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CAN RURAL COMMUNITIES COMPLY WITH THE NEW ARSENIC STANDARD FOR DRINKING WATER?*

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ABSTRACT

Our primary concern in this paper is to determine to what extent small communities have difficulty meeting the new stricter 2001 standard for arsenic levels in their drinking water. To do this we survey water users in rural Minnesota communities that had arsenic levels in their water supply exceeding 10 μg/L during 2001-2006. Our survey results show that after obtaining complete information concerning the arsenic levels in their drinking water consumers with relatively low levels of arsenic were willing to pay $8-9 annually, while those with high levels of arsenic are willing to pay $15-17 annually. We also found that consumer's willingness to pay (WTP) didn't vary by community size. Thus, we conclude that compared to compliance costs ($58-327 per capita annually) small rural communities were likely to find it difficult to cover the cost of compliance through increased water charges. Since many of the communities have to cover these costs of compliance by raising water charges, we ask the basic question: are there better treatment options for these rural communities that will lower the cost to consumers? One option might be to encourage individual householders to use household water treatment devices for communities serving fewer than 500 people. The devices could be made available by the local entity supplying the community's water possibly at a subsidized rate along with complete information about the arsenic level in the water supply.

I. INTRODUCTION

In October 2001, the U.S. Environmental Protection Agency (EPA) adopted a new arsenic standard of 10 μg/L in drinking water.[1] Prior to the new rule, the drinking water standard for arsenic had been set at 50 μg/L starting in 1975.[2] Setting the new standard was controversial and involved extensive public debates during the 1990s. It was controversial, primarily because changing the arsenic concentration level from 50 μg/L to 10 μg/L had been considered a 'gray zone' – epidemiological findings on health risks associated with the lower level were not conclusive. However, a critical turning point came when the National Research Council (NRC)'s 1999 report found that the original maximum contamination level (MCL) did not enable EPA to meet its goal of

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[1] Inorganic arsenic is a naturally occurring chemical and is found throughout the environment. Inorganic arsenic is also known to have both acute/immediate as well as chronic health risks. Especially, chronic oral exposure has resulted in gastrointestinal effects, anemia, peripheral neuropathy, skin lesions, and livers or kidney damage in human (EPA, 2005).

[2] The initial standard for arsenic (50 μg /L) in drinking water was established by the U.S. Public Health Service in 1942. EPA adopted the drinking water standard of 50 μg /L in 1975 under the Safe Drinking Water Act and, since then, has held the mandate to regulate arsenic in drinking water.

protecting public health (NRC, 1999). Following this pivotal report, EPA proposed a new rule of 5 μg/L in June 2000, but finally set the standard at 10 μg/L after expert reviews of the benefits and the costs.[3]

The new arsenic standard became fully enforceable in January 2006, after which all public water systems (PWS) must comply with the new arsenic MCL. In early 2000s, EPA estimated that the new rule would affect about 3,000 U.S. community water systems, or roughly 5.5% of the total 54,000 water systems, and that the total annualized costs of compliance would range from $180 to $206 million (in 1999 U.S. dollars). Of those affected communities, 97% are small communities, serving less than 10,000 people (EPA, 2001). One of the problems with the new rule is that it disproportionately disadvantages small rural communities. Most of the compliance cost is the cost of installing and operating the treatment technologies to reduce arsenic concentrations. Unlike large community water systems (PWS), small systems only have a limited number of consumers among whom they can spread the fixed costs. EPA has estimated that total annual cost per household would be $162-$327 for PWSs serving 25 to 500 people but only $0.86-$32 for those serving 10,000 or more. Their estimated benefit cost ratios, which ranged from .30 to .42 for the smaller communities and from 1.00 to 1.39 for communities with populations over 10,000, puts the problem in even bolder relief. A more recent EPA (2002) study reported a very similar range in competence costs across community size. In 2000, to help address this problem, the Federal government made $1.7 billion available to States and PWS for capital improvements.[4] Yet a number of small communities still appear to have difficulty covering the cost of complying with the new standard.[5]

The central question we ask in this manuscript is, therefore, whether or not consumers in rural communities are willing to pay enough to cover the cost of economically meeting the new arsenic standard. To do so, we elicit consumers' willingness to pay to reduce the arsenic standard to 10 μg/L by using a contingent-valuation survey. Our survey area is thirty communities from west and west central Minnesota. These communities have had relatively high arsenic concentrations in their groundwater source, and thus, have had detectable levels of arsenic in their treated tap water. Out of the thirty communities, 24 communities have had an average arsenic level above 10 μg/L, at least once, over the last five years and 12 of these communities still had average levels above 10 μg/L after January 2006.

In attempting to elicit consumers' willingness to pay (WTP), several issues arise. Because consumers are often uninformed regarding the level of arsenic in their tap water and the associated health risks, their expressed WTP and levels of self-protective treatment in their homes may not reflect their true WTP.[6] Furthermore, consumers may have some altruistic incentives that influence their WTP across different sized communities. To evaluate the benefits and the costs for different sized communities, this question can be important. Thus, we

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[3] This point is important, because it means that the new rule is the second drinking water regulation in which EPA used discretionary authority under SDWA Section 1412 (b)(6).

[4] These are not necessarily arsenic-related funds.

[5] For example, out of thirty Minnesota PWSs we surveyed, 12 community water systems, serving approximately 8,500 people in total, were not able to comply with the new standard as of December 2006.

[6] In the household survey in Nevada, Walker *et al.* (2006) found that consumers' perceptions about arsenic risks in their drinking water were highly heterogeneous and that their choice of treatment was closely related to their perceptions, but not necessarily to their actual exposure to arsenic.

included the arsenic concentration level and the size of community as key explanatory variables in addition to traditional socio-economic variables such as age, education, and income. In the survey, we provided comprehensive information regarding current and historical levels of arsenic concentrations (specific to each community) and detailed health risks associated with different levels of arsenic exposure with a visual aid. To examine the effects of information, we asked the contingent valuation question twice before and after providing information about the arsenic levels in their community's water supply.

Our findings will complement earlier cost-benefit analyses such as those done by Hogue (2001) and Burnett and Hahn (2001) in an important way. The Burnett-Hahn study concluded that the costs might exceed the benefits by over \$100 million annually. Their conclusion was different from the EPA study (2000), which determined that the benefits of the new rule have a value of about \$170 million annually (with the estimated range from \$140 to \$198 million). When combined with "nonquantifiable" benefits, EPA found that the total benefits exceeded the costs of compliance. Both the EPA and the Burnett-Hahn studies used the similar approach by using the value of a statistical life and the estimated reduction in mortality due to the new rule. The difference comes mainly because the Burnett-Hahn study adjusted the value of statistical life estimate for latency or the timing of the effects of arsenic exposure. Our approach differs from both of these studies in that we use a CV study to directly elicit consumers' contingent values for a reduction in mortality and morbidity risk.

Previous studies (Berg *et al*., 2001; Lockwood *et al*., 2004; Morales *et al*., 2006; Peters *et al*., 1999; Umshler, 1999) regarding arsenic contamination in drinking water have primarily focused on the dose-response relationship between arsenic levels in drinking water and its adverse effects on human health. Non-market valuation studies that attempt to quantify the economic impacts of arsenic contamination have been limited until fairly recently. However, there is a growing interest among water practitioners in quantifying the economic value of reducing arsenic concentrations, as it has become clear that arsenic contamination is occurring naturally in various parts of the world, including high concentrations in Bangladesh, China, and India. For example, Maddison *et al.* (2005) estimated the aggregate economic cost of arsenic contamination of tube wells in Bangladesh to be about \$2.7 billion annually. Unlike our study, they combined epidemiological dose-response functions with the value of statistical life estimates from Simon *et al.* (1999), adjusted with purchasing power parity exchange rates. Amhed *et al.* (2005) also estimated households' WTP for arsenic-free drinking water in rural Bangladesh. Unlike Maddison *et al.* (2005), they fitted a multinomial logit model with contingent-valuation data, and found that the rural people in arsenic-affected areas of Bangladesh are willing to pay only about 0.2–0.3 percent of the average household income to reduce arsenic levels in their water or 10–14 percent of the amount they are willing to pay for piped water.

