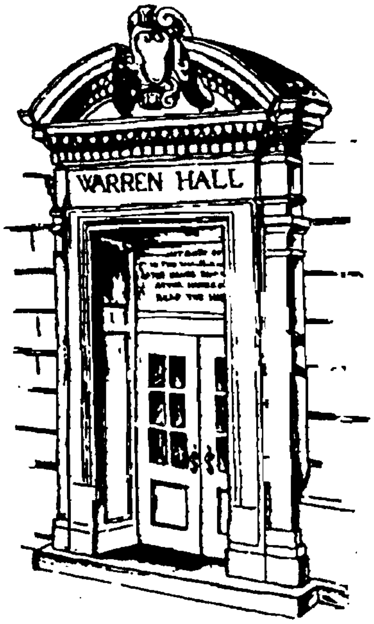
WP 96-11

September 1996
Revised Nov. 1996



Working Paper

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Do Participants in Well Water Testing Programs Update Their Exposure and Health Risk Perceptions?

by

Gregory Poe, Harold van Es,
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Abstract: Using data from two studies that elicited nitrate health risk and exposure perceptions before and after a well testing program, this paper investigates whether participants update their risk perceptions with new information. Graphical analyses demonstrate that, in the aggregate, updating occurs when well test information is provided. In particular, uncertainty about safety and exposure appears to be substantially reduced, and perceptions correspond to the distribution of nitrates. Statistical analyses indicate that individual updating of perceptions is a systematic function of prior perceptions and nitrate test levels. Evidence that updating occurs demonstrates that public information programs can be effective in modifying risk perceptions, and offer a critical first step in assessing the cost-effectiveness of such programs

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Do Participants in Well Water Testing Programs Update Their Exposure and Health Risk Perceptions?

A basic tenet of choice under uncertainty is that additional information improves decision making. This point has long been recognized in environmental and health risk policy at the federal level: the USEPA has actively implemented public information provision policies for environmental risks such as radon, and, more recently, Congress mandated that public water suppliers provide detailed information on water quality violations to their customers under the 1996 Safe Drinking Water Act Amendments. Many states and localities have similarly adopted public information policies for well water users, offering educational programs and subsidizing water testing for private wells. The purpose of this paper is to demonstrate that such well water testing programs are informative in the sense that individual households use water test results and associated information to update their exposure and health risk perceptions. Evidence that such updating does occur is a critical first step in assessing the impact and the cost effectiveness of public information programs.

Data for this paper are taken from two studies conducted in Wisconsin and New York that elicited exposure and safety perceptions before and after nitrate testing programs for private well users. The analyses utilize both graphical and statistical approaches to show that nitrate testing programs do affect exposure and health risk perceptions. Graphical presentations visually demonstrate that the distribution of household responses regarding future exposure and safety perceptions does shift with new information. The statistical analyses show that updating by individuals is systematically related to nitrate test results.

Overview of Two Studies

The data from the first study were obtained as part of a 1991-1992 contingent valuation research project focusing on willingness to pay for groundwater protection from nitrate contamination in rural areas of Portage County, Wisconsin (Poe, 1993). This county, with predominantly sandy soils that are used for agricultural production, has had extensive nitrate contamination problems over the last two decades and has been the subject of much groundwater quality research and policy innovation. At the time the study was conducted, approximately 18 percent of private wells in the county exceeded federal and state health standards of 10 mg L^{-1} for nitrate-nitrogen, and a public well had been closed because of high nitrate levels. Local lending institutions were also requiring that residential well water meet nitrate standards in order to obtain a mortgage.

"Rural" households in this area, defined as the 1980 census tracts which did not have municipally provided water, contained an estimated 22,432 residents in 1990[1]. This group was selected for the information provision study because: 1) past research on groundwater contamination indicated that a wide range of nitrate levels existed in this area; 2) a pre-test indicated that about half the households had previously tested their water for nitrates, suggesting that prior information levels varied across households; 3) public concern in the area had led to a variety of policy proposals including rezoning, installation of community wells and denitrification systems, establishment of buffer zones and regulation of farming; and 4) rural residents are not protected by state and federal health standards for nitrates in groundwater. Currently, remedial actions at the household level offer the only options for

[1] Only households east of the Wisconsin River were included in this research.

owners of private wells with elevated nitrate levels. In contrast to other chemicals such as atrazine and aldicarb, state cost sharing for well improvement or purification systems is not available for nitrate contaminated wells.

