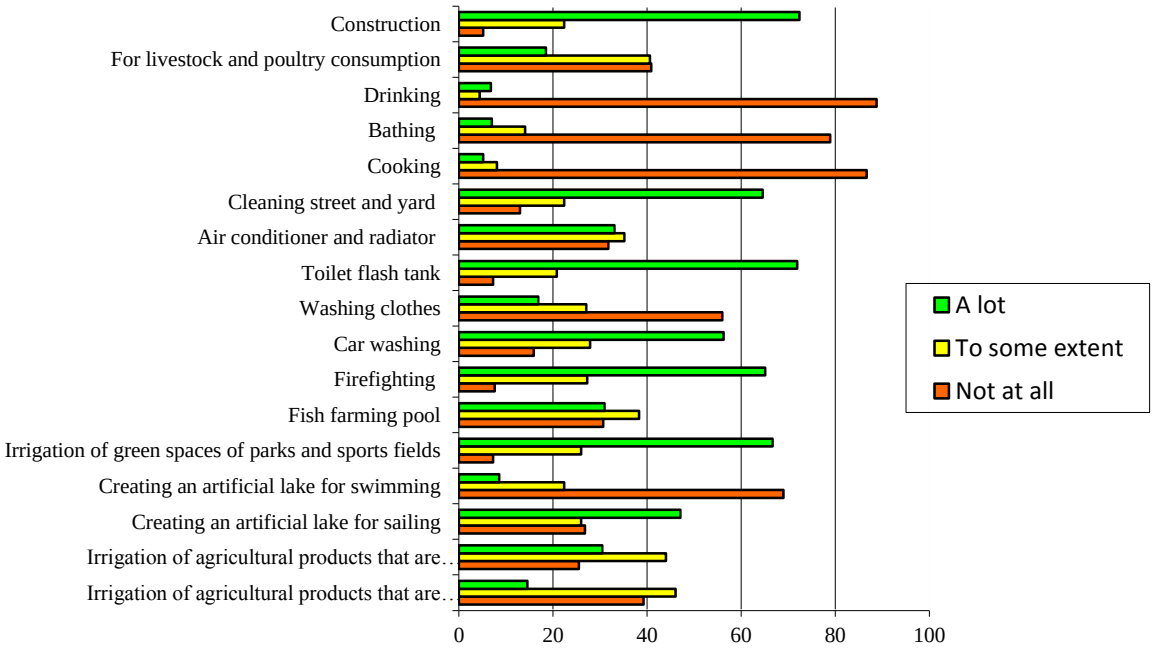

Figure 2: Relative frequency distribution of answers to acceptance of water reuse questions.

