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Estimation of willingness to pay for improved water supply service: Case of Algerian households

Sofiane Boukhari [a,*], Mourad Kertous[b], Abdelhak Nassiri[b] and Samir B. Maliki[b,c]

[a] Faculty of Technology and Sciences, University of Souk Ahras, Souk Ahras, Algeria
[b] University of Brest, UMR 6308 AMURE (Aménagement des Usages des Ressources et des Espaces marins et littoraux), Brest, France
[c] Mecas Laboratory, Abou Bakr Belkaid University, Tlemcen, Algeria
*Corresponding author. E-mail: s.boukhari@univ-soukahras.dz

SB, 0000-0002-4930-6786

ABSTRACT

The purpose of this article is to evaluate the water company in Algeria (ADE) subscribers' Willingness To Pay (WTP) for a better service offer. This study assessed the WTP for improved drinking water in the department of Souk-Ahras (Algeria), using contingent valuation survey data of 5,342 households, with a response rate of 10.86% (greater than 10% of each municipality's total number of subscribers). Then, Probit and Tobit models were applied to analyze the determinants of WTP. The results show that the majority of respondents (62.84%) testified that they were not satisfied with the quality of the service provided in terms of quantity and quality of the water distributed. This research revealed that the WTP for an improved water supply service was approximately 16.18 Algerian dinar (DZD)/m^3 (approximately 0.11 US$/$m^3$) instead of the current tariff (6.3 DZD/m^3–0.04 US$ /m^3). With this new water tariff, the average water charge for a household is around 1.37% of the average monthly income.

Key words: ADE, Algeria, contingent valuation, water supply service, willingness to pay

HIGHLIGHTS

- The households reported an average WTP of 0.11 US$/$m^3$.
- The determinants of WTP were analyzed using the Probit and Tobit models.
- 62.84% of respondents stated that they were dissatisfied with the service in terms of the quantity and quality of the water distributed.
- The application of the new tariff increased the water bill from 220%.
- If the ADE applies the new tariff, the annual revenue will be 1,691,056.62 US$.

1. INTRODUCTION

Water companies' primary responsibility is to guarantee that every resident has access to a supply of drinking water in sufficient quantity and good quality (Kiliç *et al.* 2023). However, most developing nations' water supply managers deliver unreliable and irregular service, where water is distributed discontinuously (Bulti & Yutura 2023). Among the reasons that have influenced the management of water supply services (WSS) in these countries are the rapid increase in population, the lack of water resources, the poor performance of water infrastructure and the application of a tariff that is too low compared to the real cost of water (Adeoti & Fati 2022). In this regard, WSS managers in developing countries cannot allocate sufficient financial resources to invest in improving the management of their services (Bui *et al.* 2022). However, WSS providers must have information on the willingness and ability of households to pay additional fees for improved WSS (Tarfasa & Brouwer 2013).

The estimation of the willingness to pay (WTP) of households for an improved WSS constitutes important information allowing WSS managers to plan investments for the rehabilitation and renewal of existing systems and the implementation of new projects. Several researchers have proven that WTP is the best method for analyzing the behavior of households when paying an additional amount in order to improve the quality of services (Schaafsma & Brouwer 2020; Wang *et al.* 2020). One of the representative methods of household WTP is the contingent valuation (CV) method (Kim & Kim 2023).

Existing literature on household WTP for drinking water supply is largely oriented toward improving water quality (Nouri-Khajebelagh *et al.* 2023) or increasing the quantities of water distributed by water companies (Eridadi *et al.* 2021). The WTP approach to pay based on the CV method has been applied in several service improvement studies, such as, electricity (Wen *et al.* 2022), energy (Walter *et al.* 2023), municipal solid waste management (Suryawan & Lee 2023), environmental challenges agricultural sector (Rahmati *et al.* 2023), ecosystem (Johnson & Geisendorf 2022) and other services. According to Zvobgo (2021), the majority of WSS in developing countries are inefficient, with intermittent service and poor quality of water distributed. To this end, several international researchers have widely applied the CV method to address the issue of citizens' assessment of WTP in the context of improving water quality and/or quantity (Entele & Lee 2020). In the last 10 years (2013–2022), some research has addressed the application of the CV method to estimate WTP for improved WSS in developing countries. Vásquez & Franceschi (2013) applied the CV method to analyze the reliability of the drinking water system and water quality in the city of León (Nicaragua). Their results indicate that households were willing to pay a 120% increase in their water bill for continued service, but would not pay more for improved water quality. del Saz-Salazar *et al.* (2015) used the CV method to estimate the WTP of households in the city of Sucre (Bolivia) for an improvement of the urban water supply system. The study results revealed that approximately 55% of respondents would be willing to pay an increase in their water bill for improved service. Jiang & Rohendi (2018) conducted their study on the WTP of reliable water supply in the case of Banda Aceh City (Indonesia). Respondents are willing to pay for reliable water service, with a median WTP estimated at 190% of the current monthly household water bill. Akram & Alam (2019) used the CV method to assess WTP. A survey was carried out among 120 households in Basupara and Najirghat (Bangladesh) to estimate WTP for water quality improvement. Survey results showed that 61% of respondents said they could pay an additional cost of 5.31 US$/month for reduced pollutants (e.g. arsenic, chlorides and coliforms). Entele & Lee (2020) examined household WTP for improving the quality of drinking water service in the Rift Valley of Ethiopia. The results of this study showed that the WTP of households with drinking water at home (connected to drinking water networks) is 13.45 US$/month and for households using a public tap is 6.54 US$/month. In total, an increase of 8 to 16%. Vásquez *et al.* (2021) used CV to estimate WTP on Santa Cruz Island, Ecuador. Households on this island receive brackish water from the tap for a few hours a day. The WTP for system reliability and simultaneous improvement in water quality is estimated at 36 US$/month, or approximately 2.1% of average monthly household income. Eridadi *et al.* (2021) applied the CV method to Sebeta in Ethiopia. They used a survey of 250 households. The results revealed that 66% of households would be willing to pay for improved water services. Households had a WTP approximately 12% higher than their monthly water bill. Entele (2022) applied WTP to analyze the problem of improving WSS management in the Central Rift Valley (Ethiopia). The results of a survey of 450 residents affirmed that surveyed households are willing to pay up to 75% extra (an increase of US$ 3.4 per month) on top of their current bills (US$ 4.5) for improved water services. Islam *et al.* (2022) applied the CV method to estimate WTP for improved WSS in Khulna city (Bangladesh). The authors found that households are willing to pay 5.05 US$/month on average to benefit from improved WSS, which generates annual revenues of 4.26 US$ million for drinking water companies (exceeding 2.5 times current income level). In the case of Algeria, there is abundant literature on the willingness of households to pay for improved water services. Only one study was carried out on the WTP of 172 households for the WSS of the city of Bejaia in Algeria (Kertous 2012). The author found that household WTP is 231 DZD per quarter.