To address the concerns above, the paper is organized as follows. The next section briefly summarizes our WTP estimation methodology. Section III describes the data set and the survey. Section IV introduces the survey results based on consumer perceptions and the effect of information. We then provide our regression results and the median WTP estimates. Section V compares these WTP estimates with the cost of compliance for different community sizes and suggests alternative policies to address arsenic contamination problems for small communities. The last section concludes our paper. Though primarily concerned with the arsenic rule, our discussion has important implications for drinking water standards for other toxic contaminants.

II. METHODOLOGY

We estimate households' WTP for improved drinking water quality from reduced arsenic levels, using the double-bound dichotomous choice (DB-DC) question in collecting data from Minnesota communities. As with most contingent valuation studies, we also estimate the determinants of WTP. We are particularly interested in how households' averting behaviors and perceptions influence their expressed contingent choices.

Though there are a wide variety of methods to estimate WTP (Alberini, 1995a; Cooper and Loomis, 1992; Haab, 1998; Hanemann and Kanninen, 1999; Polome, 2006), the general consensus among researchers is that no method fits all since there are pros and cons for each method, in terms of bias, efficiency, and rigidity of assumptions. Researchers are often concerned about biases in WTP estimates such as starting-point bias, yea-saying bias, and uncertainty/non-response bias as well as efficiency of estimates. As Alberini (1995b) has argued, the bias resulting from correlations between the responses to two different bids (this bias may includes starting-point bias and yea-saying effect) may not be large, and we may be better off using simple interval-data methods on the basis of efficiency gains. However, if we are interested in unbiased estimates of coefficients, bivariate or similar models may be a better option. Since we are interested in the unbiased estimates of coefficients on the key variables such as historical concentrations and self-protection actions, we selected the bivariate probit model, which is, in our view, general enough to address correlations that may arise.

The bivariate probit model was first proposed by Cameron and Quiggin (1994). It assumes that households can express two WTP values, for example, because the reference to the initial bid may influence their evaluation and thus responses to the follow-up bid. The underlying WTP values are therefore represented by the system:

$$\begin{aligned} WTP_{i1} &= x_{i1}\beta_1 + \varepsilon_{i1} \\ WTP_{i2} &= x_{i2}\beta_2 + \varepsilon_{i2} \end{aligned} \quad (1)$$

where (ε_{i1}, ε_{i2}) follow a bivariate normal distribution, BVN(μ_1, μ_2, σ_1, σ_2, ρ). WTP_{i1} and WTP_{i2} are *i*th individual's willingness to pay in the first and second questions, respectively. The advantage of the bivariate model is that it allows the error terms ε_{i1} and ε_{i2} to be correlated. The interval-data (or double-bound) model suggested by Hanemann *et al*. (1991) is a special case of the bivariate model with $\beta_1 = \beta_2$, $\sigma_1 = \sigma_2$, and $\rho=1$, which forces WTP_{i1} to be identical to WTP_{i2}. As Haab (1998) noted, the bivariate probit model allows flexibility in the modelling of DB-DC responses.

In the bivariate probit framework, we can write the response probabilities as follows:

$$\Pr(no_i, no_i) = \Phi(Z_{i1}, Z_{i2}, \rho)$$

$$\Pr(no_i, yes_i) = \Phi(Z_{i1}) - \Phi(Z_{i1}, Z_{i2}, \rho)$$
$$\Pr(yes_i, no_i) = \Phi(Z_{i2}) - \Phi(Z_{i1}, Z_{i2}, \rho)$$
$$\Pr(yes_i, yes_i) = 1 - \Phi(Z_{i1}, Z_{i2}, \rho) - \Phi(Z_{i1}) - \Phi(Z_{i2}) \quad (2)$$

where $Z_{ij} = (c_{ij} - x_i\beta_j)/\sigma_j$, c_{ij} is the *j*th bid offered to individual *i*, $\Phi(Z_{ij})$ is the standardized normal cdf, and $\Phi(Z_{1j},Z_{2j},\rho)$ is the standardized normal bivariate cdf. Using these probabilities, we can write the likelihood function. The maximum-likelihood estimation of this model can be done with standard statistical packages to estimate bivariate probit models and by transforming coefficient and standard error estimates (Cameron and Quiggin, 1994).

In the estimation, we also apply a logarithmic transformation, to preclude negative WTP values. Accordingly, WTP is assumed to be a log-normal variable. This transformation replaces c_{ij} with $ln(c_{ij})$. With this specification, mean and median WTPs can be estimated by:[7]

$$E(WTP) = \exp(\mu + \frac{1}{2}\sigma^2)$$
$$MD(WTP) = \exp(\mu) \quad (3)$$

III. DATA

This study focuses on Minnesota communities with high concentrations of arsenic in their public water supply. Minnesota has about 966 community systems that provide drinking water to people in their places of residence, including 720 municipal systems serving towns or cities. In the past, groundwater in west central and northwestern Minnesota has had relatively high concentrations of arsenic in the groundwater. As a result, public water systems in these areas that obtain their water from underground sources may find it contaminated with arsenic. According to Minnesota Department of Health (MDH, 2006) approximately 40 community water systems in Minnesota have been affected by the new arsenic standard. The 2006 arsenic monitoring data for drinking water from the Minnesota Department of Health (MDH) indicated a number of communities have not yet reached the required new lower level for arsenic. Most of these communities have a population of less than 2,000 residents.

As Table 1 shows, 30 out of 720 public water municipal systems (4.2%) in Minnesota have had an arsenic contamination problem at least once during the 2000 to 2006 period.[8] Among them, 12 communities had average arsenic levels still above the new standard level of 10 μg/L during 2006 (High-High group; 19.9 μg/L in 2006 and 20.5 μg/L on average during 2000-2005). Another 12 communities had average arsenic levels below

[7] See Alberini (1995a, p.290) for detail.

[8] Public water supply systems are categorized into community systems serving 25 or more person per day on a year-round residential basis (e.g., municipalities, mobile home parks), and non-community systems served 25 or more person per day on a transient or seasonal basis (e.g., restaurants, resorts).

10 μg/L in 2006 but have historically had high average arsenic levels (Low-High group; 4.5 μg/L in 2006, but 21.9 μg/L on average during 2000-2005). Finally 6 communities currently and historically have had, on average, safe levels of arsenic in their water (Low-Low group; 4.0 μg/L on average in 2006 and 6.7 μg/L on average during 2000-2005). The six Low-Low communities did exceed the 10 μg/L standard sometime during the 2000-2005 periods although the average was less than 10 μg/L. The study communities have a relatively higher portion of small community systems serving less than 500 person (13 out of the 30 community water systems, 43.3%). The size of population served by the public water systems of these communities ranged from 59 to 3030 persons. The total population surveyed was estimated to be 22,594.[9]

Table 1. Characteristics of Water Supply Systems in Minnesota That Have Had an Arsenic Level above the New EPA Standards during 2000 to 2006

Group by arsenic level	Community size	Number of communities	Total population served	Average population served	Average arsenic level during 2000-2005 (μg/L)	Average arsenic level in 2006 (μg/L)
High-High	Less than 500	7	1,560	223	22.3	24.9
	501-1,000	3	2,169	723	17.9	13.9
	Above 1,000	2	4,826	2,413	18.1	11.4
Low-High	Less than 500	6	1,584	264	23.0	3.8
	501-1,000	3	1,674	558	26.8	4.8
	Above 1,000	3	6,396	232	12.1	4.9
Low-Low	Less than 500	3	827	276	7.7	5.2
	501-1,000	1	538	538	4.0	1.0
	Above 1,000	2	3,020	1,510	7.5	4.9
Total		30	22,594	753	18.1	10.6

To determine the impact on WTP of community size and the arsenic level in the drinking water, we stratified our sample by the level of arsenic and by community sizes. There were 9 classes such as High-High-Small (communities that have arsenic levels still above the new standard level of 10 μg/L and population served is less than 500), Low-High-Medium (communities that have arsenic levels below 10 μg/L but have historically had high arsenic contamination levels and the population served is between 501 and 1,000), Low-Low-Large (communities that currently and historically have had, on average, safe levels of arsenic in their water, and the population served is greater than 1,000) etc (see Table 2). We set the number to sample at between 100 and 120

[9] These figures denote the population served by public water supply systems and were collected from data files for public water systems in Minnesota Department of Health.

for each category. The number of consumers initially surveyed was 990 and each sample was randomly selected from a list of city water users and from community phone directories.

