Household Willingness to Pay for Reliability of Water Supply and Quality in Chobe Suburb of Maun: An Application of the Contingent Valuation Method

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Abstract

Water supply in Maun is unreliable and unpredictable, and most households experience water shortage all year round. Coping strategies for households include water storage in tanks. Water quality is also poor due to its salty taste, presence of sediments and colour. The majority of households have henceforth embarked on coping strategies such as buying bottled water. On average, households spend about P71 per month as avoidance cost. A contingent valuation method assessment was carried out and it was found that the mean maximum household's willingness to pay for a water quality improvement fund was P55 per month. Chemical analysis carried out on water samples from the study area confirm that the water has high electrical conductivity, sediments, colour, and iron and manganese levels.

Introduction

Water demand in Maun village has increased significantly over the years due to a number of factors including the growing population and commercialisation related mainly to tourism activities. While the demand for water has been increasing, the village also experiences an unreliable water supply (Geoflux, 2002). The unreliable supply of water has adverse effects on the provision of social services and development activities in general. For instance, social institutions such as hospitals and clinics are seriously affected as they require a regular and consistent supply of water (Geoflux, 2002).

Not only is Maun experiencing the problem of unreliable water supply, there is also a problem of poor water quality. One of the major water quality problems is high salinity, which tends to increase with the depth of the boreholes (Geoflux, 2002). Deep boreholes tend to have ample water supply but of poor quality. The Total Dissolved Solids (TDS) are sometimes higher than what is regarded as permissible. The maximum levels of TDS allowable by World Health Organization (WHO) standards are 1000mg/l. According to PLANTEC AFRICA (2003), one of the problems causing high concentrations of total dissolved solids is the low precipitation and the high evapotranspiration occurring in Maun and Ngamiland as a whole. High rainfall reduces the concentration of total dissolved solids through groundwater recharge, which freshens groundwater resources in the aquifers.

The problems of unreliable water supply and water quality may be addressed by the application of economic valuation techniques. This study utilizes contingent valuation to assess the willingness of households to pay for improved water supply and quality in Maun in order to determine the potential for raising funds for improving access to water of good quality. The study also uses chemical analysis to determine water qaulity in Maun. The specific research objectives of the study are as follows: 1. to determine household perceptions of the problem of

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water quality and supply in Chobe suburb; 2. to determine the household willingness to pay (WTP) for improved water supply and water quality; 3. to determine the coping mechanisms that households have adopted to mitigate the problem of unreliable water supply and poor water quality; and 4. to determine the actual water quality by analysing the water for electrical conductivity, turbidity, suspended solids, and iron and manganese content.

Valuation Methods and Contingent Valuation

The Contingent Valuation Method (CVM) is a direct valuation technique employed to determine information about the value of environmental goods and services from respondents in a survey (Georgiou *et al*, 1997). Valuation approaches are broadly categorised by Dixon *et al* (1994) into two categories of objective valuation approaches and subjective valuation approaches. Objective valuation approaches include approaches such as change in productivity, cost of illness, human capital and replacement cost. Subjective valuation approaches include approaches such as preventative expenditure, hedonic approaches, wage differential and contingent valuation method. The latter, more relevant to the topic under discussion, are subjective, assessing the WTP on the basis of revealed behaviour (using real markets), and also on the basis of expressed behaviour (using hypothetical markets). However, the contingent valuation method is based on expressed behaviour, and utilizes the WTP and willingness to accept (WTA) questionnaire surveys to obtain information about the value of environmental goods and services. The WTP surveys ask households to state the maximum amount of money they are willing to pay in order to achieve an environmental improvement, whereas WTA surveys ask households to state the amount of money they are willing to accept in order to tolerate an environmental deterioration (Hoevengel, 1994).

Put slightly differently, the WTP is the basis for measuring people's preferences when given choices between goods and services, while the WTA reflects how much people are willing to accept in the way of compensation to keep up with a particular loss (Pearce and Turner, 1990). There are three basic components in a CVM survey: 1. a hypothetical scenario in which a description of an environmental good or service to be offered is made before questions about the WTP are asked (Whittington, 2004); 2. a series of questions about the value that people would place on the good or service based on the hypothetical scenario described; and 3. the collecting of information on the respondents' socio-economic and demographic characteristics.

