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Don't Know Responses in Water Quality Surveys

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1. Introduction

Water quality is a major environmental challenge in the United States (U.S.). The passage of the Clean Water Act in 1972, and subsequent amendments provided for the development of indicators and the monitoring of the quality of all U.S. navigable waters and analyses of the discharge of pollutants and their effects on water conditions (U.S. EPA, 2009). These indicators have focused on tracking physical water conditions and environmental impacts. The U.S. has 3.5 million miles of rivers and streams, 41.7 million acres of lakes, ponds and reservoirs, and 87,791 square miles of bays and estuaries. The 2009 National Water Quality Inventory Report to Congress on 2004 water conditions reported that 44% of all states' assessed rivers and streams were impaired or not clean enough to support at least one of their designated uses (e.g. swimming, fishing) (U.S. EPA, 2009). Sources of impairments were pathogens, habitat alterations and organic enrichment/oxygen depletion. Of assessed lakes and reservoirs 64% were impaired with mercury, polychlorinated biphenyls (PBCs), and nutrients identified as leading sources of impairment. Thirty percent of assessed bays and estuaries were reported impaired with pathogens, organic enrichment/oxygen depletion, and mercury major causes of impairment.

This legislation also specified that states and the national government were to estimate the environmental impacts and the economic and social costs of recommended interventions to achieve a level of water quality which "provides for the protection and propagation of a balanced population of shellfish, fish, and wildlife and allows recreation activities in and on the water" (U.S. EPA, 2009). It is the social aspect of getting to better water quality that this chapter addresses. Social science research and education are necessary to build an educated public that has the capacity to meet the challenges of degraded water bodies and engage in thoughtful problem-solving (Blockstein and Brunette 2008).

Water quality problems, like all other environmental issues, are social problems at root. Thus we need to not only monitor and assess biophysical conditions but also develop indicators that measure the human and social connections to water resources. Population-based water surveys and purposeful geographically focused interviews and focus groups provide useful indicators of public knowledge and willingness to address public goals for water protection (Prokopy and Floress, 2011). Understanding public awareness of water conditions and sources of impairment is a critical aspect of human capacity to solve the problems of water pollution. Knowledge built from surveys of citizens' perceptions of water quality offer useful guidance for the development of appropriate and effective environmental intervention strategies.

Social survey response items often consist of a continuum of positive and negative responses (e.g. highly agree, agree, disagree, highly disagree; excellent, good, fair, poor). Non-substantive responses, responses of "don't know" and "no opinion," are frequently absent from the survey or if present are not analyzed. Traditionally the non-substantive responses were considered as conveying no clear opinion of the respondents and were usually treated as missing. These don't know (DK) responses, however, are very useful in terms of revealing valuable insights about citizens' awareness, knowledge, or the lack thereof regarding their water conditions. Patterns of DK responses can help public policy makers and educators to better understand the public's awareness and knowledge about water quality, and guide future design and development of targeted programs for community engagement in solving water problems. In this sense, analysis of DK responses provides an important piece of information to researchers and community leaders with interest in moving from attitude and knowledge assessment to citizen action and engagement.

In this research, the authors analyze data from a national general population survey on water issues and in particular explore two questions related to DK responses. First, we ask if there are systematic patterns of don't know responses in water quality surveys. Secondly, we search for social factors that may be useful in understanding knowledge/awareness or the lack of knowledge about water quality. We propose that underlying don't know about water quality responses is a lack of visibility of water conditions in the respondent's everyday life. Although water is essential to life and used daily, it can easily be taken for granted by the consuming public. To answer these questions we propose two social factors that might be associated with DK survey responses: type of water supply system the respondent has for drinking water and community size. After describing the methodology, we report our findings and then offer conclusions and implications from our findings.

1.1 Non-substantive responses in survey research

Two core dimensions of a public opinion survey are the respondent's knowledge or awareness of the issue and their interest in the problem or concern about it (Rossi et al., 1983). A challenging issue facing social researchers is the presence of "don't know" (DK) responses in survey data and how to handle these non-opinion responses. No general guidelines exist for handling such responses. A typical practice, what is called the standard question form, is not to include a "don't know" option as part of a question (Schuman and Presser, 1981; Rossi et al., 1983). Researchers holding this position often argue that inclusion of no-opinion options in the surveys may not necessarily enhance data quality and instead may preclude measurement of meaningful opinions (Krosnick et al., 2002). The assumption is that DK is the lazy answer that respondents will choose when given the option (Rossi et al., 1983). As a result, DK responses are typically treated as a form of missing data in the analysis.

DK responses, however, differ from refusal to answer the question in nature, and should therefore be analyzed separately (Shoemaker et al., 2002). First of all, omitting a DK response option risks frustrating the respondent when she or he truly doesn't have knowledge or an interest in the item in question (Rossi et al., 1983). Without a DK option, respondents are forced to state an opinion about something they have no experience with, never thought of before and may not likely consider again (Rossi et al., 1983). Furthermore, DK responses can be indicators of lack of knowledge, low saliency of the issue (it is not important), and/or indifference. The implications of a DK response suggest disengagement from the issue or lack of confident knowledge which can be a deterrent to a readiness to act on a public problem such as water quality. Past studies have identified consistent correlates with DK responses, and respondents with certain characteristics are found to be more likely to give DK responses than others in attitudinal and opinion surveys. In particular, researchers have found that females, nonwhites, low-educated, low-income, and non-involved respondents with feelings of low political efficacy give a predictably high number of DK responses (Francis and Busch, 1975; Faulkenberry and Mason, 1978; Pickery and Loosveldt, 1998; Singer et al., 2000; Krosnick et al. 2002; Stocke, 2006).

