A Utilization-Focused and Theory-based Evaluation of an Arsenic Well Testing Program

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Abstract

A utilization-focused and theory-based evaluation study was conducted to understand how private well users responded to an educational arsenic well test program (AWTP). The common sense model (CSM), a health behavior theory, has shown that people process health threat information to formulate personal understandings (representations) that guide responses to threats. In this case the threat was arsenic. The CSM was applied to measure arsenic information use and perceived usefulness, arsenic representations, and, outcomes of water safety judgments, policy opinions, and protective behavior. 1496 surveys were delivered to households in communities that offered the AWTP with 1237 to households that tested through the AWTP and the balance to households that did not test through the program. 1233 (82.4%) of delivered surveys were suitable for analysis. Program staff estimated that about 30% of community households tested through the AWTP and study results indicated about 40% tested privately. It is important to provide arsenic information available to the general public. Information mailed with the well test is used the most by all participants and is also considered a very useful source for informing well water decisions. Participants who did not test for arsenic were less aware of arsenic risk. Over 60% of participants with arsenic levels over the current drinking water standard perceived their water as at least somewhat safe. It is important for people to understand how arsenic drinking water standards are selected and what they mean. Participants living in a community that offered the AWTP each year adopted lower arsenic safety thresholds compared to those living in a community where arsenic was highly publicized but the AWTP was offered once over 3 years. Ongoing education may promote more accurate understandings than high publicity.

Purpose

The purpose of this evaluation research is to understand *how* a Wisconsin arsenic well-testing program was working. The research sought to highlight how 1) private well users responded to an educational arsenic well test program, 2) four different types of information were related to outcomes through personal understandings of arsenic in well water, and 3) community awareness was related to adopting a lower arsenic drinking water standard. The purpose of this paper is to discuss selected study findings and implications for outreach programs.

Background

The purpose of most well test outreach programs is to educate private well users about groundwater and well contaminants to promote 1) stewardship of groundwater resources and 2) informed decisions about managing their well to optimize well water quality for various uses including safe drinking water. An educational **arsenic well test program** (AWTP) is offered in a geographic area of Wisconsin designated as an arsenic advisory area (AAA) where 23.2% of tested wells have arsenic levels at or over the current drinking water standard of 10 micrograms per liter (µg/L). It is estimated that about 4,700 wells used by about 11,700 people have levels $\geq$ 10 µg/L.

Arsenic in the AAA

The main arsenic source is from a naturally occurring sulfide deposit in the aquifer used for most private wells in the area. In the AAA, this deposit is close to the surface such that wells are likely to transect the arsenic rich deposit. Two processes are believed to release arsenic to the groundwater: 1) an oxidation process initiated when the water table drops and exposes arsenic deposits to air, and 2) reduction processes from anaerobic conditions within wells. The growth of aerobic and anaerobic bacteria within the borehole also contribute to the release of arsenic (Gotkowitz, Schreiber, & Simo, 2004). Increasing arsenic levels in the AAA have been attributed to decreasing groundwater water levels at a rate of 2 – 4 feet per year due to residential and industrial development (Riewe, Weissbach, Heinen, & Stoll, 2001).

The Arsenic Well Test Program (AWTP)

Towns make the decision of whether to offer the program because town officials do the work of notifying the community, collecting a batch of water samples and transporting the samples to the lab. Mass sampling allows test labs to charge a reduced rate in the range of $20 rather than $35 for the arsenic test. Residents pick up their samples at an educational town meeting conducted by state and local DNR, UW-extension, and county and state public health department staff. As of February 2003, 20 of 37 towns in the AAA offered the AWTP with only one town offering it more than once. Overall, about a third of residents tested through the program and about 30 – 50% (depending on the town) attended the town meeting to pick up their test results. Test results were mailed to those not attending the meeting.

