

Influences on the water testing behaviors of private well owners

Krystian Imgrund, Reid Kreutzwiser and Rob de Loë

ABSTRACT

Many private wells in the United States and Canada already are contaminated, or are at risk of contamination. Regular testing for pathogenic bacteria is one of the most concrete measures well owners can use to determine whether or not their drinking water quality is safe. This study explored the factors and causal relationships that influence well owner water quality testing behavior. In-depth, semi-structured interviews were used to evaluate the stewardship behavior of 22 well owners in Ontario, Canada. Causal networks were created for each interviewee. These were then aggregated to determine key factors and causal relationships. The research revealed that motivations for regular testing include peace of mind and reassurance. Barriers include complacency, inconvenience, and lack of a perceived problem. Knowledge and better information by themselves were found to provide a weak basis for changing behavior. Implications of this research for promoting water testing behavior are discussed.

Key words | complacency, private wells, pro-environmental behavior, reassurance, stewardship

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INTRODUCTION

Most jurisdictions in the United States and Canada place responsibility for routine maintenance of private wells on well owners (Rogan *et al.* 2009; Charrois 2010). Private well stewardship – voluntary actions well owners take to protect local groundwater resources (Green Communities Association (GCA) 2002; Simpson 2004) – is thus a critical tool for protecting the health of people who rely on private wells for their domestic water supplies. Principal actions included under the umbrella of well stewardship are ensuring proper well construction; regular water testing; maintenance and periodic inspection of the well; source water protection; proper well decommissioning; and other behaviors, such as water treatment (Simpson 2004; Treyens 2009; Charrois 2010). While all of these actions are important, water testing is one of the most crucial, as it provides information on water quality, and thus alerts well owners to the need for actions to address contamination (Simpson 2004; United States Environment Protection Agency (USEPA) 2007; National Groundwater Association (NGA) 2009; Treyens 2009).

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Water testing is recommended for multiple groundwater pollutants, such as pathogenic bacteria, nitrates, pesticides, salt, and heavy metals (Simpson 2004). However, microbial pollution is often the most common and evidence suggests that routine testing for indicator and pathogenic bacteria, particularly *Escherichia coli*, is not common among well owners in the United States and Canada. Well water quality studies in the United States and Canada have identified pathogenic bacterial contamination in up to one-third of private water supplies (e.g. Goss *et al.* 1998; De Simone *et al.* 2009). In their review of biological contamination of groundwater, Macler & Merkle (2000, p. 31) report that microbial pollution 'occur[s] in significant fractions of tested wells, both public and private, throughout the US'. Pathogenic bacterial contamination of well water has been associated with illness and disease outbreak (Raina *et al.* 1999; Macler & Merkle 2000; Schuster *et al.* 2005; Rogan *et al.* 2009).

Not surprisingly, findings from studies such as these have resulted in calls for better education to encourage water testing (De Simone *et al*. 2009; Charrois 2010). The assumption is that education will lead to appropriate behavior. However, for this to occur, a clear understanding of well owner behavior is needed. Specifically, it is necessary to understand why well owners do or do not test their well water. Few studies have been conducted to determine influences on water testing (e.g. Jones *et al*. 2006; Hexemer *et al*. 2008). Moreover, these studies have not been framed in the context of contemporary behavioral research.

Pro-environmental behavior literature offers an appropriate theoretical perspective for strengthening the foundation for well stewardship. Water testing can be understood as a form of what Stern (2000) refers to as 'private-sphere environmentalism'. Stern (2000) used the concept primarily to describe green consumerism and waste management, focusing on individuals' environmental stewardship behaviors. Routine bacteria testing is considered an essential element of private water well stewardship (Simpson 2004; Green Communities Association (GCA) 2002). As such, studies of private-sphere environmentalism can offer insights into water testing behavior. However, gaps in understanding remain. In their meta-analysis of pro-environmental behaviors, which focused primarily on private-sphere environmentalism, Bamberg & Möser (2007) identified several core psycho-social factors that commonly influence individuals' actions towards the environment. Additionally, they suggested that future research needs to focus on the causal processes suggested by theoretical models, as these are not well understood (Bamberg & Möser 2007).

This paper reports findings from a study of water testing behavior of private well owners in the Province of Ontario, Canada. The study had two specific goals: (1) To identify factors that influence testing behavior; and (2) to reveal and suggest causal relationships among factors. Accomplishing these goals provided a firmer basis for designing stewardship programs relating to private well stewardship. Private wells are an important source of drinking water for rural residents across North America. Thus, findings from the study are broadly relevant in jurisdictions where private well owners are primarily or exclusively responsible for ensuring the quality of their drinking water supplies.

