The Use of Wastewater for Irrigation Purposes: Perceptions and Willingness to Pay for Treated Wastewater

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Abstract

Insufficient freshwater resources and surplus wastewater (industrial and sewage) have constrained farmers for ample practice of wastewater irrigation. Although wastewater provides necessary nutrients to crops, the accumulation of chemicals and heavy metals are harmful to human health, soil, and groundwater resources. The efficient wastewater treatment management can provide additional and alternative water resources; however, farmers' perception and willingness to pay for this type of reclaimed water play a crucial role in its reuse. The objective of the study is to check the prevailing patterns of irrigation in peri-urban areas of Faisalabad district to identify the factors affecting the willingness of farmers to pay for treated wastewater and their perceptions to use it. Face to face interviews and group discussions were used to collect data with the help of a questionnaire with a sample size of a total of 200 farmers. The binary logistic regression model was used to evaluate the farmers' willingness to pay for treated wastewater. Results revealed that 140 out of 200 farmers were willing to pay and to use treated wastewater as an alternative option for irrigation. Based on the findings of the present study, it was concluded that willingness to pay was positively affected by age, education, income, area of cultivation, land ownership, farmers' awareness about the benefits of treated wastewater, the health-risk and productivity perceptions. The study recommends that dissemination of information and the provision of intensive agricultural extension services can encourage farmers to use treated wastewater as an additional water source.

Keywords: *wastewater irrigation, treated wastewater, willingness to pay, farmers' perceptions*

Acronyms: WTP (willingness to pay), TWW (treated wastewater), WWI (wastewater irrigation)

I. INTRODUCTION

Over time, water scarcity has adopted an upward trajectory and tends to build up progressively. Which accounts that nearly one-third (2 billion) of the global population is facing chronicle shortfall of available clean water [1]. This persistent decline of freshwater resources can result in impairing the biodiversity, eco-system, nature, and above all, human health. World water day report revealed that the death toll of people, mostly children, due to the shortage of water and water-related health problems, accounts for 3.4 million people [2]. Dynamic urbanization and modern improvement have expanded the utilization of streams as waste disposal bodies. The contamination emerging from these anthropogenic exercises and different sources, such as expanded utilization of rural synthetic substances, has made a thorough evaluation of the stream water quality fundamental [3]. The scarcity of usable (fresh) water is putting pressure on the agricultural activities, which is the most water-consuming sector (70 percent of the total water consumption) of the economies worldwide [4].

Under this scenario, farmers, especially in the vicinities of urban areas, use sewage water for irrigation purposes. Due to the presence of the vast spectrum of deadly chemical and other pathogenic micro-level organisms in sewage water [5], human health and soil fertility is at substantial risk [6]. Therefore, recycling and reusing wastewater can significantly contribute to an additional water supply. It will strengthen the available water resources, where treated sewage (waste) water would be used for irrigating purposes and freshwater for drinking purposes, exterminating both risks [7]. In this context, many countries have already invested in the treatment and reusing wastewater [8].

In Pakistan, there are two primary sources of irrigation: Surface and groundwater. The increased shortfall of surface water [9] has increased the dependency on the groundwater, which is not only declining the groundwater sources but also deteriorating its quality. Furthermore, the extraction costs are putting pressure on the value of the production of agriculture products [10]. The diminishing availability of surface and groundwater and increased demand by domestic, industrial, and agricultural sectors has made Pakistan a water deficit country [11]. Hence, there is a crucial need for recycling and reuse wastewater to meet additional water needs.

Domestic and industrial outflow in Pakistan is directly discharged into sewage drains, water bodies, or nearby fields without any prior treatment. No city except Islamabad and Karachi has biological wastewater treatment plants, which can only treat 8 percent of the wastewater produced by these cities. Thirty percent of the total sewage is directly used for irrigation purposes [12] while the rest of the wastewater is disposed of into canals, rivers, and sea without considering its adverse effects [13]. Farmers believe the effluent water valuable as it has all the essential nutrients such as nitrogen, potassium, phosphorus, etc. that may save fertilizer cost [14]. In Pakistan, more than 25 percent of the vegetable farms are being irrigated with untreated wastewater [11], [14].

Although wastewater irrigation provides certain benefits, i.e., higher yield, additional water resources for irrigation, and lowering the need for fertilizer, thus, reducing the cost of production, this practice, however, depends on the water quality and nature of crops. It is evident from many experimental studies that if the supply of plant nutrients exceeds their required demand, production may be negatively affected. On the contrary, wastewater irrigation poses potential risks to farming communities as well as fresh vegetable consumers. Irrigation with industrial wastewater contaminates soil [14] and groundwater supplies that damage the everlasting sustainability of available natural resources [15].

Undoubtedly, the consumption of crops, especially raw vegetables irrigated with untreated wastewater, brings enormous health issues to all age groups and leads to a comparatively higher prevalence of hookworm [16], and Ascariasis infections among children [17]. The valuation of public health risks, soil and groundwater contamination, and crop productivity are the critical decision variables for wastewater irrigation [15].

The researchers have explored the accumulation of heavy metals in crops irrigated with wastewater (see, for example [18]–[21] in Pakistan; [22] in Zimbabwe; [23]–[25] in China; [26] in India; [27] in Romania. Furthermore, the health implications of wastewater irrigation have been evaluated by many researchers (see, for example, [16], [28] in Pakistan.

The impact of wastewater on food security and local livelihoods was examined by [11], [14] in Pakistan. Reference [29] probed the effect of toxicant discharge in treated and untreated wastewater on environmental quality in India. Many investigations on farmers' knowledge and perceptions for the use of treated wastewater were done (see, for example [30]; [31] in Thailand; [32] in Greece; [33] in the USA; [7] in Ghana. Assessment of extended economic benefits of recycling and reusing wastewater was performed (see, for example, [23], [34] in China, and the effects of using wastewater on soil were tested (see, for instance [35] in Spain.

