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RESEARCH PAPER

# An estimate of the willingness to pay for treated wastewater for irrigation in Oman

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# قابلية الدفع لمياه الصرف الصحي المعالجة للرّي في عمان

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**ABSTRACT**. The volume of Treated Wastewater (TW) produced in Oman is increasing, due to increased connection of houses to the sewage network and increased construction of wastewater treatment plants. Despite 68% of the TW been used for irrigating urban landscapes, 10.3 $Mm^3$ TW has been discharged to the sea in 2014. Wastewater treatment plants are owned and operated by private companies, which aspire to sell excess TW, particularly to farmers, in order to recover cost of wastewater treatment. This paper has used the Contingent Valuation Method (CVM) to estimate the farmers' Willingness to Pay (WTP) for TW for farm irrigation. Seventy two farmers responded to a face-to face interview on eliciting WTP to purchase TW as irrigation water, out of a total population of 400 farmers in Seeb region who have farms in proximity to a wastewater treatment plant. The results indicated that farmers' WTP for TW was on average 0.111 $OR/m^3$. WTP for TW was significantly affected by the income of farmers and whether the farm is a market oriented or non-market hobby oriented farm. The percentage of farmers willing to pay the average price or higher was 38%. Most farmers are not willing to pay the price currently charged by the wastewater treatment company for landscaping irrigation (0.220 $OR/m^3$) given the large volumes required for farm irrigation. Even rich farmers maintaining hobby farms are willing to pay only 0.128 $OR/m^3$ versus 0.087 $OR/m^3$ by the market oriented farmers. The WTP for TW is higher than the prices reported (OR 0.005 to 0.023 $OR/m^3$) for groundwater used in agriculture in Oman. .

**KEYWORDS:** Treated Wastewater, Contingent Valuation Method, Willingness to Pay, Irrigation, Oman.

**المستخلص**: يتزايد حجم مياه الصرف الصحي المعالجة في سلطنة عمان نتيجة لزيادة ربط المنازل بشبكة الصرف الصحي وزيادة بناء محطات لمعالجة هذه المياه. وعلى الرغم من أن ٦٨٪ من مياه الصرف الصحي تستخدم لري المناطق الخضراء داخل المدن، فقد تم تصريف ١٠,٣ مليون متر مكعب من مياه الصرف الصحي إلى البحر سنة ٢٠١٤. وتدير هذه المحطات شركات خاصة ، حيث تطمح إلى بيع الفائض من المياه المعالجة خاصة للمزارعين من أجل تغطية تكلفة معالجة هذه المياه. وقد استخدمت هذه الورقة طريقة التقييم المحتملة لتقدير مدى قابلية المزارعين للدفع مقابل استعمال مياه الصرف الصحي المعالجة ثلاثياً للري. وقد شملت العينة ٧٢ مزارعا من مجموع ٤٠٠ مزارع في منطقة السيب الذين لديهم مزارع بالقرب من محطة معالجة مياه الصرف الصحي حيث تم إجراء مقابلات وجها لوجه حول استغلال المحطة ومدى القابلية لاستعمال المياه المعالجة ثلاثياً للري. أوضحت النتائج أن معدل القابلية للدفع للمياه المعالجة بلغ ٠,١١١ م / م٣ في المتوسط. وقد تأثرت النتائج بشكل كبير بدخل المزارعين وما إذا كانت المزرعة موجهة نحو السوق أو غير موجهة نحو السوق. وتقدر نسبة المزارعين المستعدين لدفع متوسط السعر أو أعلى بـ ٣٨٪ وأن معظم المزارعين ليسوا على استعداد لدفع الثمن الذي تتحمله حاليا شركة معالجة مياه الصرف الصحي لري المناطق الخضراء (٠,٢٢٠ ريال / م٣) و ذلك بالنظر إلى الكميات الكبيرة المطلوبة للري الزراعي. أما المزارعين الأغنياء الذين يمتلكون مزارعا و يمارسون الزراعة على وجه الهواية فهم على استعداد لدفع ٠,١٢٨ فقط للمتر المكعب مقابل ٠,٠٨٧ ريال / م٣ من قبل المزارعين الموجهين نحو السوق. جدير بالملاحظة أن القابلية للدفع للمياه المعالجة أعلى بكثير من الأسعار المتعامل بها (٠,٠٠٥ إلى ٠,٠٢٣ ريال / م٣) بالنسبة لمياه الأفلاج المستخدمة في الزراعة في السلطنة.

