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Public Acceptance of Treated Wastewater Reuse in the Agricultural Sector in Saudi Arabia

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Abstract: This paper examines public acceptance of reusing tertiary treated wastewater for agricultural purposes in Saudi Arabia. Data were collected through an online self-administered questionnaire from adults in the Al-Ahsa Governorate. A total of 344 eligible participants completed the survey. The results show that 77% of the participants supported the reuse of treated wastewater in agriculture. Most participants supported reusing treated wastewater because they trusted the authorities responsible for wastewater treatment and because it will augment water resources in Al-Ahsa. Participants who did not support reusing treated wastewater attributed their lack of support to health risks associated with reusing treated wastewater and for psychological reasons. Additional analysis for eight different agricultural applications showed that most participants supported the reuse of treated wastewater in applications with no direct connection to them (e.g., irrigation of public parks, green spaces, and woody trees and irrigation of animal feed crops). However, less than half of the participants supported the reuse of treated wastewater for other applications, especially for the irrigation of leafy green, raw, and cooked vegetables. Therefore, raising public awareness about the safety of reusing tertiary treated wastewater in agriculture should be a priority for authorities responsible for water management in Saudi Arabia.

Keywords: water supply; wastewater reuse; public acceptance; treated wastewater; irrigation

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1. Introduction

In Saudi Arabia, irrigation water accounts for about 71% of the annual freshwater consumption and imposes a serious burden on water resources in this water-stressed country [1]. Most of the country is located in an arid and semiarid region of the world with no rivers, lakes, or permanent running streams. The country also experiences high evaporation rates and has an average annual precipitation of less than 100 mm [2]. More than 65% of the total cultivated land in Saudi Arabia depends on irrigation water [3]. The main source of irrigation water in Saudi Arabia is non-renewable groundwater, which represents about 90% of agricultural water consumption [4]. Over the past four decades, a lack of water-related regulations and policies, insufficient monitoring and control mechanisms, and inefficient irrigation practices have resulted in the overexploitation of non-renewable groundwater resources in Saudi Arabia [5,6]. In response to water scarcity challenges and to conserve groundwater resources, authorities have explored the use of alternative water sources to meet the needs of the agricultural sector [7].

Treated wastewater has received special attention in Saudi Arabia for being a viable source to close the increasing water demand–supply gap [8]. The first regulation on wastewater treatment and reuse was published in 2000, entitled "Treated Sanitary Wastewater and Its Reuse Regulations," which required secondary or tertiary wastewater treatment levels [9]. In 2006, the Ministry of Water and Electricity (now the Ministry of Environment, Water and Agriculture [MEWA]) published two booklets related to the design of wastewater treatment plants and the use of treated wastewater for irrigation. Currently, there are 133 wastewater treatment plants in Saudi Arabia with a total production capacity of 1875 million m^3 per year [1]. Despite these initiatives and efforts to develop and use treated wastewater in agricultural irrigation, the reuse of treated wastewater is still not widely acceptable in the country [10]. Figure 1 shows treated wastewater production and reuse in Saudi Arabia from 2006 to 2021. During this period, the average reuse percentage was about 18% of the total production. The remaining treated wastewater is typically discharged into the Arabian Gulf, Red Sea, sand dunes, and wadis [11]. About 66% of treated wastewater is reused in agriculture, representing about 4% of total agricultural water consumption in 2021 [1,4].

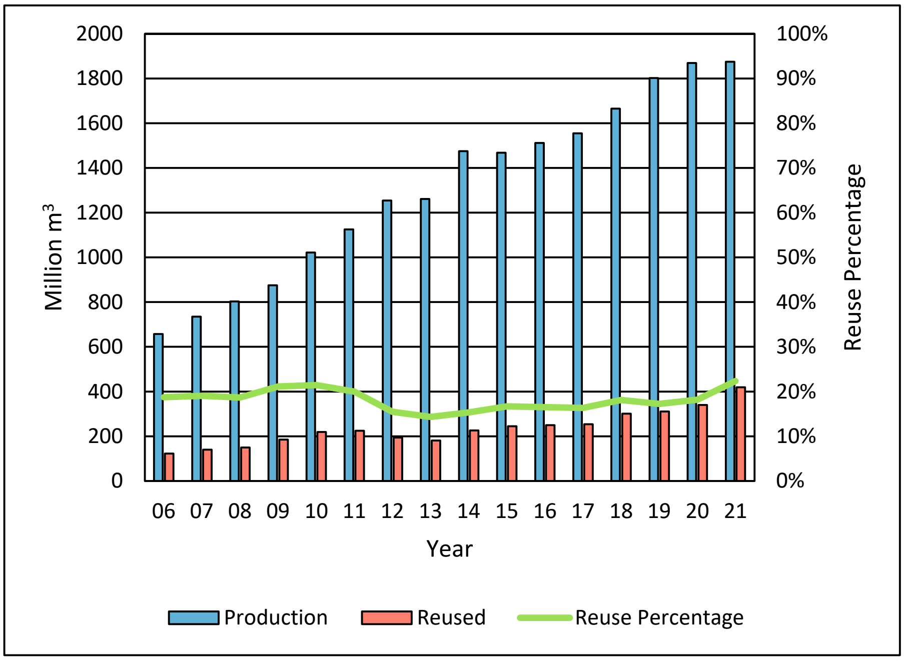

Figure 1. Production and reuse of treated wastewater in Saudi Arabia (million m^3), 2006–2021.