Nonetheless, the successful development of the reuse project is entirely based on its acceptability by the targeted audience. Therefore, barely looking for prospective users will not assure the success of the plan [9]. Identifying potential markets through developing interest among targeting audiences [30], education, and information are crucial to bridge the gap between projected and practical use of reclaimed wastewater [36].

Based on the above literature, numerous studies are conducted to assess the metal accumulation in vegetables grown with wastewater and their detrimental effects on human health and soil. However, there is a relative meagerness of literature on the relationship between farmers' perceptions, their socio-economic attributes, and their willingness to pay for treated wastewater. Consequently, the present study was administrated with three main objectives: a) to evaluate the current patterns and extent of wastewater application as irrigation; b) assessment of the perceptions of farmers about the impact of wastewater on soil, productivity and human health; and c) identification of the factors affecting farmers' willingness to pay for treated sewage water.

This research contributes empirically by providing evidence on this particular topic for the study area. It could help build understanding to fill the knowledge gap by predicting acceptance behavior by overcoming farmers' concerns on TWW use, hence, attaining the ultimate objective of agriculturalists and policymakers.

II. MATERIALS AND METHODS

A. The Study Area

This study was conducted in the Faisalabad region of Punjab province of Pakistan. This city has a concentration of an industrial hub that contains the textile industry, many engineering units, flour mills, oil refineries, and other pharmaceutical units. The industrial sector of Faisalabad has an excellent contribution to GDP, hence, contributing a large amount of wastewater to its disposals, which is furthers ejected into the rivers without any prior treatment [37]. Moreover, the city lacks in an administrative capacity for an effective system for the treatment of effluent water. Excess wastewater supply, facile generalization, reliable supply, and lower cost of production are the factors that persuade extensive wastewater irrigation near the city, especially for vegetable farms. [10].

According to the Water and Sanitation Authority of Faisalabad, there are 28 different disposals points of wastewater in the city. Some of these disposals are located in Uchkera, Paroka, Samanabad, Satiana, and Marosipura. However, merely one treatment plant with operational working is located in the area. Vegetable farming in peri-urban areas of these disposals is done by applying wastewater for the last thirty years.

Accumulation of heavy metals in the agricultural products produced with effluent water can cause various complications to human health, i.e., metabolic disorders, mental impairment, or kidney infections. Additionally, soil and land fertility are prone to higher risk with such practices [37]. Therefore, consideration of negative externalities (food security, soil contamination, and adverse effect on natural resources) is a great matter of concern [14].

B. The Sampling Strategy

A multistage sampling technique was used to collect data for the study. In stage one, Faisalabad (the third-largest city of Pakistan) was chosen for some specifically particular reasons: a) enormous numbers of wastewater disposal; b) functioning of water treatment plant; c) reliable supply of industrial effluent; d) large-scale wastewater irrigation practices.

In the second stage, based on the source of water, two peri-urban areas Uchkera and Paroka were selected purposively as these were in the catchment area of the central disposal of the city. It is impossible to collect information from the whole population in any empirical investigation. Therefore, in this proposed research, we have to generalize based on information derived from a representative sample of the population. If we take interviews of all samples in these two regions (five villages), the constraints affecting our study area were cost, time management, and challenging to handle a large amount of data procured. Therefore, on stage three, five villages from two regions (Uchkera and Paroka) were selected voluntarily as their agricultural fields were directly tapped to sewage drains. In the last stage, two hundred samples were chosen to collect data through a simple random sampling technique with a cluster of forty farmers from each village.

The several visits (for three weeks) to the study area were made to have face to face interviews with the farmers followed to proceed data collection. Respondents found this study interesting and new of its kind for that very area and assured their voluntary participation. In some cases, the language barrier was overcome by translating the questionnaire into the local language, i.e., Punjabi. Eventually, the survey was completed over 15 days, and data was successfully collected.

This study investigated the current prevalence of wastewater irrigation and farmers' WTP for TWW according to their perception of soil, productivity, and human health. WTP measures that how much amount a person is willing to pay for a good or service depending on its attractiveness and price [8]. The literature review helped us to identify the number of attributes that can affect farmers' WTP according to the scope of the research statement. Socio-economic variables that were testes for the study are age, education, income, ownership of farming land, farm size, as well as perceptions about health risk, soil, and productivity. Moreover, based on farmers' conceptions, WTP was tested by giving several choice cards, i.e., awareness about the detrimental effects of wastewater irrigation, food security, accessibility to freshwater resources, profitability, and government subsidy.

C. Data Collection

A well planned interviewing schedule consisting of structured and unstructured questions was prepared to explore the research purpose. We carried out direct face-to-face interviews as this has been the most reliable approach in contingent valuation studies [38]. During a one-week pilot survey, we tested a questionnaire on 25 farmers of vegetable farms to determine the reliability of research tools.

The results identified the need for some modifications in the questionnaire and, few items were removed from after the feedback, and required information was collected by asking both planned and unplanned questions in the interview related to our concerned study.

D. Data Analysis

An in-depth descriptive analysis of all the variables was performed to achieve our first objective, i.e., to check the current extent and patterns of irrigation. Furthermore, the study for the second objective was done using the Likert scale and inferential statistics, i.e., Cross tabulation and Chi-square test was used to check the association between different perceptions of farmers about wastewater irrigation and their willingness to pay for its treatment. Based on their perceptions, different choice cards were proposed to form of stated benefits to evaluate their WPT for TWW (Table 4), and responses were recorded in Yes and No.

The third objective was achieved by incorporating an Econometric analysis, i.e., the Binary Logistic Regression model, to identifying the factors affecting willingness to pay for treated wastewater. This model includes categorical variables and predicts the probability that an observation falls into one of the two categories. Logistic regression on the model was the most viable technique to identify the relationship between the dependent variable (willingness to pay for treated wastewater) and one or more than one independent variable such as age, income, education, price, awareness. In this study, the response variable(WTP) was categorized into two categories of yes and no.