Agency sources of arsenic information are available at the town meeting, by phone contact with staff, and from brochures and web-sites. Non-agency sources of arsenic information include: newspaper articles, television programs, salesmen of arsenic filters, well drillers, health care providers, non-agency arsenic web-sites, and friends or neighbors. Information provided at the town meeting and in brochures included: how to identify an arsenic problem, causes of arsenic in well water, how and why arsenic levels are changing with time, health consequences of arsenic exposure, and, how to control arsenic to prevent consequences. The risk message delivered with the program changed each year. The EPA proposed an arsenic standard of 5 µg/L in 2000, 10 µg/L in 2001, and, the federal arsenic standard was changed from 50 to 10 µg/L in October 2001. The Wisconsin arsenic brochure developed in 2000 recommended that people with arsenic levels between 5 and 50 µg/L *may* want to use another water source (Wisconsin DNR, 2000). The Wisconsin arsenic brochure developed in 2001 stated that people with arsenic levels at or greater than 10 µg/L should stop drinking their well water (Wisconsin Department of Health and Family Services, 2001). People may feel uncertain about how they should identify arsenic risk when different guidelines have been proposed and when the drinking water standard has been recently revised.

A utilization-focused and theory-based evaluation of the program was designed to understand how people residing in AWTP communities responded to the program. *Utilization-focused evaluation* is designed to generate findings that can be directly used by program staff (Rossi, Freeman, & Lipsey, 1999). Utilization-focused elements included measuring patterns of 1) information use, perceived usefulness, and preferences, and 2) actions used to reduce arsenic exposure among people in communities offering the AWTP. *Theory-based evaluations* identify plausible causal mechanisms to explain how program activities are related to outcomes (Rossi et al., 1999). Theory-based evaluations 1) strengthen claims of causal relationships, 2) identify successful causal mechanisms that can be applied to other programs, and 3) target measuring modifiable intermediating variables that can specify program changes (Reynolds, 1998). We selected the common sense model, a health behavior theory illustrating personal understandings of arsenic as the causal mechanism that explains how information leads to outcomes.

The common sense model (CSM) was selected as a good fit because it embodied program processes and the program philosophy of informed decision-making. Twenty-five years of CSM research shows that people process health risk information to formulate structured personal understandings or representations that guide behavioral and emotional responses to health threats. People actively process information to ‘make sense’ of a situation and respond in a way that fits their common sense understanding (Leventhal, Brissette, & Leventhal, 2003; Leventhal, Nerenz, & Steele, 1984).

Information sources used to form CSM representations are characterized as information 1) stored in the memory, 2) from external sources, and 3) from personal experience. Personal understandings, referred to as **cognitive representations**, are comprised of five or six dimensions: identity, cause, timeline, consequences, control, and sometimes coherence (Hagger & Orbell, 2003; Leventhal et al., 2003). *Identity* pertains to how a threat is recognized and labeled. *Cause* is perceived causal mechanisms for a health threat. *Timeline* is beliefs about how a threat will change over time and its duration. *Consequence* is beliefs about how the threat impacts their lives. *Control* reflects beliefs about controlling a threat. *Coherence* is the degree to which people have an overall understanding or comprehension of the threat (Moss-Morris et al., 2002). We replaced the concept of *coherence* with *uncertainty*, a central concept in risk assessment and communication (Griffin, Dunwoody, & Neuwirth, 1999). **Emotional representation**s are the emotional feelings elicited by information and the cognitive representation. **Protective responses** are a function of information use and their cognitive and emotional representations. The CSM provided a framework (see figure 1) for selecting variables used to quantify 1) information sources, 2) representations (risk understandings), and 3) outcomes of safety judgments, opinions about policies to address root causes of arsenic, and responses to reduce exposure.