According to the scientific literature, most of the existing WTP studies on improving WSS management are mainly focused on scenarios related to the technical and financial performance of WSS (e.g., reduction of water losses in the water networks and improvement of the economic viability of water companies). A major limitation of WTP studies is that there is abundant literature that addresses the management of WSS in disadvantaged areas. Studies on several municipalities in the same department have not been addressed by previous WTP studies. These limitations of the existing literature highlight the need for more in-depth empirical studies on household preferences and WTP for improving WSS management in the same area. This study aims to address these limitations. However, to our knowledge, no WTP study based on CV has been applied for the improvement of WSS management in Algeria. Only one study on WTP was conducted by Kertous (2012). This abundant literature on WTP in Algeria encouraged us to carry out this research.

In Algeria, the Algerian water company (ADE) has carried out the management of WSS since 2001 (Ali Rahmani & Chibane 2022). Following natural constraints, poor technical performance and insufficient cost recovery, ADE managers provide their subscribers with irregular and intermittent water services (Hamchaoui *et al.* 2015; Kendouci *et al.* 2019). This intermittent service has forced households to look for other alternatives to make up for the lack of water (in quantity and quality) (Nassiri & Kertous 2021). Among the most used solutions, water storage at home, consumption of bottled and

spring water, purchasing water from private suppliers (Maliki *et al.* 2009) and recovery rainwater (Guebaili *et al.* 2011), impose additional expenses on citizens (Leiva *et al.* 2023). Often, the value of these burdens is underestimated due to the lack of reliable data in developing countries (Vásquez & Beaudin 2020).

Consequently, WSS managers in Algeria have insufficient financial resources to sustainably manage their services (Boukhari *et al.* 2020). This poor financial performance of WSS is due to the low-cost recovery of these services (Kherbache & Oukaci 2020; Kertous *et al.* 2022). ADE subscribers must contribute to the cost of the service through their water bills. On the other hand, ADE managers face serious difficulties in recovering investment costs, as there is a huge gap between the financing needed to improve WSS management and the revenue generated by current water pricing (Kherbache 2020). Therefore, ADE managers will want to know the willingness of households to pay for an improved service. Therefore, the question arises, would citizens accept increases in water rates? Moreover, how much can they pay for these increases?

This study conducted a survey based on the CV method for households in the Souk-Ahras department in Algeria to study household preferences and WTP regarding potential improvements in service provision according to four aspects: continuity of distribution of water, quality of distributed water, increase in pressure and reduction of water losses in the network. The Souk-Ahras department is a typical example of a deprived area of water resources with intermittent water supply (ADE 2022). This situation has hampered the use of other alternatives such as: the use of spring water and bottled water. A better understanding of household preferences and WTP for better management of WSS could provide useful information aimed at improving the quality of WSS provision in the department of Souk-Ahras or other departments of Algeria and other regions of developing countries.

2. METHODS

2.1. Study area

The department of Souk-Ahras is located in the northeastern part of Algeria, with an area of 4,358 km^2 (ADE 2022). The Souk-Ahras department is made up of 26 municipalities (Figure 1). WSS management is ensured by the ADE in only 16 municipalities of the 26 municipalities of the Souk-Ahras department (ADE 2022).

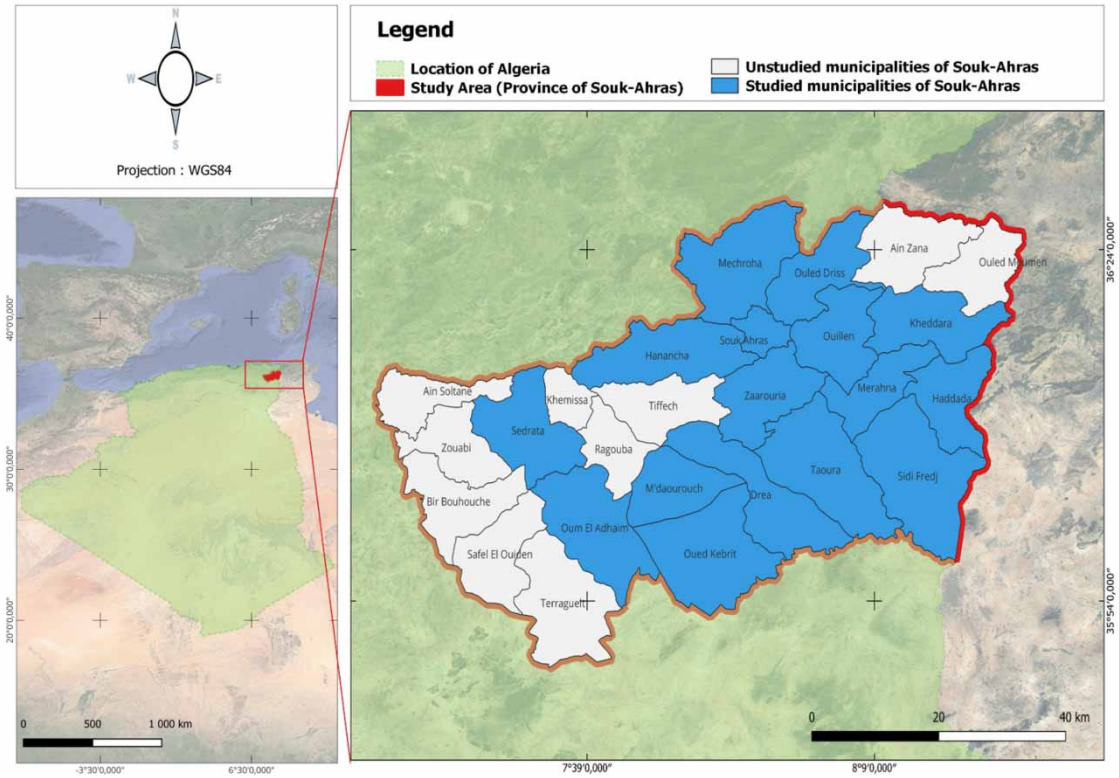

Figure 1 | Map of communes managed by ADE (ADE 2020, 2022).

