Decisions regarding Testing Private Wells in North Carolina: A Mental Models Analysis
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1. Introduction and Objectives

It is estimated that more than 13 million households rely on private wells for drinking water in the United States[1]. While people are free to choose where the get their water, the United States Environmental Protection Agency's (EPA) rules under the Safe Water Drinking Act do not apply to private well owners. Due to the lack of testing required by the EPA, private well owners could be at risk to a plethora of contaminants such as nitrates/nitrites and volatile organic compounds (VOCs)[2]. Focusing in on just North Carolina, 912,113 households are served by private wells for their drinking water[3]. The North Carolina Department of Public Health recommends monitoring private wells annually for bacteria; every two years for heavy metals, nitrates, nitrites, lead, and copper; and every five years for pesticides and VOCs[4]. While these tests are required for every municipal water line in the country, these private well owners are at risk by not testing their wells. Only 3,200 wells (0.35% of all private wells in the state) were tested at the State Laboratory for Public Health during 2011-2016[4].

Many private well owners are choosing not to test their wells; the goal of this study was to develop more effective evidence-based communications in the hope of influencing higher rates of private well testing. In this study we tested for these factors using the guidelines given in the Mental Models Approach to Risk Communication[5,6]. The approach draws together methods from the natural and social sciences, providing a framework for interdisciplinary collaboration. It is demonstrated with varied examples including electromagnetic fields, climate change, radon, and sexually transmitted diseases[7].

Outlined below are the four steps involved in the Mental Models Approach to Risk Communication (Figure 1). In the work conducted by Frank Stillo, et al., the first two steps have been completed. The purpose of this study was to further expand on the original work with a follow-up survey to a target population in Union county to further determine what underlying factors were when private well owners whether or not to test their wells. The results from this research can be used to further improve on future risk communications with the hope that it effectively promotes private well testing.

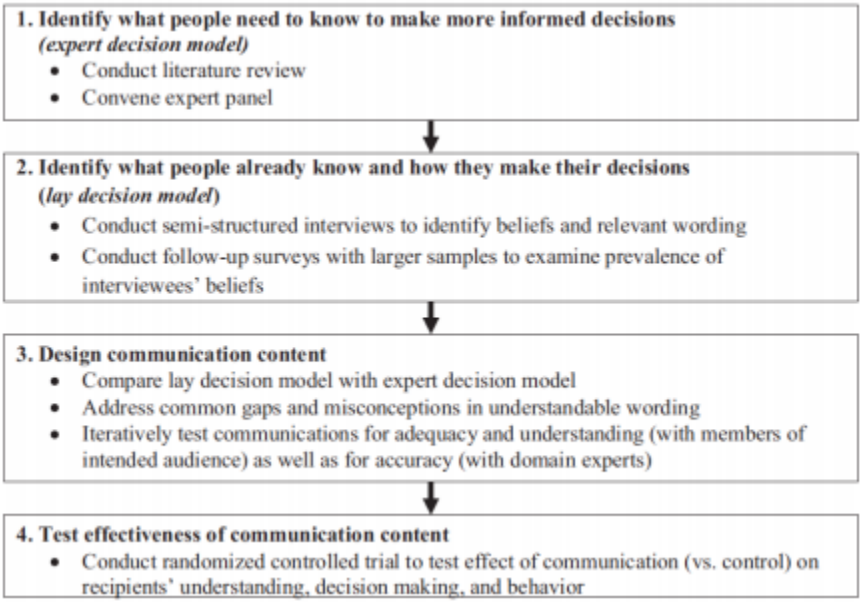

Figure 1. *Four steps in the mental models approach to risk communication (from Bruine de Bruin and Bostrom, 2013).*

2. Methods

2a. Survey Development

This survey asked randomly selected private well owners in Union County questions with the goal of determining the beliefs which affected their willingness to test their well. In a related survey conducted by Frank Stillo, et al. 18 private well owners were interviewed and the Stillo study listed some commonly held beliefs across most of the well owners. Common answers given were: low awareness of recommended testing frequency, belief that they could determine if water was contaminated through sensory perception, assumptions that water was already of good quality despite not testing, being unaware of the link between septic system failures and well water quality, and low awareness of inhalation and dermal routes of exposure to contaminants in their well water.