FACTORS INFLUENCING PRO-ENVIRONMENTAL BEHAVIORS

Private-sphere environmentalism has been studied extensively using psychologically-oriented models of behavior; these models typically suggest specific causal relationships. Ajzen's (1991) theory of planned behavior (TPB), adapted from the theory of reasoned action (Fishbein & Ajzen 1980), has been used as the theoretical core of many of these models. The theory of planned behavior posits that a given behavior is predominantly influenced by a rational intention to perform that behavior. That intention is a function of attitudes towards the behavior in question, subjective norms imposed by society, and perceived behavioral controls, which all may influence one another (Ajzen 1991).

The empirical relevance of the TPB has been demonstrated by recent studies of private-sphere environmentalism (e.g. Kaiser *et al.* 2005; Barr 2007; Bamberg & Möser 2007). Nonetheless, the predominantly ego-centric focus of the TPB has been challenged. Most notably, Schwartz's (1977) norm activation model has been used to illustrate altruistic motivations for pro-environmental behavior. In this model, feelings of responsibility or guilt regarding consequences to others or the environment shape an individual's personal norms toward a specific behavior. As in the case of the theory of planned behavior, empirical research also supports models that focus on personal norms and those that further incorporate values and beliefs (Karp 1996; Fransson & Gärling 1999; Tanner 1999).

Hines *et al*.'s (1987) first meta-analysis of pro-environmental behaviors illustrates that self-interest and pro-social motivations can be combined to produce more robust descriptions of behavior. Stern *et al*. (1993) proposed a model for the motivations behind environmental action that was the sum of three 'orientations' towards preservation: Self (egoistic), others (social), and the environment (biospheric). Others have continued to build on the TPB. For instance, Armitage & Conner (2001) recommended the incorporation of personal norms as a direct influence on behavioral intentions. Specifically regarding environmental behaviors, Harland *et al*. (1999) and Bamberg & Möser (2007) found that personal norms directly influence behavioral intentions.

The broadening of psychologically-oriented models of pro-environmental behavior has led to the inclusion of other important factors that shape behavior. Knowledge of the environment and environmental behaviors has been shown to be an important behavioral influence (e.g. Hines *et al*. 1987; Fransson & Gärling 1999; Bamberg & Möser 2007). Specifically, authors such as Bamberg & Möser (2007) suggest that knowledge informs values and attitudes towards specific behaviors. Locus of control, whether one believes that outcomes are decided by individual (internal locus of control) or by external factors (external locus of control), has also been found to influence environmental behaviors (e.g. Hines *et al*. 1987; Guagnano 1995). However, Ajzen (2000) argued that locus of control constitutes a specific type of perceived behavioral control, and thus exhibits the same causal relationships.

Other models of pro-environmental behavior have traditionally put equal or greater emphasis on external, or structural, factors. In their review of environmental behaviors, Kollmuss & Agyeman (2002) categorized external factors as economic, social and cultural, and institutional. These could potentially include variables such as political or economic structures (e.g. laws, pricing) or available infrastructure. The importance of these factors in studies of private-sphere environmentalism has been noteworthy. Derksen & Gartrell (1993) and Barr (2007) found in separate studies of recycling behaviors that the availability of recycling programs could be more important than attitudes or other internal factors. The A-B-C model of behavior, proposed by Guagnano *et al*. (1995), further posits that internal and external factors are complementary, and that both are important in accounting for environmental behavior. Specifically, the A-B-C model suggests that if external factors (e.g. laws) are pronounced, then internal factors (e.g. attitudes) become less important. Similarly, if external factors are not salient, then internal factors play a greater role.

The relative importance of structure (external factors) versus agency (internal factors) in accounting for human behavior is a fundamental concern in the social sciences. For purposes of a study such as this one, it is not necessary to take a firm position for one side versus another. For instance, many external factors are incorporated into the TPB through the lens of perceived behavioral controls (Ajzen 1991). This suggests that both internal and external factors accounting for human behavior can and should be addressed in studies of stewardship behavior. As with locus of control, external factors will influence private-sphere environmentalism, as will perceived behavioral controls. Recognizing this, it is still useful to identify locus of control and specific external factors to determine whether or not they actually demonstrate similar influences.

Ultimately, previous studies and meta-analyses have demonstrated that the influence of the different kinds of factors emphasized in the various models discussed here varies with context (De Young 2000; Stern 2000). Thus, with Stern (2000), we argue that while models of human behavior provide essential guidance, they cannot replace empirical investigations of specific behaviors in particular contexts.