1.2 Water supply systems and water quality

Public water supply systems have become increasingly complex, requiring technologies and skilled technicians to implement public safety regulations designed to ensure a safe water supply for communities. Daily monitoring for bacterial and other contaminant levels to determine treatment that assures quality and safety as well as adequate flow levels has made the provision of the public water supply complicated. Further, how the water system works and is managed can exceed the knowledge and expertise of the ordinary citizen.

Anthony Giddens, in his discussion about modernity, writes about expert systems and their implications for everyday life in the modern society. Expert systems are "systems of technical accomplishment or professional expertise that organize large areas of the material and social environments that we live in today" (Giddens, 1991, p.27). There are always experts who know about all the details and who will ensure the whole system goes all right. To a large extent, a water supply system is an expert system. As the system gets more complex, ordinary people usually do not know how their water is treated before it reaches their home for drinking. Instead, ordinary people are more likely to have only some "surrounding" knowledge such as how to turn on their tap to get water. Therefore, because "experts" are taking care of their water, they usually do not need to worry about the quality of their water source. In large communities where residents usually depend on city water supply systems, people may have little idea about where their drinking water comes from, or what is added to their water to make it safe and clean to drink. They simply trust the expert systems of water supply and turn on their tap expecting their water to be of good quality and safe to drink.

In contrast, in many smaller communities and outlying rural places where residents get water from private wells or nearby surface water bodies, the system is much less complicated. Users have more direct experience with their water and a personal responsibility to assure a safe and consistent water supply. Private wells, if monitored at all, require that home residents do their own testing and taking actions to assure safety. The mechanical condition of the well pump, water levels, and water pressure are concerns that the rural resident must pay attention to. Thus, we posit that these users are more likely to be experts on their water supply themselves and relatedly, more likely to be knowledgeable about the water quality in general in their area.

1.3 General environmental and social context

In addition to knowledge and direct experience, the general social and environmental context is thought to also exert influence on an individual's perception process and therefore, have an effect on the non-substantive responses showing up in water quality surveys. Kilbourne et al. (2002) propose a general model for the formation of environmental attitudes and motivation of behaviors that include the following aspects: (1) institutional structures, (2) value systems, (3) general environmental beliefs, (4) specific beliefs and attitudes, (5) behavioral commitments, and (6) behavior. Institutional structures, laws and regulations, cultures and beliefs are often place specific suggesting differences in political, economic, social, and environmental contexts may influence differences in attitudes, perceptions, and awareness towards water quality among residents of different regions. And these differences may translate into different degrees of concern or indifference towards water quality issues. In this sense, the DK response rate to water quality questions may well reflect how important/unimportant a water issue is to the general public within the certain environmental and social context. Based on the arguments of Kilbourne and other scholars (Kilbourne el al., 2002; Stern et al., 1995), we examine the DK response rate across several U.S. regions and states in search of detectable patterns.

1.4 Hypotheses

Based on the above argument about expert systems, we hypothesize that respondents who get their drinking water from public water supply systems (city or rural district) are less likely to have reason to learn or be aware of the water quality conditions in their area. The users of individual water supply on the other hand, are hypothesized to be more knowledgeable and thus concerned with local water quality, and therefore, less likely to give DK responses to water quality questions.

- H1: public water supply users more likely to give DK responses to water quality questions compared with individual water supply users.

Secondly, we expect the size of the community where a person lives to have an effect on water quality awareness/knowledge or the lack of such awareness/knowledge. As a community increases in size, it is more likely that the water supply system becomes more complex, and the citizens more distant from local water management processes and thus less likely to be knowledgeable about water conditions.

- H2: The larger the community size, the more likely a respondent will give a "don't know" response to questions about their water quality.

Other variables controlled for in the study include age, gender, and education. We are using these variables to test whether the previously found patterns about female, less-educated respondents and their association with don't know responses also hold true in water quality surveys.

Finally, we assume that the general environmental and social context exerts influence on one's awareness and interest towards water quality. Although an imprecise measure for the general social context, we use state as a proxy variable to capture the geo-political, regulatory and institutional conditions that people within the same state would experience as water problems are identified and addressed. Although not a formal hypothesis, we posit that the rate of don't know responses to water quality questions varies by state rather than maintains constant across all the sampled states.

The hypotheses are based on the assumption that DK responses were given purely because of lack of knowledge, awareness, or interest on the subject matter. In other words, from the nature of our data (collected via mailed survey), we assumed there were no confounding effects from interviewers' characteristics, sensitivity issues, or general attitudes toward the survey itself.

