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Estimating Willingness to Pay for Reduced Copper Contamination in Southwestern Minnesota

Hong J. Kim and Yongsung Cho

The contingent valuation method is applied to determine how much consumers would be willing to pay to reduce copper in their drinking water and what factors influence their willingness to pay (WTP). The annual mean WTP per household was estimated using survey data from nine counties in southwestern Minnesota where copper contamination is high. The annual mean WTP per household varied from a low range of $30.41 to $43.61 for Chippewa County to a high range of $39.79 to $57.06 for Nobles County. The aggregate WTP for all nine counties was estimated to range from $1.66 to $2.38 million. However, the estimated WTP may not be sufficient to pay the cost of providing improved water through public water systems for small communities in southwestern Minnesota.

Key words: contingent valuation method, copper contamination, drinking water quality, willingness to pay

Introduction

The Safe Drinking Water Act (SDWA) of 1974 requires the establishment of maximum contaminant levels (MCLs) in drinking water for contaminants that adversely affect human health. Since state adoption of the SDWA in 1977, the Minnesota Department of Health (MDH) has regulated drinking water quality. Based on 1993 MDH data for the state's public water system, copper contamination was still widespread and often exceeded the MCL in southwestern Minnesota.

The problem of copper contamination typically stems from corrosion of plumbing pipes in public water distribution systems as well as in households. Copper contamination is well known to have adverse health effects. Excessive levels of copper in the human body can cause short-term acute symptoms such as vomiting, diarrhea, and stomach distress. The more serious and long-term effects of copper contamination, such as liver damage, kidney damage, and anemia, can occur when people are frequently exposed to excessive levels of copper in their drinking water [U.S. Environmental Protection Agency (EPA)].

In 1991, the Lead and Copper Rule (LCR) set forth by the U.S. EPA established a standard level of copper in drinking water at 1,300 micrograms per liter (mg/L). Each state is responsible for implementing the LCR's requirements to optimize corrosion control in place, treat the source water, and deliver public education. If necessary, states are

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also required to install an additional treatment for corrosion control, such as replacement of service lines to the water supply system.

Copper contamination is one of the major drinking water quality problems in southwestern Minnesota. While other contaminants are found in concentrations below the MCL, the concentration level of copper in the drinking water often exceeds the MCL and poses a threat to human health in this rural area. In particular, according to results of a 1994 study published by the Minnesota Department of Health, the nine southwestern Minnesota counties included in this study—Chippewa, Yellow Medicine, Renville, Lincoln, Lyon, Redwood, Pipestone, Rock, and Nobles—have exceeded the MCL standard for copper in the drinking water.

The drinking water for these nine counties is supplied largely by small public water systems serving fewer than 500 persons. About 55% of the public water systems in the nine counties serve fewer than 500 persons, while only 8% serve over 3,300 persons (Minnesota Environmental Quality Board).

These relatively small public water systems are faced with investments in plants and equipment to monitor and treat their drinking water to reduce copper contamination. Unlike large water systems which can take advantage of economies of scale, the costs for major improvements in small systems are spread over a smaller rate base. Because the unit cost of compliance is much higher for these small public water systems compared to their larger counterparts, water rates will be high if consumers must pay the full cost of water service.

Enforcement of the EPA's 1991 copper standard has evoked new interest in studies of the social benefits of reducing copper contamination in small communities. In this study we seek to address this important issue by estimating consumers' willingness to pay for improvements in public water systems to reduce copper contamination levels. The study area is comprised of the nine counties in southwestern Minnesota where copper contamination exceeds the MCL (Minnesota Department of Health 1994), and whose drinking water is largely supplied by small public water systems.

Literature Review

Many studies have used the contingent valuation method (CVM) to measure the value of household water quality improvements with different elicitation procedures and estimation methods (Edwards; Shultz and Lindsay; Kwak; Musser et al.; Poe and Bishop; Jordan and Elnagheeb 1993; Poe). The value elicitation procedure of the CVM can take one of three forms.