Information on WTP surveys can be obtained by the following environmental elicitation methods: bidding games, close-ended referendum questions, and a payment card. Bidding games are of two types - single-bid games (open-ended questions) and interactive-bid games (Dixon *et al*, 1994; Abu Madi *et al*, 2003). In the former, a respondent is asked to state the amount he/she is willing to pay. In the latter, the interviewer starts by suggesting a certain sum to the interviewee, who may respond by either agreeing or disagreeing. If the respondent disagrees, the amount is increased and the respondent is asked again about his/her WTP. The process is continued until the agreement about the WTP is reached. The last bid is known as the Maximum WTP. In the closed-ended referendum approach, a respondent is asked to state whether he/she is willing to pay for a certain environmental good if it costs a certain amount (Tietenberg, 2000). The closed-ended referendum is also called a dichotomous or discrete approach. It is thought that this approach is mostly preferable because it reduces interviewee behavioural response bias (Perman *et al*, 2003). In the payment card method, respondents are shown a range of values to choose from (Hanley and Splash, 1993; Hoevenagel, 1994).

There are three common methods of survey responses in contingent valuation studies:

face to face, mail and telephone surveys (Perman *et al*, 2003). Face to face interviews give a higher rate of response but are costly; the mail surveys are cheaper but give low rates of responses and tend to restrict the amount of information that can be provided. Finally, telephone surveys are cheaper but also restrict the amount of information given to respondents. For instance, there is no opportunity to show the respondents the graphics describing the hypothetical situation.

The merit of CVM is that it is the only method which can be used universally to determine the value of non-marketed environmental goods and services (Perman *et al*, 2003). Other methods used for valuing environmental goods and services cannot be used to determine 'option' and 'existence' values. The former refers to the willingness of respondents to pay for environmental goods and services in order to conserve the environment for future generations, whereas the latter is the value which is associated with the existence of environmental goods and services, and is a value unrelated to either current use or optional value (Pearce, 1993; Pearce and Turner, 1990). CVM also has the advantage over indirect valuation methods in that it is consistent with the underlying economic theory as explained in the technical terms of 'compensating variation' and 'equivalent variation' (Perman *et al*, 2003).

Finally, CVM is suitable for the valuation of water resources in the study area because it is the only valuation method based on expressed behaviour. People express their behaviour as they consider the sacrifice of some of their limited income to secure a good which is offered to them against alternative uses of that income (Day and Mourato, 1998). Other valuation methods are based on revealed behaviour, and cannot therefore elicit the WTP for improved water quality and reliability of supply. In this study CVM is used as a form of market survey, as it assesses the possibility of increasing water tariffs or the raising of funds for the development of water infrastructure.

The disadvantages of CVM are that it is associated with a number of biases. There are four main biases: the starting point bias, strategic bias, information bias, and finally hypothetical bias (Hanley and Splash, 1993; Georgiou *et al*, 1997; Pearce and Turner, 1990). The starting point bias arises when a wrong starting point is selected by the interviewer so that the respondent readily agrees with a bid suggested. A solution to the starting point bias may be the use of the payment card method, as the values presented on the card represents typical expenditure by respondents in a given income group on other publicly provided services (Hanley and Spash, 1993; Georgiou *et al*, 1997; Hoevenagel 1994). Strategic bias arises when respondents do not reveal their true WTP because environmental goods are non-excludable (free-riding) (Hanley and Splash, 1993), and hence, respondents believe that their valuation will not affect the provision of goods and service as others will pay for them. Hoehn and Randall (1987) cited in Hanley and Splash (1993) found that strategic bias may be reduced by the use of the close-ended referendum valuation approach. Information bias may result from the failure of the respondent to have sufficient information or experience about the type of environmental good or service being valued. Finally, hypothetical bias may arise simply because the WTP valuations are hypothetical in nature, and not based on actual market values (Markandya, 1992). However, all the biases may be reduced to acceptable levels through suitably designed surveys (Tietenberg, 2000; Perman *et al*, 2003; Kahn, 1997).