Table 2. Distribution of Survey Sample

Grouped by arsenic level	Size of community			Total
	Above 1,000	501-1,000	Less than 500	
High-High	120	100	100	320
Low-High	120	120	100	340
Low-Low	100	110	120	330
Total	340	330	320	990

The survey questionnaire consisted of three sections. The first group of questions included a screening question concerning whether or not a respondent used city water and general questions related to the respondent's behavior and perception of the city water quality. Respondents were asked whether or not they used a water treatment device or purchased bottled water. If they answered 'yes', we asked how much they spent on bottled water per month or how much they spent to install and maintain the treatment device. Respondents were also asked their perception of the current water quality. They rated their water quality first on a 5-point scale (very poor to very good) with the rating based on the following characteristics; taste, odor, color, softness, and then second on a 10-point scale (very unsafe to very safe) for safety from arsenic contamination. This same question regarding safety from arsenic contamination was asked before providing the respondent with information about the actual levels of arsenic and then again after providing them with the information. The information provided were two different types: general information about the characteristics of arsenic, the adverse health effects, sources of arsenic contamination, and new government standards, and specific information about the level of arsenic in their community water on average in 2006 and the average level of arsenic during 2000-2005.[10]

The second part of the survey questionnaire contained two willingness-to-pay questions using a double-bound dichotomous choice question format. The same WTP question was asked before providing the respondent with information about the actual levels of arsenic in their drinking water and then again after providing them with the information. The WTP question was stated as follows:

Would you be willing to pay $ __ annually ($ __ per month), in excess of your current water bills, for strengthening the water quality standard by lowering the permitted level of arsenic from 50 µg/L to 10 µg/L? □ Yes □ No

[10] Poe (1993) found that the provision of both general information about nitrates and the specific nitrate levels found in an individual's well were necessary to get an unbiased estimates of WTP for groundwater protection.

The bid amounts were the following 5 classes: \$15 (\$5/\$30), \$30 (\$15/\$50), \$50 (\$30/\$70), \$70 (\$50/\$120), \$120 (\$70/\$200). The bid amounts were selected after a pilot survey tested different bid amounts.

The final section of the questionnaire requested information about the respondent's socioeconomic and demographic characteristics. These characteristics included gender, age, level of education, total household income, average monthly water bill, total value of respondent's house, and whether children under 7 years old were living in the household or not.

After redesigning the survey questionnaire based on results from the pilot survey, the surveys were mailed out in three different successive mailings following closely Dillman's (1978) recommendations for maximizing response rate. The survey was conducted in March through April 2007. The overall response rate was 51.0%.[11] Out of the 530 responding individuals, 109 respondents did not obtained their water from the city water systems (21.5% of the sample) and 28 respondents (2.8%) refused to answer because they were living in a nursing home, dislike surveys, or did not know enough about the water quality to answer the questions. The remaining 393 individuals obtained their water from a city water supply system.

Table 3. Distribution of Survey Responses

Grouped by arsenic level	Size of community			Total
	Above 1,000	501-1,000	Less than 500	
High-High	46	62	38	146 (37.2%)
Low-High	47	46	51	144 (36.6%)
Low-Low	45	33	25	103 (26.2%)
Total	138 (35.1%)	141 (35.9%)	114 (29.0%)	393 (100%)

[11] The actual total sample size was 1,040 rather than 990 because we replaced 50 incomplete responses at first mailing that were non-city water users. Thus, the actual response rate was 51.0% (530 out of 1,040).

IV. RESULTS

Perception of Water Quality

When respondents were asked to rate their current tap water quality, the city water users' average rating was 3.49, 3.64, 3.71 for taste, odor, and color respectively. About 20 percent (21.9%, 20.1%, 16.8% for taste, odor, and color respectively) of respondents rated the taste, odor, and color of their water to be of "poor" or "very poor" quality. Over 50 percent of respondents think that their tap water is hard (poor and very poor) and the users on average gave their water a lower rating at 2.79 for softness. Consumers who did not use treatment devices or purchased bottled water rated their tap water significantly better than those who used treatment devices or purchased bottled water on taste (3.94 vs 3.22), odor (4.01 vs 3.41), color (4.15 vs 3.46), and softness (3.13 vs 2.60). Using a two-tail t-test, the differences were tested for the drinking water quality ratings 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 4 and show that respondents who used treatment devices or purchased bottled water were significantly more concerned with their water quality than survey participants who used regular tap water. We also tested whether other factors, such as children in a household, education, and age, affect respondents' ratings of drinking water quality. Table 4 shows that neither children in a household (panel B) nor higher education (panel C) have a significant effect on the mean rating of water quality. However, respondents over 60 years of age gave their water significantly higher rating than those under 60 years old for all water quality characteristics (Table 4, panel D).

Respondents were also asked to rate their drinking water quality in terms of the arsenic contamination on a 10-point scale. On average respondents rated the tap water quality in terms of arsenic contamination at 6.77 and 6.94 for before and after receiving information about the actual level of arsenic respectively. About 57 percent of respondents (209 out of 369 responses) changed their ratings for arsenic safety after receiving information about the standards and the actual level of arsenic found in their system. Using a paired t-test, differences in quality ratings were tested for the arsenic contamination in drinking water before and after information was provided concerning arsenic levels (see Table 5). Respondents who belonged to the 'high-high' group changed their perceptions relatively little, and the changes were not statistically significant (panel A). The average safety ratings of respondents who belonged to the 'low-high' group increased significantly from 6.97 to 7.23 and the 'low-low' group respondents also increased significantly from 7.26 to 7.75 (Table 5, panel A).

Table 4. Water Quality Ratings by Respondent Groups

PANEL A	Survey Respondent Group		
Water Quality Characteristics	Respondents who use treatment devices or purchase bottled water	Respondents who did not use treatment devices or purchase bottled water	*t*-value[a]
Taste	3.22	3.94	6.70***
Odor	3.41	4.01	5.47***
Color	3.46	4.15	6.51***
Softness	2.60	3.13	4.29***
PANEL B	Survey Respondent Group		
Water Quality Characteristics	Respondents in households with children under 7	Respondents in households with no children under 7	*t*-value[a]
Taste	3.31	3.52	1.38
Odor	3.58	3.65	0.46
Color	3.53	3.75	1.47
Softness	2.76	2.80	0.20
PANEL C	Survey Respondent Group		
Water Quality Characteristics	High school graduate or less	College graduate or more	*t*-value[a]
Taste	3.42	3.59	1.49
Odor	3.57	3.73	1.41
Color	3.64	3.82	1.67*
Softness	2.77	2.81	0.38
PANEL D	Survey Respondent Group		
Water Quality Characteristics	Over 60 years old	Below 60 years old	*t*-value[a]
Taste	3.75	3.35	3.54***
Odor	3.83	3.53	2.61***
Color	3.95	3.57	3.45***
Softness	2.88	2.72	1.29

Note: Single, double, and triple asterisks (*) denote statistical significance at the 10%, 5%, and 1% level, respectively. Water quality ratings are based on a five-point scale where 1 = very poor and 5 = very good.

[a] Two-tail t-test for difference of means with equal variances.

