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Public Response to Elevated Levels of Arsenic in Drinking Water: An Investigation of Survey Participation, Risk Perception, and Averting Behavior

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Introduction and Background

The primary intent of this extended abstract is to report on preliminary results obtained from a survey of households designed to explore perceptions of mortality risks of arsenic in drinking water and behaviors in response to those risks. The sample includes households exposed to levels exceeding the new Environmental Protection Agency (EPA) standard of 10 ppb. In the survey, respondents were asked about their tap water use, their water consumption behavior, their perception of the risks they and other members of their households face due to arsenic contamination in their tap water, and their willingness to pay to reduce their risks from this contamination. The data are used to analyze risk reduction behaviors engaged in by members of the sample. By evaluating perceived risks and averting behaviors associated with arsenic in drinking water, scientists, the EPA, policy makers, and public water treatment officials will better understand the public and thereby be better equipped to protect them from the health risks posed by arsenic. We are especially interested in parent's motivations for the protection of their children against arsenic risks. Discerning the roles various factors play in influencing individuals' choices related to avoiding arsenic contamination will assist the EPA and other public agencies in developing the most effective public safety awareness campaigns and ultimately allow these agencies to better protect the public from harmful environmental contamination.

While a great deal of general risk-oriented research has focused on risk communication, few studies have specifically addressed the risks from arsenic in drinking water. Drinking water behavior and responses to risks are more complicated issues than the uninitiated might suspect. Before addressing the issues relating to arsenic risks, one must know how households consume their drinking water. Focus groups conducted prior to final survey implementation informed us that discerning accurate drinking water behavior patterns and responses to risks is somewhat complicated. These finding coincide with other risk investigations and generally held knowledge concerning challenges of communicating risks. Science-based risk estimates are in fact quite difficult to communicate in some cases, which is why we chose to collect information on the household's perceived risks. Perceived risks, rather than "scientific expert" or objective risks, are going to be extremely important determinants of drinking water behavior in situations where there are water quality problems that are associated with potential health risks. This will come as no surprise to some risk researchers (e.g. such as Paul Slovic, 1987).

Arsenic is an odorless, tasteless, semi-metal that is found naturally in rocks, soil, air, plants, water, and animals, however arsenic can also be the result of technological, agricultural, and industrial activities. Consumption of arsenic contaminated water is a pressing concern because it has been shown to cause both death and nonfatal illnesses. Human exposure to arsenic is most likely the due to contamination of the groundwater supply used for drinking water, through naturally occurring arsenic. Due to increasing water demand municipalities are facing because of population growth in their areas, more public water suppliers are turning toward groundwater as a source of potable water. This increased groundwater demand from public waters systems, combined with the existing water demand from private well owners, depletes the water level in the aquifer which can cause arsenic to release from the rock formations (USEP (United States Environmental Protection Agency) 2006). The release of arsenic is due to oxidation within the aquifer. Oxidation is a complex set of geochemical interactions between air, water, and naturally occurring sulfides, which is influenced by changes in the water level inside the aquifer caused by either municipal pumping or climate change (Schreiber et al. 2000). Additionally, due to the inconsistent structure of an aquifer, arsenic levels may vary across an aquifer causing wells pumped from the same aquifer to have different levels of arsenic.

While the majority of the water pumped out of aquifers across the nation meets the minimum safety requirements under the Safe Drinking Water Act (SDWA), geographical "hotspots" with levels exceeding the safety standard do occur. Most "hotspots" are located in the southwest United States. On January 22, 2001, to comply with the SDWA, the standard for arsenic in drinking water was lowered from 50 parts per billion (ppb) to 10 ppb. EPA administrator Carol M. Browner stated that this reduction to 10 ppb "protects public health based on the best available science and ensures that the cost of the standard is achievable" (USEP (United States Environmental Protection Agency) 2006). The original standard of 50 ppb was set in 1975 based on a Public Health Service report published in 1942. After extensive research on the chronic effects of arsenic in drinking water, the National Academy of Science advised the EPA to lower the standard immediately to protect public health and safety. The new rule was officially instated on February 22, 2002 and the compliance date was set for January 23, 2006. The new standard applies to approximately 54,000 community water systems, which are systems serving at least 25 residents or 15 locations year round. Some 20,000 smaller water systems serving 25 continuous customers for six months will also be required to meet the new standard (USEP (United States Environmental Protection Agency) 2006). Small rural systems typically serving fewer than 10,000 people are the most likely systems to be unable to comply due to lack of funds to facilitate the necessary technology changes in their water systems. According to a 2004 EPA report on drinking water and ground water statistics, a total of 40 public systems were out of compliance with the new arsenic standard at that time, with 35 of the 40 violating systems being small water systems serving 3,300 or less. Approximately 72,000 people are affected by these system violations (USEP (United States Environmental Protection Agency) 2005). Though this seems like a small percentage of the total population, it should be kept in mind that even when 10 ppb is achieved, it is no guarantee that all mortality risks will be eliminated. Additionally, it is important to remember that although the contaminant of interest in this research is arsenic, ideas and conclusions described here may transferable to other water quality contaminants such as nitrates, lead, copper, organics, and other inorganic contaminants.