This linear relationship can be written in the following mathematical form

$$\ell = \log b\ \frac{p}{1-p} = \beta_0 + \beta_1 x_1 + x_2\beta_2 \quad [39]$$

The simple algebraic expression which depicts the result suppose probability p=Y=1 is:

$$p = \frac{\rho^{\beta_0+\beta_1 x_1+x_2\beta_2}}{\rho^{\beta_0+\beta_1 x_1+x_2\beta_2}+1} = \frac{1}{\rho^{-(\beta_0+\beta_1 x_1+x_2\beta_2)}+1} \quad [39]$$

The logarithm of the odds is the logit of the probability; the logit is defining as follows in term of equations:

$$\text{Logit } p = \ln\frac{p}{1-p} \quad \text{for } 0 < p > 1 \quad [40]$$

p = Bernoulli response variable or Probability

β_1 = Is Fixed

x_1, x_2 are Predictors

b= *Base* of a logarithm

ℓ = *Log*-odds

The research tools and data analysis models were validated by a team of experts consisting of academic staff, agricultural economists, and environmental economists from the institute of agricultural and resource economics, university of agriculture, Faisalabad, Pakistan.

III. RESULTS AND DISCUSSIONS

This section entails the results derived from statistical and econometric analysis. It starts with the demographic and socio-economic features of the respondents. A closer look described the current arrangement of irrigation patterns in the study area, followed by the perceptions based choice card analysis of WTP results. Finally, we present the attributes affecting WTP by incorporating the logit model.

A. Farmers' Profile

The average age of the respondents was 38.2 years, with the majority (55.5%) farmers being in the age group of 30 to 40 years (Table 1). The literacy rate of the respondents was higher (51%) for the secondary level, whereas the next higher (32.5%) was reported for the primary level of education. Only 16.5 % of the respondents were educated at the college or university level. On average, the family size was seven members for each family, and it was minimum at two members and maximum at seventeen members for our given sample size. The average monthly income for each respondent was recorded as 97.27 thousand Pak Rupees. Moreover, the average area being used for the cultivation was 10.86 acres, with a minimum of 1 and maximum of 40 acres.

Table 1: Socio-economic Profile of the respondents

Age (Years)		38.2	12.75
a. Up to 30	28.5		
b. 30 to 50	55.5		
c. Above	16		
Education		9.52	3.88
a. Primary	32.5		
b. Secondary	51		
c. Bachelors	15		
d. Masters	1.5		
Family Size		7	4
Average Monthly Income (000)		97.27	96.87
Farm Size (Acers)		10.86	7.75
Ownership of Land		1.47	0.78
a. Own Land	70		
b. Rented in	15		
c. Rented Out	13.5		
d. Fallow Land	1.5		

Income= thousand PKR (n=200)

Most of the participants (70%) were farming on their own land while (15%) were using rented in farms for agricultural activities. Only (13.5%) of the respondents had rented out their areas. The scarcity of freshwater resources and high prices for canal water are the primary reasons for wastewater irrigation [11]. The results of this section revealed that a low literacy rate is a reason behind their lack of information and resistance against the use of TWW. Spreading awareness about the potential risks of wastewater irrigation and educating adequate water management strategies can increase the dependency on alternative water resources and willingness to pay for treated wastewater [41].

B. Extent and Pattern of Wastewater Irrigation

Farmers had various views about the history of using wastewater for irrigation, but the majority of them reported that they have been using wastewater for the last 40 years [10]. The results of the study showed that more than half of the respondents (51%) were consuming wastewater, while (28.5%) were using a mix of canal and groundwater. However, the use of groundwater sources for irrigation was significantly low with mere (2.5%), and none of the respondents were using treated wastewater (Figure 1). A closer look at the analysis revealed that higher salt concentration in groundwater and lower need for fertilizer were the main reasons for the prevalent irrigation trends. Several prior studies have claimed (see, for example, [20] that the affluent industrial and untreated sewage water is applied to crops and vegetables grown in the city [10], which in turn severely affects the groundwater by leaching through the plant roots. It is evident from the study of [42] where most of the tested groundwater samples were profoundly impacted due to industrials and sewage waste and posed higher risks to human wellbeing. The average response for wastewater application was 3 to 4 times in one crop period.

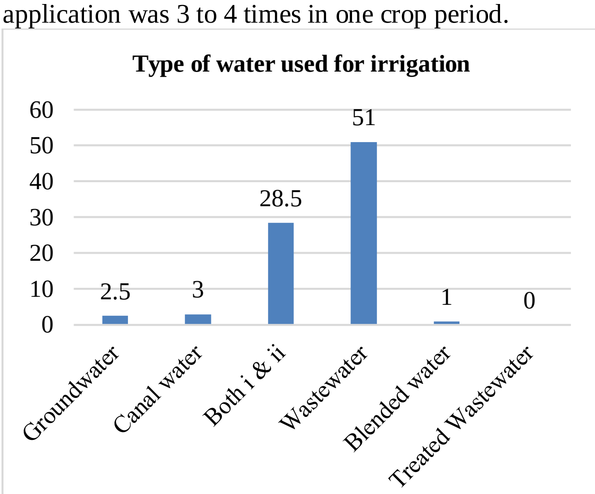


Figure 1: Water types used for irrigation in the study area (n=200)

This study indicates that more than two-thirds (71%) of the respondents were irrigating vegetable farms with wastewater compared to (23%) for cash crops, while the preference of wastewater irrigation to grow fodder was only (6%) (Figure 2). The reasons for this production pattern were increased vegetables demand in the city and ready availability of sewage water disposal. Crops irrigated with wastewater pose higher health risks to farmers and their potential consumers, such as hookworm diseases, diarrhea, kidney infections, and many other health issues. Results indicate striking health concerns for crop consumers because most of the vegetables (salads) are consumed uncooked [16]; therefore, educating farmers about food security is pivotal [12].