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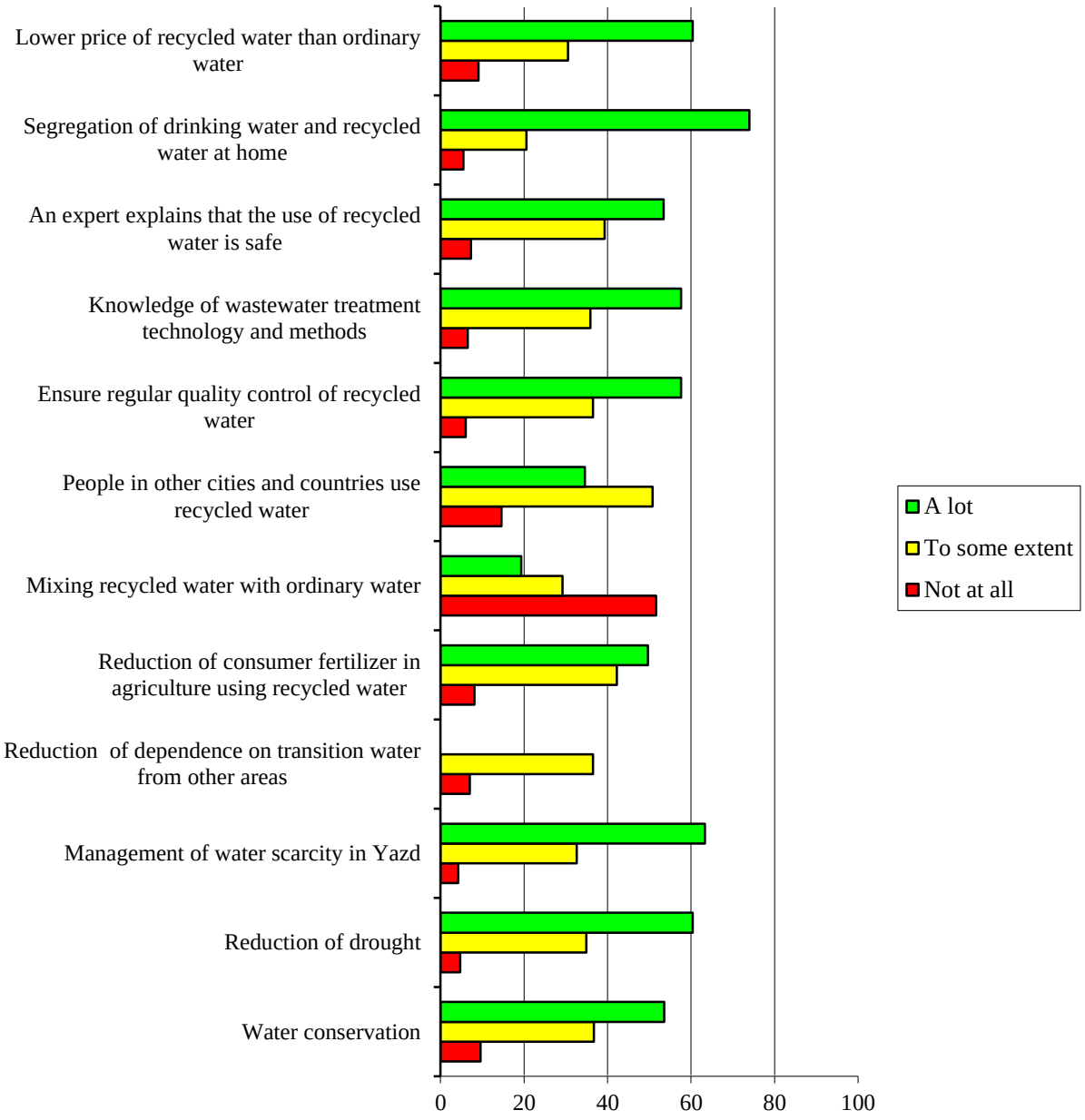

Figure 3: Relative frequency distribution of answers to facilitators of water reuse questions.

The most important barrier (65.9%) was related to "the possibility of recycled water contamination and endangering health" (Figure 4).

The status of range, mean, and standard deviation of the studied components are shown in Table 2.

The highest and lowest mean percentages of the maximum scores were related to facilitators and awareness, respectively.

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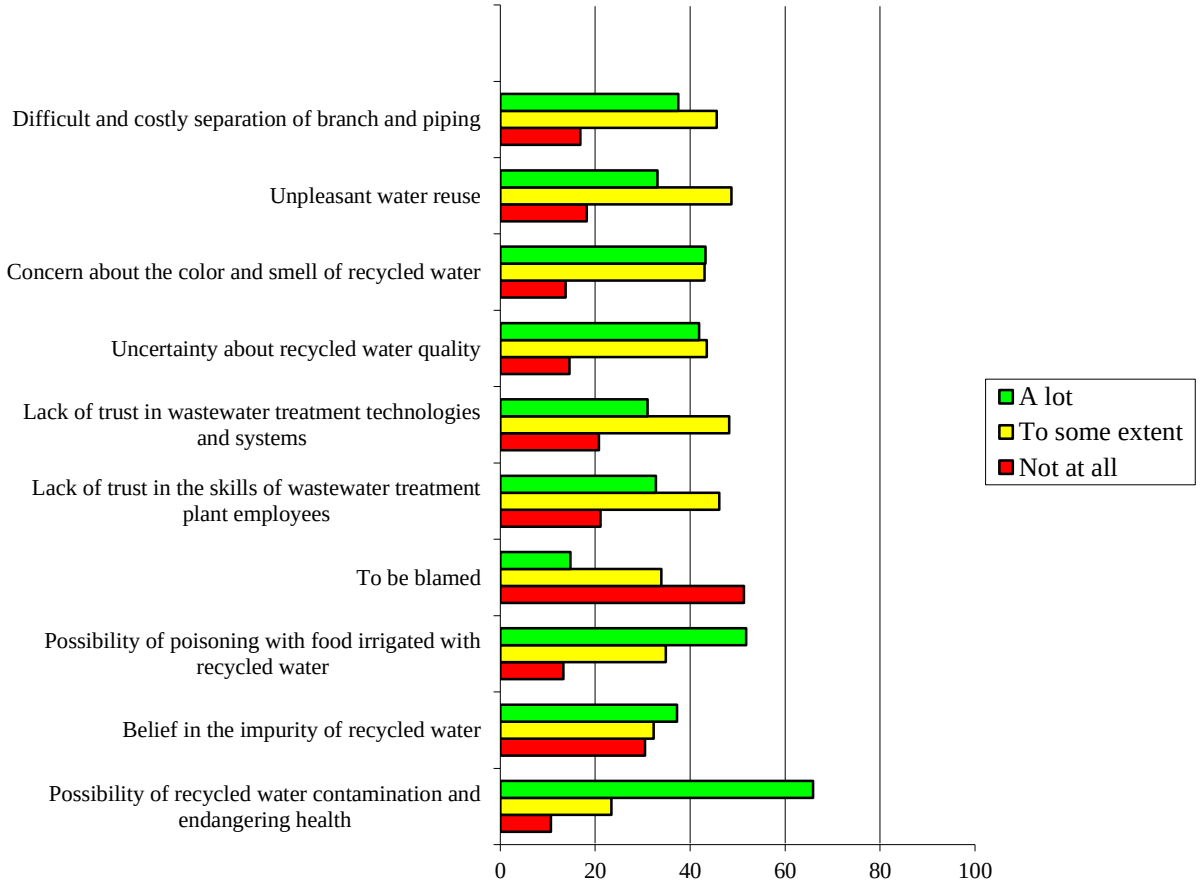

