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ARE RURAL RESIDENTS WILLING TO PAY ENOUGH TO IMPROVE DRINKING WATER QUALITY?[1]

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ABSTRACT: The concentrations of iron and sulfate in community water supplies are a concern for a number of areas in southwestern Minnesota. This study used the contingent valuation method to determine how much consumers would be willing to pay to improve their drinking water quality. On average, individuals were willing to pay US$5.25 per month (in 1995 U.S. dollars) to reduce the level of iron and US$4.33 per month to reduce the level of sulfate in their water to the USEPA's secondary standards for drinking water quality. Respondents with negative perceptions of their drinking water quality were willing to pay more to improve water quality. The aggregate annual willingness to pay (WTP) for all consumers in community water systems in southwestern Minnesota that were out of compliance with water quality standards were estimated to be US$2.4 million and US$2.0 million (in 1995 dollars) for reducing the levels of iron and sulfate, respectively. Yet the total WTP of consumers who use small community water systems may not be enough to pay the full cost of providing improved water in those systems. Economies of scale in water treatment and difficulties in financing improvements mean that technical innovation, government assistance, or institutional changes may be needed to improve water quality in these areas.
(KEY TERMS: water policy; regulation; decision making; drinking water quality; economic valuation; sulfate; iron; rural communities.)

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INTRODUCTION

Public water systems serve about 90 percent of the U.S. population, and the remaining 10 percent are supplied by private water systems (USEPA, 2004a). Ground water is a major source of water for public water systems and provides drinking water for almost 34 percent of the U.S. population (USEPA, 2004b). In Minnesota, 98.7 percent of public water supply systems rely on ground water (USEPA, 2004b). Overall, 70 percent of Minnesotans rely on ground water for their source of drinking water (GWPC, 1999).

The Minnesota Department of Health (MDH) has been regulating water quality and monitoring contaminants in public water systems since the state implemented the Federal Safe Drinking Water Act of 1977. According to a recent study by the MDH, water from public water supply systems meets or exceeds standards for safe drinking water with respect to levels of pesticides and industrial contaminants, bacterial contamination, nitrate, inorganic chemicals, radioactive elements, disinfection byproducts, lead, and copper (MDH, 2004).

However, there are a number of water quality attributes that do not affect the safety of drinking water but that nevertheless affect consumers. For example, although highly mineralized or "hard" water does not affect human health, it is considered a nuisance water problem because it interferes with cleaning tasks and adversely affects plumbing. Another concern in drinking water is its aesthetic quality, including taste, color, and odor characteristics. Iron-rich water causes no adverse health effects but may impart an unpleasant taste and produce a black or brown color in water. High concentrations of sulfates

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can cause gastrointestinal problems in humans and animals and enhance copper corrosion. Sulfate can also give water a rotten egg odor or a salty flavor. Since there are no direct public health concerns related to aesthetic qualities, they are not regulated in the United States. However, the U.S. Environmental Protection Agency (USEPA) has set secondary standards that, though not enforced, serve as a guide showing levels that may be objectionable to some individuals. Such undesirable aesthetic qualities cause consumers to reject tap water for drinking purposes and buy bottled water or products to purify tap water instead. This is costly: in 1999 the Natural Resources Defense Council (NRDC) reported that consumers pay 240 to 1,000 times more per gallon for bottled water than for tap water because of perceived differences in purity and safety (NRDC, 1999).

The concentrations of iron and sulfate in water are major concerns in Minnesota, particularly in southwestern Minnesota. Analysis of primary data from the MDH showed that more than 40 percent of community systems in the 11 counties of southwestern Minnesota exceeded the USEPA's aesthetic quality standard (secondary maximum contamination levels, SMCL) for sulfate of 500 mg/l. Most systems (60.8 percent) had iron concentrations exceeding the SMCL for iron of 300 µg/l. These findings motivated the current study of willingness to pay for improvements in iron and sulfate levels in community water systems in southwestern Minnesota. The focus is on community water systems – the subset of public water systems that serve households rather than schools, restaurants, gas stations, etc. – because the aesthetics of household tap water would be of more concern than the quality of water from other public water systems such as restaurants. Further, community water systems could most naturally be the subject of a contingent valuation study of households.

In order to evaluate whether to invest in improving drinking water quality, decision makers need to have better estimates of the benefits to consumers. Currently, it is not clear whether consumers are willing to pay for improvements in community water systems and, if so, how much they are willing to pay. This research explores people's perceptions of drinking water quality and their support for policies that improve drinking water quality. The three research objectives are: (1) to assess consumers' perceptions of their current tap water quality and determine if consumers are concerned about the quality of the water supply; (2) to estimate consumers' average and aggregate willingness to pay to reduce the current levels of iron and sulfate to the SMCLs; and (3) to compare the costs and benefits of water quality improvements in different sized communities and suggest government policies that can improve drinking water quality.

METHODOLOGY

The contingent valuation methodology (CVM) is employed to evaluate consumers' willingness to pay for improved water quality. Conceptually, this measures compensating surplus (CS), which is the amount of money an individual gives up that makes him or her indifferent between having the original lower quality level (with their old income) and having the new higher quality level (with an income reduced by the amount of money given up).