The drinking water supply to the 14 municipalities is ensured by boreholes and only the two municipalities of Souk-Ahras and Sedrata are supplied by the Ain Dalia dam. The managers of ADE Souk-Ahras experienced inefficiencies in the daily management of WSS due to:

i. a lack of water resources following the low rainfall and drought that affected Algeria in the last 20 years (Kendouci *et al.* 2019). This situation has made the water supply intermittent for citizens, with an average supply of around 4–6 h every 3 days;
ii. high rates of water loss which exceed 50% in several municipalities (Hassoun Nedjar *et al.* 2023; Boukhari *et al.* 2024);
iii. Income deficits and a lack of financial resources (operating expenses are not covered by invoiced and collected income) (Boukhari *et al.* 2023). The current water pricing system applied since 2005 does not promote the stability and financial viability of the ADE (Boukhari *et al.* 2020). The ADE applies a progressive pricing system composed of four consumption blocks with a low price for the first consumption block of less than 25 m^3 (6.3 DZD/m^3) (~0.04 US$/$m^3$) and the average selling price is 18 DZD/m^3 (0.12 US$/$m^3$), knowing that the real price of water exceeds 125 DZD/m^3 (0.85 US$/$m^3$) (Boukhari & de Miras 2019). This critical circumstance threatens the viability of the financial situation and the technical performance of the Souk-Ahras ADE.

The critical financial situation and the high rate of water losses have influenced the quality of the service provided to citizens by ADE Souk-Ahras. Even when there is political will to improve the quality of water services, ADE officials lack information on households' WTP and the amount they are willing to pay for WSS improvement in the department of Souk-Ahras. Information on household WTP for improved quality of WSS management could help policy-makers and ADE managers plan future investments and carry out sustainable water pricing reform to improve the quality of the management of WSS in Souk-Ahras or in other departments of Algeria. The assessment of citizens' WTP for the case of our study area is based on the CV method. The methodology applied in this study is illustrated in Figure 2.

2.2. CV method

According to the scientific literature, surveys based on the CV method are the most used to determine household WTP (Xu *et al.* 2023). However, the CV method uses questionnaires to directly ask citizens about their willingness to improve the quality of goods/services (Kopsidas & Anastasiou 2018).

The CV method applied in this study used a survey of ADE Souk-Ahras subscribers. The preparation of the questionnaire is based on a review of scientific articles, as well as iterative consultations with local ADE officials and researchers with in-depth knowledge of local water issues.

2.3. Preparation and design of the questionnaire

To better understand the current situation of WSS quality in the 16 municipalities of Souk-Ahras department managed by ADE, this study conducted a survey based on a questionnaire. Meetings took place with ADE officials and university

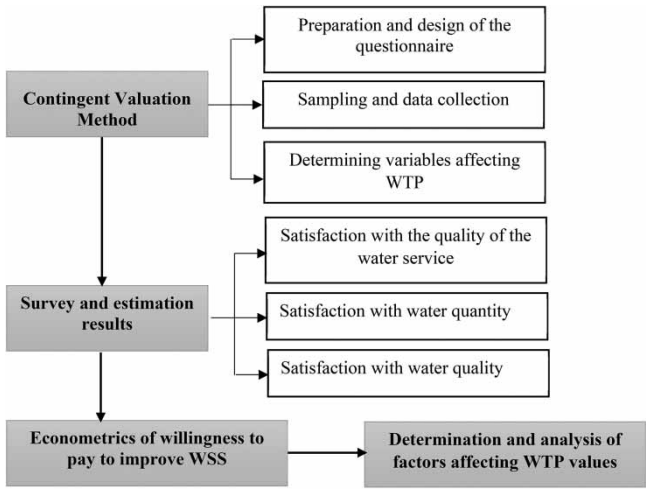

Figure 2 | Methodology flowchart.

professors specializing in the development of household questionnaires. Based on the review of existing literature and the results obtained during the interviews, the variables were adapted to the case of our study area. The preliminary questionnaire was developed and completed in two phases. The first phase was a pilot survey, during which 60 samples were collected in the three main municipalities of the department (Souk-Ahras, Taoura and Sedrata) to test the extent to which respondents understood the different questions and information that interviewers could collect among those interviewed. The interviewers conducted face-to-face interviews with all selected heads of household. In the second phase, the final version of the questionnaire was determined with questions that were clearer and easier to understand for the interviewed households (Supplementary material, S1).

The final questionnaire is made up of 16 questions divided into six main areas. In the first axis, two questions aimed to collect information on the characteristics of the housing (the type of housing and the type of occupation). The second axis is devoted to the characteristics of the family (the size of the family and the number of people in the house, etc.). Information on the following three variables: gender, age and education were not considered in this study due to local conditions in the region. The third axis contained two questions and was focused on the socio-economic characteristics of the respondents. The aim of these questions was to obtain information on the monthly income of household heads and average household consumption. The fourth part is made up of four questions, it aims to analyze the quality of the provision of drinking water services. The fifth axis includes three questions related to the quality of the water distributed. Respondents' responses were rated on a scale of three responses: 'good quality', 'medium quality' and 'poor quality'. Then, the interviewed households gave their opinion on the problems encountered with water quality: 'cloudy water', 'bad taste' and 'bad smell'. Then, households are asked whether or not they are willing to pay more for their satisfaction with different service attributes and their preferences for improved water services.