2. Methodology

Data were collected from a multi-state water issue survey completed in 36 of the 50 U.S. states (2002 through 2009). According to geographic adjacency and regional conditions, the U.S. Environmental Protection Agency divides the fifty states into ten water regions, and our sampled states covered nine of the ten regions.[1] Figure 1 provides an illustration of the sampled 36 states and which regions they belong to. States where no data were available are colored with white.

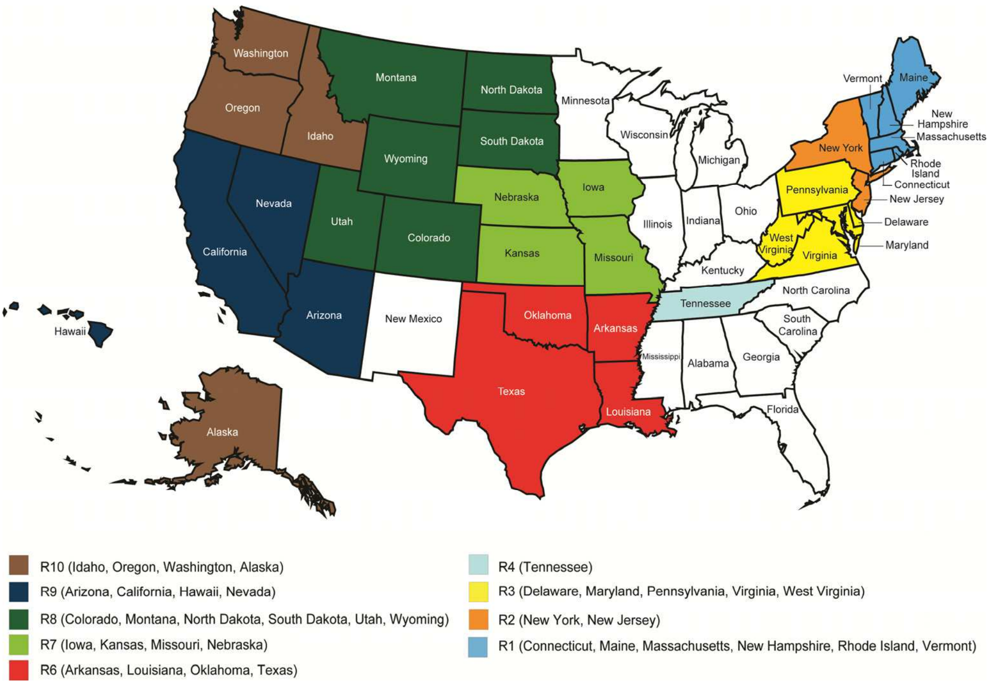

Fig. 1. Sampled States and Regions.

[1] See http://water.epa.gov/type/location/regions/ for more information about water regions and regional information.

The survey was conducted by Dr. Robert Mahler, University of Idaho under a USDA (United States Department of Agriculture) NIFA (National Institute of Food and Agriculture) Integrated Water Quality project, and the data were made available to the authors for analysis. Households were randomly sampled from phone books in each state, and calculation of targeted sample size was based on the total population of the state. Mailed surveys were sent to sampled names and addresses, with any adult in the household, whether or not addressee, invited to complete the survey questionnaire. Question content and wordings in the surveys included identical core questions as well as differing state-specific questions, with the total survey length about 50 questions. It is the core identical questions across states that asked about respondents' perceptions of water quality, water use importance, factors responsible for water pollution, sources of information about water, general environmental attitudes, and demographic information that were of interest to this study. Standard mail survey methods as recommended by Dillman (2000) were followed in each of the surveys with a total of 9332 returned surveys and response rates ranging from 37% (Massachusetts) to 70% (Wyoming).

Survey questions examined in this study include drinking water supply types (individual system, community well, or city/rural public water supply system) which represents the complexity of water supply systems, community size, three demographic items and overall ground and surface water quality. Respondents were asked where they got their drinking water, whether it is from individual system (well or surface water) or community well system (well serving 15 or more residences but not a city system), or public (city or rural) water system[2]. Community size was measured by five increments: population less than 3500; 3500 to 6999; 7000 to 24,999; 25000 to 100,000; and more than 100,000. Demographic variables were age, gender, and education. Age was divided into six increments of adult years (18-29; 30-39; 40-49; 50-59; 60-69; 70 and above). Gender responses were male or female. Educational attainment responses were five increments including less than high school, high school graduate, some college, college graduate, and advanced degrees. Two perceptions of water quality questions asked about ground and surface water conditions: "In your opinion, what is the quality of surface (ground) water in your area?" Possible responses range from "poor" to "good" to "excellent" plus "don't know/no opinion". For the purpose of analysis, responses of "don't know/no opinion" were recoded as 1 and all other substantive responses were recoded as 0. After recoding, the means reflect percentage of DK responses. The final sample with no item missing data resulted in a total number of 6401 cases.

First, Analysis of Variance (ANOVA) was used to examine DK about surface and ground water quality as percentages across groups with different water supply types, residence community size, and demographic characteristics. Post hoc Tukey tests were used to evaluate pairwise differences. This particular statistical test was chosen because of its relative advantage in statistical power and its appropriateness in pairwise comparison (Kutner et al., 2005). Then we looked at the DK variation across states. Next, all the predictor variables were fit into a logistic regression model for prediction of the occurrence of DK about ground water quality and surface water quality responses. The logistic models were then tested separately for each state to detect geographical differences.