**الكلمات المفتاحية**: مياه الصرف ، أسعار المياه، طريقة التقييم المحتلم

## Introduction

Agriculture in the Sultanate of Oman depends totally on groundwater based irrigation. The Ministry of Regional Municipalities and Water Resources has indicated that the annual groundwater over-pumping exceeded 316 $Mm^3$ (MRMWR, 2013). Further to quantitative scarcity of water, the degrading quality of groundwater has posed an added constraint (Zekri, 2008; Zekri, 2009). Land affected by groundwater salinity due to over-extraction of ground water and sea water intrusion has been estimated as 70% of the agriculturally arable land area of the country (Al-Rawahy et al., 2010). Thus, finding alternatives to overcome the shortage of irrigation water is a national priority and use of Treated Wastewater (TW) is being considered as an alternative.

There are 58 wastewater treatment plants in the Sultanate of Oman that treat domestic and commercial wastewater. Forty four of those are operated by Ministry of Regional Municipalities and Water Resources. Thirteen plants are located in Muscat the capital city and are operated by Haya a Semi-Private Company and are currently producing around 100,000 $m^3$/day of TW. It is expected that the volume of TW will increase with increased connection of houses to the sewage network.

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The major client of Haya is Muscat Municipality that is buying 68% of the supply of TW at a price of 0.220 OR/m3 to irrigate public landscapes. Although TW utilization has increased due to the expansion of public landscaping projects and some industrial uses, the volumes unutilized and disposed to the sea are also increasing. TW can be considered as an alternative or a complement to groundwater for farm irrigation. Apart from the direct benefits of irrigation on improving productivity of crops and livestock, use of TW for farming will have a positive impact on the environment, reduce the dependency on groundwater, contribute to water scarcity alleviation, and ensure sustainability of farming. Although Haya, the supplier of TW, is keen to charge a price for the supply of TW to ensure financial viability and sustainability of its business, farmers' Willingness to Pay (WTP) for TW is unknown, as TW has not been marketed for farm irrigation thus far. This paper assesses the farmers' WTP for TW for farming, using the Contingent Valuation Method (CVM). The paper is organized as follows: section 2 gives an overview of the TW supply and use in Muscat, section 3 provides a review of literature particularly on the use of CVM in estimating the WTP for TW. Section 4 presents the sampling and survey methods and the econometric model used to validate the estimated value of TW. Section 5 and 6 presents the results and conclusions, respectively.

## Treated Wastewater supply in Muscat

Table 1 shows the volumes of TW produced, marketed (utilized for landscape irrigation) and the unutilized volumes discharged to the sea or wadis (water ways) by wastewater treatment plants in Muscat, during 2014. The total annual volume of TW discharged to the sea has been 10.3 $Mm^3$ or 32% of the total TW produced in 2014. A new wastewater treatment plant which is expected to be commissioned by beginning of 2016 in Seeb will produce initially, 55,000 $m^{3/}$day and 80,000 $m^3$/day by 2025, of TW. The expected increase in TW supply up to year 2025 is given in figure 1.