This research used five attributes: improving water quality, increasing distribution schedules, increasing pressure, maintaining drinking water distribution networks and improving the quality of service. The selection of these five attributes was based on the local context of the Souk-Ahras department. Finally, the households surveyed are invited to answer with 'YES' or 'NO' to the following question: 'Are you ready to pay more for an improvement in the quality of service provided by the Souk-Ahras ADE?' If the answer to this question is 'Yes', they were asked the following question: '*How much of your water bill are you willing to pay to improve the current management of the WSS*?'. The advantage of using this open-ended question is that it is easy to understand and gives respondents the freedom to give their WTP values (Bui *et al.* 2022).

Thus, the main objectives of our questionnaire were to: (i) understand the current situation of WSS management in the department of Souk-Ahras and the satisfaction of citizens regarding the quality of the service provided by the ADE of Souk-Ahras, (ii) evaluate the WTP of local residents for an improved service (in quantity and quality of water distributed) and (iii) enable the analysis of the main factors affecting the WTP of households.

2.4. Sampling and data collection

A random sampling approach of surveyed households was applied in this study. For this purpose, a total of 5,342 questionnaires were completed by the investigators (Table 1). The sample sizes met the assumption of more than 10% of the total number of households in the study area. Interviewers visited all randomly selected houses and conducted face-to-face interviews with household heads. The investigation lasted almost six months, it was carried out from September 2019 until March 2020. The investigators involved in this study are Master's students from the University of Souk-Ahras. The team of investigators was trained for a month by two teachers and a head of the commercial department of the ADE Souk-Ahras Unit.

2.5. Determining variables affecting WTP

Determining the variables included in the WTP assessment is an important task to understand the factors that affect WTP. According to Bui *et al.* (2022), there are 21 main variables that could be considered as factors affecting WTP for improving WSS management. These variables are divided into four groups: (i) demographic, (ii) quantity of drinking water distributed, (iii) quality of drinking water and (iv) quality of daily management of the WSS. For the case of this research, 16 variables grouped into six parts were selected to determine the factors consecrating the WTP for an improved WSS. These factors were selected based on the local WSS situation in the Souk-Ahras department and following interviews with ADE officials in Souk-Ahras.

Then, WTP model regression was performed based on the two Probit and Tobit models to assess how WTP was affected by the different factors selected and used. In general, Probit and Tobit models are used in many fields because of their simplicity (Lee *et al.* 1997).

Table 1 | Distribution of surveyed subscribers in the department of Souk-Ahras (ADE, 2020, 2022)

N°	Municipalities	Number of subscribers	Number of subscribers surveyed	Percentage
1	Souk-Ahras	24,349	2,500	10.27
2	Mechrouha	2,116	215	10.16
3	Ouled Driss	1,028	115	11.19
4	Hennancha	727	110	15.13
5	Taoura	3,242	330	10.18
6	Drea	764	80	10.47
7	Zaarouria	909	110	12.10
8	Merahna	2,089	210	10.05
9	Heddada	1,248	140	11.22
10	Khedara	727	75	10.32
11	Ouillene	327	37	11.31
12	Sidi Fredj	259	30	11.58
13	Sedrata	8,012	715	8.92
14	M'Daourouch	4,962	500	10.08
15	Oum Laadaim	916	95	10.37
16	Oued-Kebrit	770	80	10.39

2.6. Theoretical models

The survey is centered on two main questions, the first making it possible to identify the households that agree to participate in the financing of water service improvement schemes: $d_i = 1$ if yes, zero if not. The second question is to encourage each household willing to participate ($d_i = 1$) to declare the amount y_i (in Algerian Dinars, DZD) that it is ready to pay (per cubic meter in its utility bill water). We therefore have two dependent variables measuring two decisions of each household i. On the one hand, d_i is a binary qualitative variable corresponding to his decision to agree to participate or not in the financing; on the other hand, y_i is a quantitative variable corresponding to the amount of his WTP.

To study these variations in the two decision variables (d_i, y_i), the survey also collected a vector of information represented by X_i, which measures different sources of heterogeneity among the households surveyed.

We use a bivariate empirical model to study the effects of these factors X_i (a vector of K rows) on the two decisions simultaneously: the Probit specification to analyze the qualitative decision d_i whether household i agrees to pay or not and the Tobit specification to analyze its qualitative decision, in this case, the variations in the amount of its WTP y_i. It also allows for the anti-selection bias implicit in the truncation scheme (on the left) of the WTP value reporting process (Heckman 1976):

$$\begin{cases} \text{Whether or not to agree to pay} : & P\left(d_i = \dfrac{1}{X_i}\right) = F(X_i\alpha), \quad F(.) \text{ Gaussian distribution} \\ \text{Willingness to pay} : & y_i = \begin{cases} y_i^* & si\ y_i^* > 0 \\ 0 & sinon \end{cases}, \quad y_i^* = X_i\beta + \varepsilon_i,\ \varepsilon_i \sim N(0, \sigma^2) \end{cases} \tag{1}$$

3. RESULTS

3.1. Survey and estimation results

A first descriptive reading of the survey results provides us with four items of information on the characteristics of the dwellings:

- Type of housing: 54% of households surveyed live in apartments, 45% in villas, and the rest live in old collective houses.
- Owners of these dwellings: 52% of the sampled households own them.

- Number of families per house: Nearly 69% of the households are composed of a single-family, and between 12 and 18% of the homes host from two to three families.
- The number of people per house: 95% of households had five to six members (two adults and three to four children per family).

Then, a second reading was carried out to assess the socio-economic characteristics of the households. From the results of the pilot survey, we observed that the heads of households interviewed did not wish to reveal their real income. For this purpose, the response for monthly income was divided into three value brackets according to the National Guaranteed Minimum Wage (SNMG). Giving an answer between the three choices made it easier for respondents to indicate their monthly income. 45% of households surveyed declared a monthly income of between 18,000 and 36,000 DZD per month (between 122.4 and 244.8 US$/month), 33% had an income of 36,000 to 54,000 DZD (244.8–367.2 US$/month) and 17% have an income greater than 54,000 DZD (more than 367.2 US$/month). The results are presented in the Supplementary material, Figure S1.