There is also considerable concern about the risks from arsenic contamination in private wells. These wells, which are predominantly in rural areas not served by public suppliers, are neither inspected nor regulated by the federal government because they are not regulated under the SDWA. An earlier study finds that a sample of Nevada households regularly drinks water with arsenic levels exceeding the new standard, and in fact, the old standard (Shaw et al. 2005). Therefore, while public treatment systems can provide safe drinking water to those connected to the systems such as public schools, restaurants and businesses, adults and children living in homes that use private wells for drinking water will continue to ingest arsenic despite public efforts to meet water quality standards (Shaw et al. 2006).

The scientific community has concluded that drinking arsenic-contaminated water has severe negative health consequences. In 1999 a National Resource Council committee found that the risk of developing bladder and lung cancer increases from 1 in 1,000 to 3 in 1,000 when arsenic exposure triples from 3ppb to 10 ppb (Pinsker 2001). Contributing the public confusion about the risks of arsenic is the fact that exact dose-mortality relationships from arsenic concentrations are still in question, particularly at very low levels (below 10 ppb). There is still a great deal of debate among medical researchers as to the lowest threshold of arsenic that will cause increased risks of lung and bladder cancer. Confounding the issue of mortality risk assessment are a host of personal and other factors, including age, smoking history and behavior, the period of exposure, frequency of ingesting drinking water that is contaminated, and some occupational hazards. Despite the degree of uncertainty surrounding the dose-mortality relationship, it is well known that consumption of arsenic contaminated water can also cause a multitude of nonfatal diseases such as ischemic heart disease, diabetes mellitus, hypertension, skin cancer, and possibly prostate cancer, nephritis, nephrosis, hypertensive heart disease and non malignant respiratory disease (Scientific Advisory Board, E.P.A. 2001). The National Research Council reports that the cancerous and non-cancerous risks of arsenic may be greater for children because of the larger water consumed per pound of body weight ratio (National Research Council 2001). Given previous literature findings, the challenge is in communicating these risks to those potentially exposed, even though exact-accurate risk assessment numbers are not currently available.

Objectives and Hypotheses

We investigated factors that influence the decisions the sample population makes in response to arsenic contamination and survey solicitation, with particular interest in the actions taken by parents to protect their children. We explore and model the decision to participate in the study, as well as the decisions to treat tap water and purchase bottled as an averting action to avoid the risks associated with arsenic contaminated public drinking water. Specifically the following hypotheses are tested using the logit model:

1. Whether households with children are more likely to treat their water than households with no children present.

This trend has been observed with previous studies concerning other groundwater pollutants and it is of paramount interest to investigate this trend in the current application. Additional hypotheses that are tested include:

2. Whether respondents with high perceived risks from arsenic contamination are more likely to drink bottled water or treat their tap water.
3. Whether people with higher incomes (greater than $45,000) are more likely to purchase bottled water than people with lower incomes.

We also investigate the effect of key variables on decisions individuals make in regard to their water quality. These include the decision to use some type of home treatment system for tap water and the decision to agree to participate in the water quality and risk perception survey. Various variables such as income, age, education, and gender will be analyzed for their influence on these decisions using a basic logit model. We test whether:

1. Age is positively correlated with the decision to participate in the survey.
2. Income is positively correlated with the decision to treat tap water.

Project Design

This preliminary research is part of a much larger project which seeks answers to questions not presented in this abstract and which incorporate much more sophisticated economic analyses. Researchers from the University of Nevada, Reno, the University of Nevada, Las Vegas, Utah State University, and Texas A&M University have all contributed to survey design for this project, which is officially titled Perceptions and Exposure of Arsenic in Private and Public Drinking Water Among Households and is funded by an U.S. EPA Star Grant. In addition to these parties, PA Consulting, an independent firm specializing in survey based research, was contracted to assist with various aspects of the project. PA Consulting and the other researchers have all contributed to the three elements compromising this project: focus groups, a survey pretest, and the full-scale survey. All of these elements have already been completed with various independent analyses pending.

