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
April 10 - 12, 2006/[Draft: April 19, 2006]

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Abstract The new regulatory standard for arsenic in public drinking water systems is 10 parts per billion (ppb) as compared to the old standard of 50 ppb. Arsenic has been shown to increase the risks of bladder and lung cancer at levels of 50 ppb. However, the exact relationship between arsenic levels and cancer risk is difficult to discern at this and lower levels. This introduces ambiguity about the mortality risks. This first workshop paper reports on the results from previous pilot studies, provides, preliminary modeling and results from focus group research. All of these help examine ways of communicating and modeling these ambiguous risks to individuals who live in arsenic "hot spots," defined as those areas where the current arsenic level exceeds the new standard of 10 ppb. Both the pilot studies and focus groups confirm that drinking water and averting behavior is more complicated than economists might initially presume. Risks, and ways of reducing it, need to be better communicated to households in hot spots.

*Contact author: W. Douglass Shaw (wdshaw@tamu.edu). Please do not distribute this manuscript without permission of the authors. The authors thank JR DeShazo for sharing very helpful thoughts on risk communication, and our colleague Klaus Moeltner for his careful comments on one of the draft survey versions. Kerry Smith provided particularly helpful thoughts on this study and preliminary survey materials and we thank him for those, and Greg Poe, our discussant at the workshop, provided helpful comments on future directions. Laura Schauer and Pam Rathbun from PA Consulting Inc. have helped design the initial survey materials and conducted focus groups. Funding from the U.S. EPA STAR grant program is acknowledged, but the authors' views do not necessarily reflect the agency's. As always, any errors remaining here are solely our responsibility.

Introduction

In this manuscript we report on our initial and preliminary research on arsenic in drinking water. Recently, the federal regulatory standards for arsenic in drinking water have been reduced from 50 parts per billion (ppb), to 10 ppb. We are particularly interested in behavioral responses to the presence of arsenic in private and public drinking water supplies, including adopting treatment devices or switching to bottled water supplies. We are also interested in deriving and estimating values for arsenic reduction risks. Several studies have been undertaken to examine the costs of compliance with the new standard, mainly in the form of capital cost for improved or new public system treatment plants. While these costs are relevant because the public may be aware of them, the current study is not about treatment or compliance costs. It concerns the benefits that the public might receive if the new standard is widely implemented. The arsenic rule cost-benefit analysis simply assumes that a standard Value of a Statistical Life (VSL) pertains to an estimate of the number of lives saved by the rule. Our efforts will lead to a more precise estimate of the benefits from mortality risk reductions accompanying the rule in that behaviors relating to drinking water in the presence of arsenic will be closely examined.

To summarize our progress to date, first, a great deal of literature on the economics of risk and uncertainty has been reviewed. Second, several papers were completed on a pilot study of arsenic in drinking water. While not directly part of this current research program, completing these papers has helped identify weaknesses in the previous research approach and related survey instruments. Models to accommodate the intricacies of the arsenic problem are proposed and presented below. Finally, in February focus groups in two locations were undertaken to study individuals' preferences and responses to certain types of survey questions. We provide some preliminary results from these focus groups in this report, below.

Background on Arsenic in Drinking Water

If drinking water is consumed regularly at levels of 50 ppb or higher, scientists generally agree that the risks of lung and bladder cancer will increase over the baseline risk levels in these diseases for the general population. This counters earlier scientific assessments that 50 ppb, the old arsenic rule level, is safe. The estimated increases in the health risks that accompany a level of 50 ppb vary. In an opinion paper, Smith et al. (2002) report that the increased risks of bladder and lung cancer from consumption at 50 ppb may be higher than baseline risks of these diseases by a factor of 30 to 60. Based on another paper that included several of these authors, they suggest that the combined cancer mortality risk may be as high as 1 in 100 for people drinking water containing 50 µg/liter (or ppb) of arsenic (Smith et al. 1992). Recent annual estimates of baseline lung cancer mortality risks for those in the general population in the United States are about 6/10,000. If one uses the larger factor of increase of 60, then this corresponds to about 3.2 deaths per 100 people drinking water at 50 ppb of arsenic. The National Research Council (NRC) agreed recently that while there is no reliable data that indicate heightened susceptibility of children to arsenic, there may be greater risk for cancer and non-cancer effects because of greater water consumption on a body-weight basis.

The NRC also indicates that smoking may be a factor that increases the risks associated with arsenic ingestion, but recommend that more research be conducted on this issue. Finally, we note that some question the NRC's estimates of risk at low arsenic levels, claiming that there is evidence to show that the human body can effectively metabolize 80 percent of arsenic ingested at low levels (Note that Burnett and Hahn, 2001, provide no supporting citation for this claim).

While very short acute effects of high levels of arsenic ingestion seem clear (doses high enough to cause immediate death), the chronic exposure effects are less so, especially for low doses or exposure levels. Experiments on animals have the usual difficulties in mapping to effects on human beings. In addition, there are many confounding factors that influence exposure and mortality rates. There is agreement that there is a latency period in contracting the cancers, but the exact length of the lag is not known. Some have suggested ten to twenty years (see Morales et al. 2000) for the length of the lag. The most common symptom of prolonged exposure relate to skin problems and these may occur as early as five years after exposure; again these problems likely relate to high doses of arsenic. Based on Chang et al. (2004), Chiu et al. (2004) and other science reports, Madajewicz et al. (2006) suggest 5 to 15 years for early effects of arsenic and 20 years for various cancers. Because of remaining uncertainty with respect to exposure danger, some scientists currently believe that the 10 ppb is too low, while others believe it is not low enough. The NRC has urged continued scientific analysis to increase our confidence in mapping from arsenic levels to health risks. This is a classic case for people to hold ambiguous and heterogeneous risks, and an economic model that accounts for them is required to account for these complications.

Economics/Risk Literature

As suggested above, the economics of arsenic mitigation is currently somewhat controversial. There have already been papers by researchers that question the new federal arsenic rule. These seem focused on what they see as a flaw in the risk extrapolation done for the rule (this is also the view taken by Kayajanian, 2003). Because of this and a failure in discounting, ex ante estimated net benefits are thought to be negative: -$100 million annually (e.g. Burnett and Hahn 2001). This is based on rough numbers, mainly taken from the Environmental Protection Agency's (EPA's) own regulatory impact analysis: Burnett and Hahn (2001) state that EPA estimates of the cost of meeting the 10 ppb rule are $200/year, and benefits are $170/year, but that benefits of lives saved did not factor in latency, and should have been discounted. The authors appear to just discount the VSL of $6.1 million to be $1.8, and make adjustments accordingly. We believe that this quick analysis suffers from several strong assumptions, and that estimates of net benefits cannot be accurately assessed until some new studies regarding microeconomic behavior and resulting benefits emerge in the literature.

The current literature that relies on actual behavior modeling in response to arsenic exposure is relatively sparse, but is reviewed below. Hedonic property valuation studies are currently underway in Maine (see Bell et al., 2005), which build on the literature that examines averting behavior in other contexts involving drinking water and other contamination issues (eg., Smith and Desvousges 1990; Poe 1998; Poe et al. 1998). Bell et al. (2005) also explore Maine community households' propensity to have their wells tested, at a cost of about $15. They use aggregate community data in a panel-count data model framework.