Figure 4: Relative frequency distribution of answers to barriers of water reuse questions.

Table 2: The mean and standard deviation of knowledge, acceptance, facilitators, and barriers of water reuse

Variable	Mean ± standard deviation	Score range	Mean percentage of the maximum score	Maximum	Minimum
Knowledge	3.26 ± 1.59	0-6	54.33	6	0
Acceptance	33.85 ± 5.98	17-51	66.37	49	17
Facilitators	29.06 ± 4.57	12-36	80.72	36	14
Barriers	21.78 ± 4.74	10-30	72.6	30	10

Among the studied variables, the acceptance correlation was only significantly positive with water reuse facilitators, so that by increasing facilitators, water reuse acceptance increased (Table 3).

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Table 3: Correlation coefficient of awareness score, acceptance, facilitators, and barriers of water reuse

		Awareness	Acceptance	Facilitators	Barriers
Awareness	The correlation coefficient	1	-0.038	0.027	0. 244*
	P-value		0.461	0.602	0.000
Acceptance	The correlation coefficient	-0.038	1	0.416*	-0.067
	P-value	0.461		0.000	0.188
Facilitators	The correlation coefficient	0.027	0.416*	1	-0.143*
	P-value	0.602	0.000		0.005
Barriers	The correlation coefficient	0.244*	-0.067	-0.143*	1
	P-value	0.000	0.188	0.005	

• Significant at the level of 0.01.

Discussion

New policies to provide water resources that meet the growing needs of the population include recycling and reusing non-conventional water resources. Given that the end product of these processes is directly related to the consumer, its social acceptance plays an important role in the success of water reuse projects [14]. Thus, the present study aimed to investigate the barriers and facilitators of public acceptance of water reuse in Yazd, Iran, in 2020.

The acceptance rate of water reuse was reported to be at a moderate level (66.37%), which is consistent with the study by Baghapour et al. which demonstrated a 60% acceptance rate [1]. Most of the participants agreed to use recycled water for construction, toilet flush tanks, and irrigation of green spaces in parks, and sports fields. Given the high acceptance of the participants regarding the use of recycled water for construction and irrigation purposes, it is recommended to declare that the use of public drinking water systems for construction and irrigation of green spaces is illegal, and citizens should be informed that they must purchase recycled water for such purposes.