The first element of the large scale project was a series of focus groups conducted in the cities of Eagle Mountain, Utah, Appleton, Wisconsin, and Las Vegas, Nevada. These focus groups were completed in January of 2006 for the purpose of testing survey questions on a small group of respondents prior to the full scale survey. One of the main objectives of the focus groups was to determine ability of the respondents to understand the visual aids designed to communicate the risk of consuming arsenic in drinking water. Additionally these focus groups allowed the researchers to gain insight into how respondents would react to the willingness to pay questions. Though the sample sizes were small and statistically conclusions can not be reasonably drawn from the results of these focus groups, the discussions and responses of the individuals participating provided valuable information in regard to the wording and format of the questions. Minor revisions were made following these focus groups to reflect concerns the respondents voiced during their sessions. In particular researcher learned that questioning lay people on their tap water use is more complicated than they initially expected. Survey questions asking how people used their tap water and other water behavior questions were reworded for the final survey to reflect these discoveries. Risk ladders presented in the focus groups were also slightly modified in an attempt to make them more understandable to respondents.

The second stage of the project was the survey pretest. Again the purpose of the pretest was to investigate if respondents understood the survey questions, the information presented in general, and the risk ladders. In addition to this, four willingness to pay bid amounts were tested on respondents in this small scale survey to determine if the bid amounts needed to be adjusted for the final survey. This preliminary survey was conducted between October 9 and 16 of 2006 by PA Consulting. Twenty-two households participated in this pretest, with ten of them continuing on to complete the final follow-up survey.

The final data collecting portion of the project was the full scale survey implementation. Again, PA Consulting was the responsible for this procedure. Implementing the survey began on November 1, 2006 and continued until February 12, 2007. This survey process consisted of three parts: a screener call, agreeing to participate and to receiving an information brochure, and a final follow-up call. The screener call consisted of a short survey used to determine if respondents were eligible for the study and to gather demographic and other important data on the respondents. 726 households were solicited for the screener call, however as the survey process preceded it was not a surprise to have response rates decline. 558 household from the initial 726 agreed to participate in the remainder of the study, however only 343 household completed the follow-up survey phone call. Combined with the 10 complete follow-ups and the 22 initial screeners from the pretest, a total of 353 households completed the entire survey process and 748 households completed the initial phone screener portion of the survey. Data from the screener call will be analyzed using a logit model to determine how variables such as age, income, education, gender, perceptions of the negative health risks of arsenic, and home ownership influence the decision to participate in the survey.

Sample Methodology

We focused on communities with naturally occurring arsenic in the groundwater that had not yet complied with the recently updated EPA standard for arsenic in drinking water of 10 ppb. Areas of particularly high arsenic levels were sought out by PA Consulting using various online resources such as the National Tap Water Database, the Environmental Protection Agency website, and the Wisconsin Department of Natural Resources. PA Consulting presented the potential study sites to the team of researchers comprising the risk perception arsenic project and four locations were selected for the pretest and the final full-scale survey: Albuquerque, New Mexico, Fernley, Nevada, Oklahoma City, Oklahoma, and Appleton, Wisconsin. Of these locations, Albuquerque, Fernley and Oklahoma City were locations where the public system was not in compliance and Appleton was selected because of the high arsenic levels in private owner's wells.

Survey Methodology

The three part survey method we used is known as the phone-mail-phone format or the implementation method. The first step in the process was an initial phone call during which time households were screened for their applicability for the study. Eligibility for the survey was based on whether respondents received their drinking water from a public or private source. For example respondents called in areas where the public system was out of compliance that indicated they were on a private well were excluded from the survey. Additionally respondents who indicated they rented their residence and that their landlord paid their water bill were also excluded. In addition to collecting information related to the source of respondents' drinking water, this initial screener call also collected information on respondents' level of concern for a variety of issues ranging from the quality of schools for children to rapid population growth in the area, their level of concern for a variety of environmental related issues and negative health effects from poor air or water quality, their concerns related to their drinking water, their tap water use, and finally a variety of demographic variables. At the end of the call eligible respondents were recruited to participate in the remainder of the study.