Opar et al. (2004) and Madajewicz et al. (2006) have considered household responses to the presence of arsenic and information about it, in Araihazar, Bangladesh. They find that households will take steps to mitigate in response to testing and labeling (posted signs were meant to be understood by those who are illiterate) wells as unsafe. The probability of switching to another well is 50% higher for those with an “unsafe” well, than for those with a safe well. However, the situation in Bangladesh studied by these researchers, is one in which people (mostly women) from villages literally walk to rural private and community wells to draw from them, and this is quite different than the domestic situation. One feature of interest is that only 1% of the Bangladesh sample is already symptomatic. It will be interesting to see what portion of hot spot area populations exhibit symptoms, if any.

Arsenic is found in several U.S. rural communities, where a considerable proportion of people are drinking water from private wells that are not regulated under federal drinking water standards. Recently, Shaw et al. (2005), and Walker et al. (2005; also see Walker et al., forthcoming, 2006) report on a pilot study of the manner in which people on private wells respond to arsenic risks. Though arsenic was well-publicized as a health threat, many people living in a hot spot for arsenic (Churchill County, Nevada) continue to ingest arsenic in their private-well drinking water. Some were aware of the level of arsenic in their wells, but many were not. This lack of awareness was found for nitrate in wells by Poe et al. (1998).

In the Nevada pilot study individuals were asked if they drank water from the tap, with many responding that they did not. But when asked if they used tap water for making ice, cooking, making tea or coffee, they said that they did use tap water, illustrating the need for clarity in framing the question. Many people in the study sample said they treated their water to avoid health risks from arsenic and other contaminants, but upon close inspection, the type of treatment they used does not remove arsenic concentrations. Finally, a model of treatment adoption suggests that the cost of in-home treatment is an important negative deterrent to treating water (Shaw et al. 2005).

In most of the studies above it should be noted that links between values or behavior and actual health risks may be indirect. For example, many studies look at responses to contamination levels or perceived contamination levels, not at responses to perceived mortality risks. We will make the link direct: we examine mortality risk affects on behavior and values, not just the role that arsenic levels play in determining averting behavior or willingness to pay for water quality improvements. Our preliminary research from focus groups (discussed below), as well as the Nevada pilot study, has demonstrated the likelihood that the following issues or problems are the most difficult hurdles to overcome on this project:

- Ambiguity and heterogeneity in risks
- Possible weighting of probabilities
- Latency in actually getting, and dying from lung and bladder cancers
- Valuation for other household members (children)

We consider each of these issues below.

Ambiguity and Heterogeneity

Ambiguity is, in short, uncertainty about risks themselves.[1] Heterogeneity in risks pertains to the fact that given any sample of individuals drawn from a larger population, there is no reason to expect each to have the same preferences for risks. Individuals can respond to health-risk information in a variety of ways, for many different reasons,

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[1] Note that ambiguity is not the same as saying a person makes a response that indicates her value for a good in a stated preference approach (contingent valuation) and then declares she is uncertain about that value. That is another strand of valuation literature. Ambiguity relates to the definite presence of outcome risks that an individual faces. In the "I am uncertain" literature, there may be risk faced, or not.

including whether they tend to be a person who worries, whether they have high or low incomes, what their gender is, or other heterogeneous factors. Among the primary factors that influence a person's response to health risks is their propensity to rely on habits, versus making decisions using careful calculations (Lindbladh and Lyttkens 2003). The nature of the arsenic risks and drinking water behavior convinces us that subjective risks of mortality are of the utmost importance in this project. Objective mortality risks associated with arsenic ingestion and exposure are important benchmarks we will use, but as scientific experts do not agree, it is hardly credible to develop a model based solely on objective risks. Added to the scientific uncertainties are personal factors (water consumption, age, personal and family history, smoking, and occupation) that may influence one's own actual mortality risks from drinking water laden with arsenic.

The idea of using perceived, rather than "objective" measures of risk or quality attributes is not new (see Slovic 1987; Adamowicz et al. 1997). Many suggest that choice behavior is best explained using (perceived) attributes such as risk.[2] Whether these are clearly stated by respondents in a survey is another matter (Viscusi and Evans 2006). If people at least think they are crystal clear on their beliefs about probabilities then there is likely no ambiguity they face. When risk perceptions are influenced by conflicting sources of "expert" or outside information, as is the case for arsenic, then there is more likely to be ambiguity.

Most of what economists know about ambiguity comes from theoretical and experimental exploration (e.g. Ellsberg 1961 for an early example; Camerer and Weber 1992; other references in Shaw, Riddel and Jakus 2005). Most economic analysis indicates that individuals are averse to ambiguity. Psychologists have tested reasons why

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[2] For example, Adamowicz et al. (1997) find some evidence to support this, though it is relatively weak.

ambiguity can be more pronounced, and whether we can know for certain that individuals are averse to it (e.g. Fox and Tversky 1991). An excellent, albeit somewhat dated discussion of ambiguity is provided by Camerer and Weber (1992). Recently, Riddel and Shaw (2006) developed and estimated a utility-theoretic model of valuation that incorporates ambiguity. Their approach is quite different than the way in which ambiguity has been modeled in experimental laboratory settings in that it allows for ambiguity as part of an econometric model of preferences. It also differs from empirical modeling that simply allows for the influence of an individual's range of risks on expected utility (see Cameron 2005; Riddel, Dwyer and Shaw 2003). In fact, it is best described as a version of a non-expected utility model, such as Machina's generalized, smooth model (1982).

Probability Weighting Functions

Many researchers of risk have found that patterns of behavior that go unexplained by the conventional EU can be explained by using alternatives to it, including models that use nonlinear probability weighting functions (PWFs). These models permit weights to transform probabilities in a nonlinear fashion, allowing several patterns of risk preferences to be explained (see Tversky and Wakker 1995). These patterns include individuals' tendencies to over-weight, or to under-weight low risks (probabilities), weight them the same as experts for middle-range probabilities, but again over- or under-weight very high probabilities. Weights are an essential part of cumulative prospect theory (CPT) [Tversky and Khaneman 1992] as well as CPT's close theoretical relative, the rank-dependent expected utility framework (Quiggin 1982).

The literature on probability weights also begins with allowance for decisions to be influenced by subjective risk assessment, but goes beyond the recommendation by some psychologists that objective risks be replaced in decision models by the stated, subjective or perceived risks. Let p be the probability of dying, and w(p) be a subjective weighting function for that probability. Over -weighting low probabilities and underweighting high probabilities leads to the inverse S-shaped probability weighting function (see Figure 1) posited by Tversky and Khaneman (1992). The function, w(p) may take a particular functional form, or it may not. (Tversky and Khaneman's 1992 used a one parameter specification of the w(p) function:

$$w(p) = \frac{p^{\gamma}}{[p^{\gamma} + (1-p)^{\gamma}]^{1/\gamma}} \tag{1}$$

The function in (1) allows for lower and upper subadditivity and has an inverse S-shape for values of γ between 0.27 and 1.[3] The parameter may be different for risks involving gains and losses Bleichrodt and Pinto (2000) simply state that lower subadditivity, for example, means a lower interval has more impact on a decision maker than an intermediate range of probabilities. Still, it may well be that for each individual in a sample, the weighting function in equation (1) varies: there is not one weighting function that best approximates relationships for everyone in the sample.