The low treated wastewater reuse rate is the result of various factors including economic and financial considerations, infrastructure availability, social acceptance, water resource availability, and other environmental aspects [4,12]. Among these factors, social acceptance is of chief importance [13]. Since Saudi Arabia aims to increase the reuse of treated wastewater in the agricultural sector, it is imperative to examine the public acceptance of reusing treated wastewater in this sector. To do so, we examine the public acceptance of reusing tertiary treated wastewater in agriculture in Al-Ahsa Governorate, which has the longest history of relying on treated wastewater as a source of irrigation water in Saudi Arabia.

The rest of this article is organized as follows. The first two sections describe the study area and provide a short historical overview and the current state of treated wastewater reuse in Al-Ahsa Governorate. Then, a literature review section provides a summary of the literature on public acceptance of treated wastewater reuse in Saudi Arabia. The next section covers the materials and methods utilized in this study. The final three sections cover the results, discussion, and conclusions.

2. Treated Wastewater Reuse in Agriculture in Al-Ahsa Oasis

Before the 1950s, water from natural springs and traditionally man-dug wells were the main sources of water for all uses in Al-Ahsa. Farmers in Al-Ahsa Oasis relied on those sources for their irrigation water by utilizing a communal irrigation system where the water was either distributed by gravity flow or lifted using human or animal efforts and was used several times at different height levels in the oasis [14]. However, with the introduction of modern diesel pumps and drilled wells in the early 1950s, water became easily available for every individual farmer in the oasis. The excessive irrigation with salt-bearing spring water and poor subsurface drainage resulted in high salt concentrations in large parts of the oasis, making those lands relatively less productive. In addition, environmental and health risks from the swamps that resulted from this traditional irrigation method caused many problems, such as the spread of mosquito-borne diseases and unpleasant odours, for the residents of nearby villages and cities. During this period, between 12,000 and 15,000 hectares of land was under intensive cultivation, but this area decreased to 10,000 hectares in the 1960s and to about 7000 hectares in the early 1970s [15]. Natural springs were also affected due to the dramatic increase in the number of wells drilled to meet the increasing demand for water for agricultural use and urban development. According to [16], in 1964 there were 162 springs and 336 wells in the oasis, and by 1967 these numbers had changed to 102 springs and 887 wells.

In an effort to control and regulate the use of groundwater in the oasis, among others, the government established Al-Hassa Irrigation and Drainage Authority in 1971 (which was renamed to the Saudi Irrigation Organization [SIO] in 2017). To conserve water resources, SIO integrated only the largest and most important 32 springs and a few hundred wells to form its irrigation concrete canals and drainage network of 1450 km [17]. This network provided irrigation water for more than 20,000 farms with a total area of about 7000 hectares of land [18]. Groundwater from springs and wells continued to be the main source of irrigation water in the oasis until the end of the 1970s. However, unplanned agricultural and urban expansions forced SIO to use unconventional water sources to supplement the dwindling groundwater supplies and to improve water use efficiency [7].

After multiple agricultural and water studies, SIO began supplying farmers with agricultural drainage water in 1980 and treated wastewater in 1987 [19]. Figure 2 shows the developments in irrigation water sources used by SIO in Al-Ahsa Oasis from 1984 to 2021. Before 2003, SIO was receiving only about 6000 m^3/day of treated wastewater from the Saudi Arabian Oil Co. (Aramco) Sewage Treatment Plant. In 2003, SIO started to receive about 180,000 m^3/day of treated wastewater from Al-Hofuf Treatment Plant (which serves the largest two cities in Al-Ahsa Governorate). In 2010, SIO also started to supply farmers with 80,000 m^3/day of treated wastewater from Al-Oyun and Al-Omran Treatment Plants. Finally, in 2018, SIO started receiving about 200,000 m^3/day of treated wastewater from Al-Khobar Treatment Plant, which made treated wastewater the main source of irrigation water in Al-Ahsa Oasis.