In order to assess how information on nitrates and exposure levels affects health risk and exposure perceptions, the survey design consisted of two sequential stages. Stage 1 survey participants were asked to complete a questionnaire and submit a water sample that would be analyzed for nitrate by the Wisconsin State Laboratory of Hygiene. In the Stage 2 survey, all participants who returned water samples and completed a Stage 1 survey were provided "specific" information about their own nitrate test results for their household water supply, a fact sheet with "general" information about nitrate contamination (sources, possible health effects, government standards, distribution of nitrate contamination in Portage County and Wisconsin wells, and potential averting options), and a second questionnaire. Both Stage 1 and Stage 2 questionnaires elicited responses to the following safety questions:

> *In your opinion are the nitrate levels found in your well safe for adults and children older that 6 months to use as their primary source of drinking and cooking water*

> *In your opinion are the nitrate levels found in your well safe for infants less than 6 months to use as their primary source of drinking and cooking water?*

with ordered categorical responses to each question being: Definitely safe; Probably safe; Not very safe; Definitely not safe; and Don't know. Individuals were also asked to assess the likelihood of future exposure in the following question:

> *Without... a groundwater protection program, do you expect the nitrate levels in your own well to exceed the government standard for nitrates during the next five years?*

Responses to this question were categorical with probabilistic interpretations: including "*No, definitely not*", "*Probably not (25 percent chance)*", "*Maybe (50 percent chance)*", "*Probably*

(75 percent chance)", and "*Yes, definitely (100 percent chance)*". The contingent valuation question required a response to this category, and, thus, a "*Don't know*" option was not offered for this question.

The implementation of the survey followed established procedures detailed by Dillman. A total of 480 participants were randomly selected for the Stage 1 survey from a private mailing list covering areas of Portage County without publicly provided water. After correcting for "bad" addresses (n_{bad}=31), approximately 78 percent of the households returned a completed Stage 1 questionnaire and water sample. The conditional response rate to the Stage 2 survey was approximately 82 percent. Combined, the response rate to both stages was about 64 percent.

The second study, conducted in Malone, New York from 1994 to 1995, had a substantially different base situation. Like the Portage County study, the area sampled was rural, without public water supplies. However, the area did not have a history of nitrate contamination problems, groundwater quality, water quality sampling, or extensive testing by individual well owners. Prior participation in a voluntary Cornell Cooperative Extension well water education program and a rising trend in nitrate test levels in a local community well did suggest that there may be elevated nitrate levels in local wells. As such, the primary intent of this study was to design an exploratory well survey to characterize the distribution of nitrates in local wells across seasons and watershed location. Based on prior testing results, topography, and soil characteristics, an approximately four-square-mile sampling area was identified for the study. Six nitrate tests were conducted for each well at roughly two-month intervals throughout the year. Water samples were tested at Cornell University's Nutrient

Analysis Laboratory.

Because the study was conducted in conjunction with a Cornell Cooperative Extension educational program, the area evaluated was relatively small, and repeated sampling was undertaken. Contacts and information exchanges were more frequent and informal than in the Wisconsin study. Nevertheless, the basic structure was similar across studies. A Stage 1 questionnaire was distributed prior to the testing program, and a final Stage 2 questionnaire was elicited after six water test results, taken approximately every other moth throughout the year, had been reported to participants. A nitrate fact sheet, provided to the Stage 2 participants, is included in the Appendix.

Like the Wisconsin study, the New York study asked both safety and exposure questions before and after the water sampling program. A 0-10 continuous, rather than categorical, response scale was used in order to facilitate the statistical analysis of the following household safety and future exposure questions:

> *In your opinion are the nitrate levels found in your well safe for your household to use as a primary source of drinking and cooking water? If you are not sure, please give us your best guess. (CIRCLE ONE NUMBER ON THE 0 TO 10 SCALE BELOW, WHERE 0 MEANS "Definitely Safe" AND 10 MEANS "Definitely Not Safe")*

> *Government health standards for nitrates as nitrogen are 10 mg/l. If nothing additional is done to protect groundwater in your area, do you expect that your own well will have more nitrates than the government standard of 10 mg/l during the next five years? (CIRCLE ONE NUMBER ON THE 0 TO 10 SCALE BELOW, WHERE 0 MEANS "No, Definitely Not (0 percent chance)" AND 10 MEANS "Yes, Definitely (100 percent chance")*

In addition to the endpoints noted in the question instructions, the future exposure question listed "Maybe (50 percent chance)" at 5, the scale's midpoint.

Participation rates in the water sampling and the survey sampling are, for the most part difficult to estimate in the New York study. Initial contacts were mailed to 133 identifiable addresses based on tax rolls. However, it was soon clear from field contacts and inquiries that this did not constitute a comprehensive listing of private wells in the target area. Some contacts were connected to the Malone public supply, while other households in the target area were not on the mail listing. Regardless, the 92 responses to the Stage 1 survey and the 85 households that provided three or more water samples across the year, represent a considerable portion of households in the area. With respect to the Stage 2 survey, there is a basis for calculating response rates. After eliminating households testing two wells and participants who dropped out of the testing progress over the year, 83 Stage 2 surveys were distributed. A total of 70 responses were obtained for a conditional response rate of 84 percent.