The first CVM procedure is an open-ended question format where respondents are asked to report their WTP for a specified change in water quality (Musser et al.). For a good with which respondents are not familiar, this method is likely to have a high nonresponse rate and a large number of outliers and "protest" zero responses to the WTP question.

The second CVM format is the dichotomous-choice method, in which respondents answer either "yes" or "no" to one randomly assigned dollar amount chosen by the interviewer. This approach has been widely used to elicit WTP for water quality improvement (Edwards; Shultz and Lindsay; Poe and Bishop; Poe). The major shortcoming of this format is that the dichotomous response data may provide less information than an open-ended question format for the respondents' WTP. A large sample also may be required to obtain a statistically significant WTP estimate by this approach (Jordan and Elnagheeb 1993).

Finally, in the payment card or checklist CVM approach, respondents are asked to circle the highest WTP from an ordered set of values. The respondent's WTP is assumed to lie between the circled value and the next higher value. Only a few studies have used CVM with a checklist format in estimating WTP for water quality improvement (Kwak; Jordan and Elnagheeb 1993).

In their 1993 study, Jordan and Elnagheeb reported WTP for improved ground water quality and residents' perceptions of potential groundwater contamination in Georgia using a mail survey. The advantage of this method is the ease it provides respondents in answering questions, and it has been shown to reduce the number of nonresponses to WTP questions.

In a related study, Jordan and Elnagheeb (1994) compared the parameter and WTP estimates from dichotomous-choice and payment-card models using Monte Carlo experiments. They found that the parameter estimates using the payment-card model were more often consistent and efficient than estimates under the dichotomous-choice model.

For the present study, a checklist question format approach was used to estimate consumers' WTP to improve their drinking water quality. However, the procedure for this analysis differs somewhat from the earlier work of Jordan and Elnagheeb. Here, WTP is estimated using a tobit model, which is more appropriate when there is a large number of zero values for WTP from the survey.

The Model

Suppose an individual's preference is presented by a utility function of the form $U = U(X, Z, Q)$, where X is a demand for use of water, Z is a composite of all other market goods, and Q is a rationed quantity of water quality. Assume the individual takes Q as given and does not have to pay a price for this "imposed" quantity. The state of welfare facing the individual is denoted by $S^0 = (P_x^0, P_z^0, Q^0)$. Then the minimum expenditure necessary for the individual to obtain a utility level (u^0) at the state of the economy (S^0) is defined as the solution to a budget-minimizing problem:

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

where P_x is the price of X, and P_z is the price of Z. The expenditure function is increasing in prices and utility (i.e., $\partial E/\partial P_x > 0$, $\partial E/\partial P_z > 0$, $\partial E/\partial u > 0$), and decreasing in water quality (i.e., $\partial E/\partial Q < 0$). If water quality ($Q$) is improved from Q^0 to Q^1 with given price levels (P_x^0, P_z^0), then the state of welfare is also changed from S^0 to $S^1 = (P_x^0, P_z^0, Q^1)$. The minimum expenditure necessary to achieve utility level u^0 at the new state of the economy, S^1, is $E(P_x^0, P_z^0, Q^1)$.

Because $\partial E/\partial Q < 0$, by assumption, $E(P_x^0, P_z^0, Q^1, u^0) < E(P_x^0, P_z^0, Q^0, u^0)$. Therefore, the absolute value of the individual's welfare changes resulting from a change in Q can be measured as:

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

where CS is the Hicksian compensating surplus. When water quality improves from Q^0 to Q^1, the CS measure represents the income taken away from the individual to place him or her at the original utility level (u^0). Therefore, CS can represent the individual's WTP to improve water quality (Bergstrom). CS can be measured by asking individuals their WTP for a change in water quality from Q^0 to Q^1 in a contingent valuation survey. The individual's WTP could be elicited from a contingent valuation question such as: "What is the maximum increase in the monthly water bill you would be willing to pay for changing water quality from Q^0 to Q^1?"