Study Area

This study was conducted in the village of Maun in Botswana. Maun is located in the North-West District, approximately 950 km from Gaborone, the capital city of Botswana. The national census of 2001 estimated the population of Maun village to be 43,776. Being the major village in the North West District and district headquarters, Maun is the centre of economic activities in the district. It is also a focal point for tourism, and a business centre for local craft industries such as basketry, skins and Basarwa crafts. Major economic activities in Maun include tourism, livestock farming, handicrafts, and small- to medium-scale industries. Arable agriculture is practiced in most of the settlements though it is constrained by poor soils (PLANTEC AFRICA, 2003).

The main source of water supply in Maun is groundwater, which is sometimes augmented by surface water from the Thamalakane River (Ministry of Local Government, Lands and Housing, 1997). Groundwater is supplied from two well-fields – the Thamalakane and the Shashe. The Thamalakane well-field is situated on the western outskirts of Maun, on the west bank of the Thamalakane River, while the Shashe well-field is situated to the north of the Thamalakane well-field. The Shashe well-field is a dry riverbed coming from the Delta with deep sand storage. The well-field is supplied by an alluvium aquifer which depends on high rainfall and the natural flooding recharge of Shashe River. The alluvium aquifer has a storage capability of 7.2 Mm^3 (Ministry of Local Government, Lands and Housing, 1997). Currently, groundwater is supplied from four electrically powered and 19 diesel powered boreholes (Department of Water Affairs, 2004), with borehole depths ranging from 20 to 60 metres (Ministry of Local Government, Lands and Housing, 1997).

The Department of Water Affairs in the Ministry of Mineral, Energy and Water Affairs is responsible for the supply of water to major urban villages such as Maun as well as medium and small villages, while the supply of water to urban centres is the responsibility of the Water Utilities Corporation. The Department's overall responsibility involves water planning, policy making, protection and development of the country. The pricing policy of water in Botswana is based on principles of equity, efficiency and affordability. Water tariffs are structured in such a way that they would achieve cost recovery and access to water resources. In urban and medium villages, the average charge for the 0-5 m^3, 6-20 m^3, 21-40 m^3 and above 40 m^3 water consumption bands are P0.9/m^3, P2.3/m^3, P4.75/m^3 and P5.5m^3, respectively (Department of Water Affairs, 2003).

Methodology

Sampling procedure

The sampling of households was conducted in the Chobe suburb in Maun. Chobe is a high income area, as it has a high concentration of employed persons. Most of the residents of Chobe are employees of the government. The residents of Chobe are also relatively more educated than residents in other areas of Maun, and on this basis it was thought that the CVM would more likely be understood here than in other areas. Research undertaken in other countries, especially in Africa, shows that CVM is understood better by more literate people (Turpie *et al*, 1999). The list of households in Chobe constituted a sampling frame of 310 households. Of the total number of households in Chobe, 92 or 30% of them were selected using systematic random sampling. Selected households that were later found to be vacant were replaced by the next household in the sampling frame. In order to compare the actual water quality with respondents' responses on water quality, ten water samples were collected from taps in Chobe using plastic bottles in February and March 2005. Purposive sampling was conducted in which samples were collected when it was though that the water had at least one of four characteristics, i.e. clear, salty, coloured, or sediments.

Data collection and analysis

The data collection methods included face-to-face interviews with the respondents using open-ended questions. The face-to-face interviews were conducted with the heads of the households. Respondents were asked to think of a hypothetical situation in which they would contribute to two funds for improving the reliability of water supply and water quality. The funds would be used to cover some of the capital costs of the improvement of water quality and supply by the Department of Water Affairs. If the households were willing to contribute to these funds, they were asked to state how much they would contribute monthly for a specified period. In addition, informal interviews were held with water authorities in the Department of Water Affairs. The purpose of these informal interviews was to collect additional information on the problem of water quality and supply in Maun.

The data from household interviews was analysed using the Statistical Package for Social Scientists (SPSS) and was summarised in the form of frequency distributions, statistical measures of central tendency, bar charts and tables. The collected water samples were analysed for electrical conductivity using a Hach Sension 7 conductivity metre in order to determine the presence of salt in the water. Suspended solids were measured by a gravimetric method in order to determine the presence of sediments in the water. Turbidity, as a measure of the water clarity, was determined using a Hach turbidity meter model 2100AN. The presence of calcium and magnesium was determined using a flame atomic absorption spectrophotometer (Spectr AA model 220), in order to assess water hardness. The presence of iron and manganese was also determined using the same instrument in order to assess the staining potential of the water. Both dissolved and acid-extractable metals were determined. In all cases, standard methods of analysis were followed (Clesceri *et al*, 1998).