About 16% of respondents were unaware of the health risk association with arsenic in drinking water, and 41% of respondents had heard about the health risk association with arsenic but didn't know much about its health effects. The average safety ratings for these two groups went up significantly after they received information about the arsenic levels in their drinking water (see panel B of Table 5). Only about 43% (33% and 10%) of respondents answered that they knew about the general health risk associated with arsenic in drinking water or had detailed information concerning the health risk. In both cases, there were no significant differences between respondents' average safety ratings before and after the information on arsenic levels was provided. These results indicated that the respondents' safety perception closely follows their knowledge concerning the health risk associated with arsenic in drinking water.

Table 5. Water Quality Ratings for Arsenic Contamination by Community Group and Knowledge

PANEL A: Grouped by arsenic level	Ex ante perception	Ex post perception	*t*-value[a]
High–High (n=135)	6.23	6.10	0.656
Low–High (n=137)	6.97	7.23	2.016**
Low–Low (n=97)	7.26	7.75	3.033***
PANEL B: Previous knowledge concerning the health risk associated with arsenic in drinking water	Ex ante perception	Ex post perception	*t*-value[a]
Don't know at all (n=54)	6.83	7.33	1.789*
Have heard of it, but don't know much (n=153)	6.24	6.55	2.108**
Know general health risk (n=120)	6.95	6.91	0.321
Have detailed information (n=40)	8.00	8.15	0.538

Note: The 'high-high' group currently has arsenic levels above the new standard level of 10 μg/L and historically has had high arsenic levels. The 'low-high' group currently has arsenic levels below 10 μg/L but historically has had high arsenic levels. The 'low-low' group currently and historically has had, on average, safe levels of arsenic in their water. Single, double, and triple asterisks (*) denote statistical significance of 10%, 5%, and 1%, respectively. Water quality ratings are based on a ten-point scale where 1=very unsafe and 10=very safe.

[a] Paired sample t-test.

Estimation of Willingness to Pay

Table 6 lists the variables included in the WTP function for this study and their summary statistics. The results of the bivariate probit analysis for WTP function are presented in tables 7 and 8 using ex-ante responses (before providing information about arsenic contamination; Models 1 and 2) and ex-post responses (after providing information about arsenic contamination; Models 3 and 4). Models 1 and 3 assume, $\beta_1=\beta_2$ and $\sigma_1=\sigma_2$, where as models 2 and 4 assume $\beta_1\neq\beta_2$ and $\sigma_1\neq\sigma_2$.

Table 6. Explanatory Variables included in the WTP function

Variable	Description	Mean	S. D.
ACT	1 if respondent uses water treatment device or purchases bottled water; 0 otherwise	0.646	0.479
PCT_an	Ex ante perception of safety in terms of arsenic contamination	6.695	2.376
PCT_po	Ex post perception of safety in terms of arsenic contamination	6.909	2.519
LEVEL_H	1 if communities still have arsenic levels above the new standard level of 10 μg/L; 0 otherwise	0.363	0.482
LEVEL_L	1 if communities levels have arsenic below 10 μg/L, but have historically had high arsenic contamination levels; 0 otherwise	0.366	0.482
SIZE_S	1 if the population of community is less than 500; 0 otherwise	0.302	0.460
SIZE_M	1 if the population of community is more than 500 but less than 1000; 0 otherwise	0.341	0.475
LnBID_B1	1^{st} amount proposed before providing the arsenic information ($ per year)	3.814	0.730
LnBID_B2	2^{nd} amount proposed before providing the arsenic information ($ per year)	3.747	0.920
LnBID_A1	1^{st} amount proposed after providing the arsenic information ($ per year)	3.814	0.730
LnBID_A2	2^{nd} amount proposed after providing the arsenic information ($ per year)	3.723	0.920
CHILD	1 if there are children under 7 years of age in household; 0 otherwise	0.168	0.374
AGE	1 if respondent's age is greater than 60; 0 otherwise	0.317	0.466
EDU	Education level. The reported intervals are: 1=eleventh grade or less; 2=high school diploma; 3=completed technical school or some college; 4=college graduate or more	2.869	0.891
INCOME	Annual household total income before tax. The reported intervals are: 1=$10,000 or less; 2=$10,001 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 $75,000 7=$75,000 to $100,000; 8=$100,001 or more	5.076	1.915

The analyses show that a number of factors affect respondents' WTP to reduce the level of arsenic in their drinking water. The first twelve rows in table 7 are for the first response while the second twelve rows are for the second response. The correlation coefficient is positive and significantly different from zero across all models indicating that there is a positive correlation between the two responses. The ex-ante WTP (before providing information about arsenic contamination) was significantly affected at the 10% level or lower by the following variables (factors): PCT_an (ex-ante perception of drinking water safety from arsenic), AGE (whether or not respondent is over 60 years), EDU (educational attainment), LEVEL_H (whether 2006 arsenic level was above the new standards), and LEVEL_L (whether 2006 arsenic level was lower than the new standards but historically

Table 7. Estimated Effects of Respondent Characteristics, Water Quality, Information and Community Size on WTP (*n* = 328)

Parameter	Using Ex-ante Responses				Using Ex-post Responses			
	Model 1 ($\beta_1=\beta_2$)		Model 2 ($\beta_1\neq\beta_2$)		Model 3 ($\beta_1=\beta_2$)		Model 4 ($\beta_1\neq\beta_2$)	
	Coefficient	Std. Error	coefficient	Std. Error	coefficient	Std. Error	coefficient	Std. Error
Constant	1.074**	0.447	1.177**	0.591	1.276***	0.453	1.249**	0.571
ACT	0.011	0.136	- 0.028	0.169	- 0.002	0.139	- 0.154	0.170
PCT_an(po)	- 0.086***	0.027	- 0.119***	0.034	- 0.116***	0.025	- 0.147***	0.032
LEVEL_H	0.332**	0.147	0.474**	0.193	0.541***	0.159	0.499**	0.207
LEVEL_L	0.241*	0.146	0.354*	0.194	0.348**	0.156	0.388*	0.202
SIZE_S	- 0.224	0.147	- 0.108	0.191	- 0.036	0.153	0.108	0.197
SIZE_M	- 0.196	0.144	- 0.293	0.182	- 0.078	0.151	- 0.046	0.188
CHILD	- 0.007	0.168	0.046	0.202	0.051	0.173	0.181	0.210
AGE	- 0.331**	0.141	- 0.160	0.189	- 0.267*	0.161	- 0.126	0.196
EDU	0.145**	0.073	0.138	0.096	0.072	0.077	0.130	0.096
INCOME	0.027	0.035	0.051	0.048	0.010	0.039	0.011	0.048
LnBID_B1	- 0.312***	0.078	- 0.318***	0.103	- 0.300***	0.076	- 0.270***	0.099
Constant	-	-	1.103*	0.594	-	-	1.338**	0.553
ACT			0.046	0.170			0.142	0.166
PCT_an(po)			- 0.061*	0.035			- 0.091***	0.032
LEVEL_H			0.205	0.184			0.585***	0.189
LEVEL_L			0.139	0.185			0.307*	0.189
SIZE_S			- 0.338*	0.193			- 0.164	0.186
SIZE_M			- 0.108	0.181			- 0.108	0.177
CHILD			- 0.059	0.213			- 0.066	0.205
AGE			- 0.499**	0.195			- 0.402**	0.204
EDU			0.153*	0.093			0.019	0.094
INCOME			0.005	0.047			0.011	0.048
LnBID_B2			- 0.332***	0.095			- 0.335***	0.089
ρ	0.402***		0.456***		0.567***		0.618***	
log L	- 413.17		- 406.06		- 396.20		- 389.77	

Note: Single, double, and triple asterisks (*) denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 8. Estimated Median WTP by Water Quality Group and Model ($/year)

Panel: A (Model 1)		Communities' size		
		Above 1,000	501-1,000	Less than 500
Group	High-High	30.89	24.92	24.88
	Low-High	27.85	22.47	22.42
	Low-Low	20.99	16.94	16.90