Gonzalez and Wu (1999) suggest a two-parameter specification for the probability weighting function, and also suggest a non-parametric approach, making no assumptions

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[3] The weighting function satisfies subadditivity if there exist constants $\varepsilon \geq 0$ and $\varepsilon' \geq 0$ such that $w(q) \geq w(p+q) - w(p)$ whenever $p + q \leq 1 - \varepsilon$. Here q is a lower value for a probability and p is a higher one. A similar expression pertains to upper subadditivity. See Figure 2 in the paper by Tversky and Wakker (1995). Without reproducing that graph here, the lower subadditivity condition basically implies a very steep portion of the weighting function near zero, with a flattening in the middle portion.

about the form. The latter would allow each individual to exhibit their own weighting function.

Finally, note that allowance for a probability weighting function is not tantamount to introducing and allowing for ambiguity in a formal model. It is quite possible that individuals have a clear sense of probabilities in their own minds, i.e., no ambiguity, but are weighting such that their subjective probabilities do not fall on the 45 degree line (Figure 1). More work needs to be done to link the concept of ambiguity to probability weighting, and at this juncture it certainly appears that it is non-trivial to elicit weights for mortality risks in an empirical/experimental analysis (see Shaw, Nayga and Silva 2006).

Latency/Cessation

DeShazo and Cameron (2005) follow Sheppard and Zeckhauser (1984) and others in developing a life-cycle approach that can be used to handle the latency problem. They suggest that an individual of age i derives expected utility, V_i from the rest of life:

$$V_i = \sum_{t=i}^{T} q_{i,t} (1+r)^{i-t} u_t (C_t) \tag{2}$$

Where u_t (C_t) is the utility of consumption in year t of life, multiplied by the probability that the individual at age i survives to age t (q), discounted to the present at discount rate r. The idea of course, is to recognize that a risk reduction might come later in life, and that utility at that point would likely be discounted. However, the combined effect of the terms in equation (2) is ambiguous. Only by making assumptions can one discern whether the willingness to pay for a risk reduction will rise, or fall, with age. DeShazo and Cameron show how the basic model can modified to let the probability enter the utility function directly, unlike (2).

They implement the model empirically by introducing health "profiles," including periods of good health, and illness, and also death. These are constructed and presented to respondents in a conjoint exercise. In each health state, a group of dummy/indicator variables can be used to denote a pre-illness, ill, recovery, or dead, state, and these, along with income, determine utility in each state.

Cessation is not the same thing as latency.[4] Ideally, one wants to know the hazard rate, or age-specific rate of risk for any pattern of exposure to arsenic. It is important to examine the number of cancer cases avoided after exposure is reduced, which is cessation. It appears from preliminary modeling (see Chen and Gibb, 2003) that lower health risks may come quickly after arsenic ingestion is discontinued. For example, Chen and Gibb (2003) report that when arsenic concentrations are reduced from 50 to 10 ppb for those older than 55, the number of transitional cell carcinomas (TCCs) avoided is substantial. The length of the lag is called the cessation lag and we will need, at minimum, to inform survey respondents about the fact that their arsenic-related health risks will disappear fairly quickly as they move onto a safer drinking water supply.

Valuation for Others/Bequest

The notion that people have values that are based on preferences for others' safety is not new, but credibly estimating such values, or distinguishing portions of values for one's own safety, versus someone else's safety, are. Liu et al. (2000) consider a contingent valuation approach where mothers are asked about their own protection against minor illness (a cold), as well as their children's. They find that the WTP in their sample to prevent comparable illness is twice as large for the child as for the mother.

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[4] We thank Trish Hall for pointing this out to us and cautioning us to examine cessation issues as part of the future research.

However, though implied, they have no formal derivation of a model (one that is utility-theoretic) that specifically accounts for the child’s welfare within the mother’s utility function. More recently, Riddel and Shaw (2003) developed a model of bequest value that decomposes the total value of a risk reduction into that portion of value attributable to one’s own protection against risks, and for others. Specifically, they consider both current and future generations’ values to accept risks. The model’s decomposition allows recovery of bequest values. We plan to extend this type of analysis to consider the well-being of children on the part of the parents.

Proposed Models

Models are currently being developed for two basic types of respondents who face an arsenic-related risk: those on public water systems, and those on private wells. The issues facing each user with a particular water source differ. Public-systems households may face increasing rates to cover their systems’ increased cost of water treatment. Rate increases could already have occurred. This does not rule out the possibility that they decide to treat in their own home as well, either because they wish to treat for non-health reasons (to improve color or taste), or because they do not trust their water supplier or the government regulator enough to rely on the piped water quality. Those on private wells must take responsibility to test their own water, and to treat it themselves. However, their decision to treat or not does not rule out the possibility that they have a non-zero WTP for public supply improvements as well, if these are relevant, such as a person’s concern about publicly-supplied water in the workplace.

Public Supply

Households in a public supply may have already faced rate increases as their supplier has improved quality to cope with the new EPA arsenic standard. They may also be facing a future rate increase if one has not yet occurred. In addition, we cannot rule out averting behavior: they can choose to treat in the home as well as support public-supply treatment. In a recent paper by Rosado et al. (2006), data on averting behavior and contingent valuation data is combined for households on a public system. In particular, they examine the distance between treatment costs and the CVM bid, and whether this distance significantly affects the variance of the error in the decision model: this is of course a form of allowing for a heteroskedastic error term. Their application is to an urban area of Brazil, and specific contaminants encountered there are not explained in the paper. The point they make is that households may treat their in-house water for different motives than that which relates to their support of public water-supply improvements.

We develop two models for the public-supply households, one that leads to the derivation of an Option Price (OP) type welfare measure based on stated preference, and one that explains the decision to treat in the home, based on revealed preference (RP). If the household indicates that they have yet to treat, but may choose to do so later, the OP is based on stated preference (SP). If the household adequately treats their water (using distillation or reverse osmosis) all arsenic is removed and they are at no increased lung or bladder cancer risk from ingesting arsenic via drinking water consumed in the home. We note that skin contact and subsequent issues with that exposure are not solved unless the treatment system is house-wide. We begin with the treatment model, as this then feeds into the stated preference/OP model.

All models follow the discrete-choice framework that compares utilities with two or more alternatives. When risk is involved, the utility functions need to incorporate the risks, and thus are expected utility models. When we integrate ambiguity in modeling the household's risks, the models are best described as non-expected utility, or generalized, EU models.

Treatment/Public Supply OP

In this section we first present a behavioral model of treatment of the household's drinking water. In the second part we present a model of the option price for improving the public water supply.

Treatment

To begin, define Y as income and X as a vector of individual-specific attributes affecting utility. Every household has the option to treat drinking water within the home. Let V^0 be utility for households not treating drinking water, such that baseline arsenic level conditions in the household pertain, as dictated by the public supply quality that determines what is in the home. Let V^1 describe utility when the household has chosen to treat their drinking water using a technique that assures arsenic removal. Households might treat their water simply to improve taste, odor, or color of their tap water, but effective improvement of taste, odor, or color may do nothing to remove arsenic. Households that treat, but not in such a way that arsenic is not removed, will be assumed to be not treating at all: their treatment technology is not effective. Assume that payment C is made by each household that adequately treats their water for their treatment device or system. Reverse Osmosis (R.O.) and Distillation system costs can vary, and there are some expensive capital investment costs for more elaborate in-home systems. There are also annual maintenance costs for R.O. systems (new filters). Define C as the capital cost of the system (K) plus the sum of the discounted annual maintenance costs (ac_t) for the life of the system, or:

$$C = K + \sum_{t=0}^{T} ac_t \rho^t \tag{3}$$

Where ρ^t is the discount factor at time t. We use the discrete form here, which could easily be generalized to a continuous form.