In the study by Baghapour et al. [1], the maximum acceptance rate was related to the use of treated wastewater for general consumption, car washing, and toilet flash tanks. In the study by Buyukkamaci and Alkan [15], the maximum acceptance was related to water reuse for toilet washing, road cleaning, construction, and firefighting systems. In the study by Gu et al. [12], most people tended to use recycled water for toilet flush tanks, road cleaning, environmental purposes, firefighting, and car washing. In the study by Msaki et al. [16], the maximum acceptance rate was related to the use of treated wastewater for irrigation of sports fields, urban gardens, forests, and farms. In the study by Akpan et al. [17], citizens preferred to use treated wastewater for purposes that are less in contact with humans, such as toilet flush tanks, power generation, construction, and car washing.

In the present study, the acceptance rate of recycled water was lower for drinking and purposes that are in contact with humans, which is consistent with other studies [16-20].

The mean acceptance score of people living in apartments was significantly higher than people living in freestanding houses, which could be due to low water pressure in apartments and higher understanding regarding the importance of water.

The most important facilitators were observed to be the segregation of drinking water and recycled water networks, compensation of water shortages in Yazd, reduction of drought, and lower price of recycled water compared to drinking water.

By creating separate piping systems for drinking and recycled water, and increasing public knowledge regarding the benefits of water reuse, such as managing water scarcity and its impact on reducing drought, the acceptance rate increases. It is noteworthy that people want different water prices based on water quality. Among the facilitators, knowledge of wastewater treatment technology and methods was more important than an expert's explanation about the safety of using recycled water. This indicates that people want to increase their knowledge about water and wastewater issues. Therefore, the first step in

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increasing people's acceptance of the use of recycled water is to clarify the trends and express the related issues in a simple and understandable manner, since many people do not accept the opinions of experts and officials without appropriate reasoning.

In the study by Scruggs et al. [21], managing water scarcity was the most important factor affecting the general acceptance of using treated wastewater. In the study by Nkhoma et al. [22], public trust in delivery agents was the most important factor affecting the general acceptance of using treated wastewater. Also, Jeuland [23] examined the challenges of wastewater reuse in the Middle East and North Africa, and their results showed that mixing recycled water with drinking water resources, reusing water with the condition of segregating recycled water for specific purposes, and knowledge about the effectiveness of successful water reuse policies, are among the facilitators of water reuse. In the study by Verhoest et al. [24], water conservation behavior and a sense of environmental group-efficacy positively affect public acceptance.

The most important barriers included the possibility of contamination of recycled water and the inducement of health problems, the possibility of food poisoning irrigated with recycled water, and having concerns about the color and smell of recycled water, which are in line with other studies in this field [22, 25-27]. These results indicated that for increasing the success rate of water reuse projects, honest transparency from experts and officials is required, and the quality of recycled water and the health of the community must be guaranteed.

In the study by Verhoest et al. [24], feelings of disgust and fear of contamination are key drivers of consumer resistance to water reuse. In the study by Rossum [18], the most important barrier to water reuse was having concerns about the presence of chemicals, such as drugs, in the effluent. In the study by Akpan et al. [17], citizens accepted water reuse, subject to the approval of doctors, experts, and university professors.

Out of the total participants, 54.33% had appropriate knowledge regarding the issue; however, Glick et al. [26] reported the lack of public knowledge about water reuse, which is not in line with the results of the present study. According to the results, the level of knowledge increases by increasing the level of education, which indicates the importance of education and increasing the level of knowledge of individuals through educational programs. Also, there was a significant relationship between age and mean knowledge score, thus the age group of 40-51 years had a comparably high level of knowledge, since they were educated and experienced.

Conclusion

One of the basic solutions to solve the issue of water stress and to meet the water needs of the growing population of the world, especially in arid areas, is water reuse. Public acceptance of water reuse is a key factor in the success of water reuse projects. In water reuse projects, failure to meet the people's demands can lead to the rejection of the project, and re-designing the project requires spending more time and money.

Acceptance of water recycling faces many barriers and facilitators, and proper identification and planning can lead to the strengthening of facilitators, removing barriers, and consecutively, increasing the acceptance of people. Knowledge level and acceptance of citizens regarding water reuse were moderate. The most important facilitator for water reuse was the segregation of drinking and recycled water networks, and the most important barrier was the possibility of contamination of recycled water and the inducement of health problems. Most of the subjects accepted to implement recycled water in construction, toilet flash tanks, and irrigation of green spaces in parks and sports fields. Given the high acceptance of the subjects regarding water reuse for construction and irrigation of green spaces, it is recommended to declare that the use of public drinking water systems for construction and irrigation of green spaces is illegal, and citizens should be informed that they must purchase recycled water for such purposes.