Suppose an individual's preferences are represented by a utility function of the form $U = U(X, Z, \mathbf{Q})$, where X is the quantity of water, Z is a composite of all other market goods, and Q is a rationed quantity of water quality attributes. Assume that the individual takes $\mathbf{Q}$ as given and does not have to pay a price for this "imposed" quality, and $S^0 = (P_x^0, P_z^0, \mathbf{Q^0})$ denotes the initial state of the economy facing the individual. Then the minimum expenditure that the individual needs to obtain a utility level, u^0, in the state of the economy, S^0, is defined as the solution to the budget minimizing problem

$$E\left(P_x^0, P_z^0, \mathbf{Q^0}, u^0\right) = \text{Min}\left\{P_x^0 X + P_z^0 Z \mid U(X, Z, \mathbf{Q}) = u^0\right\}, \tag{1}$$

where P_x is the price of X and P_z is the price of Z. The expenditure function is increasing in $\mathbf{P} = \mathbf{P}(P_x, P_z)$ and u (i.e., $E_P(P_x,P_z,\mathbf{Q},u) > 0$ and $E_u(P_x,P_z,\mathbf{Q},u) > 0$), and decreasing in $\mathbf{Q}$ (i.e., $E_Q(P_x,P_z,\mathbf{Q},u) < 0$).

Suppose that water quality ($\mathbf{Q}$) is improved from $\mathbf{Q^0}$ to $\mathbf{Q^1}$, but the prices of X and Z remain constant. The state of the economy is therefore changed from S^0 to $S^1 = (P_x^0, P_z^0, \mathbf{Q^1})$. Then the minimum expenditure that the individual must spend to achieve an utility level, u^0, at the new state of the economy, S^1, is $E(P_x^0, P_z^0, \mathbf{Q^1}, u^0)$. Since $E_Q(P_x,P_z,\mathbf{Q},u) < 0$ by the assumption, $E(P_x^0, P_z^0, \mathbf{Q^1}, u^0) < E(P_x^0, P_z^0, \mathbf{Q^0}, u^0)$. Thus, the individual's welfare change resulting from a change in Q can be measured in absolute value terms as

$$CS = \left| E\left(P_x^0, P_z^0, \mathbf{Q^0}, u^0\right) - E\left(P_x^0, P_z^0, \mathbf{Q^1}, u^0\right) \right| \tag{2}$$

which is the Hicksian compensating surplus (CS) measure. The measure CS is often interpreted as the maximum amount that the individual would be willing to pay for the opportunity to consume in the new state of the economy. In this case, compensating surplus is interpreted as the individual's WTP for an improvement of water quality, $\mathbf{Q}$ (Bergstrom, 1990).

A number of methods can be used to value the benefits of drinking water quality improvements, but for this study it was appropriate to use the contingent valuation method. Using CVM, the benefits of improved water quality are equal to the maximum amount of money that a person is willing to pay for the new good in a hypothetical situation. This method has a number of advantages in that there is no need to measure the cost of a substitute product (e.g., bottled water or a water treatment device) or to determine to what extent the substitute product is purchased to specifically avoid sulfate and iron. Problems associated with attaching a value to a consumer's time are also avoided. In addition, estimates with CVM are a direct measure of the theoretically desirable quantity rather than the approximation obtained with other methods. The main potential disadvantage to using CVM is the potential for bias stemming from incentives to misrepresent responses (i.e., strategic bias), implied value cues (i.e., starting point bias), misspecification of the hypothetical market scenario, and improper sampling and aggregation (Mitchell and Carson, 1989). Kahneman and Knetsch (1992), Hausman (1993), and Diamond and Hausman (1994) summarize the main criticisms. However, these biases can be minimized with careful survey design. The contingent valuation method was thus used in this study to estimate the economic values of drinking water quality improvements in southwestern Minnesota.

Three alternative techniques can be used in the CV method to elicit the WTP value: open-ended question, dichotomous choice question, and checklist. Each approach has its advantages and disadvantages. The open-ended question technique can cause a high nonresponse rate and a large number of implausibly high or low answers. While favored by the 1993 National Oceanic and Atmospheric Administration Blue Ribbon Panel on Contingent Valuation (as reported in Portney, 1994), the dichotomous choice approach requires a large sample size and a well specified empirical model to obtain statistical significance for the WTP estimate (Cameron and Huppert, 1989). Selecting the appropriate predetermined prices is also a difficult problem in this approach. Using the checklist (or payment card) also presents several difficulties. These are the decision concerning the proper range of values to use on the checklist (or payment card), anchoring effects, and the size of intervals displayed on the checklist (Cameron and Huppert, 1989). Cameron and Huppert (1989) argue that any payment card study can be influenced by the intervals chosen by the survey designer and by the estimation method employed in the data analysis. That is, the finer the intervals listed on the payment card, the more difficult it becomes for respondents to decide exactly which interval contains their actual WTP. While broader intervals make it easier for respondents to select the interval wherein their true WTP lies, there will be a loss of information for estimation purposes. However, regardless of the difficulties with the checklist method, there is substantial literature on the theoretical and empirical applications of the CVM using the checklist (Cocheba and Langford, 1978; Loehman and De, 1982; Boyle and Bishop, 1988; Cameron and Huppert, 1989; Halstead *et al.,* 1991; Jordan and Elnagheeb, 1993). Advantages to the checklist technique include the ease with which respondents can answer questions. This can reduce the number of nonresponses to WTP questions. In addition, the parameter estimates from the checklist approach are more efficient than their counterparts from other approaches (Jordan and Elnagheeb, 1994). Therefore, a mail survey with checklist question format approach was used for this study.