METHODS

To fulfill the objectives of this research, in-depth, semi-structured interviews were conducted with well owners in Tay Valley Township, Ontario, Canada. The population of this rural township is entirely dependent on well water. In Ontario, well owners have the opportunity to have their well water tested free-of-charge for total coliform and *E. coli* through local Public Health units. Unfortunately, as noted above, well owners in Ontario typically do not test their well water annually (Jones *et al*. 2006; Hexemer *et al*. 2008). Evidence suggested that Tay Valley Township was more likely to have well owners who performed annual testing than other townships. This was the case because the township had been selected by the Rideau Environmental Action League and Green Communities Canada as the location in which the *Well Aware* stewardship program would be initiated. Thus, it was highly likely that the township had residents who engaged in well stewardship, including annual testing, because *Well Aware* has been in operation longer than any other program of its kind in Ontario.

Questionnaire surveys by themselves typically cannot collect sufficient detailed information to explain individual behaviors (Rubin & Rubin 2005). Laboratory or field experiments can be used to uncover causal mechanisms (Bamberg & Möser 2007). However, re-creating the conditions under which testing behavior occurs in a laboratory setting is possible, but was not an option in this study. This study used in-depth, semi-structured interviews with well owners. Semi-structured interviews allow for the collection of detailed insights based on follow-up questions, deep probing, and observation of subtle cues (Rubin & Rubin 2005; Willis 2005). At the same time, this approach was considered well suited to the problem under investigation because testing behaviors occur privately at the household level.

Data collection

A sample of 22 well owners in Tay Valley Township was used to identify influencing factors and causal relationships. Purposeful sampling (Sandelowski 1995; Marshall 1996) was used to select the interviewees so that well owners who did and did not perform annual water testing could be interviewed. Community gatekeepers (Arcury & Quandt 1999) were used to recruit participants. To identify well owners who regularly tested their wells, interviewees were selected based on their participation in well stewardship programs and networking. It was assumed that well owners who participated in such programs would be more likely to commit to routine testing and would be aware of other individuals who also test water. Thirteen well owners suggested by stewardship program contacts volunteered to participate in the study. Similarly, to identify well owners who *did not* test their water, community groups in Tay Valley who were not involved with environmental issues or stewardship were asked to identify potential interview subjects. This resulted in nine well owners who, it was confirmed, did not routinely test their water. An additional seven water management professionals who had previous interactions with well owners were selected as key informants through snowball sampling (Marshall 1996). Key informant interviewees were used to verify the interview protocol and to identify and explain factors that commonly influence well owners in the area. All interviews were conducted between May 2008 and October 2008. Free and informed consent of all interviewees was obtained and the study protocol was approved by the University of Guelph's Research Ethics Board. To establish permission, and in accordance with the Research Ethics Board's regulations, all interviewees were presented with an information letter that described the purpose of the research, their rights as participants, and how the information would be used.

The interview guide for well owners was based on the literature discussed above, supplemented with insights from the key informant interviews (see Imgrund 2009). Open-ended questions were developed to elicit information about whether or not the interviewee performed annual testing, and to reveal factors that influenced individual behavior. Respecting the tension evident in the literature between the importance of structure versus agency, questions were designed to elicit insights into the role of both external and internal factors.

Questions regarding behaviors were designed to solicit answers in narrative formats (e.g. 'Tell about the last time you tested your well water'). This approach was used to avoid leading questions and to encourage elaboration on causal relationships (Patton 2002). More specific questions regarding potential external and internal influencing factors identified through the literature also were used (e.g. 'Were you aware of any problems when you decided to test your well water? Please explain'). The semi-structured format of the interviews permitted deeper probing through follow-up questions. At the same time, because the interviews with well owners occurred on their properties, detailed personal observations were recorded during each interview (e.g. how well owners reacted to specific lines of inquiry, and the physical site characteristics around their wells).

Data analysis

Well owner interviews were transcribed and coded to identify factors influencing testing behavior. Transcribed interviews were thematically coded based on influencing factors. To ensure coder reliability, descriptions of influential factors from key informants and the literature review were used as references to guide coding. To verify the results and to ensure the trustworthiness of the data, 50% of the well owners interviewed were purposefully recontacted to confirm and clarify the initial coding.

Individual causal networks for each well owner were created in Microsoft Visio™ to illustrate the connections between factors influencing each well owner's testing behavior. The causal networks distinguished antecedent conditions, influencing factors and behavioral outcomes.