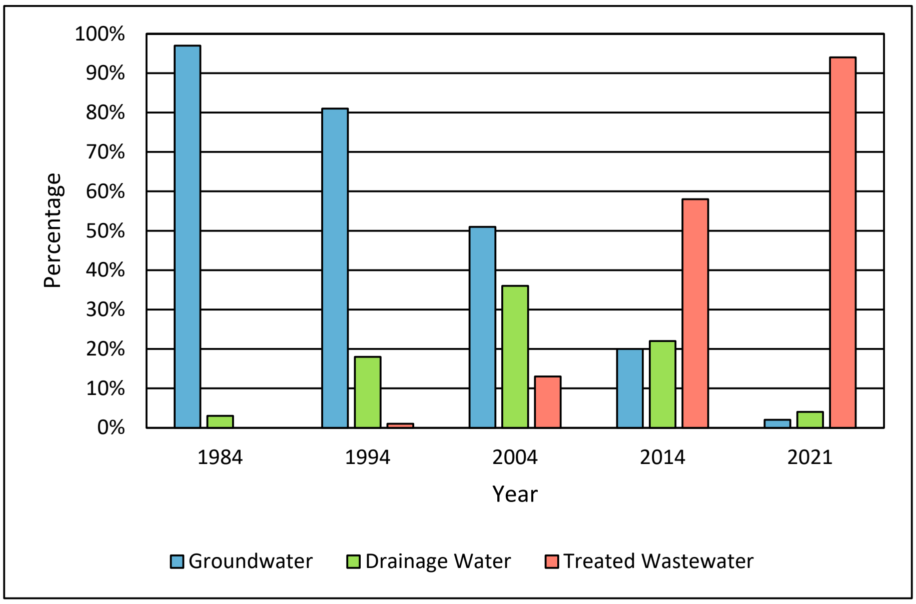

Figure 2. Developments in irrigation water sources used by the Saudi Irrigation Organization (SIO) in Al-Ahsa Oasis, 1984–2021.

3. Literature Review

Despite the importance of identifying the opinions of individuals and their attitudes towards the reuse of treated wastewater, there are very few studies that deal with this issue in Saudi Arabia, which we review in this section.

Some studies emphasized the importance of the topic. For example, Husain and Ahmed [20] noted that public opinion is an important factor in implementing wastewater reuse programs and that, without proper information, people face an unjustified physiological barrier towards reusing treated wastewater. Additionally, Ouda [21] discussed the main challenges facing Saudi Arabia regarding the use of treated wastewater. Massoud et al. [22] showed that the willingness of citizens to accept the reuse of treated wastewater is a key pillar for the success of the water management strategy.

Other studies investigated individuals' attitudes towards the reuse of treated wastewater. Alataway et al. [23] explored the public's perceptions of wastewater reuse in Al-Ahsa and Tabouk by surveying 400 consumers. Three dimensions of the acceptability of wastewater reuse were identified through factor analysis of the scale. These dimensions were, in descending order of significance, the acceptability of agricultural use (irrigate cereal crops, irrigate vegetable crops, irrigate fodder crops, and irrigate fruit crops), domestic use (drinking, bathing, cooking, and washing clothes), and public use (water public park, water sports field, water home garden, and toilet flushing). Compared to Tabouk, people in Al-Ahsa were more supportive of wastewater reuse. The authors justified the results through the familiarity of Al-Ahsa residents with wastewater reuse due to the existence of large-scale wastewater reuse projects, which reduces the public's level of concern. In another study, Al-Qasoumi [24] measured the public's attitudes toward the safe reuse of treated wastewater for residential, municipal, agricultural, and industrial purposes. Data was collected from 958 respondents in Riyadh. The results indicated that 70% of the study sample emphasized the need for safe reuse of treated wastewater for domestic, agricultural, and industrial purposes. Additionally, 55% stressed the appropriateness of reusing treated wastewater safely in cleaning and domestic irrigation. However, 51% disapproved of the reuse of wastewater in cultivating cooking vegetables, and 77% disapproved of the reuse for leaves eaten without cooking. Furthermore, 65% of the study sample acknowledged the need for more media awareness of the benefits of using treated wastewater in a safe way for various purposes. Alharbi [25] found that most farmers in some provinces of the Riyadh region irrigate more than half of their cultivated area with treated sewage water for date crops (97%), fruits (54%), fodder (40%) using immersion irrigation (71%), followed by the drip irrigation (25%). As for the farmers' attitudes towards adopting the reuse of treated sewage water, there were three categories: farmers with negative tendencies (0.3%), farmers with neutral tendencies (74.4%), and farmers with positive tendencies (25.3%). The study divided the obstacles to adopting the reuse of treated sewage water into legitimate and health obstacles (e.g., consumer non-acceptance, 45%; Sharia violation, 42%; workers' aversion, 39%) and technical obstacles (pests, 60%; lack of necessary connections, 52%; inappropriateness for the irrigation system used, 39%; problems with crops, 35%; increased soil salinity, 35%).

Additional studies elucidated the impacts of social and demographic factors on these attitudes. Al-Shenaifi et al. [26] identified the perception and attitudes of farmers in the Riyadh region towards adopting the reuse of treated sewage water to irrigate date palms. A questionnaire was distributed to 470 farmers in Dir'iya, Al-Eyienah, Al-Hayer, and Dirab, from whom 304 questionnaires were used for the analysis while 166 were excluded for invalidity. The vast majority of respondents were elderly people (95%) aged 60 and over, 52% of the respondents had an educational level below primary, and 89% of them had agriculture as their main occupation. Additionally, 62% of the respondents agreed that reusing sewage water contributes to preserving non-renewable water resources, 71% agreed that it will be the main source for agriculture in the future, 56% concurred that using it as an additional source for irrigation is a trend that has been observed throughout the world, and 57% opposed expanding its usage in agricultural sector. The study noted a significant inverse relationship between age and the farmer's attitude towards the reuse of treated sewage water in agriculture and a significant positive relationship between the educational level and the farmer's attitude, meaning that the young and educated farmers are more positive to the use of treated sewage water.