Suppose we obtain the consumer's WTP and auxiliary information about socioeconomic and demographic characteristics from a survey. The structure of the model to be considered is specified as:

(3) $$WTP_i = \mathbf{X}_i'\beta + e_i,$$

where $\mathbf{X}_i$ is a vector of theoretically important explanatory variables and β is a vector of coefficients. The e_i term is assumed to be an independent, identically normally distributed random variable with zero mean and variance σ^2, where $i = 1, 2, \ldots, n$ denotes individuals in the sample. The conditional distribution of the WTP is given by

$$WTP_i \mid \mathbf{X}_i \sim N(\mathbf{X}_i'\beta, \sigma^2), \quad i = 1, 2, \ldots, n.$$

The tobit model is of the form: $WTP_i^{Tobit} = \mathbf{X}_i'\beta + \varepsilon_i$, where WTP_i^{Tobit} is an unobserved continuous dependent variable, and ε_i is an independently distributed error term assumed to be normal with zero mean and constant variance σ^2, $i = 1, 2, \ldots, n$.

The observed WTP variable takes the form:

(4) $$WTP_i = \begin{cases} \mathbf{X}_i'\beta + e_i & \text{if } WTP_i^{Tobit} > 0, \\ 0 & \text{if } WTP_i^{Tobit} \leq 0. \end{cases}$$

The log likelihood for the censored regression model is given by:

(5) $$\ln L(\beta, \sigma) = \sum_{WTP_i = 0} \ln\left[1 - \Phi\left(\frac{\mathbf{X}_i'\beta}{\sigma}\right)\right] + \sum_{WTP_i > 0}\left[\ln\left(\frac{1}{\sqrt{2\pi\sigma^2}}\right) - \left(\frac{1}{2\sigma^2}\right)(WTP_i - \mathbf{X}_i'\beta)^2\right].$$

The maximum-likelihood estimator of β_{Tobit} is obtained as a solution to the first-order condition for maximization, $[\partial \ln L(\beta)/\partial\beta] = \mathbf{0}$. Once the optimal values of β_{Tobit} and σ are estimated, the expected value of WTP_i when censored at zero can be obtained from:

(6) $$E[WTP_i] = \mathbf{X}_i'\beta_{Tobit}^e \Phi(\mathbf{X}_i'\beta_{Tobit}^e/\sigma^e) + \sigma^e \phi(\mathbf{X}_i'\beta_{Tobit}^e/\sigma^e),$$

where β_{Tobit}^e and σ^e are the estimated values of β_{Tobit} and σ, respectively; Φ is the normal cumulative distribution function; and ϕ is the normal distribution function.

Survey Design

The population surveyed was composed of households obtaining their water from public water supply systems in southwestern Minnesota where levels of copper exceed the standard. In order to determine the WTP for reducing copper in drinking water, a survey questionnaire was mailed to 390 residents of the nine southwestern Minnesota counties.

Efforts were made to word the questionnaire for respondents from all educational levels to be able to comprehend the language, concepts, and questions used in the survey. The WTP question provided both general information about the characteristics of contaminants (e.g., the adverse health effects, sources of contamination, and government standards) and specific information about the level of copper found in the drinking water (Cho). Respondents were asked to circle, from a set of predetermined values, the most they would be willing to pay above their current monthly water bill for improvements in drinking water quality. (The appendix documents the full presentation of the WTP question and related descriptive information provided to the survey respondents.)

The checklist arrayed numbers in $1 increments up to $10, and in $5 increments thereafter until $30. The checklist was designed to capture minimum and maximum WTP values of the respondents. These intervals in the checklist were finalized after the pilot survey results. An increase in the respondent's current monthly water bill was selected as a payment vehicle because most residents are familiar with paying a water bill.

The survey was conducted in September 1995. A preliminary pilot survey was administered in May 1995 to test the design of the survey instrument. The main purpose of the pre-test was to identify any confusing parts of the survey and to determine if the survey responses appeared to be a measure of the intended variables. The instrument's wording was also reviewed at various stages in its development by outside reviewers. The pilot survey was sent to 36 households distributed across the nine counties in southwestern Minnesota. Twenty-five of the 36 surveys were returned, giving a response rate of 69.4%.