Mail surveys are frequently used in CV studies because of their relatively low cost and their potential for covering a wide geographic area. Mail surveys can also avoid biases stemming from the interviewer effect that may result from the respondent's positive or negative personal reactions to the interviewer. However, a common problem with mail surveys is sample nonresponse. Cochran (1977) referred to the term "nonresponse" as the failure to measure some of the units in the selected sample. Nonresponse bias occurs when there is an appreciable difference between the preferences of nonrespondents and those of respondents on whom estimates are based (Pearl and Fairley, 1985). In other words, the existence of nonrespondents does not necessarily mean that inference based on data from respondents will be biased, but that the collected data should be examined carefully to determine whether this potential bias is actually present. The best protection against nonresponse bias is to increase the response rate as much as possible. However, a 100 percent response rate is implausible in a mail survey. The main concern regarding the existence of nonresponse bias in CV studies is that aggregate estimates of WTP will be biased if the problem is not corrected.

As a previous study (Loomis, 1987) demonstrated, large differences in the aggregate WTP are associated with various approaches that are based on different assumptions for generalizing WTP estimates from a sample to the respective population: no adjustment, conservative zero bid, and weighted average approaches. The first approach (Pope and Jones, 1990) is to assume that there is no difference between the WTP of those who responded and the WTP of those who did not. The nonrespondents are assigned the mean estimated WTP from those who responded to the valuation question. Then, the mean WTP for the respondents and nonrespondents is attributed to the population. The second approach (Shultz and Lindsay,

1990) is an extremely conservative approach, assuming a zero WTP for those who did not respond.

Unlike the other two approaches, the weighted average method (Carson and Mitchell, 1984; Jordan and Elnagheeb, 1993) adjusts the data (e.g., average WTP) to account for differences in the distribution of the characteristics of the respondents and the target population, however they arise, by means of a statistical weighting procedure. The resulting weighted average WTP value is generalized to the entire population by multiplying this figure by the size of the target population. The weight for the ith stratum, W_i, is the ratio of the population proportion for the *ith* stratum (POP_i) divided by the sample proportion for the same stratum (SPL_i)

$$W_i = POP_i/SPL_i \quad (3)$$

This approach might be more appropriate for computing aggregate WTP than either of the other approaches in cases where nonresponse bias was detected. However, this method has problems such as the difficulty of obtaining the correct distribution of characteristics of the target population and the selection of appropriate weighting factors. Choices of different weighting factors will produce different values of the mean and aggregate WTP.

DATA

A two-step procedure was used to select the sample to be surveyed. First, communities were examined to determine if they should be included in the sample. Since the goods being valued were reductions in the levels of iron and sulfate from the current levels to the desired levels, communities that had levels of iron and sulfate lower than the standards were excluded from the target population. This resulted in the identification of 11 target communities that had levels of iron and sulfate above desired water quality standards. Then, 520 household names and address were randomly selected from a list of city water users or phone directories of these communities.

The mail questionnaire was sent in the summer of 1995 to this randomly selected sample of 520 residents from 11 communities who received their water from one of the community water supply systems in southwestern Minnesota. They were asked how they would rate their water supply and how much they would be willing to pay to reduce the current levels of iron and sulfate in their drinking water to meet government standards. The WTP response format was a closed-ended question with a checklist.

Survey questionnaires were mailed out in three successive mailings, closely following Dillman's (1978) recommendations for maximizing response rate. The initial mailing went out in July 1995. The second mailing, which included the same items as the first mailing, was sent two weeks after the original mailing to those who had not returned the questionnaire. The third mailing was sent two weeks after the second mailing to all individuals who still had not returned their surveys. The survey resulted in an overall response rate of 70 percent. It is possible to increase the response rate somewhat by more follow-up mailings or by conducting additional telephone and personal interviews; however, costs would increase dramatically. According to Mitchell and Carson's investigation (1989) of mail survey response rates for various contingent valuation studies, the response rate varied from 8 percent to 93 percent, but only 2 out of 16 studies (12.5 percent) had over a 70 percent response rate. Since the 70 percent overall response rate is very satisfactory compared to the response rate of previous studies using mail surveys, the survey was closed after the second follow-up mailing (third mailing overall).