Panel: B (Model 2)		Communities' size					
		Above 1,000		501-1,000		Less than 500	
		1st WTP	2nd WTP	1st WTP	2nd WTP	1st WTP	2nd WTP
Group	High-High	36.85	27.05	26.89	24.22	33.25	19.91
	Low-High	32.23	25.22	23.52	22.58	29.08	18.55
	Low-Low	21.44	21.62	15.65	19.36	19.35	15.91

Panel: C (Model 3)		Communities' size		
		Above 1,000	501-1,000	Less than 500
Group	High-High	17.07	15.61	16.47
	Low-High	13.57	12.41	13.09
	Low-Low	8.87	8.11	8.56

Panel: D (Model 4)		Communities' size					
		Above 1,000		501-1,000		Less than 500	
		1st WTP	2nd WTP	1st WTP	2nd WTP	1st WTP	2nd WTP
Group	High-High	14.86	19.16	14.03	17.16	16.76	16.52
	Low-High	12.87	14.21	12.15	12.73	14.51	12.26
	Low-Low	7.61	10.16	7.18	9.10	8.58	8.77

above it). The variables with a significant effect on ex-post WTP (after providing information about arsenic contamination) were PCT_po (ex-post perception for drinking safety from arsenic), AGE, LEVEL_H, and LEVEL_L. The negative sign for the estimated coefficients of PCT_an and PCT_po indicates that consumers who perceived their drinking water to be unsafe from arsenic contamination are more willing to pay to improve their drinking water. The AGE variable has a negative and statistically significant coefficient, which indicates that those who are less than 60 years old are willing to pay more to improve water quality. The estimated positive coefficients from EDU imply that the knowledge acquired in the process of education increases consumers' interest and concerns about the drinking water quality. Better educated individuals tend to be more aware of the necessity of solving community problems and have a greater willingness to support improvements (Cho *et al*., 2005). The positive signs of LEVEL_H (or LEVEL_L) indicate that respondents whose arsenic level in their drinking water in 2006 was above the new standards or who have had historically high levels of arsenic are willing to pay more than the other respondents. Household income, whether or not there are children under 7 years of age in the household (CHILD), and respondents' averting behavior (purchasing bottled water or using a home water treatment device) (ACT), did not have significant impacts on WTP. In addition, communities' size (SIZE_S and SIZE_M) are not statistically significant, implying that consumers' WTP do not differ by size of community.

Median Willingness to Pay

The median WTP rather than mean WTP was computed for each size of community and level of arsenic by using equation (4) based on the mean values of the explanatory variables for each model (Table 8). The median of the WTP is the amount for which the probability of a 'yes' answer is 0.5. This is a more robust statistic than the mean WTP (Polome *et al*., 2006). For computing welfare measures in the case of an asymmetric distribution, such as we used (lognormal), the estimated mean WTP is often very large. This is because the tail of the distribution is skewed to right. We use the median WTP because it is less sensitive to the tails of the distribution.[12]

The median WTP varies largely depending on the 2006 level of arsenic and the history of arsenic contamination (Table 8). The median estimates of panel A, B, C and D in Table 9 were calculated by using the results of Models 1, 2, 3, and 4, respectively. Households in 'high-high' group are willing to pay from $19.91 to $36.85 annually in the ex-ante case and from $14.03 to $19.16 annually in the ex-post case. Households in 'low-low' group are willing to pay from $15.65 to $21.62 in the ex-ante case and from $7.18 to $10.16 annually in the ex-post case. The median WTP in the ex-post case (panel C and D) is smaller than that of the ex-ante case (panel A and B). The WTP are also small relative to the average water bill. The estimated median WTP is only 2.9-

[12] Alberini (1995a, p.290) notes that "mean WTP is often the statistic of natural interest in applied public economics, since it yields the total benefits from the project or plan after it is multiplied by the size of the population. However, it is assumed that the researcher is interested primarily in median WTP, because of its interpretation as the maximum cost to the household of the environmental plan that would still secure a 50% major vote. Since WTP has an asymmetric distribution, mean and median WTP do not coincide, the difference being a constant scale factor, $\exp(0.5\sigma^2)$."

4.4% of the consumer's average water bill for the high-high group, 2.2-2.3% for the low-high group, and 1.4-1.9% for the low-low group (see Table 9).

Other studies estimating WTP for water quality have not explicitly considered arsenic contamination. For example, estimates of the annual mean WTP for improves groundwater quality in Georgia were reported by Jordan *et al*. (1993) at $121 for residents with public water systems. Shultz *et al*. (1990) found an annual mean WTP of $129 for residents in Diver, New Hampshire. Kim *et al*. (2002) found the annual mean WTP of households for reduction in copper concentration in drinking water varied from $30 to $57. Cho *et al*. (2005) found that, on average, individuals were willing to pay $63 per year to reduce the level of iron and $52 per year to reduce the level of sulfate in their drinking water. The differences in the annual mean (or median) among studies might stem from differences in the study area and design. Further, because the WTP estimates in our study represent a WTP for a reduction only in the arsenic standard, they are likely to be smaller than the WTP when reductions of more than one contaminant are considered. In fact, we expected low estimates for WTP since the change in the arsenic standard offered only small reductions in health risks.

Table 9. A Comparison of Median WTP for Ex-post Cases with Average Water Bill by Community Size and Arsenic Level Group

Group by arsenic level	Community size	Median WTP for ex-post ($)*		Average water bills ($)		Ratio of [a]/[b]
		Monthly	Annually [a]	Monthly	Annually [b]	
High-High	Less than 500	1.37	16.47	48.10	577.20	0.029
	501-1,000	1.30	15.61	29.65	355.80	0.044
	Above 1,000	1.42	17.07	45.65	547.80	0.031
Low-High	Less than 500	1.09	13.09	49.66	595.92	0.022
	501-1,000	1.03	12.41	46.13	555.60	0.022
	Above 1,000	1.13	13.57	48.65	583.20	0.023
Low-Low	Less than 500	0.71	8.56	45.29	543.48	0.016
	501-1,000	0.68	8.11	47.07	568.84	0.014
	Above 1,000	0.74	8.87	39.33	471.96	0.019

* Used the results of panel C of Table 8 for ex-post WTP responses.

Characteristics of Respondents and their Households

The survey found that 175 responses (45.1% of sample) were female while 213 (54.9%) were male[13]. About fifteen percent of respondents (59 out of 390) had children under 7 years old living in their home. The average age was 55 years while the ages ranged from 23 to 97 years. About 60 percent of the respondents had more than a high school education. The annual total household income using the midpoint of reported intervals was $61,200. The estimated average water bill of respondents who receive their water from the city water system was $44.21 per month.

To improve their drinking water, 251 out of 393 respondents (64%) used either bottled water or had a home water treatment device. Almost 32 percent (124 out of 393) of sample purchased bottled water regularly, and spent on average $31 per month. About 46 percent of respondents used a water treatment device (including a filter or water softener) and they spent about $405 on average on installation of the treatment device and about $23 per month on maintenance (e.g., filter changes).

When we compare the surveys' responses with the census data[14] for demographic characteristics of gender, household income, age, and education, there are some differences in the distribution of age and household income (Table 10). The hypotheses that there are no significant differences in distribution by age and household income are rejected at the 1% level of significance. Our surveys had a higher proportion of respondents over 55 years of age and a smaller number of respondents who earned less than $10,000 or more than $100,000 per year. In contrast, the hypotheses that there are no significant differences in the distribution of gender or education could not be rejected at the 1% level. The two differences between the sample and population characteristics based on the census data may result in bias in calculating the average WTP and aggregate WTP. However, the bias may not be critical if the estimates of willingness-to-pay are not highly sensitive to these variables. Also, the census data includes all people who live in the communities and, therefore, may not be representative of the population who use public water systems in our sample of small communities.

[13] The number of respondents does not add up to 393 because some people refused to provide personal information.
[14] U.S. Census Bureau, 2005 American Community Survey.