Results and Discussion

Water supply

Most of the respondents (89%) reported that water supply in Maun was unreliable and unpredictable. A large proportion of them (74%) reported that they experienced water shortages all year round, while a few (19%) experienced an irregular supply problem during the season. The causes of unreliability and unpredictability of the water supply include the frequent breakdown of borehole engines, old equipment and machinery used for the reticulation of water, pipe bursts and power cut-offs (Bombo, 2005). These adversely affects the reliability of the water supply. According to the Department of Water Affairs (2004), between January and October 2004, there were a total 249 breakdowns with a total repair cost of P329,540 (1 BWP = 0.1834 US$). Figure 1 shows the cumulative number of breakdowns and their associated expenditure during that period. The cumulative number of breakdowns rose from 37 in January to of 249 in October, while the associated cumulative expenditure rose from P268,985 in January to P329,540 in October.

Households revealed that they adopted the following strategies to compensate for the unreliable supply of water, 1. travelled to other places in search of water (35%), 2. stored water in containers (53%), and 3. asked for water from people with overhead water storage tanks (12%). Clearly, these strategies have indirect costs. These are often referred to as avoidance costs.

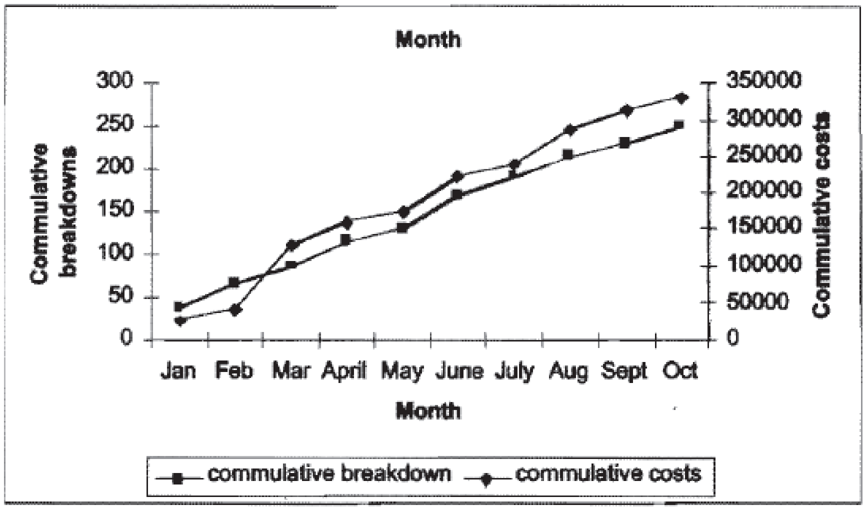

Figure 1. Cumulative breakdowns and costs between January and October 2004.

Willingness to pay for improvement in the reliability of water supply

When asked whether they would contribute to a fund which would ultimately address the problems that cause the unreliability of water, 84% of the households said they supported such a fund. The remaining 16% of the households did not support the introduction of such a fund because they regarded such a service as an entitlement that should be provided by the government. According to Hoevenegel (1994), this is a common response by households in most CVM surveys worldwide. The average maximum WTP for the improved reliability of the supply of water was P77 per month and its coefficient of variation was 45%, revealing a substantial variation from the mean. This shows that there was a high variation in the stated figures for WTP. Though CVM is associated with a number of biases, we think that most of these were avoided in the study. The starting point bias was avoided since the WTP questions were open-ended. In addition, information bias could not have arisen because the interviewed households had sufficient knowledge about the water problem. However, one could not rule out strategic bias as it is associated with open-ended questions. The households could have not revealed their true WTP since they are aware that water provision is the responsibility of government. However, by having experienced the problem of unreliable water supply for a very long time, it is assumed that the respondents have revealed their true WTP because they wanted the problem to be solved and not recur.