RESULTS AND DISCUSSION

Characteristics of Respondents

Of the 520 surveys mailed, 368 were returned, yielding a response rate of 70.8 percent. Of these 368 returned questionnaires, 299 provided complete responses to the survey questions and were used for the data analysis. About 42.1 percent of the respondents were female and 57.9 percent were male. Thirty percent of respondents had children younger than 13 years old living in their homes. The average age of respondents was 53.6 years. More than 90 percent of the respondents' houses were built before 1985, while 44.8 percent were constructed between 1900 and 1945. The estimated average water bill was US$18.60 per month in 1995 dollars. More than 80 percent of the respondents had at least a high school education. The average annual total household income was US$30,384.

Respondents were also asked to rate the current tap water quality on a five-point scale, with 1 being "very poor" quality and 5 being "very good" based on taste, odor, and color. On average, water users rated the tap water quality at 3.04, 3.09, and 3.08 for taste, odor, and color, respectively. More than 40 percent of respondents found the taste (45.8 percent), odor (41.5 percent), and color (48.1 percent) of their water to be of “poor” or “very poor” quality. Almost 70 percent of respondents (68.9 percent) reported that their community’s overall water quality was fair or better, and on average water users rated the overall tap water quality at 3.07.

More than 60 percent of respondents used either bottled water or had home water treatment devices. Almost 40 percent of respondents (37.5 percent) purchased bottled water regularly, and about 42 percent of respondents used a water treatment device (including a filter or water softener). About 15 percent of respondents both purchased bottled water and used a water treatment device. The main reasons for purchasing bottled water or using a water treatment device were taste (50.5 percent) and health concerns (40.3 percent). Other reasons were to soften the water for washing and laundry and to make better coffee or fruit drinks.

Interestingly, consumers who did not use bottled water rated their tap water significantly better than those who did use bottled water based on taste (3.45 versus 2.36), odor (3.46 versus 2.48), color (3.46 versus 2.46), and overall water quality (3.45 versus 2.43). Ratings of those who did not use a home water treatment device were also higher than those who used a home water device, but the difference for overall water quality was not significant (3.16 versus 2.94). These results imply that users of either bottled water or home water treatment devices perceive that they have lower water quality and are willing to spend extra money to improve water quality. Furthermore, a higher portion of those who had a higher education or who had children living in the home purchased bottled water regularly or used a home water treatment device.

Table 1 compares the responses obtained in the surveys with demographic information, such as gender, household income, age, and education, collected for southwestern Minnesota during the 1990 Census. The hypotheses that there are no significant differences in demographic characteristics (e.g., gender, household income, and education) between survey respondents and the population are rejected at the 5 percent level of significance. The mail surveys had a higher proportion of male respondents than the general population, as reported in the census data. Also, the surveys consisted of a larger number of respondents who earned more than US$20,000 per year and who graduated from high school. However, for age distribution, there was no significant difference between the census data and the responses obtained in the surveys. These differences between respondent and population characteristics may result in bias in calculations of the average WTP and aggregate WTP. However, the bias may not be critical if the WTP amounts are not highly sensitive to these variables. If these variables did turn out to have a highly significant effect on WTP, the problems resulting from the differences could be addressed by means of the statistical weighting procedure discussed above.

Consumer Benefits

Based on the questions shown in the Appendix, about 60 percent of the respondents (60.2 percent for iron, 56.5 percent for sulfate) said that they would be willing to pay at least US$1.00 per month to improve water quality. The WTP responses ranged from

TABLE 1. Comparison of Demographic Characteristics Between Census and Survey Data.

	Census (1990)	Survey	χ^2-Value
GENDER			
Male	2,550 (47.9 percent)	173 (57.9 percent)	11.785
Female	2,769 (51.2 percent	126 (42.1 percent	
HOUSEHOLD INCOME			
Less than US$20,000/year	1,022 (47.5 percent)	94 (31.4 percent)	30.814
More than US$20,000/year	1,131 (52.5 percent)	205 (68.6 percent)	
AGE*			
Over 55 years	1,739 (48.9 percent)	129 (44.0 percent)	2.803
Below 55 years	1,816 (51.1 percent)	164 (56.0 percent)	
EDUCATION*			
High school graduate or higher	2,421 (68.1 percent	243 (82.9 percent)	26.708
Less than high school graduate	1,134 (31.9 percent	50 (17.1 percent)	

*Used only the data of persons at least 25 years old.
$\chi^2 \alpha = 0.05 = 3.841$ with 1 degree of freedom.

TABLE 2. The Distribution of WTP for Reducing Iron and Sulfate in Drinking Water.

WTP Interval (US$)	Iron Frequency	Iron Percentage	Sulfate Frequency	Sulfate Percentage
$0	119	39.8	130	43.5
$1 to $5	125	41.8	131	43.8
$6 to $10	34	11.4	24	8.0
$11 to $15	11	3.7	10	3.3
$16 to $20	7	2.3	3	1.0
$21 to $25	2	0.7	1	0.3
$26 to $30	1	0.3	0	0.0
Total	299	100.0	299	100.0

TABLE 3. Willingness to Pay for Improved Water Quality.