[2] The water supply source question also has an option of "purchase drinking water", but this category is omitted in this study and covered in a separate research.

3. Findings

3.1 Water supply systems as expert systems

For both ground and surface water quality questions, the percentage of don't know responses given by respondents who use individual water supply (well or surface water) or community well is significantly less than that given by users of public water supply systems. Especially for the ground water quality question, 30% of respondents who used public water supply systems reported "don't knows", while only less than 6% of the users of individual/community water supply systems said "don't know". The difference between the two percentages is highly significant. This confirms our hypothesis about water supply systems – as the water supply systems get more complex, users of these systems are more likely to say they don't know about their water quality.

	N	DK Mean[3]	Std. Dev.	Std. Error
A. individual/community	1294	.079 [B]	.269	.007
B. public system	5107	.117 [A]	.321	.004
Total	6401	.109	.311	.004

Table 1a. DK surface_water by water supply type (ANOVA) [4]

	N	DK Mean	Std. Dev.	Std. Error
A. individual/community	1294	.059[B]	.235	.007
B. public system	5107	.307[A]	.461	.007
Total	6401	.256	.437	.005

Table 1b. DK ground_water by water supply type (ANOVA)

3.2 Community size

Findings about community size also support our hypothesis that people residing in larger communities are significantly associated with greater likelihood of responding DK to ground or surface water quality questions (Tables 2a, 2b). For both water quality questions, the percentage of DK responses rises as the respondents' community size increases. In communities with a population of less than 3500, fewer than 15% of the respondents said they did not know about their ground water quality. But in large communities of 100,000 people or more, about 33% of the respondents gave DK responses to the same question. With surface water quality, the differences in the percentages of DK responses are less strong as with ground water quality, but the general pattern is consistent as shown with ground water quality.

[3] The number in this column reflects percent of don't know responses. For example, a mean of .079 represents means that 7.9% of all responses were don't knows. Footnotes 3 and 4 apply to Tables 1 through 5.

[4] The letters behind DK means indicate from which group the mean is significantly different in a post hoc pairwise comparison using Tukey method.

	N	DK Mean	Std. Dev.	Std. Error
A. <3.5 thousand	821	.083^{E}	.276	.010
B. 3.5 to 7 thousand	625	.096	.294	.012
C. 7 to 25 thousand	1146	.095^{E}	.293	.009
D. 25 to 100 thousand	1794	.107	.309	.007
E. >100 thousand	2015	.133^{AC}	.340	.008
Total	6401	.109	.312	.004

Table 2a. DK surface water by community size (ANOVA)

	N	DK Mean	Std. Dev.	Std. Error
A. <3.5 thousand	821	.146^{CDE}	.353	.012
B. 3.5 to 7 thousand	625	.189DE	.392	.016
C. 7 to 25 thousand	1146	.223^{ADE}	.416	.012
D. 25 to 100 thousand	1794	.270^{ABCE}	.444	.010
E. >100 thousand	2015	.331^{ABCD}	.471	.010
Total	6401	.258	.437	.005

Table 2b. DK ground water by community size (ANOVA)

3.3 Demographics

Respondents were divided into six increments according to their age (Tables 3a, 3b). The percentage of DKs about surface water quality is higher in the youngest age group (18-29, about 10%), and the percentages in three age groups from 30 to 59 are about the same (around 8%). The age group of 60-69 has a slightly higher percentage of DKs (about 10%), and the age group of 70 and above has the highest percentage of DK responses (over 20%). DK responses to the ground water quality question tend to share the same general pattern (Table 3b). However, with ground water quality, the DK percentage within each age category is much higher than that with surface water quality. DK responses show the highest percentage in the youngest and the oldest age groups, and are about the same across all other age groups from 30 to 69.

	N	DK Mean	Std. Dev.	Std. Error
A. 18-29	273	.099^{F}	.299	.018
B. 30-39	724	.087^{F}	.282	.010
C. 40-49	1155	.078^{F}	.268	.007
D. 50-59	1541	.084^{F}	.278	.007
E. 60-69	1236	.104^{F}	.306	.009
F. 70 and above	1472	.202^{ABCDE}	.380	.010
Total	6401	.129	.311	.004

Table 3a. DK surface water by age groups (ANOVA)

	N	DK Mean	Std. Dev.	Std. Error
A. 18-29	273	.293	.456	.028
B. 30-39	724	.253F	.435	.016
C. 40-49	1155	.226F	.418	.012
D. 50-59	1541	.221F	.415	.011
E. 60-69	1236	.261F	.439	.012
F. 70 and above	1472	.311BCDE	.463	.012
Total	6401	.257	.437	.005

Table 3b. DK ground water by age groups (ANOVA)

About 17% female respondents said they don't know about their local surface water quality, while only about 8.2% among the male respondents reported DKs. With ground water quality, the difference between the two groups of respondents is even more considerable. Almost 35% of female respondents responded don't know compared to 21% of the male respondents (See Tables 4a, 4b).