Nitrate levels in both studies covered a wide range of exposure levels, and a substantial portion of the wells in the each study area exceeded government standards. In the Portage County, Wisconsin study 16 percent of wells exceeded government health standards of 10 mg L^{-1}. About 56 percent of the Portage County wells had nitrate tests between 2 and 10 mg/L, which are below health standards but do indicate some human impact. The remaining 28 percent were within natural levels. Overall these results correspond closely with previous well test results in the county. In contrast, the nitrate contamination in the Malone, New York study appears to be bimodally distributed. While a large portion, 18 percent, exceeded the government standard, the majority of wells, 51 percent, were within natural background levels (<2 mg L^{-1}). For the remaining 31 percent of the wells nitrate levels fell within the 2 to 10 mg/L range. It is interesting to note that, in contrast to past research including sampling at multiple times (e.g., Baker; Shaw), these proportions were relatively constant across the six samples collected throughout the year. Although, some evidence suggests that nitrate levels will vary widely throughout the year, this was not observable in the data collected. This result is consistent with other systematic research on individual wells (Baker *et al.*) and is to be expected at an aggregate levels when sampled well depths vary.

The different population samples and questioning formats used in the two studies provide different insights into how new information affects the distribution of safety and exposure perceptions. In particular, the high proportion of households which had already tested their water in the Wisconsin sample permitted a separate evaluation of new information on safety and exposure perceptions by prior water test experience. Analyses in the following sections thus differentiate between households which had tested their water (the "With-Test" group) prior to the Stage 1 survey and those who had not had a water test (the "No-Test" group). The questioning format in the Wisconsin sample also allowed for analyses of the "*Don't know*" responses to the safety questions as a measure of response uncertainty. In contrast, the continuous nature of the New York responses is more amenable to quantitative statistical analyses.

Graphical Analyses

Response patterns for the "infant" and "adult" safety questions are depicted in Figure 1a and 1b, respectively, for the Wisconsin Study. As demonstrated, the proportion of "*Don't know*" (DK) responses in the Stage 1 no-test group was relatively high for both the infant (0.456)

Figure 1a. Perceived Nitrate Safety for Infants, Portage County, WI Study

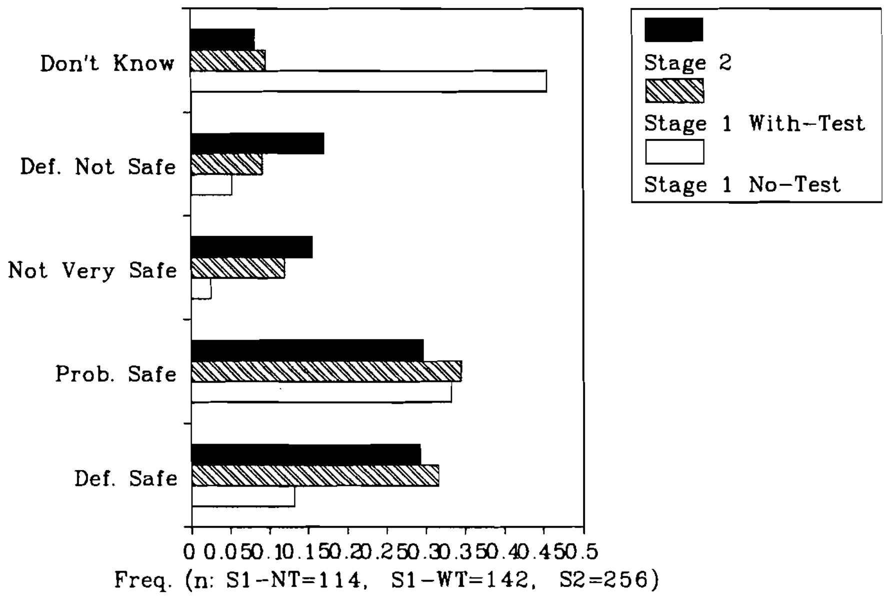
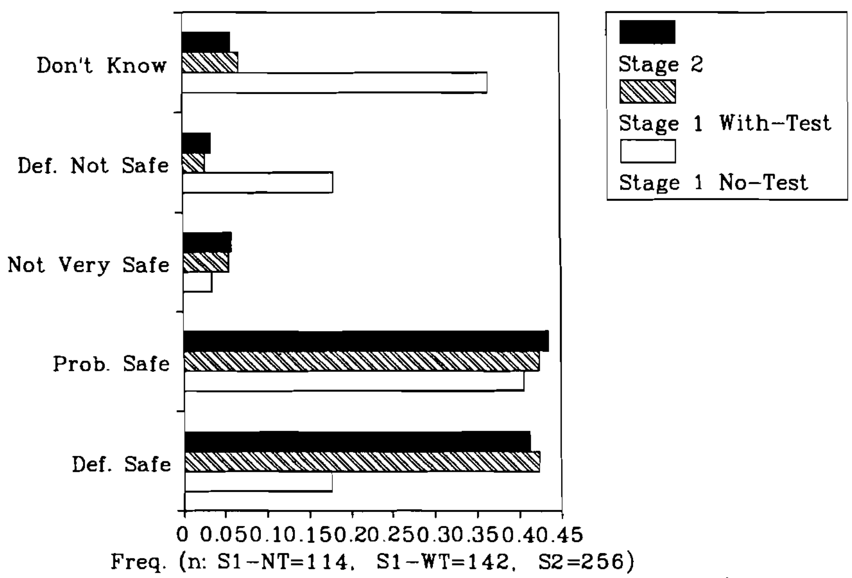