Item Category	Iron	Sulfate
Mean WTP (US$/Month, 1995 $)	$3.83	$3.00
95 Percent Confidence Interval (US$/Month, 1995 $)	$3.24 to $4.41	$2.52 to $3.48
Percent With Zero WTP	39.8%	43.5%
Mean WTP as Percent of Water Bill	20.6%	16.1%

US$0.00 to US$30.00 per month. About 90 percent of respondents' WTP was between US$0.00 and US$10.00 per month (Table 2). The survey results (Table 3) indicate that, on average, individuals are willing to pay US$3.83 and US$3.00 per month to reduce the levels of iron and sulfate in their water, respectively, levels that are between 21 percent and 16 percent of the estimated average monthly water bill.

Estimation of WTP Function

The structure of the model to be considered for this analysis is $WTP_i = X_i'\beta + e_i$. The ordinary least squares (OLS) method can be used to estimate the unknown parameters, β_{OLS}. However, if the WTP data are censored so that negative values appear as zero, then the ordinary least squares coefficient estimates would be less desirable (Maddala, 1983; Greene, 1991). The proper method for estimating unknown parameters from CV data that contain a large number of zero values for WTP is a censored Tobit model. The censored Tobit model is of the form:

$$WTP = \begin{cases} X_i'\beta + e_i & \text{if } WTPT_i > 0 \\ 0 & \text{if } WTPTi \leq 0 \end{cases} \quad (4)$$

The expected value of WTP_i is obtained from

$$E[WTP_i] = X_i'\beta_{tobit} \cdot \Phi(X_i'\beta_{tobit}/\sigma) + \sigma \cdot \phi(X_i'\beta_{tobit}/\sigma). \quad (5)$$

This study considered the following specific econometric model of the factors that influence the willingness-to-pay to obtain improved water quality

$$WTP = F\,(ACT1, ACT2, TASTE, ODOR, COLOR, GENDER, AGE, AGE2, EDUC, W\text{-}BILL, CHILD, INCOME) \quad (6)$$

Table 4 contains a short description of each variable and its expected sign. It is expected that the WTP of those purchasing bottled water (ACT1) or using a home water treatment device (ACT2) will be greater than that of their counterparts, and thus ACT1 and ACT2 are expected to be positively related to WTP. Respondents' perceptions of different quality characteristics (TASTE, ODOR, and COLOR) are expected to have a negative influence on the WTP. That is, as consumers perceive that their water is of higher quality, they will be less willing to pay for improved quality.

Hamilton (1985a) found that concern over water contamination in the communities was highest among younger respondents, women, and persons with children living at home. In another study of the public's attitude toward ground water protection in New Hampshire, Hamilton (1985b) found that respondents from more affluent households, younger and newer

TABLE 4. Explanatory Variables Included in the WTP Function.

Variable	Description	Mean	Standard Deviation
ACT1	1 if the respondent purchases bottled water, 0 otherwise	0.3746	0.4848
ACT 2	1 if the respondent uses water treatment device, 0 otherwise	0.4214	0.4946
TASTE	Perception of taste quality of tap water	3.0435	1,2074
ODOR*	Perception of odor quality of tap water	3.0936	1.1692
COLOR*	Perception of color quality of tap water	3.0870	1.2846
GENDER	Sex of respondent, 1 for Male and 0 for Female	0.5786	0.4946
CHILD	1 if there are children under 13 years old in household, 0 otherwise	0.2977	0.4580
EDUC	Categorical variable for education level of the respondent: 1: Eleventh grade or less 2: High school graduate 3: Completed technical school or some college 4: College graduate or more		
AGE	Age of respondent	53.591	18.595
AGE2	AGE squared	3,216.66	2,100.28
W-BILL	Average monthly water bill (US$/month)	18.603	10.137
INCOME	Annual household total income before tax. The reported intervals in US$ are: 1: $10,000 or less 2: $11,001 to $20,000 3: $20,001 to $30,000 4: $30,001 to $40,000 5: $40,001 to $50,000; 6: $50,001 to $60.000 7: $60,001 to $80,000 8: $80,001 to $99,999 9: $100,000 or more	3.3662	1.7766

*Rated on a 5-point scale, with 1 being "very poor" quality and 5 being "very good" quality.

residents, and women with children were more concerned about water pollution than their counterparts. Thus, the expected sign of CHILD is positive.

Education level (EDUC) is expected to be positively related to WTP. Since the level of education of the respondents may reflect a degree of awareness of the importance of quality of drinking water, it is expected that more highly educated people will be more concerned about drinking water quality and have a higher willingness to pay for improved water quality. Although the direction of the influence of a respondent's age on WTP is not clear, previous studies showed that age of the respondent may influence WTP positively. It is also arguable that the demand for better quality water would have a pattern, with greater demand in the middle-age years than during younger or older ages, since the former may be less willing to take risks. Thus, the expected sign of AGE is positive while the expected sign of AGE2 is negative. The monthly water bill (W-BILL) can be considered as the own-price of water and is expected to have a negative influence on the WTP. It is anticipated that an individual's WTP for better quality water will increase as his/her income (INCOME) increases, since water quality is a normal good.