3.2. Satisfaction with the quality of the water service

In the second category of this survey, households are asked about the quality of the water services provided (Table 2) and the quality of the water distribution.

According to Table 2, between 36 and 64% of households evaluate the quality of their drinking water as poor. Furthermore, 43 and 61% of households believe that sanitation service provision is inadequate. This assessment provides an overview of the current quality and circumstances of water services.

3.3. Satisfaction with water quantity

The majority of respondents (62.84%) were relatively dissatisfied with the quantity of water supplied by the Souk-Ahras ADE. According to the results of the survey, 40% of households surveyed consumed between 26 and 55 m^3/quarter and 38% consumed less than 25 m^3 per quarter (Figure S2). According to the commercial services of the Souk-Ahras ADE, the average consumption in the Souk-Ahras department was 28 m^3/quarter/household (Boukhari *et al.* 2020). The average allocation therefore does not exceed 60 L/day/inhabitant.

Table 2 | Quality of water services by municipality

		Quality of water supply services (%)			Quality of sanitation service (%)		
N°	Municipalities	Good	Average	Poor	Good	Average	Poor
1	Souk-Ahras	18	34	48	15	32	53
2	Mechrouha	17	44	39	13	35	52
3	Ouled Driss	23	41	36	12	34	54
4	Hennancha	12	41	47	12	38	50
5	Taoura	17	34	49	22	33	45
6	Drea	14	45	41	19	35	46
7	Zaarouria	19	32	49	15	37	48
8	Merahna	25	35	40	11	35	54
9	Heddada	26	35	39	6	41	53
10	Khedara	24	26	40	8	41	51
11	Ouillene	24	33	43	14	35	51
12	Sidi Fredj	23	37	40	20	37	43
13	Sedrata	8	28	64	9	31	60
14	M'Daourouch	12	48	40	15	37	48
15	Oum Laadaim	19	36	45	6	39	55
16	Oued-Kebrit	14	45	51	4	40	56

3.4. Satisfaction with water quality

According to the results of the survey, 78.29% of households questioned were dissatisfied with the quality of the water distributed, 16.77% considered that the water distributed is of average quality and only 4.94% of households declared the quality of the water to be good (Table S1 in Supplementary material). A more in-depth question in the questionnaire was whether citizens drank tap water without further treatment. According to the results of the study, only 40.86% of households responded that they used tap water directly. Participants reported having to treat their tap water before drinking it, usually by boiling it (3.67%) and 5.63% added chlorine to the water they dispensed. On the other hand, 42.25% of households bring water to sources, 47.30% buy bottled water and 1.14% of respondents buy water from water sellers by tanker truck. From Table S1, most households mentioned that the water sometimes had a bad smell (27.22%) and a bad taste (48.30%) and others mentioned that the water was cloudy (2.77%). The results reveal that it is necessary to improve drinking water treatment processes to meet national standards for distributed water quality. The results showed that most respondents considered poor drinking water quality to be the most serious problem.

The next phase is to assess consumer satisfaction with various options for increasing the quality of drinking water services. First, 93% of the households polled want to know what the current water price is. Furthermore, despite the fact that most consumers do not see the cost of water, 59% of respondents thought the price of water was relatively acceptable, 33% of residential subscribers thought tap water was inexpensive, and just 8% thought the price was too high for the services offered.

However, the majority of respondents were in favor of paying additional fees to increase service quality. According to the survey results, over 45% of respondents felt that enhancing water quality should be the priority for water service reform, and 23% argued/advocated for improving the quality of WSS supplies (Figure 3).

Given that many homes in the department of Souk-Ahras are not satisfied with the current water service management situation, the question is whether they are willing to pay for enhanced services. To address this topic, an open-ended question about how much subscribers are willing to pay to increase the quality of this service (increasing the performance of the WSS with better quality drinking water and continuous service) was posed.

3.5. Econometrics of WTP to improve WSS

The WTP model is estimated using the Tobit model with a Gaussian likelihood Type II. Indeed, according to the results of the non-parametric Kernel estimator (Figure 4), the empirical density of reported WTP values does not differ greatly from the theoretical Gaussian density (except that they are truncated at the zero level); 5.79% of those surveyed said they were unwilling to pay. In some localities, this figure surpasses 10.53%. WTP values average 16.18 DZD per cubic meter and vary by 10.83 DZD on average amongst homes. The average WTP varies throughout the 16 municipalities, ranging from 9.33 to 19.40 DZD/m^3.

Figure 5 contains the distribution of WTPs within each of the 16 municipalities. These distributions do not exhibit significant skews either to the left (reporting low values as a sign of protest, free-riding, or bidding) or to the right (reporting high values as a sign of bidding). Therefore, household statements do not exhibit these strategic biases (Hanemann 1994; Kahneman & Ritov 1994).

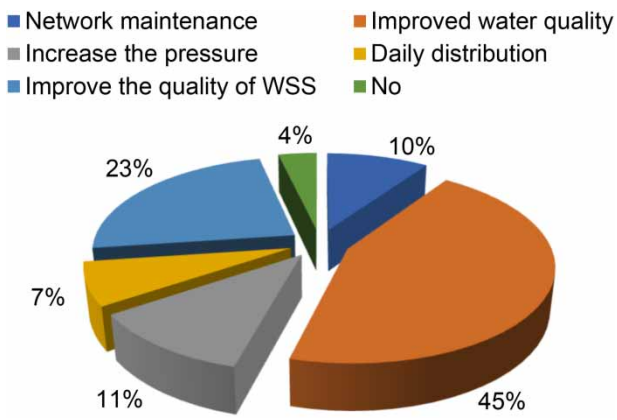

Figure 3 | Distribution of WTP for drinking water improvements.