	N	DK Mean	Std. Dev.	Std. Error
A. Female	1987	.170B	.375	.008
B. Male	4414	.082A	.274	.004
Total	6401	.109	.312	.004

Table 4a. DK surface_water by gender (ANOVA)

	N	DK Mean	Std. Dev.	Std. Error
A. Female	1987	.348B	.476	.010
B. Male	4414	.216A	.411	.006
Total	6401	.257	.437	.005

Table 4b. DK ground_water by gender (ANOVA)

Previous studies have reported a correlation between education and DK, with lower education correlating with higher DK responses. Our data, however, did not reveal a similar pattern (Tables 5a, 5b). From our findings, there are no significant differences across any educational achievement groups in terms of their DK responses to the ground water question. For surface water quality DK responses, the pattern is fairly curious – respondents who were high school graduates gave more DK responses than respondents of any other educational levels. No other significant differences were found with regards to educational levels.

	N	DK Mean	Std. Dev.	Std. Error
A. < high school	769	$.087^{B}$	.282	.010
B. high school	1087	$.146^{ACDE}$	.354	.010
C. some college	1678	$.110^{B}$	.313	.008
D. college graduate	1649	$.107^{B}$	.3.10	.008
E. advanced	1218	$.090^{B}$	.286	.008
Total	6401	.109	.312	.004

Table 5a. DK surface water by education (ANOVA)

	N	DK Mean	Std. Dev.	Std. Error
A. < high school	769	.228	.420	.015
B. high school	1087	.278	.448	.014
C. some college	1678	.257	.437	.011
D. college graduate	1649	.258	.438	.011
E. advanced	1218	.254	.435	.012
Total	6401	.257	.437	.005

Table 5b. DK ground water by education (ANOVA)

3.4 DK Percentage by state

Next we examine the patterns of don't know response percentages by state. The average DK percentage for the total sample is 13.07% for surface water quality and 27.71% for ground water quality. Generally there were more people giving don't know responses to the ground water quality question.

In only one state, Arizona, the percentage of don't know responses to the surface water quality question exceeds 20 percent. Other states with higher DK responses to surface water quality include Texas (19.9%), California (17.8%), New York (17.6%), and Utah (17.2%). In thirteen states, the percent of DK to surface water quality is below ten percent. States with the lowest percent of DK responses are Alaska (0%), Vermont (3.9%), Maine (5.9%), Idaho (6.1%), and Oregon (6.6%).

Many more people gave DK responses to the ground water quality question. In eleven states, DK responses exceed thirty percent of all valid responses to that question, and only in one state (Vermont), the DK percentage is below ten percent. States with high percentage of DK on the ground water quality question include Missouri (38.5%), Tennessee (35.2%), and Oklahoma (34.4%). On the lower end, there were Vermont (9.9%), Alaska (11.7%), Montana (13.1%), and Idaho (14.7%).

It seems that some states, states like Alaska, Vermont, Maine, Montana, and North Dakota, tend to have lower DK percentage than others on both of the two water questions, while other states like Oklahoma, Texas, New York, and California have consistent higher percentage of DK on both of these questions.