Mu'azu et al. [27] analyzed socio-demographic factors that influence individuals' attitudes to reusing gray and mixed wastewater for non-domestic uses (i.e., firefighting, swimming pools, and car washing). Data was collected from 624 households in Dammam using a questionnaire prepared for this purpose. According to the results of the logistic regression analysis, households are more likely to accept treated gray wastewater than mixed wastewater, with an odds ratio (OR) of 2.18 to 2.71 for gender, 1.32 to 1.03 for residential location, 1.22 to 0.18 for age, and 1.33 to 0.98 for education level. The study showed that the public's acceptance of the reuse of treated wastewater can be understood theoretically using the FOAM (focus, opportunity, ability, and motivation) framework commonly used in behavioural studies. Focus includes defining behaviour and the target group; opportunity represents external factors that affect whether a person accepts or rejects the behaviour; ability is the physical and emotional ability to make the required behaviour change; and motivation includes material and moral incentives to change behaviour or the associated risks. The study concluded that a wider scale of reuse of treated wastewater for unconventional uses is necessary to lessen Saudi Arabia's reliance on non-renewable groundwater and costly desalinated water. In addition, Abubakar and Mu'azu [28] investigated the public's willingness to reuse treated greywater for household applications (e.g., laundering and bathing) and the impacts of social and demographic factors on their attitudes. Education, age, and residential location were found to be significant explanatory variables, whereas gender and nationality were not. They elucidated that behavioural change campaigns are essential for expanding wastewater recycling.

To our knowledge, factors associated with public acceptance of reusing tertiary treated wastewater for agricultural purposes in Al-Ahsa have not been investigated yet. Therefore, the objectives of the current study were to assess public opinion and to identify factors associated with it in Al-Ahsa.

4. Materials and Methods

4.1. Study Area

Al-Ahsa Governorate (henceforth Al-Ahsa) is located in the Eastern Province of Saudi Arabia. It is the largest governorate in the country in terms of area (representing about 25% of Saudi Arabia) and the fifth largest in terms of population, which is about 1.3 million [29]. Al-Ahsa encompasses Al-Ahsa Oasis and Ghawar oil field, both being the largest natural oasis and conventional oil field in the world [30]. There are six major cities, 32 villages, and 55 hijra settlements located inside or around the oasis in the northern part of the governorate [29]. The major cities and the oasis are mostly surrounded by the Empty Quarter sand desert, which covers about 75% of Al-Ahsa [30]. The Al-Ahsa metropolitan area includes the largest two cities of Al-Hofuf and Al-Mubarraz. Figure 3 shows a map of Al-Ahsa Oasis and the six major cities' boundaries.

Average monthly wages for Saudi and non-Saudi workers in Al-Ahsa were about $1516.3 and $420.8 in 2020, which are approximately 22% and 40% lower than the averages across Saudi Arabia [31]. More than 60% of the workforce in Al-Ahsa are employed in construction, wholesale and retail trade, food and beverage services, healthcare, and food manufacturing sectors [32]. Agriculture is also an important economic sector in Al-Ahsa and was the main economic activity in Al-Ahsa before the oil discovery in 1935 due to its water abundance. Al-Ahsa Oasis is the fourth largest cultivation area for date palms in the country [3]. It is estimated that there are more than 2.5 million date palms grown over 70% of the oasis's total cultivated area which covers more than 8000 hectares across 25,000 farms [33,34].