Respondents willing to participate in the remainder of the study were sent an information brochure that included general information on arsenic and questions regarding their tap water use, their risk perceptions, their health, health history and the health of other members of their households, and their willingness to pay for reductions of arsenic in the public water supply. Respondents were directed in the brochure to complete these questions and to make marks on risk ladders in the brochure to indicate their perceived level of mortality risk associated with exposure to arsenic in their tap water. Various versions of the brochures were sent to respondents depending on their location and the source of their tap water. Brochures also differed by the willingness to pay bid included in the willingness to pay section.

The final step in the survey process was the follow-up phone call which was scheduled to occur ten days following the screener phone call. The purpose of this call was to obtain the answers to the questions posed in the brochure on tap water use, risk perception, health, and willingness to pay for reductions in arsenic in the water. Respondents were also asked about the marks they placed on the risk ladders.

Data Analysis

Following the conclusion of the pretest, the final data for preliminary analysis were obtained. Summary statistics consisting of means, medians, frequencies, minimums and maximums for variables of interest were obtained. The final data set consisting of 353 households completing the follow-up phone call was later analyzed for these same summary statistics. A tables featuring some the quantitative data from the final data set are featured on Table 1. The means determined for a host of variables allowed us to see on average how member of the study would respond to certain questions and gave us an idea on the characteristics of the average respondent. Frequencies provided us the opportunity to see the degree of diversity or stratification of the sample. Overall these summary statistics help us to understand basic characteristics of the entire sample population and allow us to determine important percentages about our sample.

In addition to these summary statistics of means, medians, frequencies, minimums, and maximums, a logit model is used to analyze the influencing variables in respondents' decisions to participate in the study, to treat their tap water, and to purchase bottled water. This model provides all the explanatory power necessary to test our hypotheses:

1. Whether households with children are more likely to treat their water than households with no children present.
2. Whether respondents with high perceived risks from arsenic contamination are more likely to drink bottled water or treat their tap water.
3. Whether people with higher incomes (greater than $45,000) are more likely to purchase bottled water than people with lower incomes.

Additionally we will use the logit model to test the influence of various variables such as income, age, education, and gender on respondents' decisions to participate in the study and to treat their water. As indicated above, the following hypotheses are evaluated using this model:

1. Age is assumed a-priori to be positively correlated with the decision to participate in the survey.
2. Income is positively correlated with the decision to treat tap water.

Preliminary Results

The basic summary statistics collected for the full data set revealed some interesting information about the sample. About 65% of respondents used their tap water as their sole source of drinking water and 86% used the tap as their sole source of water for cooking and making beverages. Additionally 52% indicated they incorporated some type of water treatment system in their home and 33% of the sample population purchased bottled water. These statistics are presented in Table 2. For survey purposes, respondents with children were reasonably represented with 38% of households surveyed indicating they had at least one child, which was defined as a household member under the age of 18. One surprising statistic revealed that only 62% of respondents were aware of the arsenic problems in their area prior to participating in our survey. This is discouraging for public officials and the EPA considering the problems of arsenic in the groundwater are well known and efforts have been made to educate the citizen living in the areas affected by this contamination.

A reasonable percentage of respondents were able to provide answers to the questions regarding risks and the risk ladders. Only 10% of respondents could not initially decide where to place their mark on the risk ladder to indicate their own perceived mortality risks due to their arsenic consumption. The statistic was improved after surveyors explained the risk ladder to respondents over the phone. Following this explanation only 3% of respondents indicated they either could not decide on where to place their marks or that they would not answer the question. However despite respondents' ability to choose a range or exact level of risk on the risk ladder, a later question revealed that our population followed the general adage that lay people struggle stating the risks they face in quantifiable terms. When asked to give their certainty of the marks they made on the risk ladder in a percentage, the largest percent of respondents indicated they were only 50% certain of the risk estimate they gave on the risk ladder, while the second largest percent was only 1% certain of their risk estimate. This indicates that respondents have lingering uncertainty in their responses to risk questions which may be product of their distrust of the information and the fact they may not be able to process the information on risk. A more complete view of the frequency of percentages quoted for certainty of risk perceptions are presented in Table 3.

Results for the logit modeling are forthcoming. Once these analyses are complete, they will provide insight into factors influencing respondents' choices in regard to their decision to participate in the study, their decision to treat their tap water, and their decision to purchase bottled water. The results from the logit models will be fully disclosed and discussed in the presentation of this study at the Universities Council of Water Resources and National Water Resources Institute Annual Conference in July.