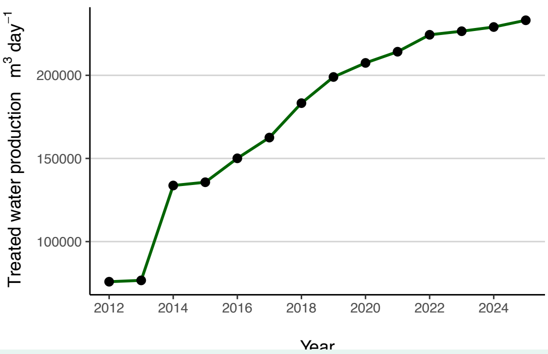


**Figure 1.** Estimate of TW production in Muscat ($m^3$/day) from year 2012 to 2025. Source: Haya Water Company (2012)

The current cost of producing TW by Haya is around 0.800 OR/$m^3$. The prices charged on sales of TW vary from 0.231 OR/$m^3$ for commercial users to 0.154 OR/$m^3$ for residential users (figure 2). Thus, on average Haya receives 0.170 OR/$m^3$ on sales of TW. Figure 3 shows the subsidy paid by the government to Haya for the services provided on treating wastewater. The subsidy covers the difference between the cost of treatment and the revenue from TW sale plus the average price paid by the different users. Taking into account that 68% of the TW is marketed the net price received by Haya for each cubic meter is 0.150 OR/$m^3$. As a result, the total governmental subsidy to Haya represents 0.481 OR/m3 or 60% of the total cost. To transform the wastewater treatment industry into an unsubsidized self-financed

**Table 1.** Production and use of TW during 2014 in Muscat.

| Plant | Production ($m^3$) | Utilized ($m^3$) | Discharged to sea ($m^3$) | Utilization (%) |
|---|---|---|---|---|
| Al Ansab | 22,476,724 | 15,479,297 | 6,997,427 | 69% |
| Darsait | 6,569,436 | 4,280,083 | 2,289,353 | 65% |
| Shattie Al Qurum | 1,470,757 | 415,800 | 1,054,957 | 28% |
| Al Mabella | 637,848 | 637,848 | 0 | 100% |
| Al Khoudh | 308,476 | 292,319 | 16,157 | 95% |
| Madinat AlSultan Qaboos | 432,961 | 432,961 | 0 | 100% |
| Al Amerat | 336,962 | 320,321 | 16,641 | 95% |
| Quraiyat | 138,130 | 107,676 | 30,454 | 78% |
| Bawsher | 79,937 | 47,370 | 32,567 | 59% |
| Al Manuma | 53,121 | 53,121 | 0 | 100% |
| Jibroo | 34,922 | 34,922 | 0 | 100% |
| Hail Al Ghaf | 49,182 | 0 | 49,182 | 0% |
| Total | 32,588,456 | 22,101,718 | 10,486,738 | 68% |

sustainable industry, users should at least pay part of the cost of wastewater treatment. One of the options is to sell part of the TW to farmers for crop irrigation. The re-use of TW in the agricultural sector is stimulated by the severe water scarcity and deteriorated water quality. Groundwater salinity in the Batinah coastal area is the consequence of over-pumping (Oman Salinity Strategy, 2011). The use of TW can partially reduce the pressure on groundwater over pumping.