Water Quality

Regarding water quality, 95% of the respondents thought that it was poor. The sample respondents reported unusual taste and discolouration of water from boreholes. The water was also reported to have residual sediments, while other households complained about water staining the surfaces of their bathtubs. Figure 2 shows the percentage number of households reporting these different undesirable water quality characteristics. In addition of household perceptions of water quality, laboratory analysis of water samples was conducted. Table 1 shows the results of the analysis of the water samples set against the Botswana Bureau of Standards water specifications (Botswana Bureau of Standards, 2000). Only the parameters that the respondents complained about were tested for, i.e. saltiness, discolouration, sediments and staining. Calcium and magnesium were also included to check for water hardness.

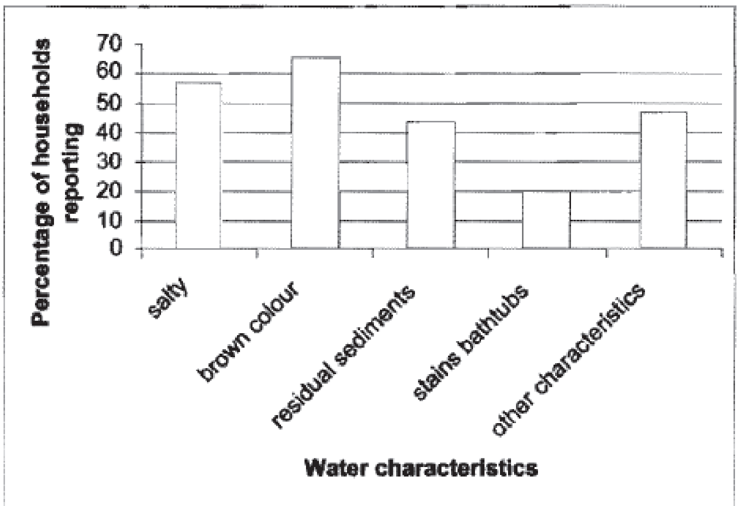

Figure 2. Percentage number of households reporting undesirable water quality characteristics.

The appearance of the water varied from clear to brown/yellow, with the presence of sediments in some samples. The electrical conductivity, a measure of a solution to carry an electrical current, was used in order to determine the 'saltiness' of the water. The results give a range for conductivity of 270 to 2510 µS/cm. For some samples, the electrical conductivity was within the ideal range (<700 µS/cm) of the Botswana Drinking Water Specifications. However, there were samples that approached the maximum allowed electrical conductivity of 3100 µS/cm. The water with the highest electrical conductivity (2510 µS/cm) would taste salty.

Turbidity in water is caused by suspended and colloidal matter. The turbidity values ranged from 1.9 to 114 NTU, with all the samples above the ideal Botswana specification of 0.2 NTU. In all, 40% of the samples had turbidity above the maximum allowed value of 10 NTU.

Table 1. Some water puality parameters of water samples from Chobe.

Parameter	**Concentration in mg/l unless otherwise stated**		
	Mean ± standard deviation	**Range**	**Botswana Standard***
Electrical conductivity (µS/cm)	712 ±837	270-2510	1500 (3100)
Turbidity (NTU)	28.4±34.5	1.9-114	5 (10)
Total suspended solids	111±148	3.6-392	None
Dissolved iron	<0.01	<0.01	0.3 (2)
Acid-extractable iron	1.53±1.67	0.19-4.76	0.3 (2)
Dissolved manganese	0.017±0.013	<0.01– 0.03	0.1 (0.5)
Acid-extractable manganese	0.33±0.45	0.111-7.88	0.1 (0.5)
Dissolved calcium	11.8±1.63	3.54-14.1	150 (200)
Acid-extractable calcium	17.81±24.67	9.9-80.77	150 (200)
Dissolved magnesium	16.01±2.37	0.76-19.7	70 (100)
Acid-extractable magnesium	4.11±7.80	12.30-40	70 (100)

*Acceptable value and maximum allowable in brackets.