Table 10. Comparison of Demographic Characteristics between Census and Survey Data

Characteristics	Census*	Sample	χ^2-value
Gender			
- Male	2,476,815 (49.6%)	213 (54.9%)	4.294
- Female	2,513,033 (50.4%)	175 (45.1%)	
Household income			
- Less than $10,000	126,881 (6.3%)	13 (3.8%)	
- $10,000 to $100,000	1,532,301 (75.8%)	303 (87.5%)	26.154
- $100,000 or more	360,962 (17.9%)	30 (8.7%)	
Age**			
- Over 55 years	1,082,385 (29.7%)	185 (48.4%)	63.782
- Below 55 years	2,556,117 (70.3%)	197 (51.6%)	
Education***			
- High school graduate or less	1,222,092 (37.1%)	152 (39.6%)	0.997
- Higher than high school graduate	2,070,082 (62.9%)	232 (60.4%)	

* Source: U.S. Census Bureau, 2005 American Community Survey

, * Used only the data of persons at least 20 years old and 25 years old, respectively.

V. COSTS & BENEFITS OF COMPLIANCE

The costs of arsenic treatment may vary significantly among water systems, depending on community size, availability of other sources, and existing treatment technologies (EPA, 2003). For example, if there are other sources available with arsenic concentrations below the MCL, either existing or new, then the system might consider utilizing those sources, by abandoning, seasonal using, or blending the problematic sources. Furthermore, some water systems may be able to simply optimize or enhance existing treatment for arsenic removal. Enhanced lime softening and enhanced coagulation/filtration are often estimated to be low-cost alternatives. Installing new treatment technologies is often the most expensive alternative, as it requires capital investments. EPA (2003) has identified six full-treatment (or centralized) technologies (iron exchange, activated alumina, coagulation-assisted microfiltration, coagulation-assisted direct filtration, and oxidation/filtration) and three point-of-use technologies (activated alumina, iron-based sorbent, and reverse osmosis). The choice of the most appropriate technology for a particular water system depends on water quality parameters (i.e. technical suitability), system size, flow rate, system preferences, and other economic/engineering conditions. Moreover, the treatment costs must include not only the capital and O&M costs of treatment per se but also those of waste handling. Therefore, it is not possible to obtain estimates for average annualized costs of arsenic treatment that can be used uniformly for all systems in our study area. Thus, we can only offer the EPA's estimates of ranges of treatment costs by community system as an imprecise guide.

The average annual household costs are shown categorized by system size in Table 11. The average annual costs for monitoring and compliance in public water systems serving fewer than 500 people was from $162 to $327 in 2002 dollars, while the annual costs per household in medium-sized systems (i.e., 3,301 – 10,000 people) was only $38. The disparity in household costs between systems of different size is due to economies of scale as discussed above. Larger systems are able to spread the costs over their sizeable customer base.

Table 11. Average Annual Costs by Household and Public Water Supply System (in 2002 $)

Size of system (number of persons served)	Annual costs per household ($/yr)	Average annual costs per public water system ($/yr)
< 500	$327 - $162	$6,494 - $12,358
501 to 3,300	$71 - $58	$22,100 - $53,086
3,301 to 10,000	$38	$111,646
10,000 and above	$32 - $0.86	$531,584 - $1,340,716

Source: US EPA, Arsenic Guidance, 2002.

As discussed in the preceding section, our ex-post median WTP estimates for lowering the arsenic standard from 50 ppb to 10 ppb are $14.03-$19.16, $12.15-$14.51, and $7.18-$10.16 annually for high-high, low-high, and low-low groups, respectively. Because system size did not have a significant impact on these WTP estimates, we can assume that they are the same across different sized communities. We can use the same estimates with different sized systems. When we do this the median WTP estimates are all lower than the average treatment costs at public water systems serving populations of 10,000 or less. Thus, a majority vote would not support the new arsenic rule in these smaller communities. However, since the new rule is already being enforced, this implies that these communities may have difficulty financing the new standard, as the primary source of financing comes from increased water bills and consumers may not be willing to pay enough to cover the costs. Though no complete estimates from the surveyed communities are available, some communities in our survey have reported increases in water bills due to the new arsenic rule. As one would expect from our earlier discussion, compliance costs seem to vary significantly among water systems.

Analogous to public treatment, private costs of treatment in homes can vary significantly, depending on type of technologies, water usage, and product brands. Thus, no uniform estimates for private treatment costs are available. The estimates in Table 12 were calculated using information offered by New Hampshire Department of Environmental Services (NHDES, 2006). The NHDES provides ranges of installation costs (including capital and labor costs) and ranges of O&M costs, respectively, for adsorptive media (e.g. activated alumina) and for reverse osmosis devices as well as point estimates for an anion exchange device. No engineering estimates were available for the years of effective life or depreciation rate for these technologies. Because reverse osmosis membranes can last up to 10 years, we assume 10 years as the capital cost recovery period. Our casual market research suggests that actual retail prices of these technologies can be lower than even the “low” estimates in

Table 12. In this regard, the "high" estimates may be thought of as upper-bound estimates of private arsenic treatment costs. These estimates seem to suggest that for small communities, home treatment devices can potentially be a viable option since the "low" estimate for adsorptive media technologies are lower than the lower bound estimate for community systems serving less than 500 people (Recall that in our study, 16 our of 30 communities serve population less than 500).

Variability of treatment costs across systems (even for the same community size), combined with our low WTP estimates, also suggests that consumers may benefit significantly from flexibility in compliance. That is, the annual costs per household of using home water treatment devices may be lower for small communities depending on what kinds of devices are selected (see table 12). Public water supply systems can provide a higher level of water quality cheaper than individuals if they can take advantage of the economies of scale. However, above a certain threshold level of water quality (i.e. making stricter standards), and below a threshold size of water system the compliance costs for public water supply systems may be higher than those for each individual household. Thus, especially for small rural communities, direct government support may be needed for individual households (i.e., providing a proper home water treatment device and subsidizing operating costs) rather than having the public water supply systems meet higher standards.[15] For example, in small communities a utility (or government) could supply drinking water with little or no arsenic separately from water for activities such as washing (i.e., bottled water or home water treatment device for drinking/cooking only). Households generally use only a small amount of tap water provided by public water systems for cooking and drinking and use the rest for washing, watering, and flushing toilets. Providing only high quality water for drinking and cooking could significantly reduce the cost of supplying water.

Currently, federal regulations (the Safe Drinking Water Act) do allow for a variance and an exemption as part of the compliance strategies for various pollutants including inorganic arsenic (Section 141.62). When a variance or an exemption is granted, the public water system may use point-of-use (POU) or point-of-entry (POE) devices at affected units (e.g. homes) to ensure protection against unreasonable health risks. However, these regulations do require that "POU and POE units must be owned, controlled, and maintained by the public water system or by a contractor hired by the public system to ensure proper operation and maintenance of the devices and compliance with MCLs" (p. 2-1, EPA, 2006). In other words, the regulations don't allow public systems to delegate their responsibility for the operation and maintenance of installed POU or POE devices to homeowners as part of a compliance strategy (p. 2-1, EPA, 2006). Due to these stringent rules, the complexity in their implementation, and state agencies' limited interests, variances and exemptions have been rarely granted.

[15] In some non-trivial cases where only expensive options are technically feasible, private treatment may be much lower cost on a per-household basis than public treatment. Consumer welfare may be greater if private treatment is allowed as an option to comply.

Table 12. Costs per Household for Private Home Treatment

Type of Costs	Adsorptive Media (POU)		Reverse Osmosis (POU)		Anion Exchange (POE)
	Low	High	Low	High	
Installation costs (S)	600	800	950	1,300	1,800
Annual O&M costs ($)	75	300	100	100	150
Annualized costs of treatment ($/year)*	135	380	195	230	330

*Assumed ten-year life.