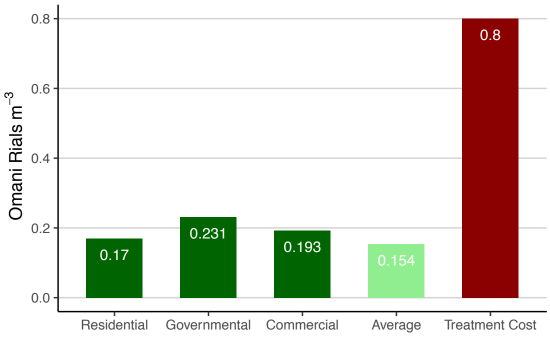


**Figure 2.** Cost of water treatment and prices paid by users for TW.

## Literature Review

Haya Water Company is interested to know how much farmers would be willing to pay for TW and how much of TW they would be willing to buy, if a project of transferring water from the treatment plants to farms was implemented. Such estimates would enable the company to examine the financially sustainability of TW transferring investment. A large proportion of farm owners in the study area are hobby/leisure, i.e. famer owners undertaking farming as a hobby and not for financial profits. On the other hand, TW is not yet available to farmers in Oman and thus its value is wholly unknown. These circumstances warrant the use of CVM to estimate the value of TW. A comprehensive theoretical review (Gunatilake, 2003) of the CVM and its applications to estimate WTP for water supply is provided by Gunatilake, et.al. (2007). CVM uses survey techniques to elicit WTP of non-marketed commodities and where revealed or indirect methods of valuation cannot be applied. In CVM respondents express their WTP on a 'described' hypothetical situation, as in this study the supply of TW. Very few studies have been undertaken to estimate WTP for TW as compared to studies on supply of fresh water for irrigation and domestic use, using CVM.

Abu-Madi (2004) has used CVM with a bidding game to determine farmers' willingness to pay for reclaimed wastewater in Jordan and Tunisia. Farmers were asked to respond yes or no in favor of paying prices for TW varying between US\$ 0 to 0.25/$m^3$ with bids increasing by US\$ 0.05/$m^3$. A logit model was used where the dichotomous responses to seven bids are entered as dependent variable. Results indicated that higher prices of conventional water as well as higher farmer's profit increase farmers' WTP for TW. About 84% of the interviewees showed interest to take reclaimed TW if the price was US\$0.05/$m^3$. The percentage declined to 47% when the price was US\$ 0.10/$m^3$.

Tziakis et al., (2009) have estimated the benefits from wastewater treatment and reuse using CVM in northwest Crete. A Tobit regression model with two dependent variables has been used, viz; WTP for the provision of wastewater treatment and WTP for recycled water as a percentage of the price of fresh water. Their results showed that farmers WTP for recycled water on average was 61.2% of the freshwater price or \$/$m^3$ 0.01 and that farmers with higher income (1200-1800 €/month) are willing to pay for recycled wastewater with higher average bids than those with lower income (less than 1200 €/month). Alebel et al., (2009) have used CVM in Addis Ababa, Ethiopia to determine the value of improved wastewater irrigation. The authors have found that the number of years with irrigation experience, education, total annual revenue, and the kind of policy option significantly affected farmers' WTP for wastewater. The authors have highlighted that household's WTP for wastewater for crop production increases with higher income from farming.

Alcon et al., (2010) estimated Murcia's citizens' non-market benefits (ecological and social) of improved treatment of wastewater used in agriculture on the Segura River. They used CVM to determine citizens' WTP to preserve the river's ecological status. The maximum WTP was elicited through an open-ended question while the payment vehicle is a monthly increase in the water bill. A Tobit model was used and the independent variables were the age, education level, gender, income size of the household and visits to the Segura River. Results showed that the average WTP was \$0.34/m3. Respondents with larger families were willing to pay less while those who use the river for recreation are willing to pay more than people who do not.

Alfarra et.al., (2013) analyzed farmers' WTP for TW in the Jordan Valley in order to evaluate the future de-


**Figure 3.** Subsidy (in %) to wastewater treatment in Muscat.

mand of TW given the expansion in supply and whether farmers will be paying a higher price in the future so as to cover a greater portion of the cost. Farmers were paying 0.01 $/m3 for both fresh and TW. Six bids were presented to farmers with prices of TW ranging from the current price to a price ten times higher. An ordered logit model which is an extension of the logistic regression model for dichotomous dependent variables was used. The WTP was used as a dependent variable and 12 independent variables ranging from cultivated area to religious prohibition were used in the model. The main findings were that; higher farm profits related to higher bids; low water prices negatively influences the farmers' decision on WTP and farmers with high concerns on health made low bids on WTP.

Azahara et al., (2012) in Spain and Tang et al. (2013) in China used CVM to estimate the WTP for 'guaranteed' water supply for irrigation under scarcity conditions and the willingness to pay for irrigation water, respectively. Azahara et al., (2012) have indicated that the respondents with higher gross income per hectare were willing to pay more for the improvement of the service of guaranteed water supply than farmers with lower income. Tang et al., (2013) have indicated that, as expected of economic theory, households with higher income have a higher mean WTP for irrigation water.