The technique of creating causal networks enables the researcher to logically trace behaviors back to causal variables by creating 'streams' or chains of variables that lead to a specific behavior (Miles & Huberman 1994; Nash 2006). These networks allow the researcher to configure variables into patterns, or causal streams, which indicate how a chain of factors ultimately influences an outcome. Importantly, the causal networks also facilitated comparison with theoretical models of pro-environmental behavior developed in the literature (e.g. Hines *et al.* 1987; Kollmuss & Agyeman 2002; Bamberg & Möser 2007). For each interview subject, a narrative explaining each of the aggregated causal networks was used to make explicit all inferences that resulted from the analysis of primary data (Miles & Huberman 1994).

Following the construction of these individual causal networks, aggregate causal networks were created: one for well owners who *did* test their water annually, and one for well owners who *did not* annually test their water. These networks revealed common trends in individual behavior. The process for aggregating individual networks was based on techniques used by Miles & Huberman (1994), Hanton *et al.* (2004), and Nash (2006). In instances where half or more well owners identified a particular influential factor, this variable was considered of 'high' cross-case importance. Variables that were identified as important in fewer than half of the cases, but by more than two well owners, were considered of 'moderate' cross-case importance. All other variables were considered of 'low' cross-case importance. Thirteen individual causal networks were aggregated for those who reported annually testing their water for bacteria, and nine were aggregated for those who reported no annual water testing routine.

RESULTS

Factors and processes facilitating water testing

The aggregate causal network for the 13 well owners who performed annual water tests for bacteria is provided in Figure 1 and a summary of influential factors is provided in Table 1. As noted in the methods section, the relative importance of each factor or relationship was determined simply based on the frequency with which factors were identified, e.g. 'high' cross-case importance occurred when half or more of the well owners identified a factor.

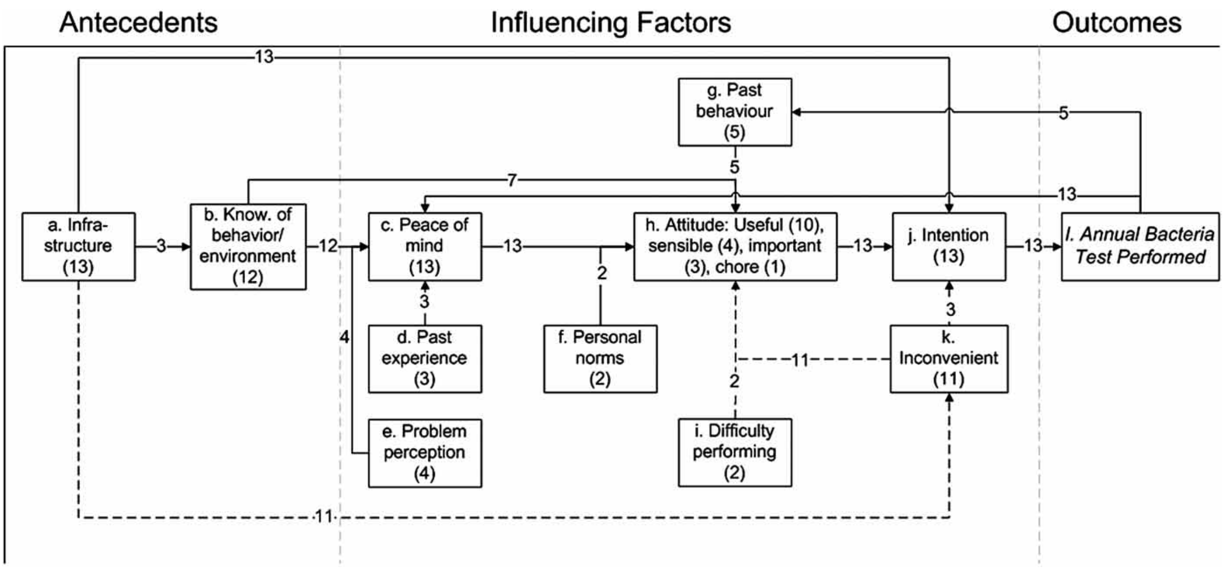

Figure 1 | Causal network of factors facilitating annual bacteria testing by well owners. Factors are individually labeled, e.g. 'a. Infrastructure'. The order of presentation of factors (left to right) approximates the order in which they occurred (antecedents and influencing factors). Outcomes (the behavior in question) are shown on the far right. The causal network also accounts for feedback, e.g. the influence of *Annual Bacteria Test Performed* (i) on *Peace of mind* (c). Relationships are depicted with arrows. Solid arrows represent factors and pathways that facilitate annual bacteria testing behavior, while dashed arrows represent factors that constrain annual bacteria testing. The number of well owners who identified a factor or causal relationship is noted in parentheses for each factor and for each causal relationship. For instance, 13 interview subjects identified *Infrastructure* (a) as an antecedent of behavior, while 3 of these people made a causal connection between infrastructure and *Knowledge of behavior and the environment* (b).