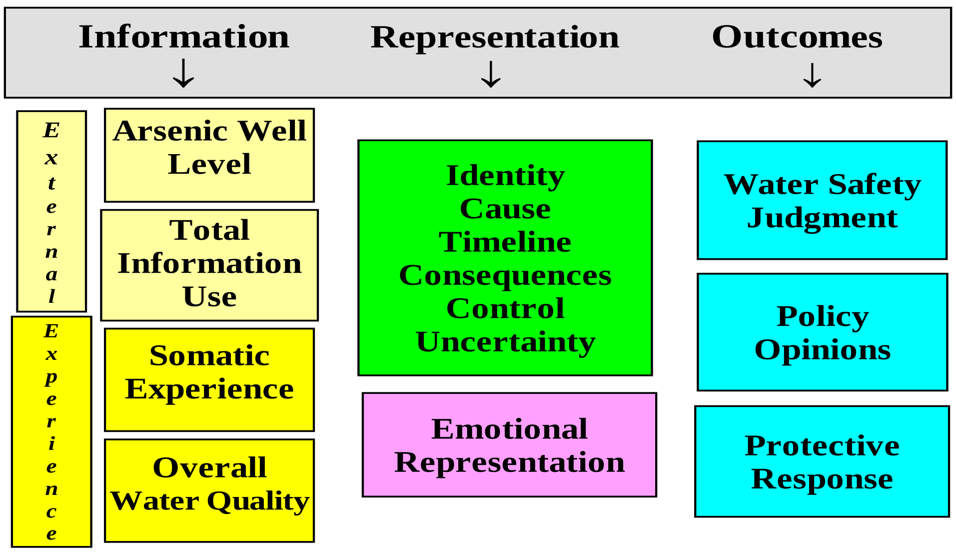

Figure 1. Study Framework based on the Common Sense Model

Methods

Survey instrument

A survey was constructed to measure concepts depicted in the study framework and to also measure the utilization of arsenic information. The survey was pre-tested using methods outlined by Dillman (2000). ***External and experiential sources of information*** were measured. *External information* sources were: 1) self-reported arsenic level and, 2) total information use (calculated by summing all sources used the how frequently they were used). Total information use reflects the amount (or dose) of information used as well as their motivation to seek information. Measures of information use, perceived usefulness, and preferences provide measures of program utilization, satisfaction and information preferences. They also indicate information sources used to supplement program information. Ex*periential information sources were*: 1) perceived arsenic-related health effects, and 2) perceived overall water quality.

Variables selected to measure personal risk understandings or **representations** were derived from interviews with AWTP staff, community residents, and research literature exploring correlates of protective behavior. Thirty-five variables were selected to measure how arsenic risk is identified, its cause, timeline, consequences, control, feelings of uncertainty, and negative emotions. Variables selected to measure **outcomes** included 1) water safety judgments, 2) policy opinions (including whether the DNR should mandate well drilling methods, if towns should discourage new industry that uses a lot of water, and, whether communities should reduce groundwater withdrawal by drilling fewer private wells and encouraging water conservation among residents), and 3) protective responses used to reduce arsenic risk. Measures of actions to reduce arsenic exposure illustrated who is doing what and were categorized as: no action, ineffective action, somewhat effective action, or as a state recommended action for reducing arsenic exposure. Quantifying total information use, representations, and the protective response allowed an analysis of relationships among these variables.

Design

Surveys were mailed at a single point in time 0.5 – 3 years after the AWTP was offered to community residents. The sample consisted of: a) all households that tested their wells through the program and had an arsenic level ≥ 5 µg/L (N=1154), and random samples of b) AWTP households with wells from 1–4 µg/L (N=100) and c) households who didn’t test their well through the AWTP (N=259). Instructions asked that one household adult was to complete the survey. A modified Dillman (2000) method was used that entailed up to five contacts by mail: 1) pre-notice letter, 2) survey, stamped return envelope and $2 incentive, 3) postcard reminder, 4) replacement survey and return envelope, and 5) final postcard reminder.

Analysis

SPSS was used for the descriptive analysis and analysis of variance. LISREL was used for structural equation modeling. The modeling analysis was conducted on a sub-sample of WTP participants with arsenic levels ≥ 10 µg/L.

Selected Results and Implications for Practice

Well testing

Two thirds of participants not testing through the AWTP privately tested their well. Across communities agency staff indicated that about 30% of households were testing through the AWTP thus about 40% were testing privately. The AWTP may prompt increased private testing due to the awareness raised by advertising the AWTP. This proposition cannot be answered with this study as it lacked a no-treatment comparison group. It is important to develop sources of arsenic information that are available to those who test privately. No-test-participants have less awareness of the arsenic problem and that their well water may be a source of arsenic exposure. Considering information use, perceived usefulness, and preferences among the no-test group it may be possible to reach no-test-participants using a mailing from the town or DNR and through newspaper coverage.