# Methodology

The objectives of this paper were to estimate the farmers' WTP for TW and to identify the socio-demographic factors affecting WTP. Shakhakhit, the study area is located in the Batinah coastal region, in northern Oman as shown in the map (figure 4). The area is very close to the new Seeb water treatment plant where a main TW network connection already exists as shown in figure 4. But the sub-connections to the farms are expected to be provided subject to farmers' WTP and the financial viability of such an investment. There are about 400 farms ranging from 1 to 36 acres/farm in the study area. Palm dates are the dominant crop due to its tolerance to groundwater salinity. Most of the farms are individually owned whilst the rest are family farms with multiple owners.

## Survey Design and Data collection

A random sample of 100 farmers out of a total population of 400 farmers was targeted. The list of farm owners and their phone numbers was provided by the Ministry of Agriculture and Fisheries. Appointments were arranged with the farm owners for a face to face interview at the farm. Only 72 farmers responded to the interviews. The questionnaire was divided into four sections. Section (1) provided the background and purpose of the survey; Section (2) covered the demographic, socioeconomic profile of the households, and socioeconomic profile of

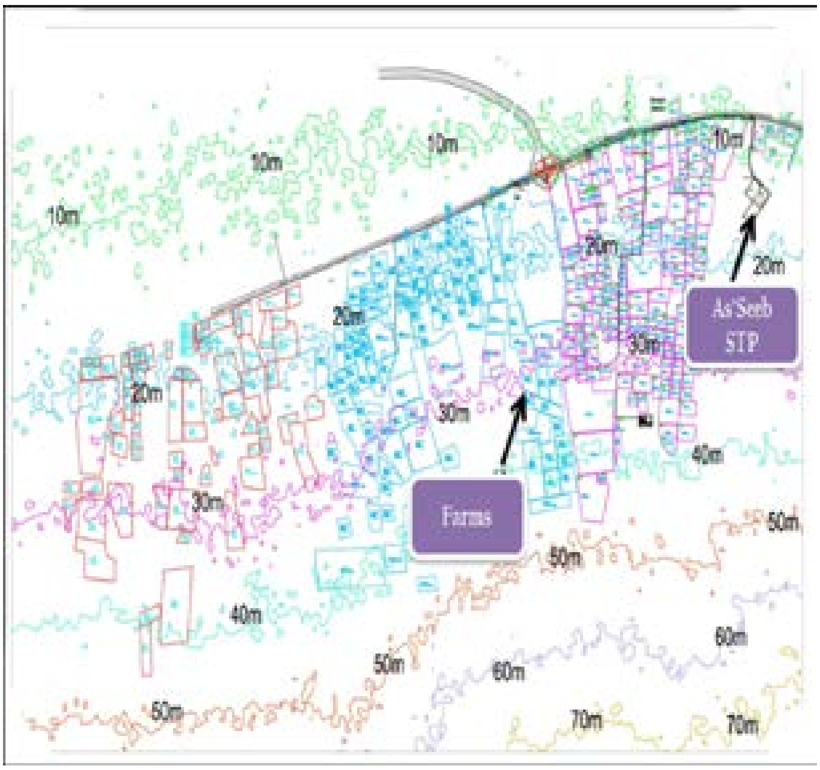


**Figure 4.** Study Area and Al Seeb treatment plant (STP).

the respondent; Section (3) addressed the current water supply conditions and consumption behaviors; Section (4) presented the Contingent Valuation (CV) market scenarios followed by questions eliciting WTP values.