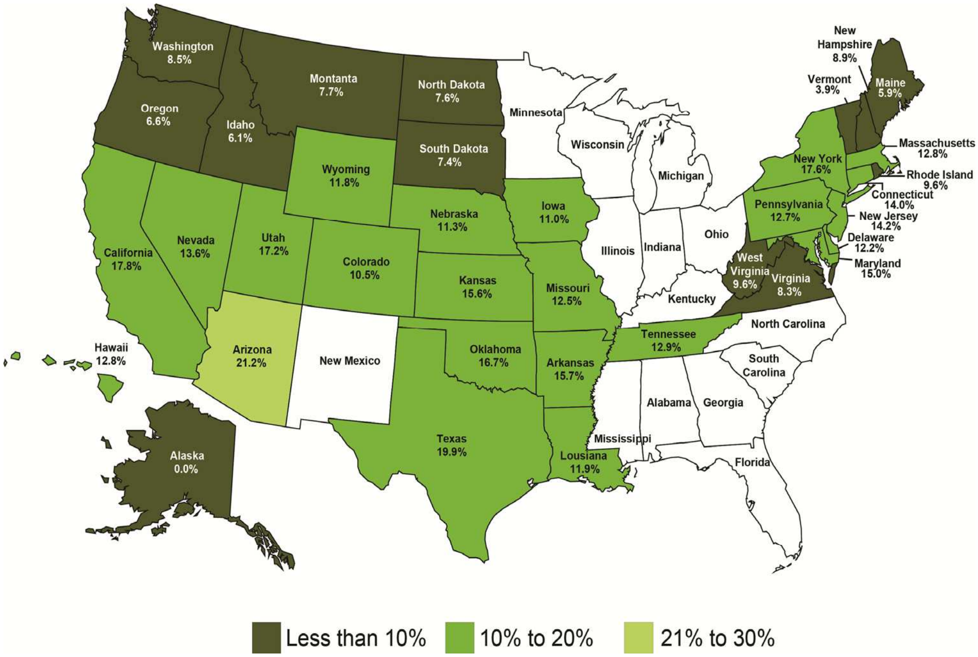

Fig. 2. DK for surface water

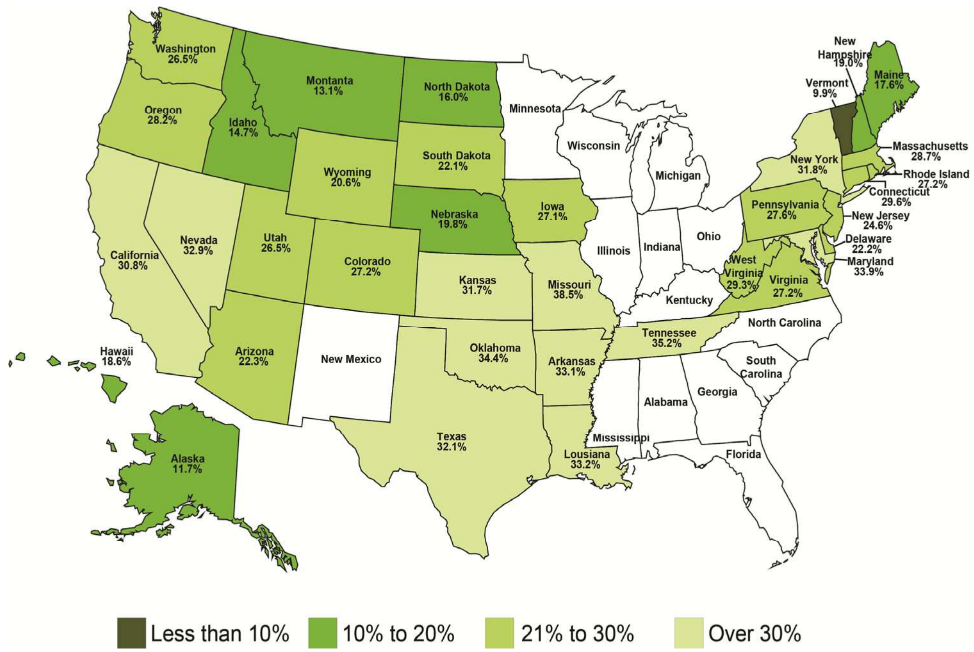

Fig. 3. DK for ground water

3.5 Results of logistic regression

The expert system and user knowledge hypotheses about water quality DK responses were further tested by a logistic regression model, where water supply type and community size were used as predictors of DK responses while demographic variables such as age, gender, and education were controlled for (Tables 6a, 6b). Although these models do not explain a large amount of the variance in DK responses (Pseudo R^2 less than 10% of the total variation in both cases), the statistical significance of tested variables confirm our hypotheses for both surface and ground water quality DKs. Public water supply system and larger community size are associated with an increased likelihood of DK responses to the ground water quality question when respondents' age, gender, and educational achievement are held constant. The logistic model for surface water showed similar results.

	B	Std. Err	Sig.	Odds Ratio
Individual/community supply	-.257	.121	.033	.774
Comm. size	.130	.034	.000	1.139
Age	.022	.003	.000	1.022
Education	-.039	.033	.239	.961
Female	.857	.082	.000	2.355
Cox and Snell Pseudo R^2	.032	Pearson Goodness-of-Fit	.023	

Table 6a. Logistic regression model: don't know about surface water quality (reference group = know)

	B	Std. Err	Sig.	OR
Individual/community supply	-1.816	.126	.000	.163
Comm. size	.149	.025	.000	1.161
Age	.008	.002	.000	1.008
Education	-.051	.025	.037	.950
Female	.692	.062	.000	1.998
Cox and Snell Pseudo R^2	.088	Pearson Goodness-of-Fit	.176	

Table 6b. Logistic regression model: don't know about ground water quality (reference group = know)

As Table 6a shows, the odds ratio of respondents using individual/community water supply systems versus public water supply system users is .774 for DK responses to surface water quality, which means the odds that an individual/community water supply user says don't know to the surface water quality question are 22.6% less than a user of public water supply systems when all other conditions held equal. Community size also showed up as a significant predictor for DK responses. Compared with a resident whose community size is one category below (for example, a resident of community size over 100 thousand people compared to another person whose community size is between 25 to 100 thousand people), the odds for a person from a larger community to report DK about local surface water quality is about 13.9% higher, as long as the two persons have the same water supply type, age, education, and gender. For a person who is older in age by one year, the odds that the person says DK to the surface water quality question are 2.2% more than a person who is one year younger, other variables being equal. Education is not a significant predictor for DK responses to surface water quality. When all other variables are held equal, there is no significant difference between respondents with different educational achievement in terms of their odds of saying "don't know" about their local surface water quality. A female respondent, when other things being equal with a male respondent, is found to be more likely to say DK to the surface water quality question, with her odds more than twice that of the counterpart male respondent.