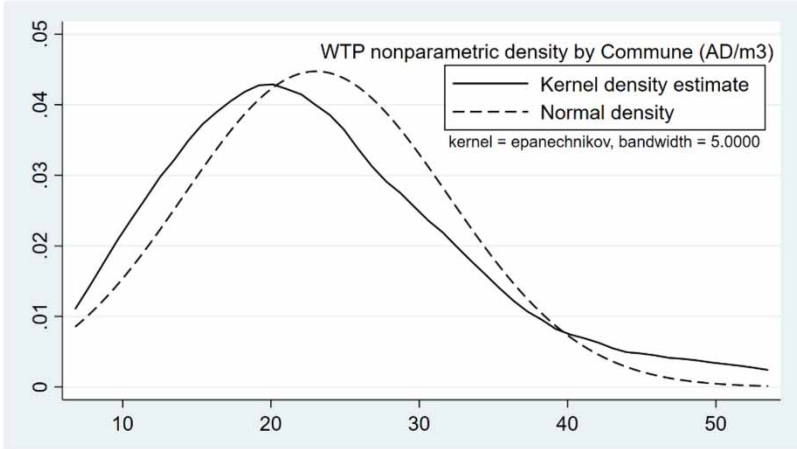

Figure 4 | WTP distribution (in DZD/m^3).

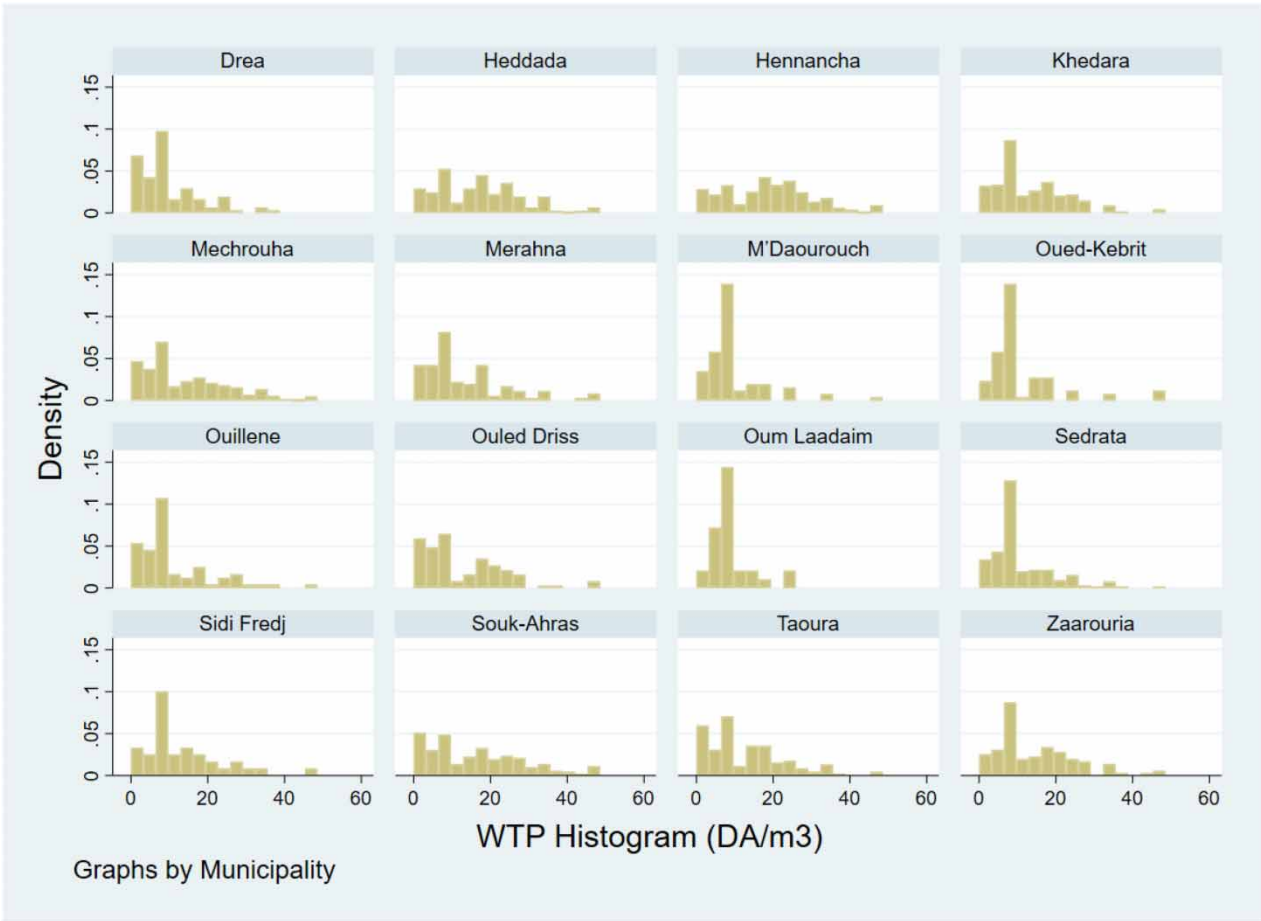

Figure 5 | WTP distribution (the scales of the abscissa (between 0 and 60 DZD/m^3) and the ordinate (between 0 and 0.15) of each histogram are given at the bottom of the figure and on its left side) in each municipality (in DZD/m^3).

Individual heterogeneity factor vector Xi has multiple levels. The first level of heterogeneity is geographical, because the survey area includes 16 municipalities with varying levels of urbanization and affluence. Furthermore, the number of homes polled varies throughout the 16 municipalities. A total of 5,342 households were questioned, with about half of

them (46.80%) in the municipality of Souk-Ahras and the rest spread unevenly among the 15 other municipalities. We use the following stratifications to account for this spatial heterogeneity.

We differentiate two strata, the first of which corresponds to the municipality of Souk-Ahras and is the most populous in terms of residents and households interviewed. We grouped the remaining 15 municipalities together in the same stratum due to their low demographic weight. We then estimated our models without the full base (column A in Table 3) and with (B) one fixed effect per municipality (see Figure 6). We also estimated these models using a single fixed effect (C) that differentiates Souk-Ahras' situation from the other 15 municipalities (the second stratum). Finally, for each stratum, we re-estimated the same models. Table 3 contains all of the results.