### Econometric model

To validate the estimate of WTP, the following regression model was developed with variables that were expected to be related to farmers' WTP for treated wastewater.

$$WTP = \alpha_0 + \alpha_1(income) + \alpha_2(year) + \alpha_3(area) \\ \alpha_4(cost) + \alpha_5(D_1) + \alpha_6(D_2) + \varepsilon_t, \\ \varepsilon_t \sim N(0, \sigma^2) \quad (1)$$

Where:
*WTP* = Willingness to pay (OR/m$^3$)
*income* = Monthly Income of household (OR)
*year* = Years owning the farm
area = Farm Area (Acres)
*cost* = Monthly Cost of alternative water (OR)
The dummy variables $D_1$ and $D_2$ are defined as follows:
$D_1$= 0, if the respondent live in the farm and '1' otherwise
$D_2$= 0, if hobby farm and '1' if business oriented farm
and $\varepsilon_t$ is the error term.

A general-to-specific modelling procedure was applied by including all independent variables in the initial step and then search for the best combination of independent variables that yielded the best model based on the highest $R^2$ value, lower sum square error (SSE) of residuals, expected sign and significance of coefficient estimate, joint significance of the variables, and residual normality (Jarque and Bera, 1987).

## Results

The average age of the farm owners was 47 years. The average number of years of owning the farm was 18.5. Most farms are family owned with several owners. Sixty three percent of the families are living in the farms and the remaining visit their farms only during weekends or holidays. All the farms are managed and operated by expatriate workers. None of the farmers interviewed depended on farming exclusively as a source of income. Farmers are engaged in their own business or employed in the government or private sector. Thirty three percent of the interviewees were self-employed, with 31% of them earning a monthly income of above 3,000 OR (1 Omani Rial = 2.6 US$). The average farm area was 10.2 acres while the average cropped area was 4.64 acres. Eighty eight percent of the farmers use groundwater despite the high salinity. Fifty eight percent of the farmers declared that the quality of groundwater was extremely poor. Some farmers used desalinated groundwater or bought TW supplied by bourses. On average the monthly cost of water used for irrigation is 70 OR per farm regardless of the source of water. The survey showed that the dominant crops are date palm in 94% of the farms followed by alfalfa and Rodhes grass cultivated for animal feed. These crops are grown as they could tolerate water salinity. A number of other crops were cultivated in a very limited area that were not productive due to high water salinity.

**Table 2.** Results of the regression analysis.

| Variables | Estimated coefficients | t-statistics |
|---|---|---|
| Income | 0.0254 | 2.56* |
| Live | -0.0169 | -0.92 |
| Area | -0.0001 | -0.07 |
| Cost | 0.0000 | 0.54 |
| D2 | -0.0354 | -2.21* |

Summary statistics: $R^2$ = 0.16, SSE = 0.06, F-test (joint test) = 2.51*, MSE = 0.004

On being asked if they would accept to use TW for irrigation, 86% of the respondents agreed to use TW, whilst 8% were undecided and 6% disagreed. Farmers considered the use of TW as an opportunity to bring back or improve farm production in farms that have been heavily affected by salinity. The respondents who were undecided and disagreed about using TW were asked to justify the reasons for their response. Only 44% of them mentioned concerns of adverse health impact and distrust about the water quality.

A bidding game was used to elicit the farmers WTP for TW and the estimated average WTP for TW was 0.105 OR/m$^3$. In order to identify the factors affecting the WTP a regression analysis was done. Results are shown in Table 2. Two variables (Income and the farm type as hobby farm or commercial farm) are significant at 5% level. The positive relation between WTP and income validates the WTP estimate. Although not all variables are individually significant they are jointly significant since the F-stat is higher than F-critical (2.505 > 2.37). A normality test was conducted and the Calculated JB was 5.1179 < 5.999 table affirming that the residuals were normally distributed. The observed mean of WTP was found to be 0.105 OR/m$^3$ and the predicted mean WTP was 0.111 OR/m$^3$.

The mean WTP (0.128 OR/m$^3$) for hobby farmers (40% of the sample) is much higher than WTP (0.087 OR/m$^3$) expressed by the market oriented farmers (60% of the sample). Correlation analysis showed that the WTP of hobby farmers was significantly related with income. The higher the income the higher the WTP to pay was. However for the market oriented farms there was no correlation between income and WTP.