Arsenic level

The arsenic level had the largest effect of all information sources on protective responses. It is an essential source of information for private well users. Arsenic well level knowledge shapes information use, personal understandings and outcomes. Other researchers have found that nitrate levels (Poe, van Es, VandenBerg, & Bishop, 1998) or radon levels (Weinstein & Sandman, 1992) were strongly related to perceived safety and/or actions to reduce risk. People have a tendency to recall lower levels of arsenic or to not remember if they have tested for arsenic. People who couldn't recall their arsenic level used less information than those who reported even low arsenic levels. Those not testing used far less information than other participants. Strategies to help people keep track of well test information such as a refrigerator magnet or a sticker that could placed in a handy location (such as a calendar) might improve the accuracy of self-reported well levels. People will likely have a better recall of the meaning of a test result than they do of the actual result. In a study of cholesterol level recall, all study participants accurately recalled their cholesterol risk status while only about half could recall their actual cholesterol value (Glanz et al., 1990). Accurate recall of the meaning of their test result may be facilitated by providing them with their risk status (eg. unsafe – safe) along with their arsenic well level. A disadvantage of this approach is the tendency for people to think that levels above a threshold are safe and levels below are unsafe rather than more accurately understanding that the relationship of exposure level to risk is usually linear with subtle differences just above and below a safety threshold (Weinstein, Sandman, & Roberts, 1989). It would be essential to communicate how their risk status was determined and to provide further information about how arsenic drinking water standards are selected.

Information use

AWTP participants used information mailed with the well test most often, rated it as the 3rd most useful information sources (after conversations with agency staff and staff presentations at the town meeting), and rated it as the most preferred source. Private well testers rated information mailed with the test as most useful and the most preferred sources of information, but it was used slightly less than information from other mailed sources; likely because some test laboratories send no information with the well test report. When information use, perceived usefulness and preferences are considered together, information mailed with the well test is the most important information for AWTP and private well testers combined. Further research is needed to understand information that is currently provided by private testing labs and the feasibility of using this channel to better meet information needs. Information received with a well test is available at a 'teachable moment' when well users are motivated to understand their test results. This information could include links to other sources of arsenic information so people can more easily seek further information from reliable sources. It is important that this information is easily understood by the general population.

On average, participants used nine ‘hits’ of information from 5 different sources. Arsenic risk information should be publicly available from a variety of mediated and personal contact sources. A meta-analysis of studies evaluating patient education found that offering information from a variety of mediated and personal information sources was related to adopting preventive behavior (Kok, van den Borne, & Mullen, 1997; Mullen et al., 1997). Attempts should be made to improve the accuracy of arsenic risk information that is provided by non-agency sources. For example, the Wisconsin DNR provides training for well drillers. In the AAA this training currently includes information about arsenic and about well drilling methods that can mitigate the amount of arsenic in well water. It may be possible to provide information through local sources such as town newsletters or local newspapers, although information from newspapers was rated as minimally useful for making well water decisions among participants who tested their wells. It is important to develop information sources for people who test privately.

Information use and outcomes

Total arsenic information use (from external sources) had its greatest influence on protective behavior through certainty about control methods. Information should promote informed decision-making about selecting appropriate control methods by providing information that allows consumers to compare different arsenic control methods based on cost and removal efficacy.

Total arsenic information use was related to policy opinions through beliefs about causes of arsenic in well water. In a synthesis of evidence related to environmental literacy, Coyle (2004) states that people need to understand causal sequences that link human actions to environmental problems in order to take action or support policies that address the root causes of environmental problems. Understanding causes of arsenic in well water was strongly related to support for policies to decrease the withdrawal of groundwater such as community-wide water conservation and reducing the number of private wells being drilled into the arsenic-containing aquifer. These results support Coyle’s claim that environmental stewardship is promoted by educating people about these causal relationships. The arsenic town meetings provided detailed information about the causal relationships between water use, groundwater levels, and aquifers that may have been a factor in developing these beliefs and opinions.