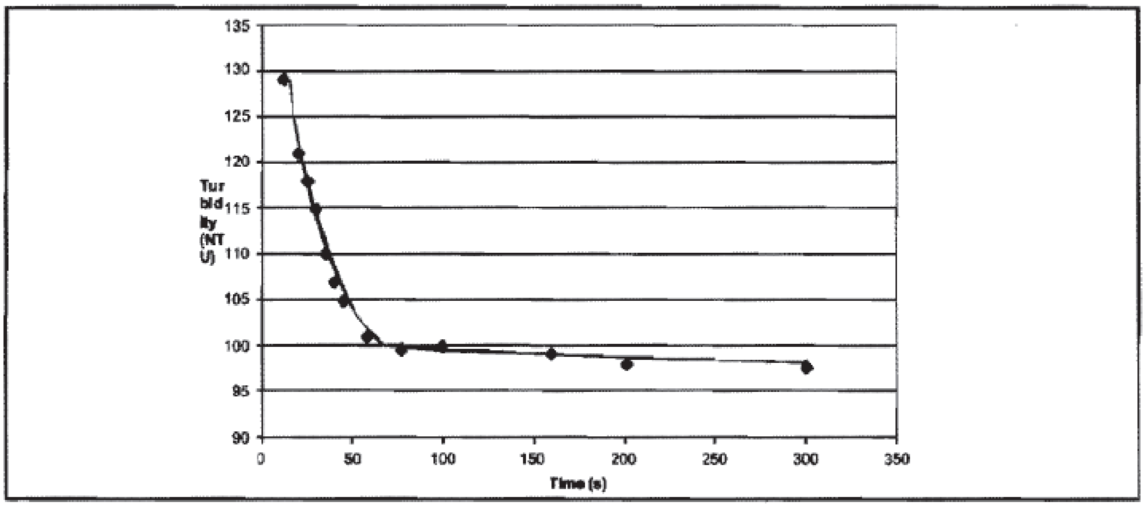

Figure 3. Variation of turbidity with time.

The turbidity of one of the samples was followed over a period of five minutes and there was a significant decrease in the turbidity during the first minute, indicating that some of the turbidity arose from solids which could settle down (Figure 3). This agrees with people's complaints about the presence of sediments in the water, and that in some cases they allow the water to stand in order to improve its quality.

The determination of turbidity was complemented by the determination of suspended solids in the water samples. The suspended solids ranged from 3.6 mg/l to 392.4 mg/l. Although there are no guidelines for suspended solids, it is expected that drinking water would have virtually no suspended solids as the water with sediments is usually filtered before distribution.

The presence of iron and manganese was analysed for in order to determine the staining potential of the water, while calcium and magnesium were determined in order to check how readily soap will sud. The concentrations of dissolved iron and manganese were generally found to be low, but were much higher in the digested samples. The Botswana drinking water standard has maximum allowable concentrations for iron and manganese of 2 mg/l and 0.5 mg/l respectively, and yet the highest concentration of acid extractable iron was 4.76 mg/l. The highest concentration of acid-extractable manganese was 7.88 mg/l. The release of some of the acid-extractable iron and manganese could cause staining of clothes and bathtubs.

Calcium and magnesium are responsible for water hardness as well as solid deposition on heated surfaces. Analysis for these ions showed dissolved calcium concentrations in the range of 3.54 to 24.67mg/l and dissolved magnesium concentrations in the range 0.76 to 19.7 mg/l respectively, with up to 80 mg/l for calcium in digested samples. The maximum concentration of magnesium in digested samples was 40 mg/l. In all cases, the concentration of calcium and magnesium were acceptable based on the Botswana drinking water standard.

Because the quality of the water from the piped distribution system was widely perceived to be poor, the majority of the households (71%) embarked on coping strategies (avoidance expenditures) in order to make the water user-friendly. According to Dupont (2005), people make expenditure choices to maximize their well-being when faced with increased health risks associated with poor quality drinking water. These strategies include among others filtering or boiling water and buying good quality water. The percentage number of households using different strategies to counteract the effects of poor water quality is shown in Figure 4. On average, households spent P71 in avoidance costs per month.