Figure 5 shows the demand curve for TW of the farmers in Shakhakhit area. The volume of TW (m3) purchased by each farmer was estimated based on farmer's current expenditures on water for irrigation divid-

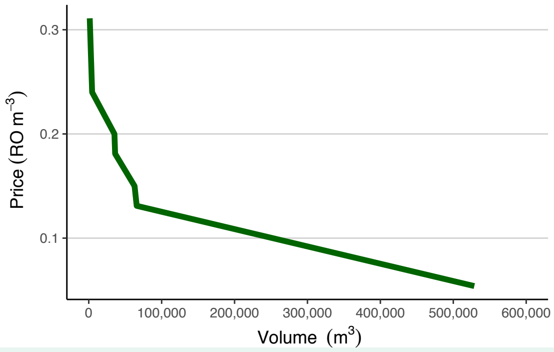


**Figure 5.** Demand function for TW in Shakhakhit area.

ed by his WTP for TW. The curve shows that the total demand would reach 545,563 m$^3$/year when prices vary from 0.310 to 0.055 OR/ m$^3$. This volume is very small compared to the capacity of Seeb plant which will start at 20 Mm3/year. In case Haya Water Company uses the average WTP of 0.111 OR/m$^3$ the demand will reach around 300,000 m$^3$/year. Finally if the price of water will be 0.055 OR/m$^3$ it is expected that demand will reach 609,000 m$^3$/year. The estimates show that the expected demand volumes are too small compared to the Seeb plant capacity even at low price. Consequently, in such a situation, Haya Water Company will have to propose a regressive TW price for farmers. The lower the price the higher the volume demanded by farmers will be. The objective is to distribute the fixed costs over the largest possible volume of water. Experiences from the long active agricultural water markets in Oman show that the water prices are rather on the low side varying from 0.005 to 0.023 OR/m$^3$ (Zekri et al. 2006). Further investigations are required, such as through use of linear programming farm models, to estimate the value of WTP and confirm the results obtained in this study.

# Conclusions

Groundwater quality is worsening in the Batinah region of Oman due to over-pumping of water for farming. Some of the highly productive farms have become unproductive over time. Given the increased salinity TW is being viewed as an alternative to groundwater for farm irrigation. Volumes of TW in Muscat are increasing due to more houses being connected to the sewage network and increased construction of treatment plants. Currently 32% of the TW is discharged to the sea and it would increase in the future. The potential to use TW to irrigate farms is considered, whilst charging a price that would enable the private companies supplying TW to be financially viable and sustainable.

CVM was used to evaluate the farmers' WTP for TW in Shakhakhit, Seeb. The study area was chosen because of its close proximity to the new water treatment plant constructed in Seeb. Seventy two questionnaires were completed for the study from a total number of 400 farms which represents 18% of total population. The average calculated WTP is OR 0.111 per m$^3$. The percentage of farmers willing to pay above this price is 38%. Sixty two percent of the farmers are willing to pay this price and below. Haya Water Company is currently selling the TW at 0.220 OR/m$^3$ which most of farmers do not accept to pay as it would make farming unprofitable. Hobby farmers are willing to pay more for TW than commercial farms. The mean WTP was 0.128 OR/m$^3$ for the hobby farms and 0.087 OR/m$^3$ for the market oriented farms. The demand that could be generated by conveying the TW up to Shakhakhit farms is very small compared to the Seeb treatment plant estimated to 20 Mm$^3$/year and represents less than 5% of total plant capacity.

The estimated WTP was validated by an econometric model in which WTP for TW was the dependent variable and farmer's income, whether farmer lived in the farm, years owning the farm, farm area, cost of alternative irrigation water and the whether the farm is a hobby or market oriented farm were independent variables. The results as expected indicate that farmers' WTP for TW is significantly affected by income and whether the farm is a market oriented or hobby farm and thereby validates the WTP estimate.

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