Let $f(\pi)$ be the arsenic risk function relating random risk to utility. When the household adequately treats, risk is zero. Finally, let an additive term (ε^i) measure the observation error for state i. Define the following levels of indirect random utility[5]:

$$\begin{aligned} V^0 &= \alpha^0{}'X + \beta \ln Y + f(\pi) + \varepsilon^0 \\ V^1 &= \alpha^1{}'X + \beta \ln(Y - C) + \varepsilon^1. \end{aligned} \tag{4}$$

If $V^1 > V^0$, the household will pay in-home costs, and treat to reduce arsenic-related health risks to zero. Because V^i is log-linear in income, it has the attractive property of diminishing marginal utility of income that is consistent with financial risk aversion. Income effects may be appropriate when the good, here health, accounts for a significant portion of a household's perceived wealth. However, a linear-in-income utility function could also be used if income effects are thought to be unimportant.

Although many authors have equated health- and financial-risk aversion, this is problematic because diminishing marginal utility of income implies little about an individual's taste for changes in health and safety risks (see Eeckhoudt and Hammitt 2004). Thus, we add a risk function $f(\pi)$ to V^0 to account for changes in utility

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[5] All notation below assumes that the model is for an individual or household, but we have omitted individual-specific subscripts to avoid clutter.

stemming from mortality-risk aversion. Analogous to financial-risk aversion, $f(\pi)$ should accommodate either linear or nonlinear relationships between mortality risk and utility. Health or mortality risk aversion is evident if utility and increasing health risk are inversely related.

We can use the functional form proposed by Cameron (2005) and used by Riddel and Shaw (2006) that assumes that risk and the squared deviation from risk affect utility so that:

$$f(\pi) = \gamma_1 \pi + \gamma_2 (\pi - E[\pi]).^2 \tag{5}$$

This expression can be used to model the treatment decision. Having done so, we will have the predicted probability of treatment T^*.

Once we know if the household treated or not, we can analyze a stated preference outcome pertaining to their willingness to pay for increased rates to support public system treatment. We might expect that households who already treat have a zero WTP to support public system water quality improvement. However, this need not be the case, as they may have motives to pay that relate to protection of others, or to protect themselves when they are in workplaces, restaurants, or other public areas that rely on publicly supplied water. It would then be assumed that the portion of any positive, non-zero WTP that relates to in-home protection is zero.

Utility associated with the decision to pay to support the public system will be designated as V^y and utility if they decide not to pay is V^n. Superscripts reflect the yes/no decision in a referendum vote.

To begin again here, let an additive term (μ^i) measure the observation error for state i. Define the following levels of indirect random utility:

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\begin{aligned}
V^n &= \alpha^0{}' X + \beta_1 \ln Y + f(\pi) + \mu^0 \\
V^y &= \alpha^1{}' X + \beta_1 \ln(Y - C) + \mu^1.
\end{aligned}
\tag{6}
$$

In the first equation in (6) the household does not support public protection at price C, and lives with some remaining risk in the public system. The second equation here pertains to a yes in response to an offer to pay to clean up the public system. If they say yes to paying, risks in the public system are assumed to be removed. We are aware of the possibility that respondents in a survey questionnaire context may be difficult to convince with regard to any remaining risks, even if told that a new level would meet the federal standard.

The derivation of the optimal price paid would lead to the expression for the OP (see Riddel and Shaw, 2006). [Note that one could also derive the OP using the planned expenditure function (for example, see Poe's discussion, 1998).] First however, we must carefully consider the latency issue, and the possibility of a bequest component. Risks from arsenic consumption are assumed to arise twenty years from the present, and differ across people of different ages. We also wish to explore an adult respondent's WTP being partly derived from the desire to protect children from arsenic risks.

Protection for Children

As mentioned briefly above, Riddel and Shaw (2003) specify two portions of a lifetime payment, one relating to one's own protection from risk and one relating to the protection of future generations (bequest value). They also decompose the risks (in their case, radioactive wastes) into two components: one affecting current generations and one affecting future generations. Similarly, we can decompose risks into those to the adult, and those to others, with a focus on children. A child's risks are almost certainly higher than an adult's, though we have to rely on subjective assessments of that to some extent, rather than on scientist's assessments of risks to children. One factor we will build into the analysis is that the latency period is about twenty years. Health risks from arsenic consumption vary with age and the amount of previous arsenic consumption they have had. For children, say age five, risks begin when they are twenty-five or so. Given the 20 year latency period, parents may time-discount their children's future health risks, as well as their own. All of this should be captured in the respondent's stated health risks for themselves and their children, and their stated values for protection. For example, a person might state that they are willing to pay almost nothing now to pay for protection against risks that may be realized in twenty years, because of their understanding of, and implied rate of private discounting.

Private Wells

As discussed above, the pilot study in Nevada examined households on private wells. From that we learned that a substantial number of people will not have a good idea of their level of arsenic in their private well. We therefore plan to offer the private well households in our study a tap water test, which we will pay for. This is going to be an attractive incentive for doing the survey, at least for some households. For some households, they may not be interested, because they have already taken steps to self-protect by treating their drinking water: common to both the pilot study and to the work of Rosado et al. (2006) is the idea that a household may choose to treat water, or not.[6] Part of the analysis for those on private wells can be revealed preference (RP), and part can be stated preference (SP).

Revealed Preference for Private Well Group

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[6] In the Rosado et al. study the household may contemplate a CVM-referendum question such as: "would you be willing to pay a cost or rate increase of $__ so that you do not have to treat your water?" This is not an option for a household on a private well, of course.

Shaw et al. (2005) model the decision of private well owners to treat their well water, and conditioned on that decision, the decision to drink their tap water. In that paper no values are examined for arsenic risk reductions. In addition, these authors note that many respondents indicate that they are treating their water for a variety of reasons, not just to eliminate arsenic risks. Presuming that the demand for water depends on risks, one could view the area under a Hicksian demand for tap water as a revealed preference value of arsenic removal.

We will take advantage of the RP nature of these decisions to extract the value of risk reductions for private well owners. However, like the public water system group, we need to elicit the respondent's subjective determination of arsenic health risks. This was not done by Shaw et al (2005). It would be difficult to obtain the data to estimate a continuous demand function for drinking water at the tap, as this would involve careful assessment of quantities consumed in the household. It is quite simple to ask whether the households consume water from the tap (0,1 variable), and perhaps some qualitative questions regarding types of use, and perhaps percentages. We hypothesize that, conditional on treatment in the home, households will drink water from the tap as a function of the price of doing so (p_w), versus the price and perceived arsenic-related health risks (π_s) of the alternatives. It is of course possible that other contaminants than arsenic in the household's drinking water may also be of concern.