Table 1 | Summary of factors influencing well owners who test their wells annually for bacteria

Type	Factor	Influence	Importance
Antecedent	Infrastructure	Facilitator/ Constraint	High/ High
	Knowledge of behavior/environ.	Facilitator	High
Influencing factor	Attitude toward behavior	Facilitator	High
	Inconvenience	Constraint	High
	Intention	Facilitator	High
	Peace of mind	Facilitator	High
	Past behavior	Facilitator	Moderate
	Past experience	Facilitator	Moderate
	Problem perception	Facilitator	Moderate
	Difficulty performing behavior	Constraint	Low
	Personal norms	Facilitator	Low

Two antecedents of high importance were identified: *Infrastructure* (a) and *Knowledge of behavior and the environment* (b). *Infrastructure* had both positive and negative effects on routine testing behavior. While the Public Health unit directly enabled well owners to have their water tested for free on an annual basis (a → j), 11 well owners also found that the Public Health unit posed *Inconvenience* to testing (a → k). Reasons for this inconvenience reported by interview subjects were primarily the travel distance to and from the health unit, and the health unit's limited hours of operation. Well owners who identified *Inconvenience* as a constraint on their well testing behavior noted that traveling to the health unit could take upwards of 80 minutes for a round trip. Despite the inconveniences, all 13 well owners who reported testing for bacteria did so at least once per year. In different ways, they all suggested that the inconvenience was minor or that testing was important enough to ignore, or to cope with, the inconvenience. *Past behavior* (g), an influencing factor of moderate importance, also made it easier for some well owners to overcome the inconvenience of testing. For example, Well Owner 14 recalled testing his well for a number of years and began to have the *Attitude* (g) that it was a regular 'chore' (g → h).

For three well owners *Infrastructure*, in the form of advertising by stewardship programs, led to their *Knowledge of the behavior and environment* (a → b), the second antecedent of high importance. For example, Well Owner 2 reported contact with representatives of the Well Aware program who convinced him of the benefits of testing: 'It just seemed like a sensible thing to do, I mean it's kind of difficult to argue against it … They gave us the idea that [testing] was something we ought to do. And we've done it ever since on a fairly regular basis'. Overall, knowing about testing and why testing was important was sufficient for these three well owners, and four others, to have the *Attitude* that testing is a sensible behavior (b → h).

Although not all well owners had a lot of knowledge of the environment, all believed that groundwater quality could change due to human influences. For 12 well owners, this knowledge led them to desire *Peace of mind* (b → c) or reassurance, an influencing factor of high importance. Specifically, well owners wanted peace of mind about their water quality, influencing their attitudes that testing was 'useful' and 'important' (c → h). This was the primary reason all well owners tested their wells, despite the fact that none reported having water quality problems. As Well Owner 4 explained, he tests 'just to know that the quality of the water is good, that it's safe to drink. That is our drinking water, so … It's because it may not always be fine I guess. You never know, who knows what gets into the groundwater right?' After tests showed no contamination well owners gained peace of mind (l → c), a positive feedback, from their behavior. This feedback, and knowing that groundwater conditions may change, encouraged routine testing.

For several well owners, a desire for peace of mind was reinforced by two influencing factors of moderate importance: *Past experience* (d) and *Problem perception* (e). Three well owners related past experiences that made them more anxious about testing their water (e → c). Four well owners identified possible sources of contamination in their communities as having an influence on their desire for peace of mind (d → c). In each case the perceived problem was chronic, meaning that groundwater could become contaminated over a period a time (e.g. uranium mining, manure spreading), rather than from an isolated event (e.g. fuel spill).

Personal norms (f) were also found to be an influential factor, but were of low importance. Two well owners felt a responsibility, as part of a community of groundwater users, to routinely test their well water. Both made the connection between general water stewardship and well water testing, which gave them the attitude that testing is 'important' (f → h), although neither stated that this was their primary reason for testing.

Attitude towards testing (h) and *Intention* (j) were influences of high importance. All 13 well owners had positive attitudes towards sampling. In each instance, a positive attitude led directly to the intention and action of testing regularly (h → j → l).