The econometric estimates of the fixed effects in Figure 6 show significant geographic heterogeneity between households in different municipalities regarding their probability of paying and the amount they agree to pay. Indeed, we note significant geographic variations in the number of volunteers who agree to participate in the financial effort to improve water service and quality. In addition, when households are willing, they pay very differently between municipalities.

3.6. Determination and analysis of factors affecting WTP values

The estimates of the determinants of WTP, with the different models (Probit and Tobit), give relatively equivalent and comparable results. The quality of water and the quality of service is a variable that does not influence the probability of payment by households. However, this variable positively influences the amount declared by subscribers. This result means that subscribers who find the quality of the water service good want to pay more than those who find it bad. Improving quality therefore seems to be an essential alternative. The income variable has a positive sign and positively influences both the probability of paying but also the amount declared by subscribers in the six estimated models.

The fact that the subscriber has an income between 36,000 and 56,000 DZD increases the probability of paying and increases the amount to pay by 12 DZD on average for models that include the total population and by 14.69 DZD for

Table 3 | Econometric results

	All (5,193[a] households)				Souk-Ahras municipality(2366) (C)	
	Without communal fixed effect (A)		With communal fixed effect (B)			
Factors	**PROBIT**	**TOBIT**	**PROBIT**	**TOBIT**	**PROBIT**	**TOBIT**
Salary 36000−54000 DZD	1.528*** (0)	12.66*** (0)	1.636*** (0)	12.78*** (0)	1.622*** (0)	14.69*** (0)
Salary > 54000 DZD	1.834*** (0)	20.51*** (0)	1.960*** (0)	20.71*** (0)	1.800*** (0)	21.56*** (0)
Number of families	−0.0231 (0.740)	0.551** (0.0290)	−0.0568 (0.433)	0.479* (0.0581)	0.00679 (0.947)	0.479 (0.263)
Owner	0.168**	1.044***	0.147*	0.715**	0.247**	1.319***
	(0.0357)	(0.00106)	(0.0845)	(0.0265)	(0.0161)	(0.00998)
Know the water price	−0.177 (0.111)	0.941** (0.0294)	−0.0866 (0.452)	0.883** (0.0391)	−0.0953 (0.488)	1.399** (0.0348)
Cheap water prices	0.387***	1.515***	0.415***	1.427***	0.306***	1.265***
	(9.83×10^{-8})	(1.16×10^{-8})	(3.24×10^{-8})	(5.67×10^{-8})	(0.00155)	(0.00498)
Water quality and service $\widehat{\sigma^2}$	0.0803 (0.363)	0.629* (0.0728)	0.139 (0.129)	0.523 (0.135)	0.184 (0.175)	1.310* (0.0618)
		83.98***		81.79***		111.7***
		(0)		(0)		(0)
Constant	0.761***	3.068***	0.485***	3.717***	0.343*	1.364
	(3.02×10^{-9})	(1.19×10^{-8})	(0.000404)	(6.42×10^{-11})	(0.0610)	(0.155)
R^2	0.228	0.07	0.2635	0.07	0.2595	0.06

p-values: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

R^2 coefficient of correlation

[a]The sample covers 5,342 households but 149 questionnaires were incomplete and eliminated in the estimation of the model.

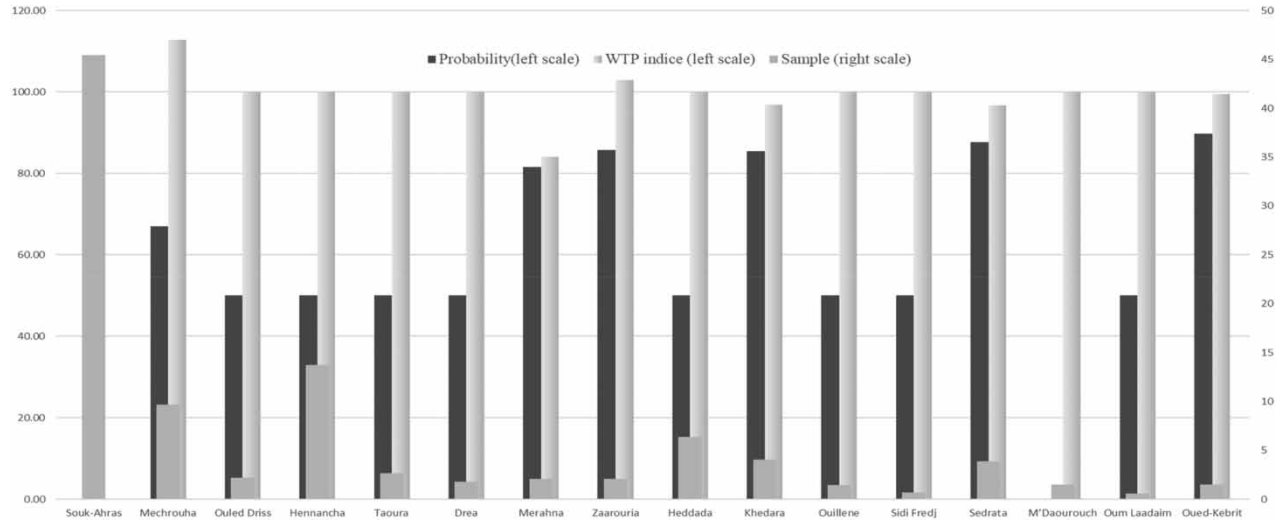

Figure 6 | Variation by the municipality in the probability of WTP to pay, the WTP index and percent sampling.

the model of the city of Souk-Ahras. For subscribers who are in the salary class above 56,000 DZD, the amount to pay is greater than 20 DZD.