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Facilitators, such as water segregation for different household purposes, public knowledge of the benefits of water reuse, and building public trust must be considered to successfully implement water reuse projects. Globally, the public acceptance of water reuse can be increased by strengthening facilitators. The most important barrier to water reuse was health concerns and problems caused by water reuse, which are related to the economic and technical aspects of wastewater recycling. The cost of processing and distributing technologies and systems required for this purpose should be reasonable and people should be assured that the quality of the recycled water, for each specific purpose, is in accordance with the standards, and their health is not threatened.

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Conflict of interests

The authors declare that there is no conflict of interest.

Ethical Considerations

In order to comply with ethical considerations, the purpose of the study and the nature of the investigation were explained to the subjects, and the necessary coordination was made with the relevant authorities, and the subjects were assured of the confidentiality of the information.

Code of Ethics

This study was authorized by Shahid Sadoughi University of Medical Sciences Ethics Committee IR.SSU.SPH.REC.1399.156.

Authors' Contributions

All authors contributed to the study conception and design. Data collection and analysis were performed by Fatemeh Hasanzadeh Mohammadi, Zohreh Rahaei and Sara Jambarsang. The first draft of the manuscript was written by Fatemeh Hasanzadeh Mohammadi and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Questionnaire

Demographic information

Gender: Male☐ Female☐

Age:

Number of household members: 1-3☐ 3-5☐ 5-8☐

Marital status: Single☐ Married☐

Level of education: High school☐ Diploma☐ Bachelor ☐ M.A☐ Ph.D ☐

Occupation:

Worker☐ Office worker☐ Self-employed☐ Housewife/househusband☐ Unemployed☐

Residence status: Apartment☐ Freestanding house ☐

Have you ever received information about the use of recycled water? Yes ☐ No☐

If yes, from what source? (You can choose up to 4 options)

Book ☐ Internet☐ Radio/television☐ Friends☐ Other☐

Which wastewater subscriber are you?

Having a branch☐ Pre-purchase☐ No branch☐

Knowledge			
Questions	**Correct**	**Incorrect**	**I do not know**
Yazd city water is supplied from well water and transfer water.			
The majority of water consumption in Yazd belongs to industry and agriculture sector.			
The city of Yazd does not have a municipal wastewater treatment plant.			
From a scientific point of view, recycled water (purified sewage) can be used for various purposes.			
Currently, in Yazd city, treated wastewater is not used to irrigate green spaces, etc.			
In order to use recycled water (purified sewage) for different purposes, there are strict environmental and health standards.			

Acceptance of water reuse			
To what extent do you accept water reuse (treated wastewater) for the following?	**Not at all**	**To some extent**	**A lot**
Irrigation of agricultural products that are consumed raw			
Irrigation of agricultural products that are consumed after cooking			
Creating an artificial lake for sailing			
Creating an artificial lake for swimming			
Irrigation of green spaces of parks and sports fields			
Fish farming pool			
Firefighting			
Car washing			
Washing clothes			
Toilet flash tank			
Air conditioner and radiator			
Cleaning street and yard			
Cooking			
Bathing			
Drinking			
For livestock and poultry consumption			
Construction			

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Facilitators			
Please specify to what extent each of the following makes it easier for you to use recycled water?	**Not at all**	**To some extent**	**A lot**
Water conservation			
Reduction of drought			
Management of water scarcity in Yazd			
Reduction of dependence on transition water from other areas			
Reduction of consumer fertilizer in agriculture using recycled water			
Mixing recycled water with ordinary water			
People in other cities and countries use recycled water			
Ensure regular quality control of recycled water			
Knowledge of wastewater treatment technology and methods			
An expert explains that the use of recycled water is safe			
Segregation of drinking water and recycled water at home			
Lower price of recycled water than ordinary water			

Barriers			
Please specify to what extent any of the following can be an obstacle for you to reuse water?	**Not at all**	**To some extent**	**A lot**
Possibility of recycled water contamination and endangering health			
Belief in the impurity of recycled water			
Possibility of poisoning with food irrigated with recycled water			
To be blamed			
Lack of trust in the skills of wastewater treatment plant employees			
Lack of trust in wastewater treatment technologies and systems			
Uncertainty about recycled water quality			
Concern about the color and smell of recycled water			
Unpleasant water reuse			
Difficult and costly separation of branch and piping			

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