While all 13 well owners in the group were chosen because they had reported testing for bacteria once a year, a few also noted factors that constrained testing behavior. In addition to inconvenience, but of low importance, were other *Difficulties performing the behavior* (n). Well Owner 2 noted that it was easy to accidentally spoil a water sample by touching the faucet or sample bottle, forgetting to take the aerator off the tap, or not letting the tap run for enough time. Well Owner 3 additionally added that she found it difficult to twist the aerator off her faucet. Both of these difficulties were substantiated with personal observations. However, neither difficulty was considered substantial enough, by the interviewees or researcher, to deter action.

Factors and processes constraining water testing

The aggregate causal network for the nine well owners who did not perform annual water tests for bacteria is provided in Figure 2 and a summary of influential factors is provided in Table 2. *Infrastructure* (b) was of high importance as a constraint, and of low importance as a facilitator. As with those who did perform routine bacteria tests (above), the distance to, and operating hours of, the Public Health unit were identified as being inconvenient (b → e). Almost all well owners in this group indicated that travelling to the health unit was a deterrent to routine testing, often due to occupational constraints. For example, Well Owner 10, a fulltime dairy farmer, found it was difficult to make extra time when considering other farm chores: 'There's only so many things you can do, so it usually doesn't get done. That's about the only way you can put it'. Well Owners 9 and 19 specifically stated that they would test more frequently if it were not so inconvenient.

Knowledge of the behavior and environment (a) was also an antecedent of high importance for well owners who did

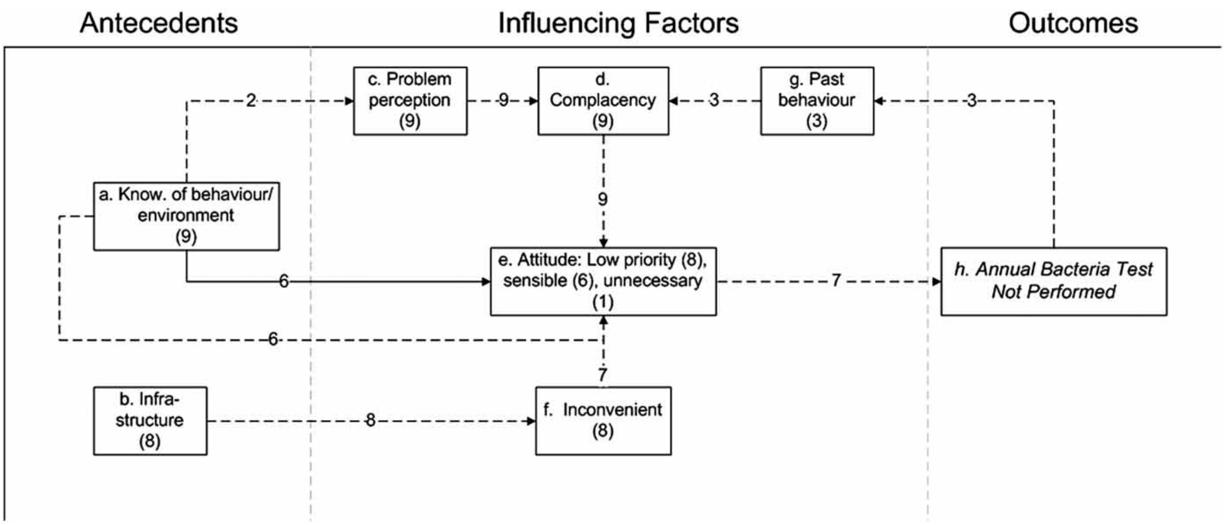

Figure 2 | Causal network of factors constraining annual bacteria testing by well owners. Factors are individually labeled, e.g. 'a. *Knowledge of behavior and/or environment*'. The order of presentation of factors (left to right) approximates the order in which they occurred (antecedents and influencing factors). Outcomes (the behavior in question) are shown on the far right. The causal network also accounts for feedback, e.g. the influence of *Annual Bacteria Test Not Performed* (h) on *Past behavior* (g). Relationships are depicted with arrows. Solid arrows represent factors and pathways that facilitate annual bacteria testing behavior, while dashed arrows represent factors that constrain annual bacteria testing. The number of well owners who identified a factor or causal relationship is noted in parentheses for each factor and for each causal relationship. For instance, 9 interview subjects identified *Knowledge of behavior and/or environment* (a) as an antecedent of behavior, while 2 of these people made a causal connection between knowledge and *Problem perception* (c).