We normally think of state-dependent utility functions as depending on such risks, with the states of relevance being healthy (alive) or sick (dead). If the decision to drink water from the tap was an exogenous to the household then we might explore state-dependent (dead/alive) utility functions in an expected utility framework. However, the decision to drink from the tap or not is endogenous, and averting behavior arises when the household chooses to drink bottled water. Thus, we hypothesize that the perceived or subjective probability of health risks leads to an expected demand for water, which flows from the expected utilities.

As in the above, we first model the decision to treat, though with private well owners they have no option of having a public supplier do that treatment for them. The model of treatment follows the above model derivation for the public water system group, resulting in the predicted probability of treatment, T*. This simple model assumes that treated and bottled water carry no arsenic-related risk. The drinking water decision will result in utility V^{DT} if drinking *treated* from the tap, V^{DNT} if drinking *nontreated* from the tap and V^{ND} for drinking only bottled water and not drinking from the tap. The corresponding indirect utility functions are:

$$\begin{aligned} V^{DT} &= V^{D}(Y - p_w - C, Z) \\ V^{DNT} &= V^{D}(Y - p_w, \pi_s, Z) \\ V^{ND} &= V^{D}(Y - p_b, Z) \end{aligned} \tag{7}$$

where Z in equation (7) is a vector of other household characteristics (perhaps household size, and age of children, which may reflect convenience of getting water from the tap). If they do not drink from the tap, we assume they obtain drinking, cooking and other water ingested from the cheapest alternative source, say home-delivered bottled water at a cost of p_b. For private well users the price of tap water (p_w) best relates to pumping costs, which vary with the price of energy and depth of the well. Residents of the same area, with similar well depths, will face a uniform price, and they likely all face the same price of bottled (delivered) water.

Note that the household will make the decision to drink from the tap if either of the first two conditional indirect utility functions exceed the utility from not drinking from the tap. Thus T*, the probability that the water is treated, is equal to the joint probability $P(V^{DT} > V^{DNT}; V^{DT} > V^{ND})$. Note also, that subjective risks determine behavior, but here imperfect information may also be relevant because it may well be that the household's perception of risks without treating are quite different than what experts say that the risks are. In this case it is important to realize that the choice is made on subjective risks, which may involve imperfect information. At some later date, after a latency period has elapsed, a different utility function is relevant, which is one dependent on actual risks. If these risks lead to poor health, then realized utility from consumption is quite different than utility based on the initial choice. This echoes the work of Foster and Just (1989), or more recently cast within the random utility model context, Leggett (2002). The main point of these papers is that there are two utility functions that matter: one that determines what we observe an individual does based on the information that he or she has, and one (ex-post) that determines his or her actual welfare upon consuming the good under imperfect information. The implication is that welfare measures need to combine the two utility functions. However, the exact formulation in a discrete choice model needs to be considered before proceeding, especially in light of recent developments on information models with several sources of risk (e.g. Eeckhoudt, Godfroid and Gollier 2001).[7]

Once the relevant utility functions are estimated we can, in theory, explore welfare measures for actual risk reductions that would accompany a cleaner well water

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[7] We thank Kerry Smith for sharing views on the derivation of welfare measures with imperfect information within the discrete choice modeling context.

supply, as we will with the public-supply system group. However, to do so is problematic, because there is no public policy we know of that would lead to improvement in the household's well quality.[8] However, we might explore a program that would subsidize water treatment system installment in individual homes, or bottled water distribution, whichever is more cost-effective.[9] For the group that already treats effectively we can recover an RP-based measure of welfare under risk by comparing utility differences in the usual way: it informs us of the value of the risk reduction to households that self-protect through treatment.

We can model the differences in the utility from drinking and not drinking separately for the group that treats and for the group that does not treat. We hypothesize that the estimates of this RP-based welfare measure for the treatment group may differ from that constructed for the group that does not treat. The household may not treat because of the cost (this is supported empirically by Shaw et al. 2005; Walker et al. 2006). We can extract a welfare estimate for the non-treatment group by simulating a cost decrease that might lead to a switch from no treatment, to treatment.

Stated Preference for Private Well Group

Those on a private well, as discussed above, may also have a non-zero, positive WTP for improving public supplies in their community or elsewhere. Therefore, we will also ask a discrete choice SP question of this group. Again, the motives for this could be because household members drink water from a public source while at work, school, or elsewhere in the community, or because they are concerned about the health effects on

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[8] It is possible that arsenic concentrations may be lower at different well depths, suggestive of subsidized drilling, but difficult to imagine any program that would provide such subsidies.

[9] Currently, some local governments and water district suppliers that cannot comply with the new arsenic rule are considering delivering bottled water to its residents.

others in the community. Next, we present results from focus groups that were held thus far.

Results from Focus Groups

Three focus groups were held in January of 2006: one in Eagle Mountain, Utah, and two in Appleton, Wisconsin. Both areas were identified as arsenic hot spots, though they are quite different from one another. Eagle Mountain's population of residents are virtually all on a public water system. In contrast, many residents of Appleton are on private wells, though the sample obtained for the Appleton focus groups had a mix of household water sources.

Eagle Mountain Group

Table 1 reports the results of the Eagle Mountain group of eleven respondents. The Eagle Mountain group was not told what their current arsenic level is. We in fact knew that it was 26 ppb, which is not in compliance with the new rule. We learned from this group that once the group was told that the material to be discussed in the group meeting pertained to the community arsenic issue, this could not really be avoided: it was a mistake to tell them upon convening what the subject was, but this was difficult to avoid. Naturally, one cannot engage in purposeful lying to respondents, but many focus group leaders recommend being vague at the beginning of a meeting, so that respondents can be eased into discussion material without biases.

The Eagle Mountain group was able to understand the risk ladder, but wanted to know the source of the information on the risks, especially those pertaining to arsenic. We did not cite the source (which was a branch of the Center for Disease Control). One respondent was unable to understand the issue of latency in risks, and one respondent (a different one) had a very difficult time understanding that if she did not drink water at 50 ppb, then she did not face the risks reported in the risk ladder. All other participants in the Eagle Mountain group understood the relative risk concepts, but wanted to also see events that they were familiar with, such as the risk of fatality in an automobile accident. All participants said that they understood that children were at higher risk. However, one subject (#359) indicated children's risk that were lower than their own risks. It is possible that this is because the respondent was a smoker, but we are unable to discern that from the data we obtained because we did not ask about smoking behavior in the focus group.

Appleton Group

The second set of focus groups was held in Appleton, Wisconsin, which is a rural area of Wisconsin. Unlike Eagle Mountain, the Appleton public system has very low arsenic levels, at 1 ppb. Those on a public water supply should not be thinking they are at high risks from arsenic. Still, the focus groups are a good check on whether those actually at low risks can understand this, or whether their concerns cause them to elevate the risks in their own minds. Several subjects were on private wells.

Twelve subjects from Appleton were split into two groups, which met at different times. All subjects were on the public supply and used their water for drinking and cooking purposes. (Only one subject in group1 did not use water for drinking/cooking.) The first group received a risk ladder to communicate baseline risks, and Group 2 received a "grid," as in Corso, et al. The grid representing both initial risks and changes in those risks is presented in Figure 2, below. The risk ladder presented to Group 1 had information to both the left and right of the ladder, which proved confusing. They wanted to relate to both the left-hand, and right-hand side information, but could not sort out what was the difference in scales (there was actually, no difference: the left-hand scale was just providing larger intervals than the right-hand side scale). They also expressed a preference for seeing a common event, such as the risk of dying in an automobile accident (car crash). In contrast, Group 2 found the risk grid too dramatic and not informative.