2b. Survey Coding

Questions were designed to determine which factors were statistically significant in influencing private well testing. These questions were formatted on the Likert scale with five options ranging from "completely disagree" (0) to "completely agree" (4), or as "Yes/No/Maybe/ Unsure ", or as fill-in-the-blank. To analyze these different types of questions, "Yes/No/Maybe/Unsure" questions were entered as 0.5 ("No"), 2 ("Unsure"), 2.5 ("Maybe"), and 3.5 ("Yes). All questions were de-identified to preserve anonymity among responders.

2c. Survey Analysis

To analyze the data we used an Exploratory Factor Analysis (EFA) which is described as "the method of choice for self-reporting questionnaires" [8]. This technique allows us to reduce the dimensionality of the survey questions. This allows the researcher to see relationships among questions because they are grouped by a common factor determined by the test. A separate EFA was conducted for all 13 sections of the Union county data except for Section 4 which was used for determining the outcome variable which was private well testing behavior.

For this analysis, we used principal components extraction method with promax oblique rotation in SPSS. Promax rotation was chosen because of the high correlation among the factors since most of them all related in some way to testing of well water.

We used logistic regression to determine whether or not each factor influenced private well water testing. Stillo et al. tested the influence of the factors on two frequencies of testing: whether the respondent had tested their well within the past two years, and if the respondent had tested their well within the past five years. This study only tested the influence of the factors on if the respondent had tested their well within the past two years.

3. Results

3a. Respondent Demographic Characteristics

The respondents for this study were taken from a larger population analyzed by Stillo et al. The Stillo study had a population of 317 respondents from 3,000 people surveyed throughout North Carolina. This study looked at 84 respondents from Union County. Table1 shows that among the respondents, 2.4% were black/African American, 85.7% were white, 1.2% were Asian, 2.4% were Hispanic, and 8.3% preferred not to disclose their race. 91.4% of respondents had at least some higher educations or a technical degree. 57.4% of the respondents household

income fell within an income range that the Pew Research Center considered middle class/upper middle class.

3b. Well Age

The average age of respondents wells is 24.26 years with the standard deviation being 10.22 years as shown in **Table 1**. If we assume that the age of wells is a value distributed normally, then we can calculate that 91.92% of wells are older than 10 years given these parameters. This means that the 91.92% of the wells predate North Carolina law requiring testing initial water quality of wells, which took effect on July 1st, 2008.

Table 1: Demographics of respondents

Sex (n=80)	
Male	51.2
Female	48.8
Age (n=83)	
Mean participant age (years)	mean = 55.55, (st. dev. = 18.31)
Race (n=84)	
American Indian	0.0
Black/African American	2.4
White	85.7
Asian	1.2
Hispanic	2.4
Prefered Not to Answer	8.3
Education (n=82)	
Less than High School	0.0
High School or GED	8.5
Some College	19.5
2 year or Technical Degree	13.4
Bachelor's Degree	37.8
Graduate School	20.7
Household Income (in $1000s ; n=76)	
Less than $15	1.30
$15-$30	5.30
$30-$50	13.30
$50-$75	20.00
$75-$100	18.70
$100-$125	18.70
$125-$150	5.30
$150-$175	9.30
$175+	8.00
Home Ownership (n=83)	
Rent	8.4
Own	91.6
Well Age (n=112)	
Mean well age	mean = 24.26 , (st. dev = 10.22)

3c. Factors Influencing Well Testing

Initially, our factor analysis identified 20 latent constructs, or groups, that the survey questions fit into. After finding these factors, we conducted a logistic regression to determine which of these factors were significant in influencing water testing in the two-year time period. These factors are titled "Lack (of) Testing Knowledge and Urgency" and "Testing Cost Barrier". **Table 2** shows the questions associated with these questions. The columns list in order: question, mean response value (standard deviation of response value) for the testers, and the same values for the non-testers. We conducted a one-sample t-test to determine if the individual questions within each factor were significant in influencing testing in the two-year period. The factor called "Lack Testing Knowledge and Urgency" describes sentiments of not knowing proper testing procedures or why it is important to test their wells in the first place. The factor called "Testing Cost Barrier" shows that responders feel that they cannot afford to test their wells for various contaminants.