Table 2 | Summary of factors influencing well owners who do not test their wells annually for bacteria

Type	Factor	Influence	Importance
Antecedent	Infrastructure	Constraint	High
	Knowledge of behavior/environ.	Facilitator/ Constraint	High/ High
Influencing factor	Attitude toward behavior	Constraint	High
	Complacency	Constraint	High
	Inconvenience	Constraint	High
	Problem perception	Constraint	High
	Past behavior	Constraint	Moderate

not test their water for bacteria annually. Six well owners recognized why testing should be performed, which influenced their attitudes that testing was 'sensible' (a → e). However, this understanding was insufficiently thorough for all nine well owners to have the attitude that testing was a 'low priority' (a → e). For two well owners, lack of knowledge of the behavior and environment led them to a lack of problem perception (a → c). For example, Well Owner 10 thought that rigorous water use precluded the need to test.

None of the nine well owners noticed any problems with their wells or water. Lack of *Problem perception* (c), a constraint of high importance, reinforced all nine well owners' senses of complacency (c → d). For three well owners, *Past behavior* (g), a factor of moderate importance, also contributed to a sense of complacency (g → d). All had used their wells for over 20 years, and felt this experience was sufficient evidence of water safety: 'We went probably 50 years and never tested it. And it always tastes good, so we assume that it's alright'. This repeated inaction did not lead to water quality problems, and this feedback (h → g → d → e) deterred the consideration of future testing.

Complacency (d) affected well owners to varying extents. For example, Well Owner 18 thought she was moderately complacent: 'I should really do it more frequently. But ya, nobody around here has ever complained about water issues on any of the properties. So that's probably a big part of it. We're happy with it'. Whereas Well Owner 21 expressed more confidence, and more complacency: 'I just don't feel there's any [reason to test] – it's a good well, there's nowhere that there's runoff, there's no reason that I could think that it would be contaminated. None of us are sick. So … maybe someday [I'll test]'.

This complacency tempered attitudes that testing was 'sensible' by enforcing the notion that it is also a 'low priority' (d → e). For example, Well Owner 9 acknowledged reasons to test for bacteria and, while he noted inconvenience as a constraint, he was retired, and did not have any immediate reasons for not testing. Rather, Well Owner 9 was complacent, and did not feel that testing was urgent:

> 'I guess after all these years I guess I've become a bit blasé. It's always provided us with water that tastes good and looks okay … I guess as time and years have gone by, you sort of get lulled into a sense of security of some sort. The water looks good, it tastes good, we're not sick, it must be O.K.'

Although none of these nine well owners tested their water for bacteria on a routine basis, most indicated that they had tested for bacteria at least once. Reasons identified for why a test had been performed at least once previously included aesthetic changes in water quality (e.g. murky water, odor), changes in health (e.g. gastrointestinal upset), or legal or policy reasons (e.g. mortgage renewal).

DISCUSSION

A number of factors were found to clearly influence well owners' testing behaviors. Stern (2000) and Jensen (2002) suggested that knowledge often acts as an antecedent, in other words, it directly enables behavior. In this study, knowledge and understanding of testing and environmental conditions indirectly influenced testing behavior among participants. Ignorance and misinformation contributed to some well owners not testing, mostly by influencing their attitudes. Knowing why testing is important appealed to well owners' sensibilities, but this knowledge was not sufficient in and of itself to motivate action in most cases. This finding supports Barr's (2003) suggestion that more information and better education by themselves rarely alter behavioral patterns. In this study, accurate knowledge simply contributed to peace of mind, and thus acted mostly as an antecedent for other factors.

Problem perception also acted as both a facilitator and constraint. Whereas behavioral models proposed by Bamberg & Möser (2007) and Kollmuss & Agyeman (2002) focused more on *general* awareness of environmental problems, results from this study suggest that local and personal problem perception were more important for water testing. Some well owners were encouraged to perform routine testing due to perceived sources of contamination in their vicinities (e.g. landfills). Others performed one-off testing in response to acute problems, such as changes in water aesthetics or their families' health. Interestingly, this suggests that the perceived nature of the problem (i.e. chronic versus acute) may be relevant to whether or not the behaviors motivated by problem perception become routine rather than one-time or sporadic.

Lack of a perceived problem acted as a constraint by creating a sense of complacency in some well owners. Well owners were lulled into a sense of security about their water supplies – a condition that occasionally was reinforced by a lack of prior testing behavior. Diametrically opposed to complacency was the need for peace of mind or reassurance, which was the most prominent influence on well owners who performed annual bacteria testing. Overall, these two opposing factors often provided the most obvious explanations for well owners' testing behaviors.