Based on the assessment of findings from the pilot survey, we concluded the participants responded positively to the survey questions, and the survey instrument appeared to be successful in eliciting responses to the WTP questions. Forty percent of the respondents (10 out of 25) in the pilot survey reported they would not be willing to pay any amount to reduce the level of copper in their drinking water. The survey also asked respondents to indicate why they selected zero WTP. Four of these respondents noted that their drinking water from the public water supply system was "good enough." Five respondents stated they already paid extra money to obtain a better quality of water, either by using water treatment devices or by purchasing bottled water. Respondents who use water treatment devices may care more about their drinking water quality after it is treated and care less about the water quality supplied by the public water municipal systems. Consequently, their WTP may be smaller than for those individuals who do not use water treatment devices. Finally, one respondent selected zero WTP because he/she thought it was the responsibility of the county/city to improve the water quality.

Whatever the reasons for zero WTP, the zero WTP can be categorized into "valid zero" WTP and "protest zero" WTP. A respondent's zero WTP is valid when he/she reports the water quality change is not worth anything, or when the zero amount of money is all the respondent can afford. In contrast, a zero WTP is considered to be a protest zero WTP when the good has some value for the respondent. Among the 10 individuals in the pilot survey who selected zero WTP, only one response might be categorized as a protest zero WTP—the respondent who noted it was the responsibility of the county or city to improve the water quality. From these pre-test survey results, we concluded that most zero WTP choices are valid responses, and therefore did not include additional questions about zero responses in the main survey.

After revising and refining the design of the survey questionnaire based on initial results from the pilot survey, a total of 390 final survey instruments were sent to respondents. Closely following Dillman's recommendations for maximizing response rates, three successive mailings were completed. A cover letter explaining the purpose and importance of completing the survey accompanied the questionnaires sent to the sample of residents in the nine southwestern Minnesota counties. A reminder letter with a duplicate questionnaire was sent to nonrespondents two weeks after the original mailing. Two weeks later, a third and final letter with survey instrument was mailed to all remaining nonrespondents.

Data Analysis

Of the 390 surveys mailed, 272 were returned, yielding a response rate of 69.7%. Of these 272 returned questionnaires, 186 provided complete responses to the survey questions and were used for the data analysis. Demographic statistics by percentage of distribution are compared in table 1 for the survey sample and the actual census population of the nine southwestern Minnesota counties comprising the study area. Although the proportion of respondents sampled does not exactly match the proportion of the population across counties, responses were well distributed across the nine counties in southwestern Minnesota.

Table 1 also provides comparisons of several demographic variables from the survey with their census counterparts. About 48% of the survey respondents were female, slightly lower than the census percentage (51%) for the nine counties. The average age of the survey respondents was 52, while the average age for the population of the nine counties was 36.5. This large age difference is not unexpected. Survey respondents are likely to be the heads of the households, while all household members, including children, were considered in calculating the average age for the census population.

Further comparisons from table 1 show both the percentages of the households with children and households with high school education were higher for the survey group than for the nine-county census population (38% vs. 32% and 92% vs. 83%, respectively). At $35,700, the average annual household income of survey respondents was slightly higher than the average population income ($34,034) for the nine counties in southwestern Minnesota in 1993.

Respondents were asked to rate the current quality of their tap water on a five-point scale, where 1 = very poor and 5 = very good. Ratings were based on taste, odor, color, softness, and safety from a copper contamination. Table 2 reports the mean ratings of water quality between the respondents with zero WTP (only for respondents who do not use water treatment devices or purchase bottled water) and those with positive WTP. As seen from table 2, the respondents with zero WTP rated water quality significantly higher on average than did those respondents with positive WTP, suggesting the zero WTP responses are not protest votes.

Table 1. Comparison of Demographics from the Survey and Actual Census Population, 1993

Description	% of Survey Responses	% of Population, Census[a]
Southwestern Minnesota Counties:		
Chippewa	11.8	10.0
Lincoln	5.9	4.9
Lyon	14.5	19.5
Nobles	15.1	16.0
Redwood	13.4	12.9
Renville	11.3	13.2
Ripestone	10.8	5.6
Rock	7.5	7.4
Yellow Medicine	9.7	8.5
Socioeconomic Characteristics:	Survey, All Counties	Census, All Counties[b]
Female (%)	48.3	51.2
Average age (in years)	52.0	36.5
Households w/children < 13 years old (%)	38.0	32.4[c]
Households w/high school education (%)	92.0	83.0
Mean household income (dollars)	$35,700	$34,034

[a] Source for census population statistics: U.S. Department of Commerce/Bureau of the Census.
[b] Weighted average by county population.
[c] Percent households with persons under 18.