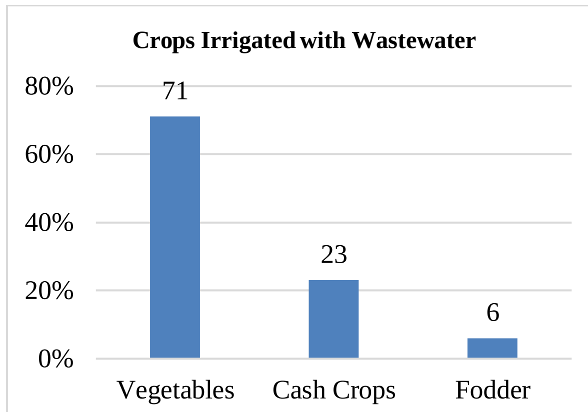


Figure 2: Type of crops produced with wastewater irrigation (n=200)

The government should announce policies to increase the use of canal waters and legitimize the treatment of sewage water before using it to irrigate vegetables [43].

C. Farmers' Perception and attitude towards Wastewater Irrigation

This section covers the analysis of farmers' perceptions of wastewater irrigation and its impact on human health, soil, and agricultural yield. The Likert scale has been used to record individual responses, and opinions were filed in five given ranges, i.e., strongly disagree (=1), disagree (=2), not sure (=3), agree (=4), and strongly agree (=5). The findings of the perceptions are presented in Table II.

i. Perceptions about Human Health

Wastewater irrigation can accumulate toxic metals to the soil above critical limits, and consumption of crops produced on such land can harm human health [44]. More than 80 percent of the respondents were of the view that applying wastewater to the crops may harm human health, and 93.5 percent positive responses were recorded for skin diseases (Table II).

However, farmers' agreement about chronic diseases in relation to wastewater was comparatively low at 49.5 percent, with 23.5 percent were disagreeing with the notion. Moreover, 27 percent of them were having a neutral opinion as they were not very sure if wastewater application to the vegetables may cause any chronic disease. The study revealed that farmers were considering only direct and visible health implications. Many studies have documented evidence on consumer health-risk that support the results of these perceptions; see, for example, [7], [41]. Table III highlights the results of the chi-square test for these three health perceptions. P-values value for first (wastewater irrigation is harmful to human health; $p > 0.034$) and third (wastewater irrigation causes skin infections; $p > 0.012$) health perception was less than 5 percent level of significance. Hence, it reveals evidence of the association between farmers' health risk perception and their willingness to pay for treated wastewater. It is important to note that no evidence of association was found for chronic diseases. Wastewater irrigation can result in different deadly maladies such as skin allergies, hepatitis, tuberculosis, influenza, and fever [45]. Several surveys commissioned by food sciences authorities have confirmed the impact of wastewater on chronic diseases; see, for example, [19], [27], [45], [46]. Disseminating the results and information of such studies with farmers is crucial to make them aware of associated health risks.

Awareness about wastewater irrigation and knowledge about the benefits of using treated wastewater can substantially improve farmers' willingness to pay and desire to use. This finding is in line with [47], who reported that knowledge and information are positively related to the use of treated wastewater.

ii. Perceptions about Soil Quality

Wastewater irrigation can result in the accumulation of heavy metals in soil and crops at the toxic level, and other pathogenic infections [48]. These accumulations of metal contents in the soil can adversely affect crop productivity and the environment [49]. But with farmers' perspective, land irrigated with wastewater is considered more productive than the land irrigated with canal water, as it increases the yield as well as the number of crops that can be grown in a season [14]. Farmers' perceptions about the soil quality amid wastewater applications were recorded for three different aspects. Our first question was about soil fertility. Forty-two percent of the farmers disagreed, and 23.5 percent were agreeing that wastewater irrigation harms land fertility. In contrast, 34.5 percent of the respondents had a neutral opinion. The magnitude of the indifferent opinions for soil erosion was higher at 38 percent, followed by the 36.5 percent disagreement. At the same time, only 25.5 percent were of the view that wastewater irrigation is responsible for soil erosion. Thirty-four percent of the respondents agreed that wastewater irrigation causes metal accumulation, which reduces essential ingredients from the soil.

Table II: Health risk, soil quality and production related farmers' perception towards wastewater (n=200)

Statement	Health risks (%)					Mean	S.D
	SD	D	N	A	SA		
HR1 WWI is harmful to human health	5.5	6.0	5.5	32.0	51.0	4.17	1.130
HR2 WWI cause chronic diseases	3.0	20.5	27.0	40.0	9.5	3.32	1.002
HR3 WWI cause kin infections i.e., itching and blisters	1.0	1.0	5.5	36.0	56.5	4.46	0.736
Statement	**Soil Fertility (%)**					**Mean**	**S.D**
	SD	D	N	A	SA		
SF1 WWI adversely effect land fertility	9.0	33.0	34.5	16.5	7.0	2.79	1.048
SF2 WWI is responsible for soil erosion	5.5	31.0	38.0	16.0	9.5	2.93	1.035
SF3 WWI cause metal accumulation that reduces important soil ingredients	8.0	21.0	37.0	26.0	8.0	3.05	1.055
Statement	**Farm Productivity (%)**					**Mean**	**S.D**
	SD	D	N	A	SA		
FP1 WWI brings higher yield	2.5	6.0	8.0	31.5	52.0	4.25	1.005
FP2 WWI reduce cost of production	3.0	4.0	7.0	32.5	53.5	4.30	0.976
FP3 WWI produce low quality vegetables	1.5	6.0	19.0	43.0	30.5	3.95	0.934

WWI= Wastewater Irrigation, SD= Strongly Disagree, D= Disagree, N= Neutral, A= Agree, SA, Strongly Agree

However, 29 percent of responses denied this assertion, and neutral opinions for this perception were recorded higher at 37 percent (Table II). By incorporating chi-square test, no evidence of association was found for all three soil-related perception and willingness to pay i.e., ($p < 0.214$, $p < 0.208$, $p < 0.482$) (Table III). Bioaccumulation of the metal contents is an important consideration, especially when vegetables are re-grown with the seeds that farmers obtain from their own cultivation, which is previously irrigated with wastewater. Consumption of such vegetables is not safe, and massive health risks [50], [51]. During the survey of the fields in Uchkera, we observed an interesting practice of periodic removal of the upper layer of soil. Our further investigation revealed that this strategy was found useful in removing the layer with heavy metal contents. This might be one of the factors that wastewater irrigation is being practiced for many decades without realizing its harmful effects on the soil of the cultivated area. However, it is worthwhile considering that metal contents found in vegetables and their associated risks are many folds greater than previous studies [28].

iii. Perceptions about Productivity

Mostly untreated wastewater is consumed for irrigation in peri-urban areas across Pakistan [14]. Farmers consider wastewater a reliable source as it fulfills water as well as nutritional requirements for the crop plants.