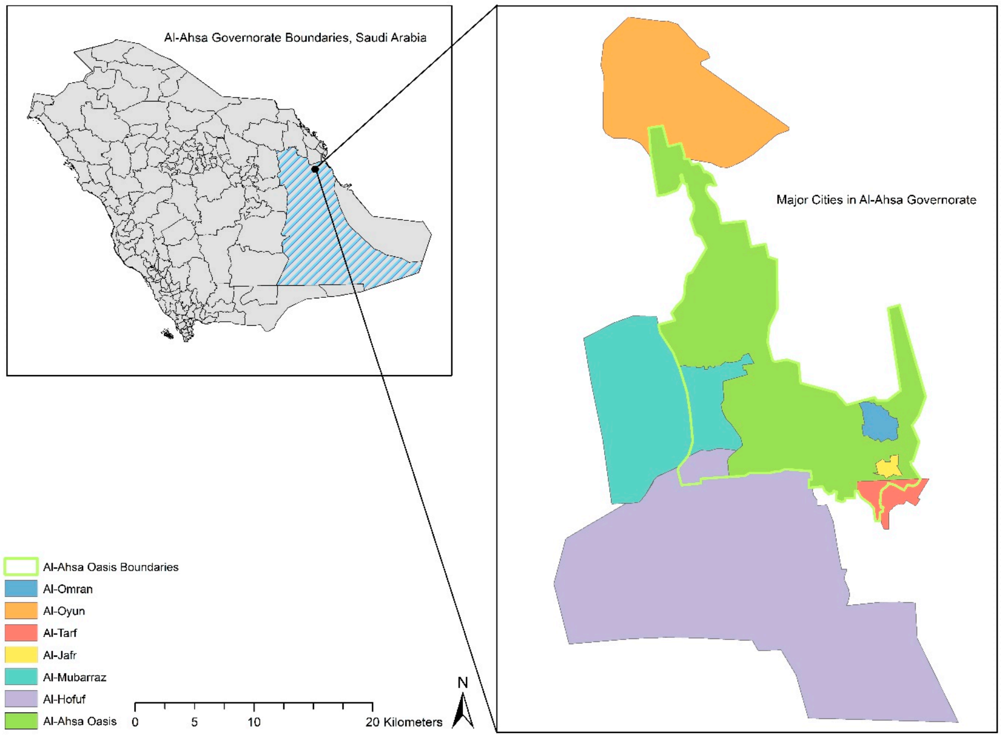

Figure 3. Al-Ahsa Governorate and its major cities.

4.2. Sample Selection and Survey Procedure

The study was conducted using an online survey between September and October 2022. A web-based structured questionnaire was administered via Google Forms. A convenience sample was recruited through a website link circulated using social network platforms (e.g., WhatsApp and Telegram) and an email announcement to all persons affiliated with King Faisal University. The inclusion criteria for participants' eligibility include those being more than 18 years old and being Al-Ahsa residents. The participants were requested to take part in the survey by completing the questionnaire without any time restrictions.

The questionnaire was developed based on previous validated research articles [22,35,36]. It comprised four parts with a total of 40 questions. The first part of the questionnaire collected participants' demographic and socio-economic characteristics. The second part measured the participants' awareness of water resources and wastewater reuse. The third part determined the respondents' attitudes toward reusing treated wastewater in agriculture. The fourth part included questions related to other economic and religious factors that might affect the acceptance of reusing treated wastewater in agriculture. More than half of these questions (25 out of 40) were graded on a three-point Likert scale (agree, disagree, and neutral).

The study relied on preliminary data collected from a sample of Al-Ahsa residents. The sample size was based on the following equation [37]:

$$n = \frac{4N}{4 + \frac{(N-1)e^2}{pq}}$$

where: n is the size of the required sample, N is the size of the population, e is the margin of error, p is the proportion of the population which has the attribute (awareness of water resources and wastewater reuse), and $q = (1 - p)$. A margin of error of 6% has been assumed, and $p = 0.5$ and $q = 0.5$ were assumed to give them equal opportunities, avoid bias, and obtain maximum variability. Given that the population of Al-Ahsa was about 1.3 million, the sample size was estimated at 278. Accordingly, for its economic analysis, the study relied on a simple random sample of 344 individuals.

4.3. Statistical Analysis

Statistical analyses were performed using Statistical Package for Social Sciences (SPSS) version 26. Simple descriptive analyses, including frequencies, percentages, means, and standard deviation (SD) were computed for demographic and socio-economic characteristics and the other variables of interest such as participants' attitudes and awareness about treated wastewater. The Chi-square test was carried out to determine the significance level of association and the relationship between the categorical independent variables of demographic and socio-economic factors and the outcome variable of acceptance of treated wastewater reuse in agriculture.

5. Results

5.1. Participants' Characteristics

A total of 344 eligible participants completed the survey. Table 1 shows the demographic and socio-economic data obtained from the questionnaires. A slightly higher percentage of men (50.9%) than women participated. They ranged in age from 18 to 79, with an average age of 30 (SD = 13.4). Specifically, 53.2% were in the 18–24 age range, 16.9% were 25–34, 9.9% were 35–44, 13.7% were 45–54, and 6.4% reported being 55 or older. The majority (90.1%) were Saudi citizens. Participants were fairly well educated, with 58.8% having a bachelor's degree or higher. Most also lived in cities, with 79.1% of them living in the Al-Ahsa metropolitan area (Al-Hofuf and Al-Mubarraz). Over half of the respondents were unmarried (57%) and unemployed (64%). The monthly income was 5000 Saudi Riyals ($1333) or more for about 44% of the participants.

Table 1. Participants' demographic and socio-economic characteristics (Observations = 344).