Conclusion

Although public awareness and understanding of water quality issues and other natural resource issues has gradually increased over the past few decades, the general public knowledge in this arena does not consistently coincide with the knowledge held by scientists and natural resource managers from various fields. Economic elements of water quality and other environmental products and services are often misunderstood by the public and even natural resource professionals. Economic concepts such as willingness to pay and averting behavior have proven to be essential elements in analyzing and evaluating various alternatives for the development, preservation, and enhancement of natural resources, however all to often these concepts are not understood by those making these decisions. In some cases these concepts are completely foreign to them. This study seeks to address the disparity of knowledge of these economic elements existing in both public and private spheres by investigating the averting behavior, risk perceptions, and willingness to pay of people living in areas where arsenic levels exceed that of the EPA drinking water standard and presenting the findings in more familiar terms. Additionally a model used to describe consumer behavior will be used to help explain key factors in individuals' decisions to participate in a survey aimed at addressing the above issues, to treat their water and to buy bottled water to avoid the negative health risks of drinking arsenic contaminated water. This project will provide valuable information to the EPA and assist them in achieving their objective of ensuring the safety of the national public drinking water supply. This project is also unique in that although it involves economic elements, it is designed for professionals in fields outside of economics. The ideas and findings presented in this research will benefit water resource and natural resource professionals and managers by providing a clear explanation of the importance of considering economic elements in their areas of interest and by specifically addressing public responses to risks posed by arsenic contaminated tap water. Simply stated, water quality is a concern for everyone and as such this research has the potential to make a significant impact in public communities, professional fields, and governmental agencies.

References

National Research Council. 2001. *Arsenic in Drinking Water: 2001 Update*. Washington, DC: National Academy Press.

Pinsker, L.M. 2001. Health Hazards: Arsenic. *Geotimes*: November: 32-33

Schreiber, M.E., Simo, J.A. & Freiberg, P.G. 2000. Stratigraphic and geochemical controls on naturally occurring arsenic in groundwater, eastern Wisconsin, USA. *Hydrogeology Journal* 8(2): 161-176

Scientific Advisory Board, E.P.A., 2001. Review of economic analysis of Arsenic in drinking water rule.
Shaw, W.D., Walker, M. & Benson, M. 2005. Treating and drinking well water in the presence of health risks from Arsenic contamination: Results from a U.S. hot spot. *Risk Analysis* 25(6):1531-1543
Shaw, W.D. et al. 2006. Incorporating perceived mortality risks from Arsenic into models of drinking water behavior and valuation of Arsenic risk reductions: Preliminary results. Presented at the U.S. EPA Workshop on Mortality Risks.
Slovic, P.1987. Perception of risk. *Science* 236:280-285
USEPA (United States Environmental Protection Agency). 2005. Factoids: Drinking water and ground water statistics for 2004.
USEPA (United States Environmental Protection Agency). 2006. Arsenic in Drinking water. Available at http://www.epa.gov/safewater/arsenic/.

Table 1. General Summary Statistics		
Gender	**Frequency**	**Percent**
Male	200	56.66%
Female	153	43.34%
Race		
American Indian or Alaskan Native	17	4.82%
Asian or Pacific Islander	3	0.85%
African American or Black	6	1.70%
White	303	85.84%
Type of Water System		
Public Water System	242	68.56%
Private Water System	111	31.44%

Table 2. Drinking Water Behavior		
Tap Sole Source of Drinking Water	**Frequency**	**Percent**
Yes	231	65.4%
No	122	34.6%
Tap Sole Source for Cooking and Beverage Making	**Frequency**	**Percent**
Yes	302	85.6%
No	51	14.4%
Treat Water in the Home	**Frequency**	**Percent**
Yes	182	51.6%
No	171	48.4%
Member of HHS Drinks Bottled Water	**Frequency**	**Percent**
Yes	117	33.1%
No	5	1.4%

Table 3. How Certain Respondent is of the Risks They Face		
Percent Stated by Respondent	**Frequency**	**Percent of 297**
1	24	8.08%
2	2	0.67%
3	4	1.35%
4	7	2.36%
5	4	1.35%
10	13	4.38%
12	1	0.34%
15	4	1.35%
16	2	0.67%
17	1	0.34%
20	13	4.38%
23	1	0.34%
25	19	6.40%
30	12	4.04%
33	1	0.34%
35	4	1.35%
40	10	3.37%
45	6	2.02%
50	75	25.25%
55	1	0.34%
60	16	5.39%
65	1	0.34%
70	5	1.68%
75	15	5.05%
80	12	4.04%
85	8	2.69%
90	14	4.71%
95	2	0.67%
98	1	0.34%
100	19	6.40%
Min	1	
Max	100	
Mean	46.1	
Median	50	
SD	29.73	