Many in these groups treated their water. However, in Group 1 subjects 13 and 14 are on private wells, and neither treats their water. In Group 2, subjects 21, 22, 23, and 26 are on private wells, and all of these households treat their water. We looked to see if there was a clear indication, in group 1, that subjective risks were lower if treating their water, but we cannot make that inference. One subject wondered whether water softening is the same as a treatment, indicating the need for clarity in what we mean by water treatment. One subject had water tested and knew only that it was “safe” but didn’t know exactly the arsenic level. As in other studies, one reason given for water treatment was to make the water taste better. But some said water treatment made them “feel safe.”

Group 2 was not asked their subjective risks of arsenic because they only received the grid. They were only asked the level of “concern” for arsenic in their drinking water. It was at this point that respondents should have been asked to indicate their subjective risks after viewing the grid, but we failed to ask them these at this time. In both groups we attempted trade-off questions that would allow identification of a probability weighting function. Subjects in both groups had a great deal of difficulty with these questions. They did not find them “realistic” and thought they were much too long. Trade-off questions may work best when the risks at hand are those that relate to a financial gamble.

Conclusions from Focus Groups

The "concern" question we have was poor, and had to be changed. The need to clearly communicate what treatment systems remove arsenic is great, as is the importance of finding out in advance (if possible), what level of arsenic that people have in their water. The grid might be used to help respondents discern the change in risk, and the ladder might best be used to convey baseline risks.[10] The probability weights questions either must be abandoned or a new way of eliciting the weights must be found than the method we were trying in the groups.

As a consequence of the focus groups and informal analysis of results, we will redesign the survey and the approach to implementing it. We had planned for, and budgeted for a mail survey. However, the complexity of the risk issues, as well as the need to ensure that respondents do not skip ahead to material that needs to be digested sequentially, strongly suggest the need to survey by telephone (in-person interviews are outside of the budget allocated for the project). We plan to use a phone-mail-phone approach, wherein individuals will be recruited by telephone, and then mailed an information brochure that they can refer to during the actual telephone interview. Fortunately we also discovered that this approach would allow us to conduct the tap water test just after the initial contact, possibly allowing identification of arsenic levels at the tap before the actual survey takes place. Another advantage of the approach is that we can obtain some demographic information in the very first contact by telephone, which can then be used to model potential sample-selection bias.

Finally, it came to our attention that many are now using questions that match those found in another survey in order to assess potential sample-selection bias. We will

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[10] We thank J.R. DeShazo for engaging in discussions with us about this.

therefore also redesign questions about standard demographics to match those questions found in reliable national surveys.

Summary/Conclusions

Substantial progress has been made in efforts to develop a national (with focus on hot spots) survey on arsenic risks in drinking water. Arsenic is yet another example of risks that are difficult to characterize, highlighting the importance of allowing for ambiguity in a model of behavior and valuation. Drinking water involves potential for averting behavior through treatment and, or through drinking water from sources other than the tap. Though complicated by this potential, the survey can be used to discern drinking water and averting behavior, as well as find out about respondents' subjective risks from drinking water with arsenic in it. At this juncture, it appears that eliciting probability weights for mortality risks, which would be highly desirable to have in theory, is quite difficult.

References

Adamowicz, Wiktor; J. Swait; Peter Boxall; Jordan Louviere; M. Williams. 1997. “Perceptions versus Objective Measures of Environmental Quality in Combined Revealed and Stated Preference Models of Environmental Valuation.” *J. of Environ. Econ. and Manage*. **32**: 65-84.

Agee, Mark D. and Thomas D. Crocker. 1994. “Parental and Social Valuations of child Health Information.” *J. of Public Economics* 55: 89-105.

Agee, Mark and T.D. Crocker. 2001. “Smoking Parents’ Valuations of Own and Children’s Health.” Presented at the Risk Workshop, EPA, Bar Harbor, Maine.

___________________ “Parents’ Discount Rates for Child Quality” 1996. *Southern Ec. Journal* 63 (1/July): 36-50.

Bell, Kathleen et al. 2005. “Behavioral Responses to Arsenic in Drinking Water.” Discussion paper, presented at the annual meetings of the American Agricultural Economics Association, Providence, Rhode Island.

Burnett, Jason K. and Robert W. Hahn. 2001. “A Costly Benefit.” *Regulation*, (Fall): 44-49.

Camerer, Colin and Martin Weber. 1992. Recent Developments in Modeling Preferences: Uncertainty and Ambiguity. *J. of Risk and Uncertainty*, **5**: 325-70.

Chang, CC. et al. 2004. “Ischemic Heart Disease Mortality Reduction in an Arseniasis-Endemic Area in Southwestern Taiwan After a Switch in the Tap-Water Supply System.” *J. of Toxicology and Environmental Health* 67 (1): 1353-61.

Chen, C.W. and H. Gibb. 2003. “Procedures for Calculating the Cessation Lag.” *Regulatory Toxicology and Pharmacology*, **38** (2/October): 157-65.

Chiu, H.F. et al. 2004. “Lung Cancer Mortality Reduction After Installation of Tap-Water Supply System in an Arseniasis-Endemic Area in Southwestern Taiwan.” *Lung Cancer* 46 (3): 265-70.

DeShazo, J.R. and Trudy A. Cameron. 2005. “Mortality and Morbidity Risk Reduction: an Empirical Life-cycle Model of Demand with Two Types of Age Effects.” Discussion paper, University of Oregon.

Eeckhoudt, Louis; P. Godfroid; C. Gollier. 2001. “Multiple Risks and the Value of Information.” *Economics Letters* **73**: 359-65.

Ellsberg, Daniel. 1961. “Risk, Ambiguity, and the Savage Axioms,” *Quarterly Journal of Economics,* Vol. **75**(4): 643 – 669

Foster, W. and R. Just. 1989. “Measuring Welfare Effects of Product Contamination with Consumer Uncertainty.” *J. Environmental Economics and Management*, **17**(3):266-283.

Fox, C.R. and A. Tversky. 1991. Preference and Belief: Ambiguity and Competence in Choice Under Uncertainty." *Quarterly Journal of Economics* **110**: 585-603.

Hammit, James K. and J. Liu. 2004. "Effects of Disease Type and Latency on Value of Mortality Risk." *J. of Risk and Uncertainty* **28** (1): 73-95.

Kayajanian, Gary. 2003. "Commentary: Arsenic, Cancer, and Thoughtless Policy." *Exotoxicology and Environmental Safety*, Vol. **55**: 139-42.

Leggett, Christopher G. 2002. "Environmental Valuation with Imperfect Information." *Environmental and Resource Economics*, **23**(2):343-355.

Lindbladh, Eva and Carl Hampus Lyttkens. 2003. "Polarization in the Reaction to Health-Risk Information: A Question of Social Position?" *Risk Analysis* **23** (4): 841-55.

Liu, Jin-Tan; James K. Hammitt; Jung-Der Wang; J. Liu. 2000. "Mother's Willingness to Pay for Her Own and Her Child's Health: A Contingent Valuation Study in Taiwan." *Health Economics* **9**: 319-26.

Machina, Mark. 1982. "Expected Utility Analysis without the Independence Axiom." *Econometrica* **50**: 277-323.