Table III: Relationship between perceptions and WTP (n=200)

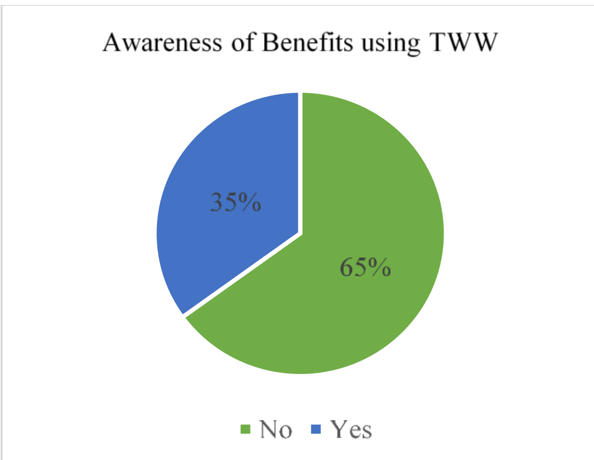
Willingness to Pay (%)		Health Risk (%)							
		SD	D	N	A	SA	Total	Chi-Square	P-Value
HR1 and WTP for TWW	Yes	3	2	4	22.5	38.5	70	10.44	0.034
	No	2.5	4	1.5	9.5	12.5	30		
	Total	5.5	6	5.5	32	51	100		
HR2 and WTP for TWW	Yes	2.5	15.5	21	25	6	70	5.244	0.263
	No	0.5	5	6	15	3.5	30		
	Total	3	20.5	27	40	9.5	100		
HR3 and WTP for TWW	Yes	1	0	3	22	44	70	12.822	0.012
	No	0	1	2.5	14	12.5	30		
	Total	1	1	5.5	36	56.5	100		
Willingness to Pay		Soil Fertility (%)							
		SD	D	N	A	SA	Total	Chi-Square	P-Value
SF1 and WTP for TWW	Yes	7	22.5	26	9	5.5	70	5.81	0.214
	No	2	10.5	8.5	7.5	1.5	30		
	Total	9	33	34.5	16.5	7	100		
SF2 and WTP for TWW	Yes	4	22.5	29	9	5.5	70	5.886	0.208
	No	1.5	8.5	9	7	4	30		
	Total	5.5	31	38	16	9.5	100		
SF3 and WTP for TWW	Yes	6	16	27	16	5	70	3.47	0.482
	No	2	5	10	10	3	30		
	Total	8	21	37	26	8	100		
Willingness to Pay		Farm Productivity (%)							
		SD	D	N	A	SA	Total	Chi-Square	P-Value
FP1 and WTP for TWW	Yes	1.5	2	4.5	23	39	70	10.872	0.028
	No	1	4	3.5	8.5	13	30		
	Total	2.5	6	8	31.5	52	100		
FP2 and WTP for TWW	Yes	2	1.5	3	20.5	43	70	15.934	0.003
	No	1	2.5	4	12	10.5	30		
	Total	3	4	7	32.5	53.5	100		
FP3 and WTP for TWW	Yes	1	5	13	27	24	70	5.398	0.249
	No	0.5	1	6	16	6.5	30		
	Total	1.5	6	19	43	30.5	100		

WWI= Wastewater Irrigation, SD= Strongly Disagree, D= Disagree, N= Neutral, A=Agreed, SA, Strongly Agree
HR1= WWI is harmful to human health, HR2==WWI causes chronic diseases, HR3=WWI causes skin infections
SF1= WWI adversely affects land fertility, SF2= WWI is responsible for soil erosion, SF3= WWI causes metal accumulation in the land , FP1= WWI brings higher yield, FP2=WWI reduces cost of production, FP3=WWI produces low quality vegetables

Wastewater contains organic matter contents, which ultimately lowers the need for fertilizer application, resultantly reducing the cost of production and higher yield [15], [44]. Despite all of the social and environmental impacts of wastewater irrigation, the economic benefits of this practice play a demining role in this option [48]. Responses about the productivity perceptions explained that more than half of the respondents (52%) strongly agreed that wastewater irrigation brings higher yield, and 31.5 percent were agreed. However, 8.5 percent of them disagreed with the assertion, and neutral responses were merely 8 percent. The majority (86%) of the farmers were of agreement that wastewater irrigation reduces the cost of production while disagreement was recoded only 7 percent. Farmers' perception of the inferior quality of vegetables had an agreed response at 73.5 percent.

Nonetheless, 19 percent of the respondents had undecided answers about the quality of vegetables produced with wastewater, and only 7.5 percent were disagreeing with it (Table II). The chi-square test showed evidence of an association between perceptions of higher yield ($p > 0.028$), reduced cost of reduction ($p > 0.002$), and willingness to pay for treated wastewater (Table III). The study revealed although more than 80 percent of the farmers aware of the adverse health implications of wastewater irrigation, yet, reduced cost of production and higher yield was two primary attributes having a significant impact on farmers' decision for WTP.

The descriptive analysis of the knowledge attitudinal factors showed that 35 percent of the respondents were aware of the potential benefits of TWW, while 65 percent of them were uninformed (figure 3).