Results of the Tobit analyses of factors that affect consumers' WTP for reducing the level of iron and sulfate in drinking water are presented in Table 5. With respect to iron, the factors having a significant effect at a 10 percent or lower significance level were ACT2 (use of a home water treatment device), COLOR (perception of water color quality), GENDER, EDUC (educational attainment), AGE, and AGE2 (age squared). The variables with a significant effect on WTP for reducing the level of sulfate were ACT2, COLOR, EDUC, and INCOME. The positive sign of estimated coefficients of ACT2 indicates that users with home water treatment device are more willing to pay to reduce the levels of iron and sulfate in their water supply system than consumers without these devices. The COLOR variable carries a negative and statistically significant coefficient for both iron and sulfate cases, which indicates consumers who perceived that their water was of poor quality in terms of color are

TABLE 5. Results of the Tobit Analysis of Factors Affecting WTP.

Variable	WTP for Reducing the Level of Iron		WTP for Reducing the Level of Sulfate	
	Coefficient	t-Ratio	Coefficient	t-Ratio
CONSTANT	-12.128	-2.347**	-6.644	-1.485
ACT1	0.519	0.508	0.418	0.461
ACT2	1.946	2.165**	1.272	1.606*
TASTE	0.682	1.248	0.356	0.741
ODOR	-0.481	-0.809	-0.279	-0.527
COLOR	-1.018	-2.046**	-0.776	-1.768*
GENDER	1.811	1.980**	0.549	0.684
CHILD	0.956	0.804	0.872	0.839
EDUC	1.709	3.074***	1.357	2.774***
AGE	0.316	1.859*	0.121	0.819
AGE2	-0.028	-1.890*	-0.011	-0.827
W-BILL	0.049	1.098	-0.002	-0.006
INCOME	0.335	1.206	0.643	2.639***
σ	6.908	17.634***	6.021	16.943***
Log-Likelihood	-688.814		-633.137	

*Denotes significance at the 10 percent level; **denotes significance at the 5 percent level; ***denotes significance at the 1 percent level.

more willing to pay for reductions in iron and sulfate. The estimated coefficients of EDUC are positive and very significant. The explanation for the positive effect of education may be that the knowledge acquired in the process of education increases consumers' interest and concerns about the drinking water quality. More educated individuals tend to be more aware of the necessity of solving the community problem and have higher willingness to support improvements. As expected, the estimated coefficients in the iron regression of AGE and AGE squared (AGE2) are significantly positive and negative, respectively. However, WTP is decreasing with age over the range of respondent ages. This implies that as age increases, consumers' WTP increases but at a decreasing rate. Men are more willing than women to pay for reduced iron levels, which may be due women's increased iron requirements. As expected, household income was shown to have positive and significant impacts on WTP for sulfate, which is in agreement with previous studies (Shultz and Lindsay, 1990; Halstead *et al.,* 1991; Jordan and Elnagheeb, 1993). For all variables except income, the coefficients are greater for the iron regression than for the sulfate regression, and income is not even significant in the iron regression.

Aggregate Willingness to Pay

Table 6 shows the annual mean WTPs and the aggregate WTPs under the three different approaches discussed in the "Methodology" section. An extremely conservative approach is to assume that nonrespondents have zero value for the good (Shultz and Lindsay, 1990), so this method represents a lower bound on aggregate values. The second approach is to assign the mean estimated WTP to nonrespondents. The third approach is a "weighted average" method, which is to adjust the WTP to account for differences in the distribution of the characteristics of the respondents and the target population. The education variable was used to construct the weights, because results of estimating valuation functions showed that the education variable had the most significant effect on WTP for both iron and sulfate and differed significantly between respondents and the target population. Thus, the level of education was used to adjust for the difference between the respondents and the population in calculating aggregate WTP for reducing the level of iron and sulfate. Table 1 showed overrepresentation of the high education group and underrepresentation of the low education group. The 1990 Census found that 68.1 percent of the population had graduated from high school, while this figure was 82.9 percent in the surveys. In the census, 31.9 percent of the population had not earned a high school diploma, while this figure was 17.1 percent for the surveys. To account for the difference, the sample observations were weighted by multiplying the high education group by $W_{high\_edu} = POP_{high\_edu}/SPL_{high\_edu} = 0.681/0.829 = 0.821$ and the low education group by $W_{low\_edu} = POP_{low\_edu}/SPL_{low\_edu} = 0.319/0.171 = 1.865$. The weighted aggregate WTP was then computed by multiplying the weighted average WTP by the size of the target population. Using the three approaches, annual per capita benefits from reducing sulfate ranged from US$25.49 to US$36.00 in 1995 dollars. Abatement of iron from the current levels to the desired levels would result in benefits of US$32.54 to US$45.96.

TABLE 6. Comparison of Approaches for Aggregating Survey Estimates.