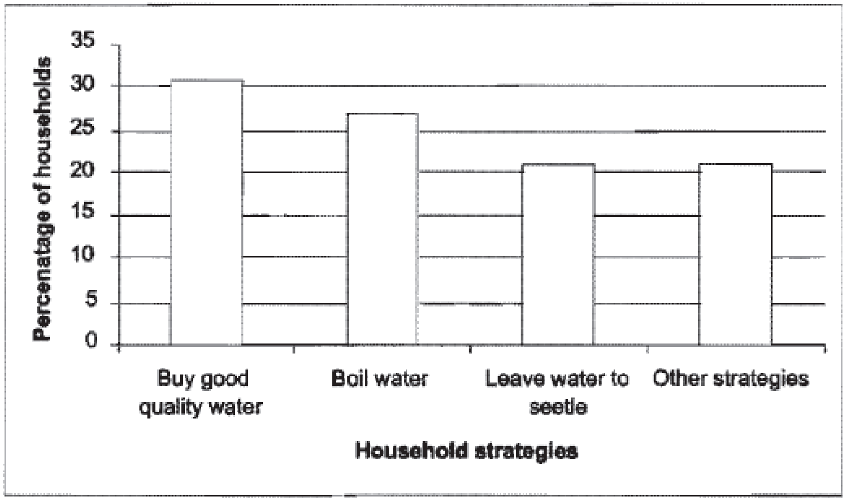

Figure 4. Household coping strategies for poor water quality.

Willingness to pay for Improved Water Quality

People are already paying much more than their water bills through unofficial channels and coping strategies, and they would be willing to contribute to a water quality improvement fund to secure better services. Most of the households (78%) confirmed that there was a need for improved water quality because they believed that the problem of poor water quality was a health risk. The mean maximum amount they were willing to contribute to a water quality improvement fund was P55 per month, with a coefficient variation of 44%. This figure is significantly less than the WTP for the improved reliability of water supply of P77, suggesting that households could be more concerned about the reliability of supply as compared to improved water quality. This makes sense because it is probably better to have water of poor quality than to have no water at all during other periods. Poor quality water could be improved by boiling and could also be put to general household uses, such as flushing toilets and cleaning houses. As with the WTP for unreliable water supply, we think that the reasons given for reducing the strategic, information and hypothetical biases equally apply in the stated mean WTP for improvement in water quality. By contributing P55 to the fund, households would reduce their avoidance costs as well as the health risks associated with drinking poor quality water. Thus, if a fund aimed at improving water quality could be introduced, the government could expect to raise this amount, on average, from each of the households.

The results of the WTP for improvement in water supply and water quality should be considered indicative as they were derived from a small sample. A broader study involving a larger sample, which would enable the use of methods such as regression analysis, should be undertaken in the future in order to influence water pricing policy. This is especially important given the fact that water is a grossly under-valued natural resource in Botswana.

Conclusion

The study has revealed that Maun residents are willing to pay extra money for the improvement of the quality and reliability of water supply. Their WTP for improved water supply was more than that for improved water quality, probably because it is felt to be better to have water of poor quality rather than to have a very unreliable supply of water. The findings also suggest that if such funds could be tapped, they could be used for the improvement of water supply and quality, and hence lead to an improvement in the welfare of the people. Improvement in the reliability of water supply would also allow households to avoid the inconvenience of travelling to other places in search of better water. The results of water quality analysis are in agreement with people's perceptions about the poor quality of the water in Chobe suburb. For instance, electrical conductivity, turbidity, and concentrations of iron and manganese from some water samples were above acceptable levels, confirming the perceptions of households that the water was salty, had sediments, and also stained bath tubs. An improvement in water quality would reduce the cost of coping strategies such as buying good quality water and filtering the water.

This study has also shown that the WTP surveys can provide information that can help in the technical planning and investment decisions for pricing policies. For instance, while the provision of water services in rural areas is the responsibility of the government, people can also contribute to improvements in the provision of water services. By implication, they will be contributing to the improvements of their welfare by sharing the costs of water provision services with the government. The government should therefore explore the possibility of undertaking WTP surveys country-wide in order to assess whether they can give guidance on the possibilities of fund-raising and the formulation of water tariffs.

There is a need for a comprehensive study on WTP for improved water quality and supply in Maun and other parts of Botswana. The findings from such studies should be more widely disseminated in order to inform the policy debate, including guidance on the formulation of water tariffs. The study should have a larger sample size and should try to test the relationship between WTP and economic/demographic variables using regression analysis. This technique was not used in this study to analyse the data due to the smallness of the sample.

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