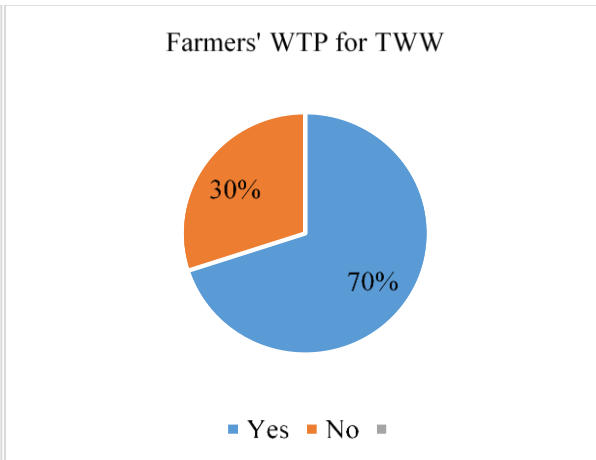


Figure 3: Farmers' awareness about the benefits of using TWW (n=200) **Figure 4:** Perceptions based WTP for TWW (n=200)

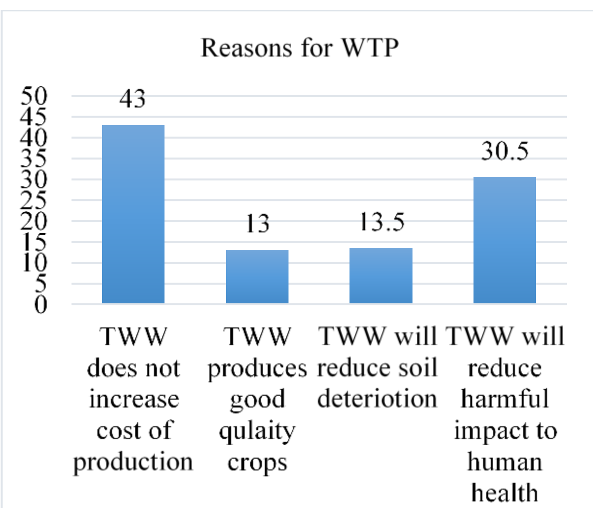


Figure 5: Percentage response for WTP (n=140)

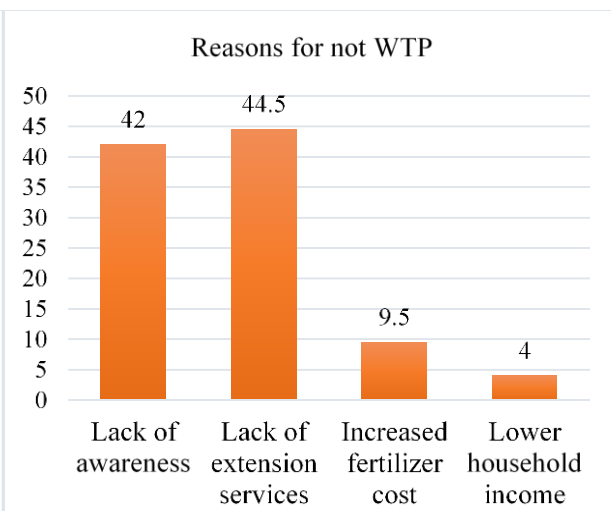


Figure 6: Percentage response for unwillingness to pay (n=60)

Based on the perceptions, 140 out of 200 farmers were willing to pay for treated wastewater, and 60 of them were unwilling to pay (Figure 4). It is important to note that the reduced cost of production and impact on human health were two significant reasons for these findings. Forty-three percent of the positive responses reported that TWW irrigation does not increase the cost of production (Figure 5). According to farmers, treatment of the wastewater eliminates only harmful metal contents from the water, yet has almost all the necessary nutrients required for crop production. Thus, it may not necessarily increase the cost of production. Additionally, during the fieldwork, farmers indicated that they were more concerned about the cost of ejecting groundwater and its associated indirect expenses. Ready availability, lower price of TWW compared to freshwater, and lower need of fertilizers were the factors of having a positive influence on willingness to pay for TWW. This conclusion is supported by the evidence of [36], who reported different factors affecting farmers' WTP for TWW. The second important reason for WTP was avoiding health-risk. This response was recorded at 30.5 percent. Farmers explained that apart from selling their products in the market, they were consuming these crops in the households. Therefore, they perceived that using TWW will reduce out of pocket expenses for illness. The survey data shown in Figure 5 delineates that farmers were least concerned about soil deterioration (13.5%) and the quality of crops (13%). The above discussion put a convincing case of our chi-square test results, which has previously explained the association of these perceptions with WTP.

In the next stage, 60 respondents with the unwillingness to pay were asked about the background of their decision. Surprisingly, 44.5 percent of them reported that there is a lack of extension services to encourage the use of TWW (Figure 6). It is important to note that the provision of help and expert advice about water quality and its potential health and environmental risks is pivotal. This approach could help government authorities by providing powerful tools to inform many framers about the regulation and use of TWW [52]. Although extension services cover a broad spectrum, and most of the farmers are not fully aware of the benefits of such assistance. Many studies (see, for instance, [53]) explained that the farmers are most concerned about the services for access to credit and farm inputs. It is compulsive to note that about 70 percent of the farmers' decisions about the use of TWW is based on communication through mass media [36]. Finally, dissemination of sufficient information through well-organized programs can help to increase the framers' WTP for TWW.

The second primary reason given for unwillingness to pay was a lack of awareness. According to 42 percent of the respondents, educating farmers about the benefits of different water supplies is essential to make them familiar with water treatments. Farmers reported that field observations, and talking to other wastewater users were the primary sources of getting information about wastewater implications. Though numerous studies had been conducted about the wastewater content to date, framers were having inadequate knowledge about associated risks and benefits; this implies the dire need for dissemination of useful information, which can strongly influence the farmers' decision about the use of TWW [54]. These results are similar to [55], who reported that apart from practical experience, farmers usually integrate new concepts and information learned from agricultural extension officers, input suppliers, and media into their farming methods. That means having more awareness about the reuse of wastewater, and its impacts can change farmers' attitudes.