Approaches	Annual Mean Per Capita Willingness to Pay (US$)	Aggregate Annual WTP (US$)
IRON (N = 42,081)*		
Conservative Estimate[1]	$32.54	$1,369,302
No Adjustment Estimate[2]	$45.96	$1,934,043
Weighted Estimate[3]	$42.22	$1,776,805
SULFATE (N = 42,545)*		
Conservative Estimate[1]	$25.49	$1,084,387
No Adjustment Estimate[2]	$36.00	$1,531,620
Weighted Estimate[3]	$35.13	$1,494,649

*The populations to be surveyed are households who obtain their water from a community water supply system in southwestern Minnesota that have levels of iron and sulfate above the secondary standard. The populations to be sampled were estimated to be 42,081 for iron and 42,545 for sulfate.

[1]Attached a zero WTP for nonrespondents.
[2]Assigned the mean estimated WTP to nonrespondents.
[3]Estimated values using a weighted average WTP based on education level.

The calculated aggregate WTP indicates the amount of money that community water users of southwestern Minnesota would be willing to pay annually for better quality water (i.e., the estimated aggregate benefits resulting from improved water quality). However, these figures differ appreciably when comparing across estimation methods due to the impact of differences in mean WTP (Table 6). As expected, the first approach ("conservative zero bid") produced much smaller aggregate WTP estimates. The estimated total annual benefits of reducing the levels of iron with this first approach range from US$1.4 million to US$1.9 million in 1995 dollars. Reducing sulfate to the recommended levels would result in estimated total annual benefits ranging from US$1.1 million to US$1.5 million.

Even using this conservative approach, the average annual WTPs are relatively large when compared to the per capita expenditure of Minnesota's 87 county governments in 2003 on sanitation (US$12), health (US$35), public safety (US$119), and human services (US$264), all in 1995 dollars (Office of the State Auditor, 2004). Compared to the average annual expenditure of the State of Minnesota for the drinking water program (US$4.2 million) and for monitoring and analytical work (US$2.8 million) in 1995, these aggregate WTP estimates indicate that community water users in southwestern Minnesota desire better quality water and are willing to pay for it.

Problems of Small Water Supply Systems

However, this study also found that residents in small communities may not be willing to pay enough to cover the full cost of providing improved water through the community water system. This is illustrated in Table 7, where the estimated average annual WTP is lower than the average household cost (US$99 in 1995 dollars) for water systems serving 500 or fewer consumers. Furthermore, the median willingness to pay may well be lower than the average willingness to pay (Hoehn and Krieger, 2000), suggesting that a majority of residents of small communities would be unwilling to accept a tax increase in the amount of the average WTP figure. This cost includes the monitoring and compliance cost for a ground water treatment system. If the capital and operating costs can be spread over a large number of customers, a central treatment system is cost effective. However, the average household cost of a central treatment system increases rapidly as community size decreases. The economies of scale make the construction, operation, and maintenance of a central treatment system difficult for small communities. Although the annual average WTP estimates of residents in small communities are not much different from those in relatively large communities (Table 8), the estimated total WTP of all water users in small communities is not enough to finance the installation and maintenance of a new treatment system. Almost 55 percent (53 of 97) of community water supply systems in southwestern Minnesota served less than 500 persons and are thus likely to have a problem financing these improvements. Statewide, 38 percent of small community water systems will have special problems financing improvements in water quality.

However, other water quality improvements may be implemented at the same time that would increase the value of the benefits. In addition, technical and institutional changes may make these improvements more affordable. Clark (1987) emphasized the role of economic principles (e.g., economies of scale) in order to cope with the financing difficulty in small water systems. The proper choice of technology or development of a cost effective treatment technology can minimize the unit cost and economies of scale problem in small water systems. For example, home water treatment devices are more cost-effective for 200 to 300 homes than central treatment for fluoride removal but become increasingly expensive as the population served increases. The USEPA is also considering decentralized approaches including home water treatment devices and bottled water to solve the problem of small systems.

TABLE 7. Annual Average WTP and Average Household Cost for Treatment Facility.

Size of System (No. of persons served)	Annual Average WTP (1995 US dollars)		Average Cost (1995 US dollars)
	Iron	Sulfate	
Less than 500	$45.60 ($36.84~$54.48)	$35.52 ($28.20 ~$42.72)	$99
500 to 1,000	$55.92 ($40.68~$71.16)	$42.84 ($30.84~$54.84)	$42
1,000 to 3,300	$29.76 $19.44~$40.20)	$27.72 ($17.04~$38.40)	$23

*Parenthesis indicates 95 percent confidence intervals.
Source of Cost Data: U.S. Congressional Budget Office, 1995.

TABLE 8. Results of Test for Differences in Preferences by Size of Water Supply System.

Characteristic	F-Statistic	p-Value
Iron	2.6361	0.0740
Sulfate	0.5558	0.5742

The null hypotheses of no differences were tested by means of one-way analysis of variance (ANOVA) and are not rejected at the 5 percent level of significance.