Perceived water quality

Sensory qualities of water were most strongly related to identifying risk, health consequences/negative emotions, and water safety judgments. People need specific guidance for how to interpret and respond to sensory qualities of water. While people generally know that arsenic cannot be sensed, it is important to remind the public that arsenic cannot be tasted, smelled or seen and that well testing is the only way to know whether they have arsenic-contaminated water. It is likely that sensory qualities of water will remain a strong influence on perceptions of water quality/safety and to a lesser degree on protective behavior because experience is a psychologically powerful source of information (Leventhal, Safer, & Panagis, 1983).

Somatic experience

There was a clear linear relationship between arsenic level and perceived arsenic related health effects, but relatively few perceived these health effects (about 11%) which attenuated its effect as a source of information in the modeling analysis. Somatic experience was most strongly related to beliefs about health consequences and negative emotions.

Safety threshold

People selected a wide range of personal safety thresholds (the highest arsenic level they considered safe) ranging from 0 µg/L to > 100 µg/L. Safety thresholds were related to the protective response through safety judgments. When a safety standard has been revised, people need more information about why and how it is selected. Media sources tend to cover controversy more than synthesize facts and tend to cover opposing points of view about an issue to provide balanced reporting (Dunwoody, 1999). These reporting tendencies may lead the public to perceive more controversy about the revised drinking water standard than was the case. Agency professionals should assess beliefs about safety thresholds so specific public questions about safety thresholds can be addressed.

Protective response

About half of participants with arsenic levels over the current drinking water standard are not effectively reducing arsenic exposure. Researchers exploring responses to radon risk found that roughly half of participants with high radon levels were not taking action to reduce exposure (Weinstein & Sandman, 1992; Doyle, McClelland, Schulze, Elliott, & Russell, 1991). Selecting a higher safety threshold than the current drinking water standard, optimistic beliefs about water safety, perceived barriers (cost and effort) to controlling arsenic, and uncertainty about arsenic control methods may partially explain why participants do not take action to reduce their exposure. These are all elements that can be addressed in educational materials provided to private well owners. For example, people need information about arsenic control methods that allow them to compare the costs and benefits of each method to promote informed decisions.

Community awareness and adopting a lower arsenic drinking water standard

Participants living in a community that offered the AWTP each year adopted a lower arsenic safety threshold compared to those living in a community where arsenic was highly publicized but the AWTP was offered once. Education may promote more accurate understandings than publicity.

Application of the CSM to outreach programs

A meta-analyses of health education and health promotion programs found that the application of social science theory to program planning was a strong determinant of effectiveness (Kok et al., 1997). Environmental communication researchers recommend applying psychosocial behavioral theories to the design of outreach programs to enhance program effectiveness (O'Keefe & Shepard, 2002). The CSM, together with findings from this study, could be used to modify information provided to well owners to meet information needs identified by this study and to employ CSM derived knowledge about how people use and apply information about health risks.

Summary

Efforts should be made to make well test results and the water safety implications of their results easier for people to recall. User-centered information should be included with the arsenic well test and should also be available from a variety of sources. Information should clearly explain the revised arsenic drinking water standard, provide information about various arsenic control measures that allow people to compare measures based on cost and effectiveness, and provide guidance for how people should interpret and respond to perceived sensory qualities of well water. Programs should provide education about the causal sequences that link human activities to increasing arsenic levels to promote support for policies to address the problem on a larger level. The CSM may be a useful framework for designing risk information provided to private well users. Information designed to educate the public based on cognitive understandings of threats would include: 1) how they can identify an arsenic problem (an arsenic level compared to a safety threshold); 2) how safety thresholds are determined; 3) factors that identify their level of exposure to arsenic (arsenic level, amount of well water consumed, and length of time used); 4) potential health consequences of exposure; 4) how arsenic levels are expected to change over time; 5) methods of reducing exposure including the costs and benefits of each; and 6) causes of arsenic in groundwater. Outreach programs that foster a comprehensive understanding of well water quality and well water safety promote informed beliefs and decisions about water treatment and groundwater protection.

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