As evident in Figure 6, very few (9.5%) of the negative response was linked to the increased cost of fertilizer. Farmers perceived that treatment of the wastewater would eliminate nutrients required for crop production, which will lead to higher the need for fertilizer. This perception, again, connect to farmers' awareness. Several previous studies have revealed that TWW includes almost all necessary nutrients needed for good crop production, which can result in higher yield [52], [56], [57]. Communicating the results of such studies through different means can significantly change the attitude towards the use of wastewater. It was further reported that merely a 4 percent response for unwillingness to pay was due to household income. The price for the TWW was lower compared to the available freshwater resources; therefore, less income did not have a significant impact on farmers' WTP decision.

B. Willingness to Pay under given Choices

Farmers WTP for TWW was further tested by giving six different hypothetical scenarios in the form of choice cards, and responses were recorded in Yes (1) and No (0) (Figure 7). It is evident in figure 7 that 75.5 percent of the respondents were WTP for TWW if it improves the food security for crop producers and consumers.

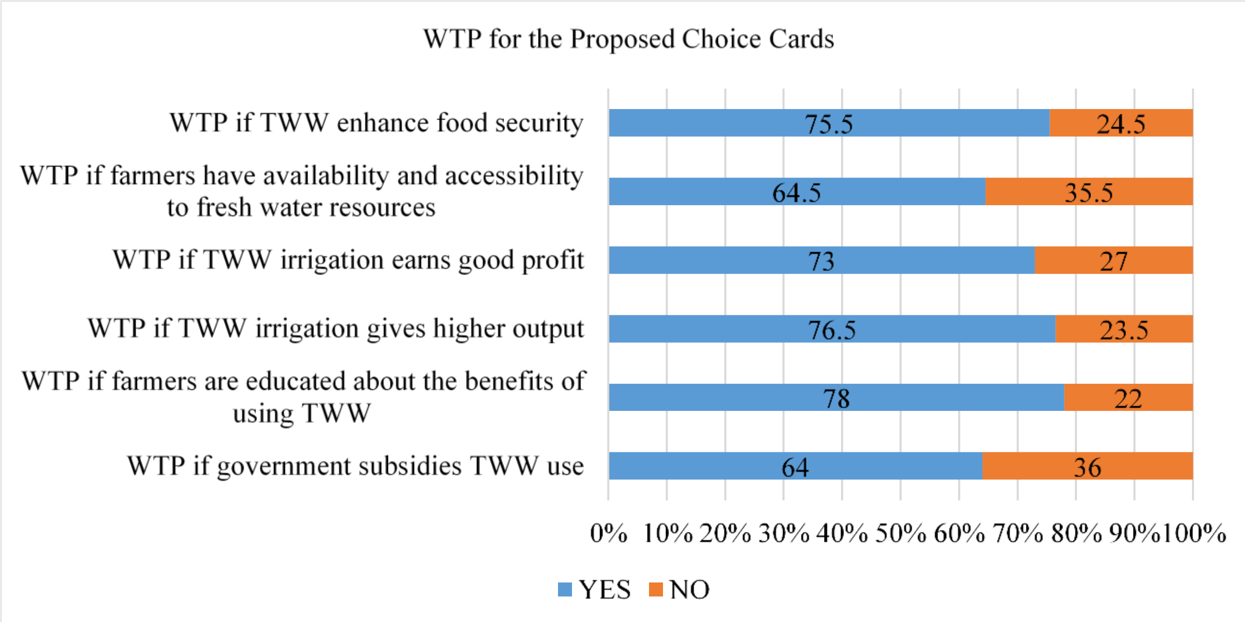


Figure 7: Farmers' percentage response for WTP under given choices (n=200)

This result implies that the majority of the farmers were aware of associated health risks by the consumption of crops irrigated with wastewater. Whereas, 24.5 percent of farmers gave a negative response, by simply overlooking its health implications. WTP for TWW was 64.5 percent with the availability and accessibility of freshwater resources. Farmers reported that this WTP is subject to the reliable supply of TWW, and higher induction cost of freshwater sources. However, 35.5 percent of the respondents preferred freshwater irrigation over TWW.

Descriptive analysis in the above section has proved a strong relationship between WTP and farm profit. Our third choice card revealed that 73 percent of the farmers were WTP for TWW if it increases farms profit without increasing production cost, while 27 percent of them were unwilling to pay. These negative responses suggested that farmers were not aware of the various benefits and composition of TWW. For the fourth choice card, 76.5 percent of farmers showed their WTP if TWW gives higher farm output. It is worthwhile to note that 78 percent of the farmers carried a positive response for WTP if they were given education about the potential benefits of TWW. Therefore, education and awareness programs can have absolute advantages for the use of TWW.

Subsidizing the use of TWW is another crucial scenario that can hugely impact farmers' WTP. Figure 7 exhibits that 64 percent of the farmers were WTP for TWW if the government subsidizes it.

Based upon the analysis, it is consequential to state that wastewater irrigation is encircled with high risks; mainly, in low-economic conditions, where untreated or inadequately treated effluent water is used as an alternative source of irrigation. Thus, communicating the positive and negative impacts of such practices would be beneficial to the decision-making process [58]. Moreover, information and education have a massive effect on WTP. The use of appropriate strategies such as price reduction, farmers' incentives, and extension training courses can significantly impact WTP for TWW [36].

C. Empirical Results

Binary logistic regression explained that the overall percentage of the cases correctly predicted by the model is 74.5 percent (Table IV). The value of Nagelkerke R square (0.26) showed that logistic regression had a reliable prediction power and goodness to fit the model of variability in the dependent variable, which was the willingness to pay for treated wastewater in binary form. The analysis revealed that important socio-economic variables, i.e., age, education, and average monthly income, are positively affecting WTP yet having an insignificant relationship. However, two demographic variables, area of cultivation and land ownership have a significantly positive impact on WTP for TWW. Hence, higher landholding (in acres) of an operational farm, higher will be the WTP for TWW.

Moreover, the probability of WTP will rise with an increase in farmers' owned land. Before incorporating the regression model, the average response for all three types of perception (health risk, soil fertility, and farm productivity) was taken to check the impacts of attitudes WTP. It is evident from Table IV that health risk and farm productivity perceptions have positively significant relationships with farmers' WTP. This implies that improvement in health issues and an increase in farms' productivity will increase the probability of WTP. On the contrary, soil perceptions have an insignificant negative relationship with WTP for TWW. Averagely, farmers' awareness about the benefits of using TWW had a significantly positive impact on their WTP. A composite variable for the proposed six choice cards was made to evaluate the effects of given choices on WTP. Results exhibit a positively significant relationship between both variables. This means the provision of certain benefits associated with TWW irrigation can positively affect farmers' WTP.