Figure 1b. Perceived Nitrate Safety for Adults, Portage County WI



and adult (0.362) safety perceptions in comparison to those in the With-Test group ($P_{Infant,\ with\text{-}test}(DK)=0.127$, $P_{Adult,\ with\text{-}test}(DK)=0.069$). Tests of proportions indicate that these responses are significantly different across question formats at the 5 percent significance level, indicating that information gathering associated with prior testing does reduce uncertainty about current safety levels. However, additional information provided with the water testing program further involved a statistically significant reduction in the proportion of "*Don't know*" responses to the safety category for both the No-test and With-Test groups.[2] Examination of the distribution of safety responses depicted in Figure 1b indicate that the water tests tend to assure respondents that their water is safe for adults to consume as the major source of drinking and cooking water. Over 80 percent of respondents felt that the nitrate levels in their water were probably or definitely safe for adults and older children. This high level of safety perception reflects the observation that 83 percent of the wells had nitrate levels within health standards. Shifts in safety responses for infants were more mixed, with less than 60 percent agreeing that their water was definitely or probably safe for infants. In spite of the generally "safe" test results and an explicit government standards, participants seemed to be more hesitant to proclaim the safety of their water for infants.

The future exposure questioning in the Wisconsin study did not contain a *"Don't know"* response. Comparisons of the Stage 1 and Stage 2 distributions are insightful,

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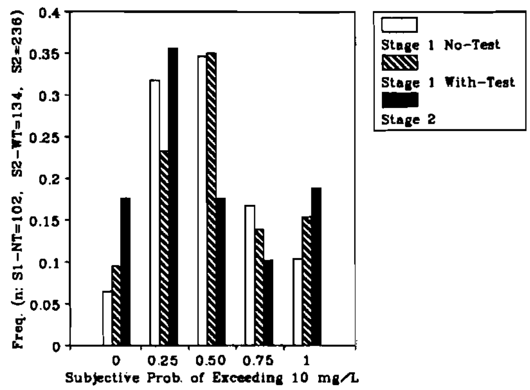
[2] The one-tailed z values, with correction for continuity, for the Stage 1 with Stage 2 No-test Infant, No-Test Adult, With-Test Infant, and With-Test Adult proportions test of "*Don't know*" responses are 5.403, 4.583, 2.094, and 1.370, respectively. The first three values are significant at the 5 percent level while the With-Test Adult comparison is significant at the 10 percent level. The Stage 2 responses are pooled in the graphical analyses because the overall response patterns are not significantly different at this stage.

Figure 2: Subjective Probability of Exceeding 10 mg/L in Five Years, Portage County WI



however. As demonstrated in Figure 2 the fairly bell shaped Stage 1 distributions centered on *"Maybe (50* percent chance)" shift towards a more bimodal distribution in Stage 2, with distinct peaks at *"Probably not (25 percent chance)"* and *"Yes, definitely (100 percent chance)"*. It appears that the expectations of future contamination have evolved from a distribution characteristic of uncertainty (especially the No-Test group) to one that more closely reflects the actual nitrate distributions. Approximately 16 percent of the well tests exceeded the 10 mg L^{-1} standard, while more than 60 percent had nitrate levels less than 5 mg L^{-1}.

This shift from a modal point at the center of the probability distribution is particularly evident in the New York safety and exposure responses in the Stage 1 and Stage 2 questionnaires. As demonstrated in Figure 3, there was a prominent mode at the midpoint of both the safety and exposure scales in the Stage 1 survey, exceeding 25 percent of responses in the safety question and 50 percent of the responses for the exposure question. With Stage 2 information, this apparent uncertainty was drastically reduced for the safety question. Stage 2 responses clearly reflect the bimodal nature of nitrate exposure. A large portion felt that their water was "Definitely safe" in the Stage 2 responses, while another smaller group felt that their well water was "Definitely not safe."

The future exposure questions similarly shifted toward a greater assessment that well tests would not exceed health standards in five years. Again reflecting the actual nitrate distribution, a smaller group felt that their well water would definitely exceed health standards in 5 years. Whereas only a small proportion of respondents remained uncertain in the Stage 2 safety questions, a large portion of responses, exceeding 20 percent, to the question concerning future exposure levels, remained in the "Maybe" category in the future. This result is consistent with that found in the Wisconsin study, indicating that the elicitation of future contamination may require greater cognitive processes. In essence, assessment of future exposure probabilities ask respondent to formulate guesses about complex hydrologic outcomes rather than simply formulating perceptions of health safety.