Table 2. Mean Rating of Water Quality (on a five-point scale) Between Zero WTP and Positive WTP

Water Quality Characteristics	Zero WTP (excluding respondents who use treatment devices or purchase bottled water) (n = 37)	Positive WTP (n = 107)	t-Value[a]
Taste	4.14	3.74	2.31**
Odor	4.21	3.81	2.56**
Color	4.23	3.94	1.85*
Softness	3.26	2.51	4.21***
Safety	3.46	2.42	5.76***
Overall quality	3.97	3.49	3.81***

Notes: Single, double, and triple asterisks (*) denote statistical significance at the 10%, 5%, and 1% levels, respectively. Water quality ratings are based on a five-point scale where 1 = very poor and 5 = very good.
[a] Two-tailed test for difference of means with equal variances.

Using a two-tailed t-test, differences were tested in quality ratings of the drinking water between respondents who used a water treatment device (and/or purchased bottled water) and those who did not. The results are tabulated in panel A of table 3. Respondents who used treatment devices or purchased bottled water were more concerned with their water quality than survey participants who used regular tap water.

Table 3. Water Quality Ratings by Respondent Groups (five-point scale)

PANEL A	Survey Respondent Groups		
Water Quality Characteristics	*Respondents who use treatment devices or purchase bottled water* (n = 95)	*Respondents who do not use treatment devices or purchase bottled water* (n = 91)	t-Value[a]
Taste	3.57	3.93	2.56**
Odor	3.78	3.98	1.46
Color	3.94	4.04	0.82
Softness	2.52	2.86	2.28**
Safety	2.68	2.88	1.19
Overall quality	3.46	3.71	2.17**
PANEL B	Survey Respondent Groups		
Water Quality Characteristics	*Respondents in households with children under 13* (n = 70)	*Respondents in households with no children under 13* (n = 116)	t-Value[a]
Taste	3.80	3.72	0.56
Odor	3.94	3.84	0.76
Color	3.96	4.01	0.38
Softness	2.88	2.56	2.11**
Safety	2.70	2.83	0.75
Overall quality	3.69	3.53	1.14
PANEL C	Survey Respondent Groups		
Water Quality Characteristics	*Income less than $70,000*[b] *a year* ($n$ = 168)	*Income more than $70,000 a year* ($n$ = 18)	t-Value[a]
Taste	3.89	3.73	0.64
Odor	4.02	3.89	0.54
Color	4.33	3.97	1.73*
Softness	2.77	2.50	0.79
Safety	2.79	2.67	0.45
Overall quality	3.73	3.62	1.04
PANEL D	Survey Respondent Groups		
Water Quality Characteristics	*High school graduate or less* (n = 83)	*College graduate* (n = 103)	t-Value[a]
Taste	3.83	3.63	1.45
Odor	3.99	3.71	2.25**
Color	4.05	3.85	1.67*
Softness	2.73	2.65	0.65
Safety	3.01	2.62	2.56**
Overall quality	3.71	3.51	2.09**

Notes: Single, double, and triple asterisks (*) denote statistical significance at the 10%, 5%, and 1% levels, respectively. Water quality ratings are based on a five-point scale where 1 = very poor and 5 = very good.
[a] Two-tailed t-test for difference of means with equal variances.
[b] High-income households that comprise a small proportion of all households might have different water quality ratings than the average households. Households with the highest 10% income reported incomes of $70,000 or more.

We also tested whether other factors, such as children in a household, education, or income level, affect respondents' ratings of drinking water. Table 3 shows that those who use water treatment devices and/or purchase bottled water (panel A) and those who have a college education (panel D) gave their water lower ratings in water quality. In contrast, the socioeconomic characteristics of children in a household (panel B) and income level (panel C) did not reveal a significant difference in the mean rating of water quality.