Household size (the number of families) has no impact on the probability of paying, but this variable has a significant effect on subscribers' WTP. The increase in wealth can undoubtedly explain this depending on the number of families living together. Indeed, in Algerian traditions, parents and children living in the same house and sharing the same water meter increase the amount of WTP because there are often many assets. The status of the homeowner positively influences the probability of paying in the three models from 14 to 24% and positively influences the value of the subscriber's WTP. The sign of this variable is undoubtedly the consequence of an effect of wealth and the standard of living of households, and of the specific needs of this social category.

Finally, suppose that the subscriber declares that he knows the price of water. In this case, this variable has a negative but not significant impact on the probability of paying, but it has a positive and significant influence on the amount declared. This result is corroborated by the variable 'do you find the price of water cheap?', which has a positive and significant impact on the probability of paying and on the amount to pay. If the subscriber finds the price of water cheap, this increases the probability of paying between 30 and 41%.

The results of the six models revealed that monthly household income, family size, quality and quantity of water supplied are the most important factors influencing household WTP for improving WSS management. To this end, policy-makers and WSS managers should consider these factors when assessing the quality of consumer-facing WSS.

3.7. Profit estimate

In this section, a comparison was made between the application of the new drinking water tariff (16.18 DZD) estimated by the WTP study for improved service and the current unit tariff (6.30 DZD). This comparison aims to analyze the benefits for households and ADE following the increase in the unit water rate. The application of the new tariff increased the water bill from 100 to 220%, depending on the increase in volume consumed.

3.7.1. For households

According to the Souk-Ahras AED subscriber file, the average household consumption is 28 m^3/quarter (Boukhari *et al.* 2020), which is equivalent to an average water bill of 764.18 DZD/quarter. However, most households use other alternatives to address the lack of water (water storage in tanks) and the poor quality of distributed water (bottled water consumption). These alternatives increase water prices, for example, the installation of storage tanks and bottled water consumption (5-L bottle for 85 DZD).

Water charges = Water bill + amortization of galvanized tank installation costs + purchase of bottled water

- Average monthly water bill = 764.18/3 = 254.73 DZD/month (1.73 US$/month)
- Amortization of costs for the installation of galvanized tanks. However, this type of storage has a cost that includes the price of tanks, pipes, labor and sometimes an electric pump to raise the water. Households that have used these storage devices have invested over US$500 to install tanks on the roof. Tank prices vary according to the size and quality of the tank material used. Monthly amortization is therefore 1.39 USD/month.
- Purchase of bottled water = 85 * 30 = 2,550 DZD/month (17.34 US$/month)

Total water costs = 1.73 + 1.39 + 17.34 = 20.46 (US$/month)

Applying the new Unit Tariff for water (16.18 DZD), the average water bill is 1,236.38 DZD/quarter (412.13 DZD/month = approximately 2.80 US$/month).

Consequently, the difference between the current water rate and the rate with the new tariff is 17.66 US$/month (211.89 US$/year).

3.7.2. For the local ADE

With the current tariff, ADE's annual sales for the year 2022 are 948,054.11 US$ (ADE 2022). On the other hand, if ADE applies the new tariff, annual revenue will be 1,691,056.62 US$, with an annual gain equal to 743,002.52 US$. This amount of money can help managers improve the quality of their service.

4. DISCUSSION

4.1. Quality of WSS management

As summarized in the literature review section, previous studies on WTP for improving WSS management mainly focus on water quality or water quantity. However, as we found in this study, several subsamples of households in Souk-Ahras municipalities did not show significant preferences for improving the quality or quantity of water distributed. To this end, WSS management performance must focus on both attributes at the same time. The implication for policy-makers is that efforts to improve the quality of WSS management in developing countries should take into account not only improving the quality and quantity of drinking water, but also other attributes to ensure the well-being of households, management of pressure in distribution networks and reduction of water losses to avoid water-borne diseases.

4.2. Households' preferences and WTP

This study revealed a significant disparity between municipalities in household WTP for improving WSS management performance. Such disparity between municipalities in WTP could be partly attributed to the difference in monthly household incomes between different municipalities. From the results of the six models (Probit and Tobit) applied in this study, we found that the significant factors affecting WTP are income, water consumption, family size, quantity satisfaction and water quality. Disparities between districts in household income and WTP suggest the need to consider equality between municipalities in future studies.

Such information on household WTP could help policy-makers and WSS managers design sustainable tariff structures. The application of the new tariff resulting from the WTP study makes it possible to reduce household charges for water and increase ADE revenues (economic viability).

5. CONCLUSION

This research conducted a survey based on the CV method on 16 municipalities in the Souk-Ahras department in Algeria to study household preferences and WTP to improve WSS management performance. Nearly 95% of households in Souk-Ahras store water at home. This can be explained by the fact that most households have already invested in the installation of costly infrastructure to store water at home (e.g. rooftop tanks) and also pay extra for good quality water (purchase of bottled water). Following this research, 78.29% of households surveyed were dissatisfied with the quality of water distributed by ADE, and 62.84% of respondents considered that the quantity of water distributed did not cover their daily needs. In fact, around 78% of subscribers are prepared to accept an increase in the price of water for improved WSS management.

The average WTP of households surveyed for an improved WSS is estimated at 0.11 US$/$m^3$ instead of the current rate of 0.04 US$/$m^3$. Even with this increase in the water bill, affordability remains assured and water bills will not exceed 3% of monthly household income. The results of this study showed that there were significant disparities in household WTP between the different municipalities of Souk-Ahras. This study contributes to a better understanding of household preferences

for household preferences and provides useful information for prioritizing investments to improve the quality of WSS management with limited resources. The WTP technique offered authentic results that enabled realistic recommendations to be made to policy-makers without any complications in designing an appropriate water tariff. The methodology we developed for this study can be applied to other similar fields (wastewater management, energy, etc.).

This study has certain limitations. For example, there is a large difference between the number of households surveyed in the municipality of Souk-Ahras (capital of the department) and the number of households in other municipalities. This difference in sample size is explained by the inequality between the number of subscribers in each municipality, which is directly related to the population of each municipality. The limitation of sample sizes requires caution when interpreting modeling results. Empirical studies are needed to further reveal the disparities between municipalities, and to add any municipalities not managed by the ADE. Questions of social equality can be explored in greater detail in future studies.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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