Madajewicz, Malgosia; A. Pfaff; A. van Green; J. Graziano; I. Hussein; H. Momotaj; R. Sylvi; and H. Ashan. 2006. “Can Information Alone Change Behavior? Arsenic contamination of groundwater in Bangladesh.” Discussion paper, Earth Institute, Columbia University.

Morales, K.H. et al. 2000. “Risk of Internal Cancers from Arsenic in Drinking Water.” *Environmental Health Perspectives* **108** (7): 655-61.

National Research Council. 2001. “Arsenic in Drinking Water, 2001 Update.” Washington, D.C. 310 pp.

Opar, A.; A. Pfaff; A.A. Seddique; K.M. Ahmed; J.H. Graziano; and A. van Geen. 2004. “Responses of 6500 Households to Arsenic Mitigation in Araihazar, Bangladesh.” Discussion paper, Lamont-Doherty Earth Observatory, Columbia University

Poe, Gregory L. 1998. “Valuation of Groundwater Quality Using a Contingent Valuation Damage Function Approach.” *Water Resources Research* **34** (12): 3627-33.

Poe, Gregory et al. 1998. “Do Participants in Well Water Testing Programs Update Their Exposure and Health Risk Perceptions?” *J. of Soil and Water Conservation* (4th Quarter): 320-25.

Riddel, Mary and W.Douglass Shaw. 2006. "A Theoretically-Consistent Empirical Non-Expected Utility Model of Ambiguity: Nuclear Waste Mortality Risk and Yucca Mountain." *Journal of Risk and Uncertainty,* Vol. **32** (2/March): xx-xx.

____________ 2003. "Option Wealth and Bequest Values: the Value of Protecting Future Generations from the Health Risks of Nuclear Waste Storage." *Land Economics*, Vol. **79**, No. 4 (November): 537-48.

Riddel, Mary; C. Dwyer; W. Douglass Shaw. 2003. "Environmental Risk and Uncertainty: Insights from Yucca Mountain." *Journal of Regional Science*, Vol. **43**, No. 3 (August): 435-58.

Rosado, Marcia, et al. 2006. "Combining Averting Behavior and Contingent Valuation Data: An Application to Drinking Water Treatment." Discussion paper, Universidade Nova de Lisboa (Lisbon, Portugal)

Shaw, W. Douglass; Rudolfo Nayga; Andres Silva. 2006. "Perceived Mortality Risks for a Healthful Food Product: Some Experimental Evidence." Unpublished discussion paper, Texas A&M University (March).

Shaw, W. Douglass; Mary Riddel; Paul Jakus. 2005. "Valuing Environmental Changes in the Presence of Risk: An Update and Discussion of Some Empirical Issues." Chapter 7 in <u>International Yearbook of Environmental and Resource Economics: A Survey of Current</u>

Issues: 2005/2006, Henk Folmer and Tom Tietenberg (eds.) Northampton, Mass: Edward Eglar Press

Shaw, W. Douglass; M. Walker; M. Benson. 2005. “Treating and Drinking Well Water in the Presence of Health Risks from Arsenic Contamination: Results from a U.S. Hot Spot” *Risk Analysis*, Vol. **26** (6):1531-43.

Sheppard, D.S. and R. Zeckhauser. 1984. “Survival versus Competition.” *Management Science* **30**: 424-39.

Smith, Allan; Peggy A. Lopipero; Michael N. Bates; Craig M. Steinmaus. 2002. “Arsenic Epidemiology and Drinking Water Standards.” *Science*, vol. **296** (June 21st): 2145-46.

Smith, Allan et al. 1992. *Environmental Health Perspectives* **97** 259 as cited in Smith, Lopipero, Bates and Steinmaus (2002).

Smith, V. Kerry and William H. Desvousges. 1990. “Risk communication and the value of information: Radon as a case study.” *Rev. of Econ. and Statistics* **68** (2):137-42.

Viscusi, W. Kip and W. Evans. 2006. “Behavioral Probabilities.” *J. of Risk and Uncertainty* **36** (2): 5-15.

Walker, Mark; W. Douglass Shaw; Marnee Benson. 2006. “Analytical Arsenic Consumption and Health Risk Perceptions in a Rural Western U.S. Area,” Forthcoming, *Journal of the American Water Resources Association.*

Walker, Mark; Marnee Benson; W.Douglass Shaw. 2005. “Significance of private water supply wells as a route of exposure to aqueous arsenic.” *Journal of Water and Health,* ***3*** *(No. 3 - Sept):* 350-362.

Table 1: Results from Eagle Mountain, Utah Focus group

Id	Concern	Tap	Use	Risk1	Risk2	Wtp	Education	offer
1029	5	0	1	1.5/100	-	0	3	12
298	3	1	1	0	0	Don't like	4	6
816	5	1	1	Dk	Dk	1	4	12
156	4	1	1	1/million	-	1	2	6
814	5	0	1	0	-	1	2	3
105	2	1	1	2/10mill	> 1/100,000	1	4	3
359	5	0	1	< 1/100	Child below	1	4	6
360	4	1	1	2/1 mill	5/1 mill	1	4	12
142	2	1	1	5/10 mill	> 1/1 mill	0	2	6
111	4	1	1	1/10 mill	To 1/1 million	0	4	12
1032	2	1	1	5/10 mill	-	1	3	3

Notes:

1. Concern is 1 to 5 (very concerned)
2. Tap = 1 if they said they drink, 0 if not.
3. Use = 1 if they in fact indicate they did some use.
4. Risk1 is mark (rough) on ladder for adult (DK = don't know)
5. Risk2 is mark for child
6. WTP = 1 if they said yes to bid offer, 0 if No
7. Ed = 1 high school, 2 some college, 3 tech college, 4 college grad.
8. Offer is $3, $6, or $12 per month.

Table 2: Results from Appleton Focus group 1

Id	Concern	Treat	Risk1	Risk2	Offer	Wtp	Age	Kids	Gen	Educ	Inc
11	2	0	1/10M	1/1M	-	-	5	0	1	2	1
12	4	1	1/500000	1/10000	-	-	6	0	1	2	2
13	1	0	1/1M	1/10000	3	1	4	0	1	2	4
14	5	0	1/100M	1/1M	12	1	3	1	0	2	4
15	5	1	1/10M	1/250000	-	-	2	0	0	4	5
16	3	0	1/500000	-	-	-	5	0	1	2	4

Table 3: Results from Appleton Focus group 2

Id	Concern	Treat	Offer	Wtp	Age	Kids	Gen	Educ	Inc
21	5	1	12	1	4	0	0	3	4
22	2	1	3	0	3	1	0	2	3
23	5	1	6	1	3	1	1	4	6
24	2	0	-	-	1	1	0	2	3
25	2	1	-	-	3	1	1	3	5
26	4	1	12	1	3	1	0	4	4

Notes:

1 Concern is 1 (not at all) to 5 (very concerned); Treat = 1 if they treat, 0 if not
2 Risk1 is mark (rough) on ladder for own risk (Only group 1)
3 Risk2 is mark for child's risk (Only group 1)
4 Offer is \$3, \$6, or \$12 per month. (Only private well)
5 WTP = 1 if they said yes to bid offer, 0 if No (Only private well)
6 Age = 1: 18-24, 2: 25-34, 3: 35-44, 4: 45-54, 5: 55-64, 6: >65
7 Kids = 1 if yes, 0 if no
8 Gen = 1 if male, 0 if femele
9. Educ = 1: high school, 2: some college, 3: tech college, 4: college grad
10. Inc = 1: if annual income <\$19999, 2: \$20000-\$39999, 3: \$40000-\$59999, 4: \$60000-\$79999, 5: \$80000-\$99999, 6: >\$100000