Fifty-eight percent of those surveyed said they would be willing to pay at least $1 a month to improve water quality. The mean WTP was reported at $3.19, while individual WTP responses ranged from zero to $30 or more per month. About 96% of the WTP responses were between zero and $10 per month. The distribution of WTP for reducing copper in the drinking water is presented in table 4.

Estimation of Willingness to Pay

Previous empirical studies have estimated the WTP function to identify a range of determinants of WTP for drinking water quality. Table 5 lists the variables included in the WTP function for this study and their summary statistics. Because the data are not dichotomous (i.e., the data contain a large number of zero values for WTP from the survey), a tobit model was used to estimate the WTP function. The results of the censored tobit analysis for the WTP function are presented in table 6. Table 6 also reports the marginal effects, their standard errors, and the means of the explanatory variables at which the marginal effects were computed. The coefficients and standard errors of marginal effects were calculated by multiplying the coefficients and their standard errors of the tobit model with the scale factor of 0.4846.

As observed from table 6, *SAFETY* has a negative and significant effect on WTP to reduce copper levels in drinking water. If respondents perceive their water is unsafe because of copper contamination, they are willing to pay more to improve drinking water quality. Simultaneity between *SAFETY* and WTP was tested in a simultaneous-equation model (Greene, pp. 763–64), and the null hypothesis that *SAFETY* is exogenous was not rejected.

CHILD shows a positive and significant effect on WTP. Respondents in households with one or more children under 13 years of age report a higher WTP compared to those without a child. A statistically significant association is found between *HIGHINC* and WTP. Households with annual incomes over $70,000 are willing to pay more for improving the drinking water quality to reduce the risk of copper contamination. Other socioeconomic characteristics of the respondents, including age, education level, and monthly water bill, are not statistically significant, implying those factors may not contribute to WTP for reducing the risk of copper.

The mean WTP for reducing copper from current levels to below the standard level in the drinking water was computed for each county by using equation (6) at the mean values of the explanatory variables for each county in the estimated WTP function. One difficulty involved in expanding a contingent valuation sample to the general population is how to assign WTP to nonrespondents. To address this concern, nonrespondents can be assigned the mean estimated WTP from those who responded to the valuation question (Poe and Jones). A zero WTP can also be assigned to those who did not respond (Shultz and Lindsay).

In this study, we constructed a range of WTP using zero and mean WTP for nonrespondents. Table 7 gives the ranges for the annual mean and the aggregate WTP for each county in the survey sample. The mean WTP for each county in southwestern Minnesota varies largely depending on the current level of copper in that county. Households in Nobles County are willing to pay from $39.79 to $57.06 annually to reduce their

Table 4. The Distribution of WTP for Reducing Copper in Drinking Water

WTP Interval ($)	Frequency	Percentage (%)
0	78	41.9
1–5	84	45.2
6–10	17	9.1
11–15	4	2.2
16–20	1	0.5
21–25	0	0.0
26–30	2	1.1
Total:	186	100.0

Table 5. Explanatory Variables Included in the WTP Function: Definitions and Summary Statistics (n = 186)

Variable	Description	Mean	Minimum	Maximum	Std. Dev.
*ACT*1	1 if respondent purchases bottled water; 0 otherwise	0.16	0	1	0.37
*ACT*2	1 if respondent uses water treatment device; 0 otherwise	0.41	0	1	0.50
SAFETY	Perception of safety from a copper contamination	2.78	1	5	1.12
COPPER	Actual level of copper (micrograms/liter)[a]	2,611	1,500	4,300	943
AGE	Age of respondent (in years)	52	23	96	17.22
COLLEGE	1 if respondent attended college/university; 0 otherwise	0.55	0	1	0.50
WATER_BILL	Average monthly water bill (in $)	18.95	2.17	98	14.62
CHILD	1 if there is a child under 13 years of age in household; 0 otherwise	0.38	0	1	0.49
HIGHINC	1 if annual household income is over $70,000; 0 otherwise	0.04	0	1	0.02

[a] Actual copper levels taken from survey conducted by the Minnesota Department of Health (1994).

copper level from 4,300 mg/L to below the standard level, while households in Chippewa County, with a current level of copper at 1,500 mg/L, are willing to pay from $30.41 to $43.61. The aggregate WTP for all nine counties was estimated to range from $1.66 to $2.38 million.