Variable	Category	Frequency (Percentage)
Gender	Male	175 (50.9)
	Female	169 (49.1)
Nationality	Saudi	310 (90.1)
	Non-Saudi	34 (9.9)
Residence	City	296 (86.0)
	Village	48 (14.0)
Marital status	Married	148 (43.0)
	Unmarried	196 (57.0)
Family size	2–4	77 (52.0)
	5–7	49 (33.1)
	≥8	22 (14.9)
Age	18–24	183 (53.2)
	25–34	58 (16.9)
	35–44	34 (9.9)
	45−54	47 (13.7)
	≥55	22 (6.4)
Education	Less than Bachelor's	142 (41.3)
	Bachelor's degree	143 (41.6)
	Graduate school	59 (17.2)
Employed	Yes	124 (36.0)
	No	220 (64.0)

Table 1. *Cont.*

Variable	Category	Frequency (Percentage)
Employment sector	Public	88 (25.6)
	Private or self-employed	36 (10.5)
Monthly income (Saudi Riyals)	<5000	193 (56.1)
	5000–10,000	63 (18.3)
	10,001–15,000	45 (13.1)
	>15,000	43 (12.5)

The statistical analysis (Chi-square test) of participants' demographic and socio-economic characteristics revealed that, except for age (χ^2 = 8.406, p = 0.078) and nationality (χ^2 = 4.265, p = 0.039), there were no statistically significant relationships between participants' characteristics and whether they support or do not support the reuse of treated wastewater in agriculture.

5.2. Participants' Awareness of Water Resources and Wastewater Reuse

In terms of participant awareness about water resources, less than half of the participants (41%) were aware of the water scarcity problem in the country. About 54% believe that Al-Ahsa could suffer from severe water shortage problems in the future. Moreover, the results also indicate that 90.4% of the respondents have heard about the term 'treated wastewater' previously. However, only 37.8% of the respondents knew about treated wastewater being the main source of irrigation water in Al-Ahsa.

We also measured participants' general knowledge and awareness of treated wastewater by constructing a five-item awareness scale using the five items shown in Table A1 (Appendix A). Factor analysis verified that the awareness scale was unidimensional and the Cronbach's alpha for the items was 0.81. The score of awareness was used as a proxy for the overall knowledge of the participants. The response scale ranges from 1 to 3, where 1 = disagree and 3 = agree.

For participants' awareness about treated wastewater reuse, the mean of our composite variable was 2.58 (SD = 0.48), indicating a high level of awareness about treated wastewater reuse among the participants. The Chi-square test shows that there is a statistically significant relationship between the awareness scale and participants' attitudes toward reusing treated wastewater in agriculture (χ^2 = 150.857, p = 0.000).

5.3. Participants' Attitudes toward Reusing Treated Wastewater in Agriculture

Results show that the majority of participants (77%) supported the reuse of tertiary treated wastewater for agricultural purposes when they were asked the following question: "Do you accept the use of tertiary treated wastewater for agricultural purposes?" Based on their answer, the participants were then asked a check-all-that-apply question about the reasons that make them support or oppose the reuse of tertiary treated wastewater in agriculture. Table 2 summarizes the results of these two questions. More than 47% of the participants supported the reuse of treated wastewater in agriculture because they trusted the authorities responsible for sewage treatment or because it will provide a new water source. In addition, about 44% of the participants support the reuse of treated wastewater because modern technologies are able to produce high quality treated water, and 40% believe it is environmentally safe. On the other hand, 14% did not support the reuse of treated wastewater for agricultural purposes because of the health risks associated with reusing it and 15% opposed it for psychological reasons.

To figure out attitudes concerning various agricultural purposes, we asked the participants for their opinions about eight different agricultural applications for reusing treated wastewater. Figure 4 shows participants' attitudes toward reusing treated wastewater for those purposes. Out of the eight applications, irrigation of public parks, green spaces, and woody trees was supported by 82.3% of the participants, followed by irrigation of animal feed crops (64%). Less than half of the participants supported the remaining uses. It is worth noting that irrigation of the three types of vegetables (leafy green, raw, and cooked) with treated wastewater had the highest rate of rejection among the eight uses.

Table 2. Reasons for supporting and not supporting the reuse of tertiary treated wastewater for agricultural purposes (from check-all-that-apply questions).

#	Reasons for Accepting the Reuse of Treated Wastewater	Frequency
1	I trust the authority responsible for sewage treatment	165
2	Finding a new water source	163
3	Scientific progress and modern technologies have succeeded in producing treated water whose qualities are very close to the specifications of drinking water	153
4	Because it is environmentally safe to reuse it in agriculture	136
5	Because there are no health risks from reusing it in agriculture	129
6	Protect the environment from pollution	118
7	Its economic cost is reasonable compared to desalinated water	116
8	The existence of a fatwa by the Council of Senior Scholars that it is permissible to use sewage water after treatment	38
9	Other	5
#	**Reasons for Not Accepting the Reuse of Treated Wastewater**	**Frequency**
1	For psychological reasons, regardless of their safety from a health point of view	52
2	Because there are health risks from reusing it in agriculture	48
3	Because it is environmentally harmful to reuse it in agriculture	19
4	I do not trust the authority responsible for sewage treatment	13
5	Its high economic cost	13
6	Other	6