Source: New Hampshire Department of Environmental Services

The cost estimates for public and private treatment in Table 11 and Table 12 points out another important issue. Our median WTP estimates are in most cases smaller than the cost of either the private or public treatment option for small communities which suggests that both private and public treatment *decreases* consumer welfare, at least on average. An average household in small communities would be better off without *any* additional treatment (provided that these estimates are correct). Because there may be subpopulations who are susceptible to arsenic and have high health risks or who are highly risk-averse, it is not necessarily socially optimal to forgo the publicly mandated risk level of 10 ppb for drinking water, simply on the basis of the cost-benefit analysis.[16] A basic question of fairness may also come into play – is it justifiable to provide "public" treatment to only the susceptible subpopulations whereas the non-susceptible subpopulations still face *some* level of risks. Furthermore, it may not be feasible to appropriately define susceptive subpopulations since health risks can depend on many factors such as age, sex, habit, and other co-morbidities.

To try to deal with some of these issues, Wilson (2001) suggested a two-step regulation for smaller water systems: a mandatory 50 µg/L standard and an advisory 10 µg/L standard for water systems with users who have been active participants in the systems' decision-making. For those systems, all users would be informed of the possible effects of arsenic exposure on health, and the costs of lowering arsenic concentrations in their water. They would then be able, through ordinary democratic procedures, to participate in the decision of whether to adopt the 10 µg/L standard for their system or to maintain the 50 µg/L standard. Umshler (1999) also suggested that EPA should provide communities with the mandatory national standard and a range of optional lower standards with their associated costs and hypothetical benefits. The communities would then be allowed to choose the amount of risk they are willing to take and their level of commitment of financial and personnel resources to meet lower standards. However, even with this participatory approach, the issue concerning heterogeneous subpopulations at risk still may not be fully resolved, as long as some majority decision rules are used. Given this heterogeneity in susceptibility to water contaminates, and preferences regarding health risks,

[16] A caveat is in order regarding the costs of arsenic treatment, which may need to be evaluated while considering the benefits and costs from treating other pollutants, since many of the treatment strategies listed above can simultaneously treat multiple pollutants.

allowing for private treatment along with extensive information programs may require financial assistance particularly for low income groups ("tagging" policies in the sense of Zivin and Zilberman, 2002) if the private alternative is to be viable.

CONCLUSION

This study shows that community water users' WTP were not significantly different among different-sized communities, but there were significant differences in WTP among communities that had different level of arsenic in their drinking water. The estimated median WTP are \$14.03-\$19.16 annually for communities with high levels of arsenic in their water, \$12.15-\$14.51 annually for communities that use to have high levels of arsenic, and \$7.18-\$10.16 annually for those communities with low levels of arsenic. The estimated median WTP, however, may not be sufficient to pay the full cost of providing improved water quality through public water systems for the small communities. Especially, for systems serving 500 or fewer people, the costs per household could be very high because they cannot take advantage of economies of scale in water treatment systems. Alternatives for small public systems should be considered, including encouraging the use of bottled water or a home treatment device for drinking water and water for cooking while the city continues to provide water with arsenic levels above 10 μg/L but below 50 μg/L. If such flexibility is not allowed, small water systems may have to divert funds from other very important waste treatment investments to use in lowering arsenic levels because of limited funds.

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APPENDIX 1

Response Frequencies for the Double-bounded Interval

PANEL A : Ex ante WTP		Responses			
Thresholds 1st (2nd)	n	YY NY	YN NN	%YY %NY	%YN %NN
$15 ($5, $30)	78	28 15	17 18	35.9% 19.2%	21.8% 23.1%
$30 ($15, $50)	78	16 13	18 31	20.5% 16.7%	23.1% 39.7%
$50 ($30, $70)	70	21 9	12 28	30.0% 12.9%	17.1% 40.0%
$70 ($50, $120)	81	14 12	21 34	17.3% 14.8%	25.9% 42.0%
$120 ($70, $200)	86	6 17	21 42	7.0% 19.8%	24.4% 48.8%
PANEL B : Ex post WTP		Responses			
Thresholds 1st (2nd)	n	YY NY	YN NN	%YY %NY	%YN %NN
$15 ($5, $30)	78	33 12	13 20	42.3% 15.4%	16.7% 25.6%
$30 ($15, $50)	78	15 9	14 40	19.2% 11.5%	17.9% 51.3%
$50 ($30, $70)	70	19 13	9 29	27.1% 18.6%	12.9% 41.4%
$70 ($50, $120)	81	15 12	17 37	18.5% 14.8%	21.0% 45.7%
$120 ($70, $200)	86	9 12	18 47	10.5% 14.0%	20.9% 54.7%

APPENDIX 2

I. WATER QUALITY

1. Does your household use water from the **city water system** or **public water supply system**?
   □ Yes (➔ go to Question #2) □ No (➔ go to Question #3)

2. How would you rate your current **tap water quality** in terms of the following specific characteristics? (Please, check one by one for each characteristics)

	very poor	***poor***	***fair***	***good***	***very good***
TASTE					
ODOR					
COLOR					
SOFTNESS					
SAFETY*					

* *Safety in terms of possible contamination by pollutants such as nitrates, sulfur and copper.*

3. How much do you currently know about **health risk associated with <u>ARSENIC in drinking water</u>**?

   □ Do not know at all
   □ Have heard of it, but do not know much about it
   □ Know general health risk associated with arsenic in drinking water
   □ Have detailed information on health risk as well as the current arsenic levels in our water

4. How would you rate your ***drinking water safety level*** from the **ARSENIC** contamination **<u>before you use any home treatment device</u>**? Please circle the level that best describes your perception. Rate it on a 10-point scale, with 1 being "very unsafe" and 10 being "very safe".

Very Unsafe		**Unsafe**		**Somewhat Unsafe**		**Somewhat Safe**		**Safe**	**Very Safe**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

5. Does your household regularly use **bottled water** as a main source of water for drinking?

□ Yes (➔ go to Question #6)　　　　　　　　□ No (➔ go to Question #7)

6. Over the last six months, approximately how much money did your household spend on bottled water purchases **per month**?

About ______________ dollars **per month**

7. Does your household use any type of **water treatment devices** in your home?

□ Yes (➔ go to Question #8)　　　　　　　　□ No (➔ go to Question #12)

8. **What types** of water treatment devices are used in your household?

- □ Removable water filter
- □ Installed water treatment
- □ Other (please specify) ____

9. How much did your household spend **on installation** of the treatment device?

About ______________ dollars

10. Over the last six months, how much money did your household spend **on maintenance** of this device (e.g. filter changes) **per month**?

About _____________ dollars **per month**

11. How would you rate your ***drinking water safety level*** from the **ARESENIC** contamination **<u>after your home water treatment</u>**? Please circle the level that best describes your perception.

Very Unsafe		**Unsafe**		**Somewhat Unsafe**		**Somewhat Safe**		**Safe**	**Very Safe**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

12. If your household regularly uses **bottled water** or a **water treatment device**, why do you do so?

- □ Better for health, Free of harmful contaminants
- □ Tastes better or smells better
- □ To eliminate visible contaminants
- □ Other (please specify) ____

The U.S. Environmental Protection Agency established a **new standard for ARSENIC** in drinking water, which requires that arsenic concentration levels must be **below 10µg/L**. The new rule replaces the old standard of **50µg/L**. Your community may need to install a new or improved treatment system to meet the new arsenic standard in your community water. Note that your community, even if it currently meets the new standard, may violate this new standard from time to time, and therefore, have to incur increased costs to maintain compliance with the new standard.