The mean WTP in this study is smaller than for other studies measuring WTP for improving drinking water quality. Estimating the annual mean WTP for improved ground water quality in Georgia, Jordan and Elnagheeb (1993) reported a WTP of $120.84 for residents with public water systems. Shultz and Lindsay found an annual mean WTP of $129 for residents in Dover, New Hampshire. The disparities in the annual mean WTP among studies might stem from differences in the study area and design. Further, because the WTP estimates in this study represent a WTP for copper reduction only, they are likely to be smaller than the WTP when reductions of other contaminants are also considered.

Table 6. Results of Censored Tobit Analysis of Factors Affecting WTP (n = 186)

	WTP for Reducing the Level of Copper				
Variable	Coefficient	t-Ratio	Marginal Effects[a]/(Std. Errors)		Mean of **X**[b]
CONSTANT	3.2839	0.548	1.5915	(2.918)	—
ACT1	0.6254	0.268	0.3031	(1.130)	0.16
ACT2	-2.8359	-1.570	-1.3744	(0.877)	0.41
SAFETY	-3.4875***	-4.087	-1.6901***	(0.407)	2.78
COPPER	0.0017	0.180	0.0008	(0.004)	2,611.83
AGE	0.0472	0.657	0.0229	(0.035)	52.01
COLLEGE	0.2815	0.142	0.1364	(0.963)	0.55
WATER_BILL	0.0650	1.031	0.0315	(0.031)	18.95
CHILD	5.6212**	2.358	2.7242**	(1.157)	0.38
HIGHINC	14.4193***	3.547	6.9880***	(2.014)	0.04
σ	10.7365***	14.169			
Log Likelihood	-458.23				

Note: Single, double, and triple asterisks (*) denote statistical significance at the 10%, 5%, and 1% levels, respectively.
[a] Marginal effects are calculated by $\beta\Phi(\beta'\mathbf{X}/\sigma)$, where Φ is the normal cumulative distribution function. The numbers in parentheses are standard errors of the marginal effects calculated using the delta method (Greene, p. 278). This method, however, provides no additional information about the precision of the estimated marginal relationships.
[b] The means of all explanatory variables at which the marginal effects were calculated.

The U.S. Congressional Budget Office (CBO) estimated the average household cost of monitoring and treating drinking water to meet the standards specified by the existing rules of the Safe Drinking Water Act. The CBO used a municipal expenditure survey to estimate compliance costs at the local level. The survey was conducted in a total of 312 cities and 128 counties with public water systems. Each city or county reported monitoring and total capital cost for treating drinking water. The total capital cost was annualized over 20 years with a 7% discount rate. Operating cost was not included. Based on CBO estimates, the average household cost for monitoring and compliance by size of public water system serving fewer than 500 people was \$91 in 1992 dollars. The average household cost of a central treatment system decreases as the size increases.

Using results reported by the CBO, table 8 shows the cost (in 1992 dollars) of a central treatment system by size of community. Economies of scale make the construction, operation, and maintenance of a central treatment system more costly for individual households in small communities. Fifty-five percent of the public water supply systems in southwestern Minnesota serve fewer than 500 households. In those small communities, clearly the WTP may not be sufficient to finance improvements in public water systems.

The WTP estimated in this study is for copper reduction only. Households might also be willing to pay for reductions in hardness, iron, sulfate, and lead in their drinking water. According to survey findings by the Minnesota Department of Health (1994), most public water supply systems in southwestern Minnesota reported concentration levels of contaminants below the MCL—except copper. We therefore assumed that respondents' WTP for reducing other contaminants might not be large. However, it is still likely the WTP estimates for water quality improvement are underestimated in this study.