The results of this research lend support to, and build upon, a number of causal relationships suggested by models of pro-environmental behavior. Baldassare & Katz (1992) were among the first to observe a positive relationship between those who perceived and were concerned about environmental threats and those engaged in pro-environmental behaviors. However, other studies suggested that this link is not consistent (Rohrschneider 1988; Tanner 1999). While Blake (2001) suggested that contextual factors may alter how threats are perceived, this study reveals that behavioral feedback may also be important. Water testing produces feedback (i.e. test results) which provides specific information about environmental concerns (i.e. groundwater contamination). This type of feedback is not always present for other environmental behaviors that produce ambiguous or indiscernible results. For some well owners, a lack of negative consequences despite inaction was sufficient feedback to discourage testing behavior. Alternately, these results also indicate that complacent well owners could discern fewer results from testing behaviors because they already felt assured, and thus were constrained by a lack of meaningful feedback. This finding is supported by Kollmuss & Agyeman's (2002) model of environmental behaviors, which identifies insufficient feedback as a notable constraint on pro-environmental behavior.

This interpretation, along with the minor role played by personal norms, suggests that selfish motivations predominantly drive testing behavior. This is consistent with the theory of planned behavior, which suggests that people often, although not always, act to seek rewards and to avoid negative consequences (Ajzen 1991). In general, the role of attitudes toward behaviors and intention proposed by the TPB, and supported by Bamberg & Möser (2007), was consistent with findings from this research. While they often led to action, intentions did not typically illuminate other reasons for testing. In other words, knowing that a well owner intended to test did not provide insights into her/his reasons for testing. This pragmatic limitation with the TPB is partly attributable to the fact that the model was also designed to predict behavior, not just to explain it. Attitudes often revealed how well owners assimilated different influential factors and arrived at an intention; they also accounted for inaction. For example, a number of well owners who did not perform bacteria testing still maintained conflicting, positive attitudes towards the behavior.

Perceived behavioral controls were most evident in the form of inconveniences. Well owners who did not test on a regular basis were also disinclined to test because of their complacency. Those who did test on an annual basis, while recognizing the inconvenience, were able to overcome this constraint because they thought it was important to test. In other words, attitudes did influence perceptions.

Arguably, this constraint can be also interpreted as a structural or external constraint, as the inconveniences were often imposed by the location and operation of the Public Health unit. Inconvenience was also exacerbated by social circumstances, in particular having the time to take off work. This is consistent with Derksen & Gartrell's (1993) and Barr's (2004) insistence that social context, particularly access to infrastructure, is an important control on environmental behaviors. This suggests that the accessibility of some drop-off locations for samples – which can be a function of distance, mobility, and a host of other concerns – may be as much a barrier to testing as the perceived inconvenience of taking a water sample.

From a practical perspective, better education alone clearly is not an appropriate approach for ensuring that owners of private wells engage in a critical form of stewardship behavior: annual testing for pathogenic bacteria. Creating better access to Public Health units (e.g. extending hours, establishing additional sample drop-off locations) may be a more effective strategy in light of the fact that inconvenience easily can be interpreted as an external or social constraint. However, improving access is only a partial solution because complacency will continue to be a significant barrier for well owners. Different kinds of 'feedback', such as municipal tax rebates for water tests, may be a way to mitigate complacency. However, before any such program can be implemented, cost, and interactions with other factors, should be explored as potential constraints on water testing behavior. This is a particularly important concern in regions where bacteria tests are not free.

While providing a number of contributions, the nature of the research presents some limitations. The factors identified in this research cannot necessarily be extrapolated to all well owners in rural Ontario. It is possible that in varying contexts different factors can influence behavior (Ajzen 1991; Knowler & Bradshaw 2007). Continuing research should focus on testing hypotheses that arise from the causal networks in longitudinal studies and predisposition towards certain psychological factors that influence water testing behavior.

CONCLUSIONS

This research revealed that private well owners' motivations for annual pathogenic bacteria testing often centre on peace of mind and reassurance. The most important barriers identified include complacency, inconvenience, and lack of a perceived problem. Knowledge and better information by themselves were found to provide a weak basis for changing behavior, but did influence behaviors in combination with other factors.

Addressing these barriers to routine water testing, and reinforcing motivations, will prove to be a continuing challenge for water managers. Removing structural constraints, such as inconvenience, is an important first step, but longer-term initiatives should aim to change well owners' perceptions of water safety or create other incentives for testing.

Further research will be needed to explore more deeply than was possible in this study the causal relationships among factors. Figures 1 and 2 offer a starting point from which to generate hypotheses regarding the causal processes involved in water testing behavior. One particular line of future research should focus on why some individuals develop a need for reassurance while others are more inclined to become complacent. Determining whether or not there are predispositions for these feelings will create opportunities for improving outreach efforts that focus on the importance of annual bacteria testing.

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