In all, the graphical analyses suggest that information is used by participating households. *"Don't know"* and *"Maybe"* responses to the safety question fell dramatically and significantly with additional information, and the Stage 2 distributions reflect the nitrate test results. However, such aggregate analyses fail to show whether individuals are acting "rationally" with respect to information provided. Although suggestive, it is not certain, for example, that individuals with high (i.e. relatively unsafe) test results adjusted their safety responses upward, while those with low levels adjusted their safety responses accordingly.

Figure 3: Perceived Safety for Household, Malone NY

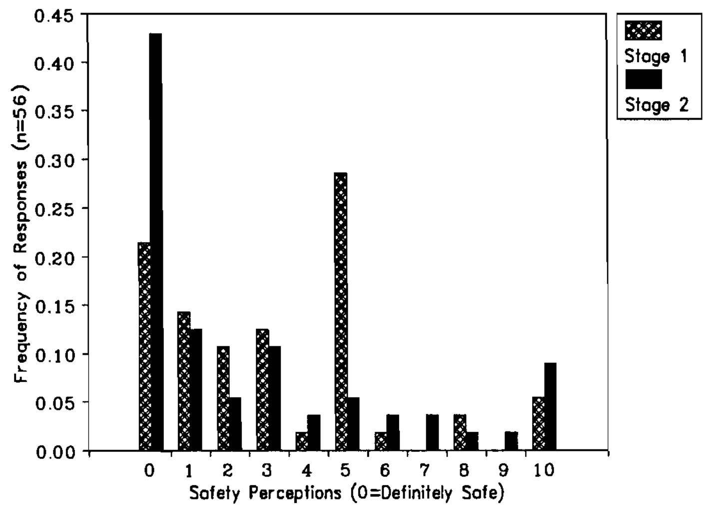
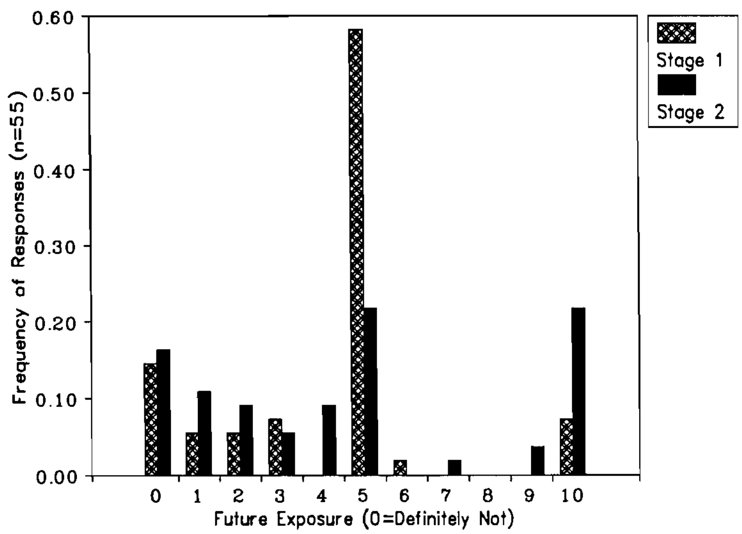


Figure 4: Subjective Probability of exceeding 10 mg/L in Five Years, Malone NY



Such a conclusion requires systematic statistical analyses such as those provided in the next sections.

Statistical Risk Updating Model

A general model of risk updating with respect to new information would consist of a Stage 2 risk assessment (R_2), that is a function of the reported Stage 1 risk perceptions (R_1), the sample risk (R_s) associated with the information message, and weights (ω) placed on each source. A simple form of this relation is a weighted linear average:

$$R_2 = \omega_1 R_1 + \omega_s R_s \tag{1}$$

where ω_1 is the relative weight placed on the prior risk perception, ω_s is the relative weight placed on the information message, and $\omega_1+\omega_s=1$. Interpretation of R_1 and R_2 is straightforward: they are probability assessments reported by the individual before and after receiving information. Whereas these Stage 1 and Stage 2 risk assessments are observed directly through responses to survey questions, the sample risk must be estimated from relationships between R_2 and R_1. Similarly, the relative weights ω_1 and ω_s are not observed directly. With some additional assumptions it is, however, possible to infer the average sample risk equivalent of the new information and to recover the relative weights (ω_s/ω_1) of prior perceptions and sample information [Viscusi and O'Connor; Smith and Johnson]. For nitrate testing, this can be accomplished by assuming that posterior risk is specified by the following linear relationship:

$$R_2 = \beta_o + \beta_1 R_1 + \beta_2 N_s \tag{2}$$

where, R_2 and R_1 were defined previously, N_s corresponds to the nitrate test results, and β_j are coefficients to be estimated. Assuming further the relationship expressed in equation (1), algebraic manipulation provides the following derivations for sample risk:

$$R_s = \frac{\beta_o + \beta_2 N_s}{1 - \beta_1} \tag{3}$$

This inferred sample risk is assumed to be "equivalent to observing additional Bernoulli trials concerning riskiness" of the event in question [Viscusi and O'Connor, p. 950] or more generally "similar to an estimated sample risk" [Smith and Johnson, p. 2]. The relative

$$\frac{\omega_s}{\omega_1} = \frac{1}{\beta_1} - 1 \tag{4}$$

weights placed on the sample risk and initial perceptions can be recovered as follows: While this model is consistent with Bayesian updating of subjective risk preferences it also conforms to many other updating models [Smith *et al.*].

For statistical estimation purposes the updating model of equation (2) can be restated as:

$$\begin{aligned} R_{2i}^{*} &= B_o + B_1 R_{1i} + B_2 N_{si} + U_i \\ &= BX_i + U_i \end{aligned} \tag{5}$$

where the addition of the subscript i to stated risk perceptions and observed nitrate levels denotes the individual respondent, and U is assumed to be a normally distributed error term with mean 0 and variance σ^2. Because the probabilities have a lower bound of zero and an upper bound of one, it is necessary to define R^*_{2i} as an index variable for predicted outcomes. R_{2i} is defined as follows:

$$\begin{aligned} R_{2i} &= 0 \quad \text{if } R^*_{2i} \leq 0 \\ R_{2i} &= R^*_{2i} \quad \text{if } 0 < R^*_{2i} < 1 \\ R_{2i} &= 1 \quad \text{if } R^*_{2i} \geq 1 \end{aligned} \tag{6}$$

The corresponding likelihood function is given by

$$L(B,\sigma | R_{2i}, X_i) = \prod_{R_{2i}=0} \Phi\left(\frac{-BX_i}{\sigma}\right) \prod_{R_{2i}=R^*_{2i}} \frac{1}{\sigma} \phi\left(\frac{R_{2i} - BX_i}{\sigma}\right) \prod_{R_{2i}=1} \left[1 - \Phi\left(\frac{1 - BX_i}{\sigma}\right)\right] \tag{7}$$

where ϕ and Φ are the normal probability density function and cumulative distribution function respectively, and X_i is a vector that includes the variables R_{1i} and N_{si} defined in equation (4) [Rossett and Nelson; Maddalla; Smith and Johnson].

Results of Statistical Analyses

Statistical analyses using techniques described in the previous section were conducted for the future exposure question in the Wisconsin study, and the safety and exposure questions in the New York study. Because of the ordinal nature of the responses to the safety questions in the

Wisconsin study, the statistical techniques detailed in the previous section are not appropriate.[3]

Because of the probabilities attached to each response category, the future exposure question in the Wisconsin study was amenable to the estimation processes detailed in the previous section. Results of this estimation for the No-Test and With-Test groups, using the Stage 1 and Stage 2 response data along with the nitrate test value, are reported in the first column in Table 1. For both the No-Test and the With-Test groups, the coefficients are significant and of the expected sign. The results indicate that while positive weights are placed on prior risk assessments, updating of perceptions has resulted from the assimilation of new information. Estimated sample risk and risk coefficients are reported in the middle portion of Table 1, and descriptive statistics for the analysis are reported in the lower portion.

A comparison of the estimated models provides results that are consistent with the Stage 1 conclusion that before receiving the nitrate test results the No-Test group is less certain about their nitrate levels . Although both models have highly significant coefficients on the nitrate test values, the level of significance of the initial risk perception coefficient on

[3]Instead of the two limit "Tobit" model proposed in equations (5) to (7), an ordered probit model was used to demonstrate that safety perception updating was related to nitrate test results. In each of the four test/question combinations (No-test/Infant Safety, No-Test/Adult Safety, With-Test/Infant Safety, With-Test/Adult Safety), both the coefficients on the Stage 1 safety assessment and the water test level were statistically significant explanatory variables of the Stage 2 safety assessment. This suggests that both prior expectations and the nitrate test results were used in forming the Stage 2 assessment, and that, because of the significance on the nitrate coefficient, the null hypothesis of no updating is rejected. Moreover, it indicates that safety perceptions are systematically correlated with well nitrate levels. However, the ordinal nature of the data precludes the derivation of the inferred sample risk and the relative weight placed on prior perceptions and nitrate test results. See Poe for further details.