Table 2: Factors significantly influencing whether private well water has been tested in the past two years

Factor	Test	Did Not Test
Lack Testing Knowledge and Urgency (n=84)	0.91(1.04)	1.74 (1.19)
I don't know where to get my well water tested (n=84) *	0.87(1.41)	1.75(1.64)
I don't know how to get my well water tested (n=84) *	0.80(1.38)	1.65(1.61)
I don't know what to test my well water for (n=84) **	1.20(1.48)	2.04(1.55)
I havent tested my well water because I forgot (n=84) *	0.47(0.74)	1.13(1.19)
I plan to test but haven't gotten around to it yet (n=84) **	1.20(1.47)	2.12(1.42)
Testing Cost Barrier (n=84)	1.00(1.28)	1.64(1.23)
I can't afford the cost of testing my well water (n=84) **	1.20(1.47)	1.58(1.43)
I couldn't afford to fix my well water if it were tested and found to be contaminated with bacteria (n=84) *	0.73(1.28)	1.64(1.38)
I couldn't afford to fix my well water if it were tested and found to be contaminated with chemicals (n=84) *	1.07(1.47)	1.71(1.34)

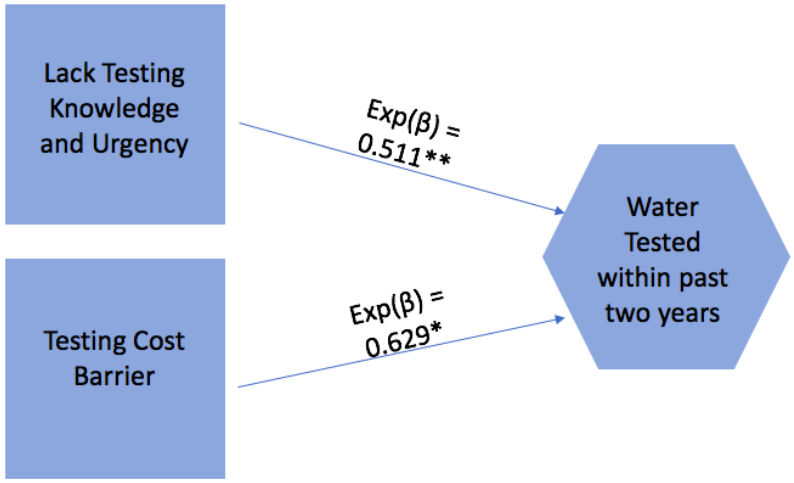

Figure 1: *Latent constructs influencing whether or not a respondent tested their well within the past two years. Solid lines indicate significant associations, with arrows pointing in the direction of influence. Exp(β) = odds ratio, **p≤0.01; *p≤0.05.*

Figure 1 shows the effects of the two latent constructs effect on whether the respondents had tested their wells within the past two years. The odds ratio term shows the change in testing likelihood (scale 0 to 1) for every one unit change in the respondents factor score. These results show us that among respondents there was:

- A lack of knowledge on the specifics of water testing and a lack of urgency to test their well because of the lack of information decreases the likelihood of water testing; and
- A perceived cost barrier to testing their wells for contaminants which decreased the likelihood of water testing.

4. Discussion

This study was done as a follow-up to a study performed by Stillo et al. The Stillo study looked at residents served by the Jackson County Department of Health, the Union County Department of Health, and Albemarle Regional Health Services. This study just looked at the Union County responses to determine if the same influencing factors were obtained with a more focused population. The Stillo study found three factors that influenced testing behavior:

1. Contamination can be detected through sensory perception like smell, taste, sight, etc.
2. Lack of knowledge about water testing procedures, and a lack of a sense of urgency about the importance of testing.
3. Problems with the septic system.

All of these factors found in the Stillo study decrease the likelihood of well owners testing their well. This study found two factors that influenced testing behavior:

1. A lack of knowledge on the specifics of water testing and a lack of urgency to test their well because of the lack of information decreases the likelihood of water testing
2. A perceived cost barrier to testing their wells for contaminants which decreased the likelihood of water testing.

This study did find one factor in common, but it did not find a factor about “Sensory Perception” or “Problems with the Septic System”. This suggests that certain sub-populations of the total population surveyed by Stillo have different influencing factors when deciding whether or not to test their well water.

These findings suggest that future communications with well owners should only include information providing a clear set of instructions on how to test their well while conveying a sense of urgency on the importance of well water testing, and providing information on the cost of well water testing with way of mitigating the cost if possible. Based on the Mental Models approach future communications should not include other information as it is extraneous and could even decrease the chance of respondents testing their well water. The extra information could take focus away from the factors that influence well water testing that could prompt action.

5. References

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