The problem of small water systems can also be mitigated by merging small utilities, thus achieving economies of scale. Sharing purchasing capability or facilities among a number of utilities will reduce the overall unit costs and provide better-quality water service. Another advantage of this strategy is that these new, larger bodies could better afford to hire the full time technical and financial expertise needed to manage system operations. One problem with this strategy is that any economies of scale in the treatment facility must be balanced against the increased costs associated with the distances involved in rural areas.

Besides the economies of scale problem, most small water systems have difficulty accessing credit markets, since this requires a strong financial base, a strong credit rating, and some financial expertise. The financing cost per dollar borrowed is also more expensive than it is for large systems because the fixed costs per dollar borrowed usually decline as the size of the loan increases.

To help small communities, government agencies can provide technical assistance and facilitate access to credit. More specifically, government agencies can help small water systems with training programs and help them make the appropriate choice of cost effective treatment technology that has low construction and operating costs, simple operation, low maintenance, and low operating labor requirements to minimize costs. Government policy can create the necessary institutional framework to encourage joint planning and project development as discussed above. Such water systems can also provide standardized financial disclosures and achieve financial stability, which will facilitate financing.

Another alternative would be for the communities to contract for private operation and maintenance of their water utilities, which can improve operations and reduce costs since private firms must be profitable. These private firms' purchasing power, technology, and experience can be consolidated and transferred to all of their projects. A 1997 survey of 261 U.S. cities found that 40 percent had some form of private-public partnership (Callahan, 2000). If communities contract with a private firm to design, build, and operate the public water system rather than separating the construction and management tasks as is typically done, it may result in a more integrated and better-performing facility. Siedenstat *et al.* (2000) report that estimated cost savings under such contracts are roughly 25 percent for construction and 20 to 40 percent for operations. Yet to successfully turn over operation and management of a public water system to a private firm, the public must be fully engaged. If the turnover is not done transparently and with pricing and service requirements included in the contract, monopoly pricing issues are likely to arise.

CONCLUSION

This study showed that users of community water systems in southwestern Minnesota were willing to pay up to 16 percent more on their water bills to reduce iron levels and up to 21 percent more to reduce sulfate. Planning for new water systems should explicitly recognize that consumers are willing to pay for improvements in water quality that go beyond primary water quality standards relating to health and safety. However, further research is needed to examine the willingness to pay for water quality improvements in other locations and for other attributes.

For small rural systems, however, aggregate willingness to pay may not be enough to cover the cost of improved facilities. For systems serving 500 or fewer people, costs per capita would be too high due to economies of scale in water treatment systems. In total, the shortfall for a community may not be large, but in times of tight budgets, it is likely to block improvements. Both institutional and technical solutions to this problem need to be developed if these small communities are to reach U.S. and international water quality standards that have become stricter over time. Targeted government policies and programs may be necessary.

APPENDIX
WTP QUESTIONS FOR IRON AND SULFATE

The WTP Question for Iron Was Stated as Follows

Sulfates occur commonly in Minnesota waters, with higher levels in the western part of the state. Ingestion of water containing high concentrations of sulfate can have a laxative effect, and may cause gastrointestinal problems, especially diarrhea, in people and animals. Sulfate also leaves hot tap water with a rotten egg odor and makes the water taste salty.

In 1993, the U.S. Environmental Protection Agency (EPA) established a standard level for sulfate in drinking water. This **standard level** is exceeded if the level of sulfate is greater than **500 milligrams per liter**. Monitoring results from the Minnesota Department of Health shows that your community water system has ____ milligrams per liter of sulfate.

Your community could install a new or improved treatment system that would <u>reduce sulfates from current levels to below standard level</u> (500 mg/l). But, since this would involve increased costs, it would be necessary to increase your water bill to support this treatment.

What is the **LARGEST monthly payment ABOVE** your current water bill that you would be willing to make for a new or improved treatment system that would reduce the level of sulfates to below the standard level in your drinking water? (Please circle ONE answer):

$0, $1, $2, $3, $4, $5, $6, $7, $8, $9, $10, $15, $20, $25, $30 or more <u>EACH MONTH</u>

The WTP Question for Sulfate Was Stated as Follows

Although iron is an essential element in human nutrition, iron in the water supply stains laundry and plumbing fixtures and has an unpleasant taste. Iron leaves an objectionable reddish-brown color in the water. The U.S. Environmental Protection Agency (EPA) has established a **standard level** for iron in drinking water. This standard level is exceeded if the level of iron is greater than **300 micrograms per liter**. Monitoring results from the Minnesota Department of Health shows that your community water system has ____ micrograms per liter of iron.

In order to <u>reduce the current level of iron to below standard level</u> (300 µg/l), your community could filter water in the public water system. But, since this would involve increased costs, it would be necessary to increase your water bill to support this treatment.

What is the **LARGEST monthly payment ABOVE** your current water bill that you would be willing to make for a new or improved treatment system that would remove objectionable taste and color resulting from iron in your drinking water? (Please circle ONE answer):

$0, $1, $2, $3, $4, $5, $6, $7, $8, $9, $10, $15, $20, $25, $30 or more <u>EACH MONTH</u>

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