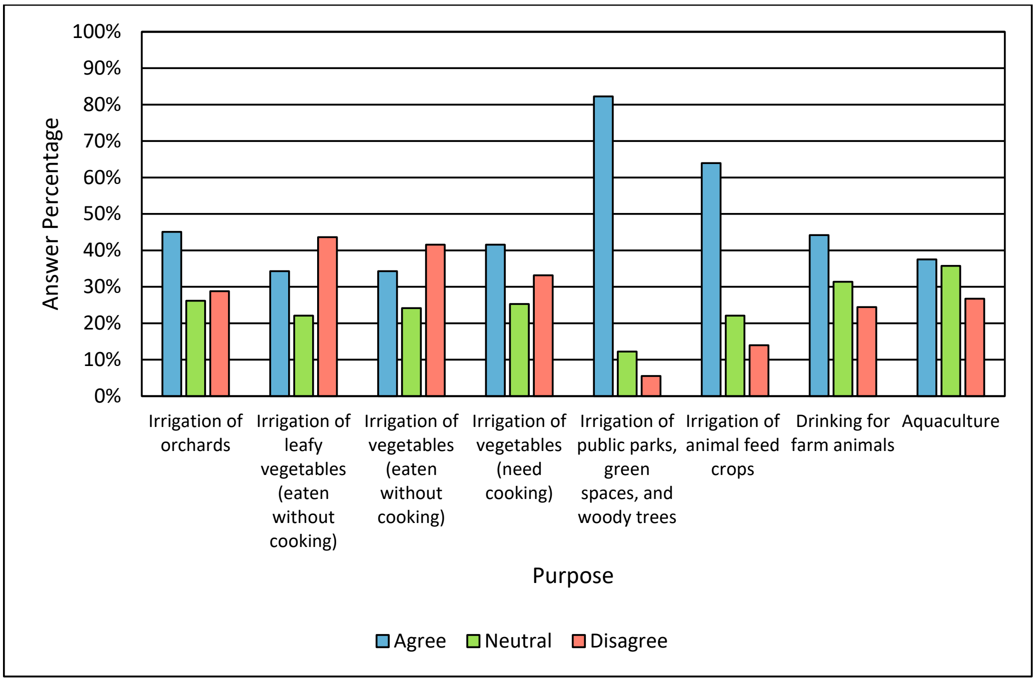

Figure 4. Public attitude toward reusing treated wastewater for various purposes.

5.4. Other Economic and Religious Factors Related to Participants' Attitude

We asked participants two questions to examine what factors might induce them to accept the reuse of treated wastewater in agriculture. The results showed that approximately 44.8% of the participants agreed they would consume agricultural products irrigated with tertiary treated wastewater if the prices of those products were lower. In addition, 55.5% of the participants agreed they would consume agricultural products irrigated with tertiary treated wastewater in the event that the Council of Senior Scholars issued a fatwa permitting its use.

6. Discussion

Water scarcity is one of the main challenges threatening agricultural development. This challenge is intensified by the increasing costs of developing new water sources, land degradation in irrigated areas, groundwater depletion, water pollution, and ecosystem degradation [7,38,39]. Reusing treated wastewater for irrigation offers numerous environmental and economic benefits (e.g., increasing water supply, fulfilling demand, managing water shortages, preserving freshwater, enriching soil and plants with organic matter and nutrients, increasing agricultural production, minimizing soil chemical fertilizers, and lowering costs) [40,41]. This non-conventional water source is considered a valuable asset for agriculture and a reliable source of water and nutrients [42]. The importance of water reuse was recognized in the 2017 World Water Development Report [43]. However, there are some concerns associated with treated wastewater reuse in irrigation (e.g., health risks, soil salinity, and toxicity hazards) [42,44]. Proper treatment and use of wastewater, appropriate irrigation systems, efficient management, advanced technologies (e.g., nanofiltration, reverse osmosis, photodegradation, and photocatalysis), and effective governance and monitoring can alleviate these risks [39,40,45].

The history of wastewater reuse is a testament to humanity's evolving understanding of water resource management. Wastewater reuse dates back thousands of years to ancient civilizations (e.g., the Indus Valley, Egypt, China, Mesopotamia, the Greek and Roman Empires), where rudimentary systems were developed to collect and channel wastewater from settlements to irrigate crops [46]. However, it was during the 19th and 20th centuries, with the advent of modern sewage treatment plants, that the concept of wastewater reuse gained prominence. The reuse of wastewater occurred in "sewage farms," first in European locations (e.g., Poland in 1531 and Edinburgh in 1650) and later in the USA (1876). In 1918, the first water reuse regulations for the irrigation of crops that are consumed cooked were established by the California State Board of Public Health [46]. Today, wastewater plays a crucial role in addressing water scarcity, reducing environmental pollution, and promoting sustainable water management practices in many parts of the world [47]. This historical progression highlights the ongoing evolution of wastewater reuse as a vital component of water sustainability.

The reuse of treated wastewater has grown and attracted great interest in recent years as an alternative water resource and a sustainable solution to water insecurity. Some existing studies carried out a bibliometric analysis [48–50], whereas other studies carried out a systematic review or structured review [13,51,52]. Although the public acceptance of wastewater is well rooted in the literature, there are very few studies that provide insight into the public acceptance of treated wastewater in Saudi Arabia.