13. **Would you be willing to pay $ <u>120</u> annually ($ <u>10</u> per month), in excess of your current water bills, for strengthening the water quality standard by lowering the permitted level of arsenic from 50µg/L to 10µg/L?**

□ Yes (➔ go to Question #14)

□ No (➔ go to Question #15)

14. **Would you be willing to pay $ <u>200</u> annually ($ <u>16.67</u> per month), in excess of your current water bills, for strengthening the water quality standard by lowering the permitted level of arsenic from 50µg/L to 10µg/L?**

□ Yes (➔ go to INFORMATION SHEET)

□ No (➔ go to INFORMATION SHEET)

15. **Would you be willing to pay $ <u>70</u> annually ($ <u>5.83</u> per month), in excess of your current water bills, for strengthening the water quality standard by lowering the permitted level of arsenic from 50µg/L to 10µg/L?**

□ Yes (➔ go to INFORMATION SHEET)

□ No (➔ go to INFORMATION SHEET)

A. Arsenic Information Sheet

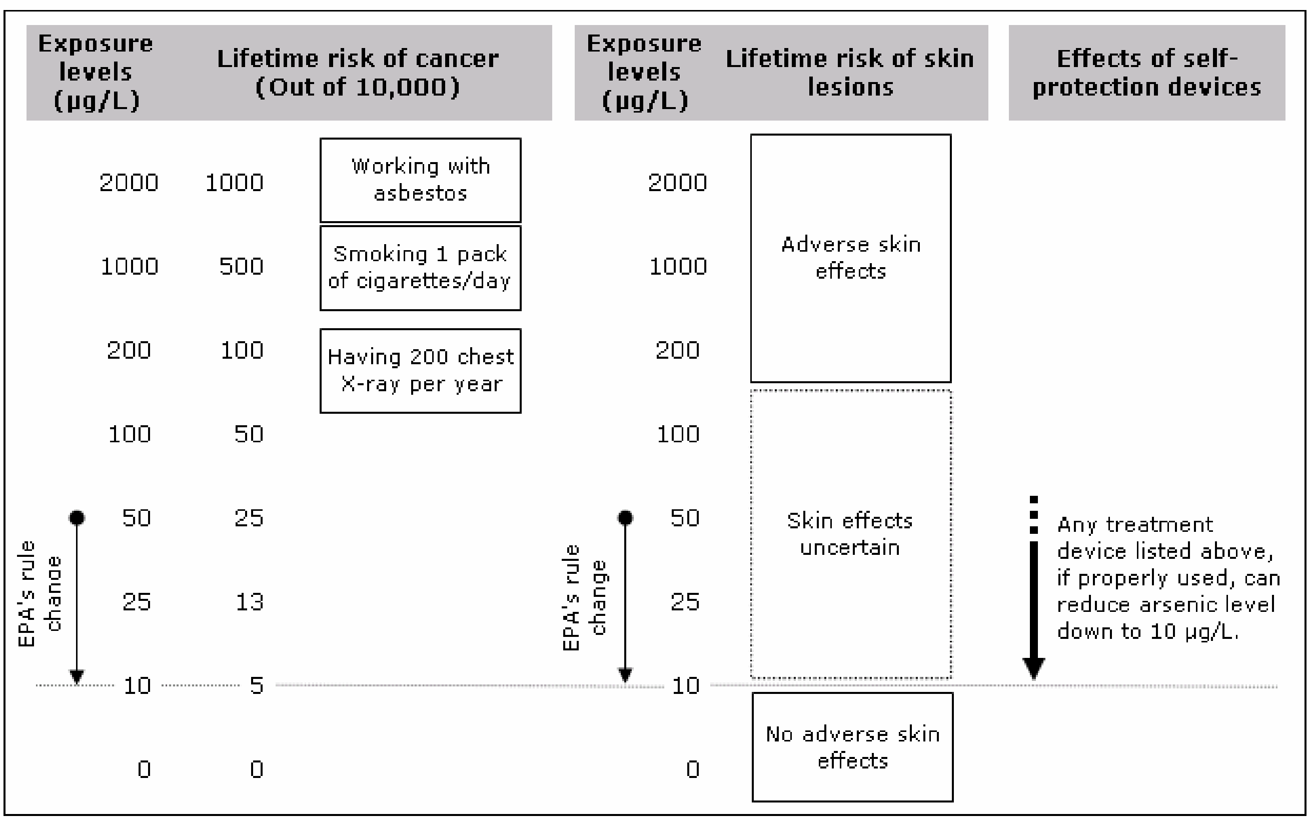
Groundwater in the west-central and northwestern parts of Minnesota tends to have higher concentrations of arsenic, although arsenic can be found throughout the state. As a result, public water suppliers that obtain water from underground sources may become contaminated with small amounts of arsenic. The national drinking water standard for arsenic was tightened **from 50µg /L to 10µg/L**.

Although arsenic is found in very small levels in groundwater, long-term exposure to low-level inorganic arsenic in drinking water can cause adverse health effects such as the increased risk of **skin cancer**, **bladder cancer**, and **lung cancer**.

Water softeners and activated carbon filters **do not** reduce arsenic levels effectively. The following treatment devices, if used properly, will reduce arsenic level below **10µg/L** : (A) installation of **reverse osmosis (RO)** treatment; (B) installation of **distillation** treatment; and (C) installation of **activated alumina** treatment, as will using **bottled water for preparation of foods and drinking**. All treatment devices require regular maintenance.

The monitoring records from Minnesota Department of Health (MDH) show that your community water system contains: ______ **µg/L** of arsenic on average in 2006 and ______ **µg/L** of arsenic on average *during 2000-2005*.

Please examine the table below to evaluate your lifetime health risk associated with the arsenic levels above.



Source: US Environmental Protection Agency, Integrated Risk Information System.

16. Was the **ARSENIC INFORMATION SHEET** helpful in improving your understanding of arsenic issues?

□ Yes □ No

17. Based on the Arsenic Information Sheet, how would you rate your ***drinking water safety level*** from the **ARSENIC** contamination **before you use any home treatment device**?

Very Unsafe	Unsafe	Somewhat Unsafe	Somewhat Safe	Safe	Very Safe

1 — 2 — 3 — 4 — 5 — 6 — 7 — 8 — 9 — 10

18. Do you **currently** treat your water using a **reverse osmosis**, **distillation,** or **alumina treatment**?

□ Yes (➔ go to Question #20) □ No (➔ go to Question #19)

19. Will you use **reverse osmosis**, **distillation** or **alumina treatment devices in the future**?

□ Yes □ No

We would like to ask your willingness to pay for arsenic reduction once again, based on the information provided above. Please, do not go back to Question #13 to change your answer.

20. **Would you be willing to pay $ 70 annually ($ 5.83 per month), in excess of your current water bills, for strengthening the water quality standard by lowering the permitted level of arsenic from 50µg/L to 10µg/L?**

□ Yes (➔ go to Question #21) □ No (➔ go to Question #22)

21. **Would you be willing to pay $ 120 annually ($ 10 per month), in excess of your current water bills, for strengthening the water quality standard by lowering the permitted level of arsenic from 50µg/L to 10µg/L?**

□ Yes (➔ go to Question #23) □ No (➔ go to Question #23)

22. **Would you be willing to pay $ 50 annually ($ 4.17 per month), in excess of your current water bills, for strengthening the water quality standard by lowering the permitted level of arsenic from 50µg/L to 10µg/L?**

□ Yes (➔ go to Question #23) □ No (➔ go to Question #23)

II. Information about Household

23. What is your **average water bill**? ____________ dollars per **month**.
Note that the water bill should not include the other utilities such as gas, electricity, etc.

24. Do you have any children under *7 years old* living at home?
□ Yes □ No

25. How many persons are living in your house? _______________

26. What is the **approximate value** of your house?
□ $40,000 or less □ $40,001 – $80,000 □ $80,001 – $120,000
□ $120,001 – $200,000 □ $200,001 – $300,000 □ $300,001 or more

27. What is your gender? □ Male □ Female

28. In what year were you born? 19____.

29. Which best describes the highest level of formal education you have attained?
□ Eleventh grade or less □ High school diploma
□ Completed technical school or some college □ College graduate or more

30. What was your approximate total household income, **before taxes**, last year?
□ $10,000 or less □ $10,001 – $20,000 □ $20,001 – $30,000
□ $30,001 – $40,000 □ $40,001 – $50,000 □ $50,001 – $75,000
□ $75,001 – $100,000 □ $100,001 or more

31. Please make any comments about this survey:
____
____

THANK YOU FOR YOUR PARTICIPATING IN THIS SURVEY. YOUR ANSWERS WILL REMAIN COMPLETELY CONFIDENTIAL. PLEASE FOLD AND RETURN IN THE ENCLOSED SELF-ADDRESSED, STAMPED ENVELOPE.