Figure 1: Probability Weighting Function (Inverse S shape)

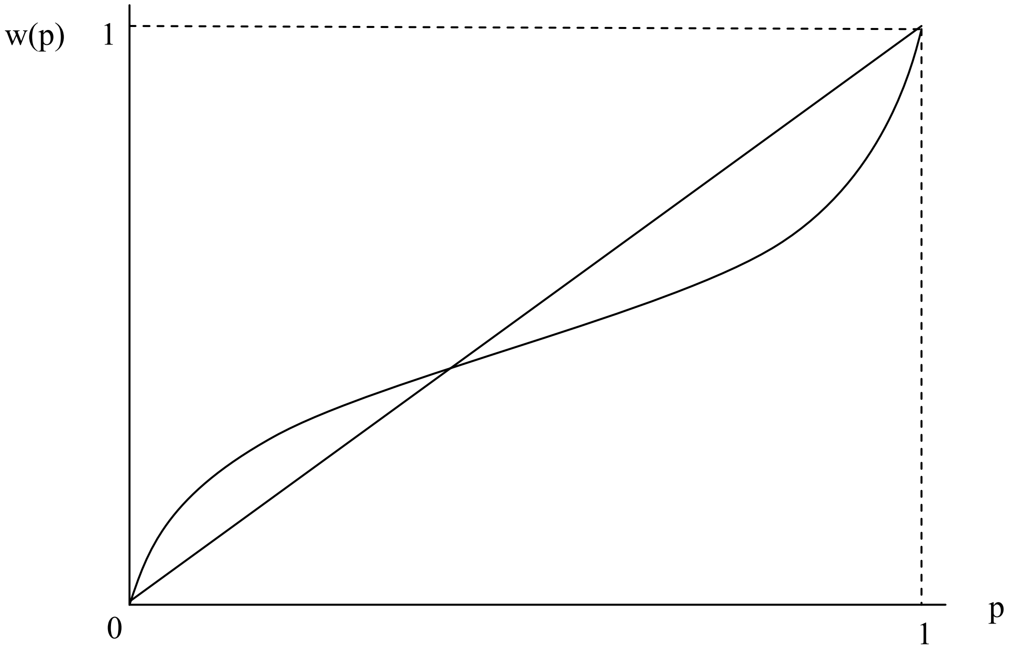

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Figure 2. We want to take a minute to explain how we will describe your risk over 20 years. Imagine that each small square below represents one person, so that the whole picture represents 1,000 people. RED squares show the people who die over 20 years. WHITE squares show the people who live.

🟥 = DEAD

□ = ALIVE

In the picture below, 18 out of 1,000 nonsmoking adults die from an illness over 20 years.

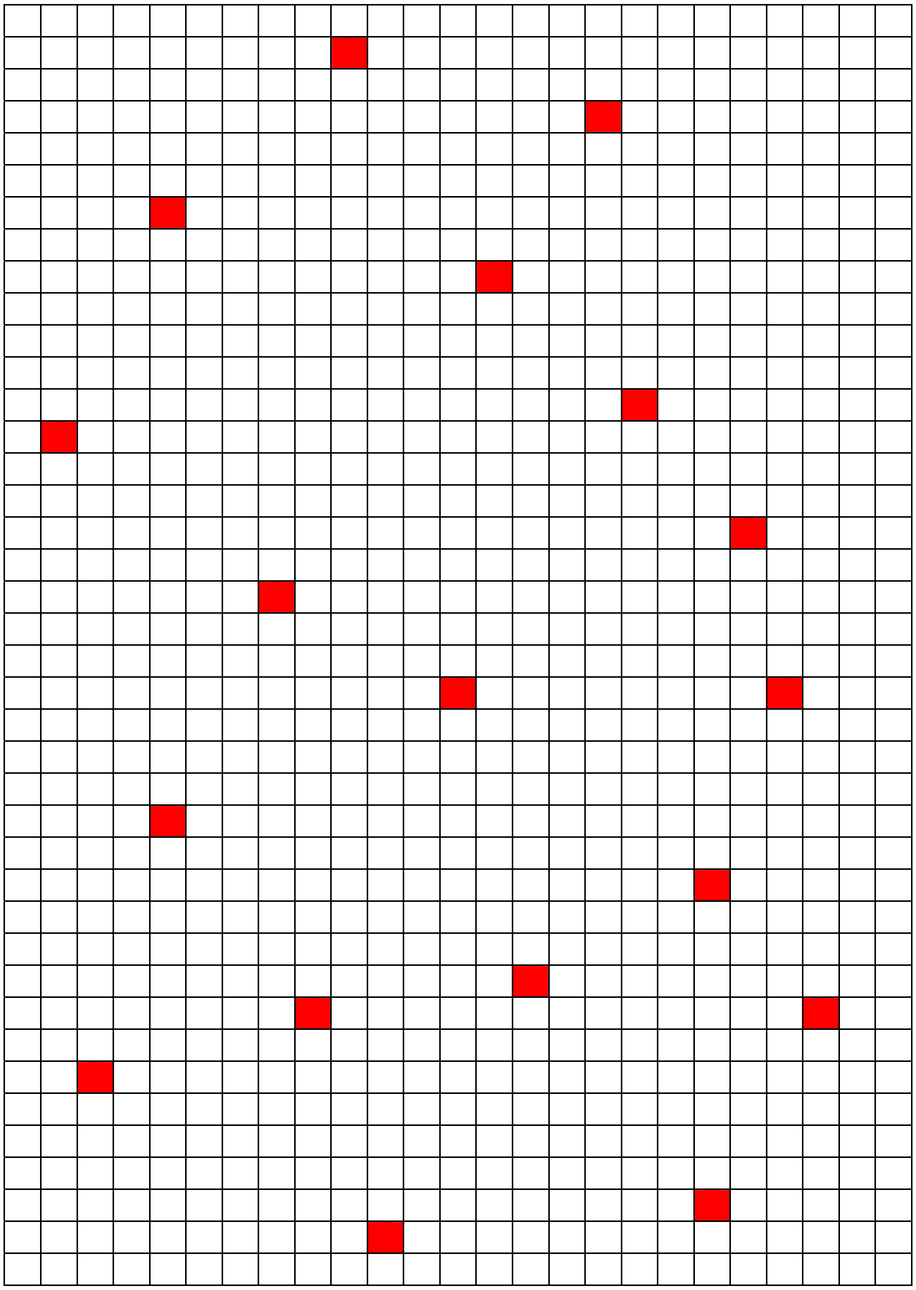

Figure 2. (cont)Regular consumption of water with 50 ppb of arsenic, increases a chance that a nonsmoking adult die in 20 years by 1 in 100🟦BLUE squares ( ) represent the increase in mortality risk from the arsenic🟥and RED squares ( ) represent the original risk from the illness from the previous page.

In the picture below, 28 out of 1,000 nonsmoking adults die from an illness and the consumption of arsenic in drinking water over 20 years.