In our study farmers' household characteristics (age, education, average monthly income) had least or no significant impact on their WTP for TWW. Table IV illustrates that age has a positively insignificant relationship with WTP, this results tallies with the [59] who reported that age in terms of farming experiences have positive significant impact on famers decision to adopt new things; however, this finding opposed the results of few previous studies [36]. It is usually perceived that older farmers are resistant to adopt new agricultural advancement.

Nevertheless, the descriptive analysis of our study indicates that the farmers' foremost concern was the reduced cost of production. Hence, farmers having extensive agricultural experience were informed that the price of TWW is comparatively lower than other freshwater resources. Farmers' education has a positive, but insignificant relationship with WTP for TWW. This suggests that learning will elevate informed decision-making, and knowledge attitudinal factors among farmers; thus, this result is in line with previous studies [7]. The average monthly income had a positive and insignificant impact on WTP. This result is supported by the descriptive analysis presented in Figure 6, which shows that responses for unwillingness to pay for TWW were only 4 percent for lower household income. Furthermore, our analysis revealed that farm characteristics (area of cultivation & land ownership) have a significantly positive impact on farmers' WTP. The farm profitability was seriously affected by higher prices of TWW in Jordan and Tunisia [30]. This positive relationship includes the presumption that higher the ownership of farmers owned land will enable farmers to accept the higher bid for TWW [38].

The results of health risk perceptions exhibit a positively significant relationship with WTP. During the field interviews, farmers stated that they were facing different skin problems due to wastewater irrigation. Respondents also perceived that irrigation with untreated sewage water had detrimental health effects on farmers and their families (Table II).

Table IV: Factors affeting WTP for TWW

Variable	B	Sig.	
Age	0.275	(0.324)	
Education	0.029	(0.537)	
Average Monthly Income	0.000	(0.526)	
Area of cultivation(acers)	0.084	(0.004)**	
Land ownership	0.772	(0.010)*	
Average health risk perception	0.807	(0.009)*	
Average soil fertility perceptions	-0.178	(0.398)	
Average farm productivity perception	0.309	(0.044)*	
Awareness of benefits using TWW	0.960	(0.60)***	
Index variable for choice cards	1.644	(0.042)**	
Nagelkerke R Square			0.26
Overall percentage of predicted model			74.50

Values represent regression coeffients; values in prentheses are p values

* significant at $P < 0.05$, ** significant at $P < 0.01$, ***significant $P < 0.10$

Fear of ailments and skin diseases was the prime factor determining framers' WTP for TWW. [16], [28], [52] also found that wastewater irrigation is hazardous to human health, and this knowledge positively affected farmers' WTP for TWW. Our empirical analysis found a negative and insignificant relationship between WTP and soil fertility perceptions. This is explained in Table II, where framers were least concerned about the soil fertility and metal accumulation in the land. Periodical removal of the upper layer of the soil in the study area could be the reason for these results. Framers' perception of productivity and yield had a significant positive relationship with their WTP. Respondents were informed that, despite the different level of treatments, TWW still have nutrients required for good crop production. Moreover, the price of reclaimed wastewater is lower compared to freshwater resources. This result is in line with [38] that the majority of the farmers were accepted TWW for irrigation, and more than 55 percent of the respondents were willing to pay more than five times of freshwater resources.

The logit model shows that awareness of the benefits of using TWW positively affected its WTP. Knowledge and awareness about potential benefits help to shape attitudes and perceptions. A positive attitude towards TWW could escalate its WTU for irrigation purposes. This result is consistent with [33], who reported that information hugely influences the decisions for the use of TWW in agriculture. To check the impact of proposed benefits on WTP, an index variable was made for six given choice cards (Figure 7) by taking average of the responses. Our analysis revealed a significant positive impact of these benefits on WTP for TWW. This implies that provision of certain benefits such as; enhanced food security, increased awareness, higher yield, lower production cost, and governmental facilities can positively influence the willingness to pay and desire to use for TWW. These empirical findings are similar to the proposition by [7], [30], [38], who reported that associated benefits with the use of TWW have a definitive effect on its WTP.

IV. CONCLUSION

This investigation evaluated the current extent of wastewater consumption, and patterns of irrigation analyzed framers' perception towards the use of wastewater and examined factors affecting farmer' WTP for TWW in the Punjab province of eastern Pakistan. A significant part of the agricultural land in the vicinity of the city was irrigated with sewage and industrial water. Farmers conceded that wastewater irrigation is harmful to human health and causes dermal infections. However, higher yield and lower need for fertilizer were the prime factors influencing the extensive use of wastewater. Respondents perceived that wastewater irrigation had least or almost no implications on soil fertility. Lower prices for TWW, reduced cost of production, quality crops, and health concerns were the crucial reasons for WTP. Lack of awareness about the benefits of using TWW and dearth of extension services were found responsible for framers' unwillingness to pay. None of the socio-economic variables (Age, education, income) had a remarkable impact on WTP; however, farm attributes. i.e., operational landholding and ownership of the farm had a significant effect on WTP.

Moreover, health-risk and farm productivity perceptions had paramount positive support for WTP. It is noteworthy that awareness about the potential use of TWW and its integrated benefits can substantially improve its WTP among farmers. The study explains the existing gaps that can encourage predicted acceptance behavior for TWW. Furthermore, the research contributes strong evidence for the need for dissemination of knowledge and information to farmers through intensifying extension services. The judicial subsidization of the use of TWW, elevating awareness among stakeholders, and addressing local water needs are serious policy implications. Thus, the state should invest in water treatment technologies to strengthen irrigation alternatives, and to ensure the health and food security in all peri-urban areas of industrial regions.

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