Table 7. Annual Mean and Aggregate WTP for Each County ($)

County	No. of Households	Mean WTP[a]	Aggregate WTP
Chippewa	4,872	30.41–43.61	148,202–212,516
Yellow Medicine	4,125	31.08–44.57	128,227–183,873
Renville	6,385	32.09–46.02	204,902–293,822
Lincoln	2,393	32.49–46.50	77,609–111,288
Lyon	9,465	33.43–47.94	316,433–453,753
Redwood	6,260	33.76–48.42	211,372–303,100
Ripestone	3,684	34.43–49.38	126,852–181,901
Rock	3,617	39.06–56.01	141,349–202,690
Nobles	7,759	39.79–57.06	308,625–442,557
Total	48,560		1,657,692–2,377,069

[a] For the first number in the WTP range, zero WTP was assigned to nonrespondents; for the second number, the estimated mean WTP was assigned to nonrespondents.

Table 8. Average Household Cost for Treatment Facility (in 1992 $)

Size of System (number of persons served)	Average Household Cost ($)
< 500	91
500 to 1,000	39
1,001 to 3,300	21
3,301 to 10,000	16

Source: U.S. Congressional Budget Office.

Investment in public water systems could be funded through issuing bonds, increasing local taxes, or increasing rates for water use. Some respondents to our survey might vote in favor of a bond issue for financing the improvements even though they would not be willing to pay more on monthly water bills. The WTP estimate in this study is based on an increase in the respondent's current monthly water bill. Different financing options for water improvement could alter the respondents' WTP elicited in this study. Therefore, our analysis is limited in fully comparing the benefits and costs of reducing copper to the standard specified by the Safe Drinking Water Act. This limitation points to the need for continued research in this area.

Conclusions

The contingent valuation method was used in this analysis to determine how much consumers in nine counties in southwestern Minnesota would be willing to pay to reduce copper in their drinking water and what factors influence their WTP. The annual mean WTP by household in Chippewa County was estimated to range from $30.41 to $43.61, while WTP estimates for households in Nobles County ranged from $39.79 to $57.06. The aggregate WTP for all nine southwestern Minnesota counties was estimated to range from $1.66 to $2.38 million.

Respondents who live in households with children and who hold a negative perception of the safety of their drinking water are willing to pay more to reduce the risk of copper contamination. Households with annual incomes over $70,000 are also willing to pay more to reduce copper in their water. The estimated WTP, however, may not be sufficient to pay the full cost of providing improved water through public water systems for the small communities characterizing southwestern Minnesota. Because of the high cost per consumer of small water systems, small communities may have a difficult time financing new or improved facilities without assistance from the state or federal governments.

While this study focused mainly on the economic benefits to households of copper reduction in the drinking water, it is essential to conduct further studies on the costs of improving water quality. Information on benefits and costs will assist policy makers in identifying the socially optimal level of abatement of water contamination.

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Appendix: WTP Question and Related Descriptive Information Provided to Survey Respondents

The WTP question for copper was stated as follows:

Copper enters water primarily as a result of the corrosion of materials containing copper in the water distribution system and household plumbing. Even if you receive your water from a public water supply, your water may still have a copper problem if the water was not treated by an additional process in the water system. Exposure to copper over a long period of time can cause adverse health effects, including vomiting, diarrhea, stomach cramps, and nausea.

In 1991, the U.S. Environmental Protection Agency (EPA) established a standard level of copper in drinking water. This standard level is exceeded if the level of copper is greater than 1,300 micrograms per liter (mg/L). Monitoring results from the Minnesota Department of Health show that your community water system has [______] micrograms per liter of copper.

Your community could install a new or improved corrosion control treatment that would reduce copper from current levels to below the standard level. But, since this would involve increased costs, it would be necessary to increase your water bill to provide this treatment. What is the largest monthly amount you would be willing to pay, above your current monthly water bill, for a control treatment that would reduce copper from current levels to below the standard level in your drinking water?

[*Please circle one amount:*]

$0, $1, $2, $3, $4, $5, $6, $7, $8, $9, $10, $15, $20, $25, $30 or more each month