Table 1. Safety and Future Contamination Updating Models, Malone, NY[1,2]

		Wisconsin		New York	
		Future Exposure No-Test	Future Exposure With-Test	Safety Perceptions	Future Exposure
ESTIMATED MODEL	Constant	-0.0553 (0.0906)	-0.0505 (0.0683)	-0.1490* (0.0828)	0.0548 (0.1182)
	R_I(Initial Risk)	0.281* (0.152)	0.324*** (0.111)	0.0765 (0.1766)	0.4294* (0.2528)
	Nitrate Level (N_s)	0.0592*** (0.0090)	0.0658*** (0.0078)	0.0795*** (0.0119)	0.0585*** (0.0143)
	σ	0.368*** (0.036)	0.330*** (0.027)	0.301*** (0.045)	0.389*** (0.051)
	n	102	134	56	55
	-log(L)	58.29	62.84	23.12	32.09
DERIVED COEFS	ω_s/ω_I (weight ratio)	2.560	2.091	12.073[3]	1.329
	R_s (Sample Risk)	0.393	0.571	0.187[3]	0.669
DATA	R (Stage 1 Risk)	0.493 [0.269]	0.500 [0.295]	0.314 [0.276]	0.412 [0.256]
	R (Stage 2 Risk)	0.402 [0.341]	0.480 [0.344]	0.263 [0.333]	0.454 [0.302]
	Mean Nitrate Level (mg/L)	5.71 [6.79]	6.65 [6.91]	4.044 [5.983]	5.9465 [11.655]

*,**,*** significant at the 10, 5, and 1 percent levels, respectively.
[1] Numbers in ( ) are standard errors.
[2] Numbers in [ ] are standard deviations.
[3] Calculated using insignificant coefficient on R.

the Stage 1 coefficient is lower for the No-Test group. The estimated weight placed on initial perceptions and the corresponding ratio ω_s/ω_1 are also slightly lower for the With-Test (2.091) group than for the No-Test group (2.560). Combined these results provide strong evidence of risk updating in both groups, but suggest that the relative weight placed on new information is higher for the group of individuals who had not previously tested their water. Further evidence of consistency in responses is that the lower estimated sample risk for the No-Test group reflects the lower average nitrate test for this group.

The last two columns of Table 1 provide the statistical analyses for the safety and exposure updating in the New York study, in which the 0-10 response scale was rescaled to a 0-1 range to reflect a probability assessment. For the safety perceptions, the coefficient on the nitrate level was significant at the 1 percent level, suggesting that the nitrate information had a strong effect on Stage 2 safety response[4]. However, the original safety perception was not significantly different from zero, and had a low positive value. This suggests that very little weight was placed on initial Stage 1 safety perceptions, a result that is consistent with the extreme mode at 5 in the Stage 1 graphical analysis for the No-Test group shown in Figure 3. The extremely high relative weights ratio, ω_s/ω_1 reported in Table 1 further supports this observation. The low inferred safety level from the sample information is also consistent with the actual distribution of nitrates for most households as well as the graphical shift towards safe responses depicted in Figure 3.

[4] Ideally, additional explanatory variables, such as household composition, would be included in these analyses to further define updating process. However, the small sample size in each study, and limited information on socio-economic variable in these experiments, precluded such analyses.

The last column of Table 1 shows that the new information contained in the New York sampling program also affected individual exposure risk perceptions in a systematic manner. Estimated coefficients for the safety and exposure perceptions are highly significant and of the expected sign. The estimated weight ratio exceeded parity, indicating that respondents placed greater weight on the sample risk than on their prior Stage 1 risk perception. In comparison with the other sample weight ratios, the relative weight placed on the new information was relatively low. As with the Wisconsin study, this persistent uncertainty may reflect the greater degree of caution associated with predicting future, highly complex hydrologic trends, even though respondents possessed water quality data covering one year.

In all, the statistical analyses support the conjecture that individual participants do use nitrate information testing to update their safety and exposure perceptions and that the updating is systematically related to the nitrate levels.

Summary and Implications

The graphical and statistical analyses provided in the previous sections support motivation for testing private wells. There is strong evidence that, in the aggregate, participants update safety and future exposure perceptions in a manner consistent with underlying nitrate distributions. The statistical analyses further support the conclusion that such information is used in individual updating. Evidence of such updating has not, to our knowledge, been demonstrated in previous research.

While these results are important because they demonstrate that individuals do use information provided in testing programs, many policy relevant questions remain. First, although it is clear that information does enable updating of perceptions, this does not prove that individuals actually make better decisions -- i.e., that individuals who "should" protect their water actually do take averting actions. Such a result would require a "Stage 3" follow-up questionnaire asking households if they adopted averting activities as well as an objective determination of which households "should" adopt averting activities. A corresponding question is whether public investment in information programs would pass a social benefit-cost criterion. While people do update their safety perceptions, this study cannot provide the needed information for conducting such a comparison. A complete benefit-cost analysis would require an assessment of health outcomes before and after the testing programs, including the presumable adoption of averting activities where needed. Finally, both the Wisconsin and New York studies used the same type of information provision -- a nitrate test result with a corresponding two-page fact sheet. A remaining, and important, question is whether such a fact sheet and testing program is the most effective and efficient communication form.