The logistic regression model for don't knows about ground water follows the same pattern (Table 6b), except that education is a significant predictor. For a person whose education is one category higher (for example high school graduates compared with less than high school), the odds that the person responds with DK to ground water quality question are reduced by 5% when compared with a person with lower education. In addition, the difference in odds between individual/community water supply users and public water supply system users are even more pronounced with ground water quality DK responses. Compared with a city water supply user, an individual/community water supply user's odds associated with ground water quality DK responses are reduced by 83.7%. Findings about community size, age, and gender are very similar to those for surface water quality DK responses.

For logistic regression, there is no straightforward statistic like R^2 in ordinary least square regression which measures the variance explained in the dependent variable. However, several statistics, among which Cox and Snell pseudo R^2 is one, can be used to measure the strength of association between the dependent variables and explanatory variables. Cox and Snell pseudo R^2 for the surface water quality model is .032, and .088 for the ground water quality model. The proposed explanatory variables seem to be more useful predicting DK responses for the ground water quality questions. The ground water quality model also has a better goodness –of-fit, which means that the proposed model well represents the variance structure in the sampled data.

3.6 State as an explanatory variable

We then added the state where the respondent lives as a variable in our logistic model to predict their DK responses. Due to the long list of thirty-six states, we are not presenting the logistic regression results in tables, but the results show that, as hypothesized, it does matter what state the respondent is from. For the surface water quality question, the results show that with all other conditions being equal, if a respondent is from New York, Utah, Arizona, California, or Texas, then the person tends to have a higher chance of responding with DK to the question. Our results also show that with everything else being equal, if a respondent is from Vermont, Montana, Alaska, or Idaho, chances are less that the person is going to respond with DK to the ground water quality question. These results are consistent with what we found from the two DK percent maps.

3.7 Logistic regression models tested on individual states

Based on the previous findings that state is an important factor influencing residents' non-substantive responses to water quality questions, we tested the two proposed models on each individual state to see how the proposed explanatory variables predict DK responses within states when the variance caused by residence is controlled. The following tables (Table 7a and 7b) present a summary of the strength of association between the explanatory variables and the DK response and the model goodness-of-fit.

In some states, the set of explanatory variables show higher association with DK responses than in other states. For example, in Delaware (.223), Rhode Island (.151), Louisiana (.149), Arkansas (.147), Maine (.133), Wyoming (.132), Massachusetts (.108) and New Hampshire (.104), the explanatory variables show higher association with DK responses for the surface water quality questions. And for the ground water quality question, the model has higher Cox and Snell pseudo R^2 in the states of Connecticut (.225), Missouri (.183), Delaware (.170), Louisiana (.170), Montana (.152), Wyoming (.150), and Oklahoma (.150).

State	Cox and Snell	Goodness-of-Fit
Connecticut	0.041	0.173
Maine	0.133	1.000
Massachusetts	0.108	0.995
New Hampshire	0.104	0.000
Rhode Island	0.151	1.000
Vermont	0.052	1.000
New York	0.048	0.794
New Jersey	0.034	0.280
Delaware	0.223	0.434
Maryland	0.032	0.159
Pennsylvania	0.063	0.006
Virginia	0.047	0.659
West Virginia	0.024	0.588
Iowa	0.047	0.644
Kansas	0.066	0.402
Missouri	0.018	0.233
Nebraska	0.073	0.686
Colorado	0.022	0.467
Montana	0.022	0.370
North Dakota	0.058	0.272
South Dakota	0.027	0.603
Utah	0.051	0.683
Wyoming	0.132	0.644
Arizona	0.043	0.326
California	0.025	0.637
Hawaii	0.032	0.401
Nevada	0.063	0.322
Alaska	NA[5]	NA
Idaho	0.091	0.274
Oregon	0.029	0.349
Washington	0.011	0.117
Arkansas	0.147	0.335
Louisiana	0.149	0.999
Oklahoma	0.080	0.454
Texas	0.096	0.491
Tennessee	0.039	0.181

Table 7a. Surface water

[5] Not applicable because there were no DK responses for the surface water quality question in Alaska.

State	Cox and Snell	Model Fit
Connecticut	0.225	0.011
Maine	0.130	0.719
Massachusetts	0.120	0.079
New Hampshire	0.112	0.184
Rhode Island	0.101	0.407
Vermont	0.096	0.995
New York	0.115	0.354
New Jersey	0.110	0.866
Delaware	0.170	0.714
Maryland	0.140	0.391
Pennsylvania	0.128	0.120
Virginia	0.106	0.514
West Virginia	0.110	0.090
Iowa	0.104	0.229
Kansas	0.119	0.491
Missouri	0.183	0.568
Nebraska	0.137	0.831
Colorado	0.130	0.730
Montana	0.152	0.998
North Dakota	0.110	0.018
South Dakota	0.062	0.280
Utah	0.069	0.538
Wyoming	0.150	0.849
Arizona	0.045	0.412
California	0.096	0.181
Hawaii	0.046	0.194
Nevada	0.139	0.488
Alaska	0.067	0.526
Idaho	0.042	0.168
Oregon	0.035	0.296
Washington	0.089	0.315
Arkansas	0.139	0.493
Louisiana	0.170	0.635
Oklahoma	0.150	0.285
Texas	0.071	0.278
Tennessee	0.062	0.529

Table 7b. Ground Water

Overall, the model has better usefulness in predicting DK responses for the ground water quality question than for the surface water quality question. In both cases the model fits the data structure fairly well in most states, except for New Hampshire and Pennsylvania in the surface water quality case, and Connecticut and North Dakota in the ground water quality case.