The most commonly investigated socio-demographic variables in the literature are gender, nationality, age, family size, education, profession, and income [52]. The relationships between demographics and treated wastewater water acceptance are mixed in the literature. The Chi-square tests in our study revealed statistically significant relationships between age and nationality and the acceptance of the reuse of treated wastewater in agriculture. We found no statistically significant relationships between public acceptance of treated wastewater reuse and gender, residence, marital status, family size, education, employment, or income. Al-Shenaifi et al. [26] indicated a statistically significant inverse relationship between age and the acceptance to reuse treated wastewater in agriculture and a statistically significant positive relationship with the level of education. In Abubakar and Mu'azu [28], education, age, and residential location were statistically significant while gender and nationality were statistically insignificant. The inconsistent results in the literature might imply the variance in the social acceptance of treated wastewater reuse cannot be explained solely by socio-demographic variables. According to Savage [53], attitudinal and contextual factors other than demographics account for 80–90% of the difference in risk perceptions across individuals.

Aligning with the literature, similar to Alataway et al. [23], the study found that Al-Ahsa residents were supportive of wastewater reuse. Their familiarity with wastewater reuse and the presence of the SIO in Al-Ahsa may explain the acceptance of reusing tertiary treated wastewater in agriculture. The public acceptance of reusing treated wastewater varies according to the purpose. In general, studies found that people accept reusing treated wastewater for non-domestic and industrial purposes, while there is concern for reusing wastewater for some agricultural purposes. The majority of participants in this study found it acceptable to reuse tertiary treated wastewater for public parks, green spaces, and woody tree irrigation, while acceptance for using tertiary treated wastewater for leafy green, raw, and cooking vegetable irrigation was somewhat distant. In Al-Qasoumi [24], participants thought it was acceptable to reuse treated wastewater in cleaning and domestic irrigation but there was less agreement with reusing wastewater to irrigate cooked vegetables and leaves eaten without cooking. Lower price and religious factors were also found important in determining participants' attitudes toward the reuse of treated wastewater in agriculture. Al-Qasoumi [24] found similar results regarding the importance of religion in participants' attitudes. Although there exists a fatwa from the Council of Senior Scholars in Saudi Arabia since 1978 permitting the reuse of treated wastewater, people seem not to be aware of it. Thus, the need for awareness-raising campaigns about the safety of treated wastewater reuse should be a priority for authorities responsible for water management in Saudi Arabia. Moreover, this study found that prices of agricultural products irrigated with treated wastewater also play an important factor in determining the attitude towards the reuse of treated wastewater in agriculture. However, few studies have tested the relationship between pricing or pricing concerns and acceptance of treated wastewater [13].

Since socio-economic assessment is an essential tool for the proper management of wastewater and its uses for different purposes, more research is needed to bridge the information gaps and provide the knowledge necessary in this field in Saudi Arabia. Examples include investigating the predictors of treated wastewater reuse acceptance, attitudes in rural or urban areas towards using treated wastewater, comparing the social acceptance in different regions, management financing, pricing and willingness to pay, business models, and cost–benefit analysis for this water source.

7. Conclusions

Water scarcity is considered one of the main challenges that is facing the agricultural sector in Saudi Arabia. Alternative water supplies, such as treated wastewater, offer a viable, cost-effective, and sustainable solution to this challenge. Despite these benefits, consumer opposition can limit its adoption, particularly for applications involving food crops.

In this paper, we examined the public acceptance of reusing tertiary treated wastewater for agricultural purposes in Al-Ahsa, Saudi Arabia. Using data from an online survey, we found that 77% of the participants support the reuse of treated wastewater in agriculture. Additional analysis for eight different agricultural applications showed that most participants supported the reuse of treated wastewater in applications that have no direct connection to them, such as irrigation of public parks, green spaces, and woody trees (82.3%) and irrigation of animal feed crops (63.9%). However, less than half of the participants supported the reuse of tertiary treated wastewater for other agricultural applications, especially for the irrigation of leafy green (34.3%), raw (34.3%), and cooking (41.5%) vegetables. These findings reinforce the need for awareness-raising campaigns about the safety of treated wastewater reuse in agriculture.

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Appendix A

Table A1. Treated wastewater awareness scale development.

Item	Mean	SD	Component 1	Cronbach's α
The reuse of treated wastewater in Saudi Arabia is an important and indispensable alternative resource	2.62	0.63	0.75	0.81
There is an urgent need to safely use tertiary treated wastewater for agricultural purposes	2.62	0.64	0.81	
Modern technologies for wastewater treatment have succeeded in producing water that is healthy and environmentally safe for use in agriculture	2.60	0.60	0.77	
Wastewater treatment and reuse in the agricultural sector protects the environment from pollution	2.42	0.70	0.69	
The use of tertiary treated wastewater will help preserve water resources in Al-Ahsa	2.64	0.60	0.76	

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