Nitrate Information Sheet

Your Nitrate Levels were:	____	____	____	____	____	____	mg/l
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	

Note: X indicates that we do not have test results for this round of testing.

Nitrates in Groundwater

- Nitrate (NO_3) is an inorganic chemical form of nitrogen (N) that can pollute groundwater. Nitrates in water are measured in milligrams per liter (mg/l).
- Some nitrates in groundwater come from natural sources, but high levels are usually caused by human activities. The most common sources of high nitrate levels in groundwater are: farm, lawn and garden fertilizers; septic systems; livestock holding areas; and land applied manures.
- Causes of contamination of a particular well depend on local factors such as well location and regional factors such as geology, land use, and farming practices. For this reason, sources of high nitrate levels in individual wells vary from area to area.
- Unless they drink water from wells with high nitrate levels, most people get more nitrates from their food than from the water they drink.

Nitrates in Malone Area Wells

- Based on the test results from 87 wells and springs over the entire year, nitrate levels (NO_3 as N) in the study area near Malone are distributed as follows:

  52 percent of the sampled wells and springs have nitrate levels of less than 2 mg/l: The natural level of nitrates in groundwater is usually less than 2 mg/l.

  31 percent of the sampled wells and springs have nitrate levels of 2 to 10 mg/l: These levels are of concern because they indicate contamination of the groundwater by human sources.

  17 percent of the sampled wells and springs have nitrate levels of 10 mg/l or greater: These levels are of concern because they exceed the federal and state health standards of 10 mg/l.

- Nitrate levels in most wells and springs were relatively constant throughout the year. Only a few wells had large variations in nitrate levels across tests.
- Average nitrate levels did not vary with well depth. High and low nitrate levels were found at all well depths, including springs.

Health Standards for Nitrates

- Health standards for nitrates were established to protect infants from blue baby syndrome.
- Federal and state authorities have established a safety standard of 10 mg/l of nitrates (NO_3 as N) for municipal or other public water supplies. The federal and state standards are not enforced for private wells serving individual homes, but are used as very important guidelines.

- The following are actions recommended for different ranges of nitrate test results for private wells:

  Nitrate levels of less than 2 mg/l: Test your water annually at a certified lab for coliform bacteria and nitrates.

  Nitrate levels of 2-10 mg/l: Start by testing your water seasonally to find the highest and lowest expected values for the year. Then test annually as above. Be aware that nitrates should not exceed the 10 mg/l standard. Evaluate your well location and construction. Evaluate potential pollution sources in your area. If other chemicals are extensively used in your area, seek advice on testing for them as well.

  Nitrate levels of 10 mg/l or greater: Do not give water to infants under six months of age. Try to find details on the type of construction and depth of your well so specialists can help you better. You should consider bringing in drinking and cooking water from a known safe source, installing an approved nitrate removal system, or purchasing bottled water.

Nitrates and Blue Baby Syndrome

- For some infants, consumption of high nitrate water can reduce the ability of the blood to carry oxygen. Affected infants experience symptoms of suffocation, and they may turn a bluish-gray color. This disease is called methemoglobinemia or "blue baby" syndrome.

- Blue baby syndrome can be fatal. You can protect infants from blue baby syndrome by using water that meets the government safety standards for nitrates (less than 10 mg/l of nitrates).

- This disease is thought to only affect infants younger than six months of age; older children and adults are not known to be affected.

Nitrates and Cancer

- Some areas with high nitrate levels in the drinking water have unusually high rates of stomach, gastric, and lymph cancer, although scientists have not yet determined whether or not these cancers are caused by nitrates in well water.

- Nitrates may be converted to nitrosamines, which are chemicals thought to cause cancer.

- Despite these concerns, scientists have not established that nitrates in drinking water cause cancer.

Solutions to High Nitrates Found in Drinking Water

- Communities can avoid high nitrates in drinking water by regulating, reducing, or eliminating sources of contamination, installing a community well, or by finding other sources of safe water.

- Individual households can avoid high nitrates in drinking water by using one of the following options:

  Well reconstruction or installation of a new well can cost several hundreds of dollars. However, improving your well does not guarantee low nitrate levels.

  Bottled water that is delivered to your home is an alternative that costs about $160 to $175 per person per year.

  Purification systems that remove nitrates from water supplies can be purchased, leased, or rented locally. Distillation and anion exchange units can be leased for about $360 per year. Reverse osmosis units can be leased for $240 to $580 per year, depending on the type of unit selected. These reverse osmosis units can be rented for about $18 to $45 per month. Purchase options and prices vary with the type of unit.

- Water softeners and simple charcoal filters do not remove nitrates. Also, do not boil water to remove nitrates. Boiling actually concentrates nitrates due to evaporation.

For further advice, contact:
Cornell Cooperative Extension-Franklin County, 63 West Main Street, Malone, NY 12953-1817
518-483-7403

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