4. Discussion

Water supply system type is found to be a highly significant predictor for DK responses to water quality questions. Public water supply users are much more likely to give DK responses to the water quality questions than users of individual or community water supply systems. This confirms our hypothesis about the system complexity. Public water supply users are more likely to trust water experts for their safe drinking water, and therefore are found to be less knowledgeable or concerned with the water quality in their area. In contrast, users of individual or small community well water systems are more likely to be experts themselves about their water supply, and they are also more concerned or knowledgeable about their local water quality because it is closely related to their daily drinking water safety. The size of the community where one lives is positively associated with don't know responses to the water quality questions. As the community size increases, there is increased chance that respondents say they do not know the quality of either the ground or surface water in their community. It may be due to the fact that in a smaller community residents have more opportunities to participate in community water activities including conservation and protection activities or decision-making processes regarding their water. They may have a personal well, belong to a cooperative rural water system, and/or personally use the community well or water supply system and know how it functions and what the water quality is like. Furthermore, those in smaller communities may be more likely to observe their lakes, streams, and rivers which are sources of their water supply.

Our findings about water quality questions also confirm that females are more likely to give DK responses. Older respondents are also found to be associated with higher rates of DK responses. The association between education and DK responses to water quality questions is not consistent across ground and surface water. Education shows as a significant predictor for DK responses to the ground water quality question, but not for the surface water quality question. This may be due to the nature of these two water sources. Surface water is more visible and its quality may be perceived as easily judged by its appearance, whereas the quality of ground water is not directly experienced. The public learns through other sources such as media, tech reports, water-related activities, etc. about the condition of ground water which may explain the connection to a person's education.

Generally there are more DK responses to the ground water quality question than to the surface water quality question. As discussed earlier, this may in general be related to visibility and direct experiences (swimming, fishing, viewing) with surface water (e.g. lakes, pond, rivers, and streams) and perceptions of quality seem easier to judge based on clearness, turbidity, algae and other plant growth conditions.

State is found to be an important factor associated with personal DK responses to water quality questions. In some states the DK responses to both surface and ground water quality questions are consistently higher than in other states. In addition, when we tested our proposed model within the individual states, the results show that the predictability and model goodness-of-fit also vary by state. Geographic and climate differences, as well as political, cultural and social settings in the states likely play a role in influencing residents' awareness and knowledge in water quality problems. More research is needed to better understand these variations. Local water programs and educational outreach programs, for example, might be a key factor in promoting the public's concern for their water quality. Also, in arid and rain-rich states, people's awareness of water quantity and quality might also substantially differ because of their collective experiences with flooding, drought, and water shortages. Future research is encouraged to test potentially significant explanatory state level variables, such as annual precipitation, state laws and regulations governing public water supplies, and funding on water programs.

5. Conclusion and policy implications

In everyday life we interact with hundreds of "expert systems": bank systems, computer systems, automobile systems, etc. We give full, almost blind trust to these expert systems, but the trust comes inherently with risk – that the system may not function, or that it functions well but not to our benefit. As our water resources become more limited and their quality being impaired, the risk to human health and well-being increases. Science and technology are valuable and essential resources for responding to the challenges of ensuring sustainable and secure water (Blockstein and Brunette 2008). But ultimately, improving water quality will require an engaged public that is concerned, willing to invest resources and act to protect the environment. This means ordinary citizens must move from not knowing or caring about local water conditions to a personal knowledge about their ground and surface waters, sources of pollution and what actions are necessary to counteract or reverse harmful trends and reinforce positive ones.

A high percent of DK responses on water quality issues signals that much education and communication remains to be done if public unawareness and lack of knowledge patterns are to be altered. It is important that water quality surveys include opportunity for respondents to mark their "don't knows". This response provides valuable information for the design of educational interventions, state-wide and regional media campaigns as well as strategic targeting of specific audiences. Traditional environmental education often focuses on formal school curricula and classroom education, which might explain why people of higher education tend to have lower percentages of don't know responses regarding their ground water quality. In order to reach a wider range of audiences, formal and informal environmental education programs need to be more diversified and age and gender tailored. Awareness of local water quality could be increased by providing people of all ages more opportunities to personally experience their water resource base through volunteer clean up river days and recreational services. Efforts should be made to reach older residents, those with lower education and females, and especially the more distant public water users who live in large communities. Awareness of water quality is a first step in addressing local water contamination and degradation issues. If citizens are to be mobilized to act on water concerns, they must first be motivated to increase their awareness and encouraged to learn about their water resources.

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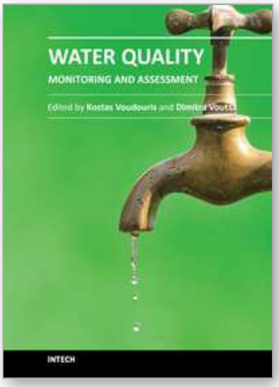

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