

An investigation of bacteriological and chemical water quality and the barriers to private well water sampling in a Southwestern Ontario Community

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ABSTRACT

Private well owners in Canada are responsible for maintenance, including routine sampling, of their private drinking water supply. Sampling rates in a Southern Ontario community are well below the public health recommendation. A study with private well owners was conducted to improve private well water sampling rates through the removal of two significant barriers to private well water testing.

During the pilot and extended study phases, 549 nitrate and 425 bacteriological water sampling bottles were delivered to private well owners and water samples were collected the following day. A follow-up telephone survey was conducted with both study participants and non-participants to identify barriers to private water sampling that were encountered by the study sample population.

Participation rates in the pilot and extended study phases were less than 50% prompting the follow-up telephone survey. Inconvenience and lack of time [statistically significant, $P < 0.01$] were found to be the main barriers for participation in the study.

The findings from this study illustrate the influence that certain barriers have on the frequency of private well water testing in a Southern Ontario community. The findings provide guidance for other health authorities to improve sampling rates.

Key words | communication barriers, data collection, nitrates, water microbiology

INTRODUCTION

Waterloo region is a community of approximately 500,000 residents in Southern Ontario, comprised of both urban and rural areas. It is estimated that there are 8,000 private residential water wells in Waterloo region. Region of Waterloo Public Health encourages private well owners to sample drinking water for bacteria three times per year and for nitrates once per year, in accordance with provincial recommendations (OMHLTC 2003). In 2005 and 2006, drinking water sample bottles were provided to private well owners for bacteriological (*E. Coli* and total coliforms) sampling at no charge and nitrate sampling for a modest fee of \$14.

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In 2005, 1,935 private wells were sampled for bacteria in the Waterloo region and 105 private wells were sampled for nitrates. The bacteriological sampling rate (slightly less than 25 per cent) in Waterloo region is consistent with rates reported elsewhere (Thompson 2003; Corkal *et al.* 2004; Jones *et al.* 2006). Furthermore, in 2005, 1,185 private wells were only sampled once for bacteria; 382 were sampled twice; 167 were sampled three times; and 201 were sampled more than three times. These statistics illustrate the disparity between the Ontario recommendations for private well water sampling and the actual rate practiced in this community (and other communities across Ontario).

A postal survey of private well owners perceptions of their water quality in the nearby City of Hamilton, Ontario found that only 8% of respondents tested their private water supply for bacteria three times each year (Jones *et al.* 2006). As groundwater quality can change over time, these sampling rates are insufficient to prevent possible public health risks. As described by Jones *et al.* (2006) private well owners noted the following barriers to more frequent well testing: inconvenience and time issues; no health problems or noticeable water changes; and, forgetfulness or procrastination.

Elevated nitrate levels in groundwater are common in agricultural areas (Aelion & Conte 2004; Benson *et al.* 2006; Manassaram *et al.* 2006). Parts of Waterloo region are known to have historically high nitrate levels in the groundwater. Elevated nitrate levels in drinking water represent a health concern for infants and pregnant women due to the *in vivo* conversion of nitrates to nitrites. An accumulation of nitrites is associated with methemoglobinemia or 'blue baby syndrome' and miscarriages (Knobeloch *et al.* 2000; Manassaram *et al.* 2006).

In 2005, Region of Waterloo Public Health implemented a private water study with well owners in areas known to have historically high nitrate levels in the groundwater or low bacteriological sampling rates. This study was performed to improve private well water sampling rates.

Based on previous findings which have reported that ease of sample collection and drop-off and cost are two significant barriers to well water testing, this study was specifically designed to remove these barriers and therefore improve participation (Jones *et al.* 2006). The nitrate testing in this study was provided at no charge and Region of Waterloo Public Health invested staff time to both deliver and collect sample bottles for each residence in the study areas.

METHODS

Two areas in Waterloo region known to have high nitrate levels in the groundwater were selected for the pilot phase of this study. Region of Waterloo Public Health staff delivered well water sampling kits to each residence in the selected areas for one week in November 2005. Well water

kits included: a letter to explain the study to residents; an information package about private wells; a nitrate fact sheet; and a nitrate water sample bottle. Well water kits were left in each residential mailbox and water samples were picked up the following day. Approximately one-quarter of the well water kits delivered also included a bacteriological water sample bottle.

The extended phase of the private water study was conducted throughout five areas in Waterloo region. The areas were selected based on historically high nitrate levels in the groundwater or low bacteriological sampling frequency and did not overlap with the pilot study areas. Well water kits were delivered between February and March 2006 (by Region of Waterloo Public Health staff) in a clear plastic bag and were hung on the main entry doorknob of each residence. Water samples were collected the following day by public health staff. Well water kits were identical to those used in the pilot phase, although a bacteriological water sample bottle was included in every kit. Nitrate and bacteriological sampling were offered to well owners at no charge during the pilot and extended phases of the study. Water sample results were mailed to participants. Results were interpreted for well owners and resources for treatment of adverse drinking water were provided if needed. Residential addresses were obtained through Region of Waterloo GIS Locator software. Municipal water customer data was also consulted to ensure that identified addresses were not receiving municipal water.

A telephone survey was conducted in June 2006 on a purposively selected group of participants (who submitted samples of well water for testing) and non-participants (who did not submit a well water sample for testing) of the pilot and extended phases of the study. The survey had 15 questions and took approximately 10 minutes to complete by telephone. Respondents were randomly chosen from the original participant and non-participant contact lists used in the earlier phases of the study. The objectives of the survey were to determine whether there were significant differences between study participants and non-participants with respect to concerns for the bacteriological or chemical safety of their water supply and to identify barriers to private water sampling that were encountered by the study sample population.

All statistical analyses were performed with Stata Version 8.1 (Stata Corp., College Station, Texas). Contingency table chi-square analyses were employed to examine the associations between participant and non-participant responses for the following variables: interest in chemical and biological water quality, interpretation of instructions which accompanied the water testing kit, and having the sample ready for next-day pickup.

RESULTS AND DISCUSSION

During the pilot phase of the study, 184 well water kits were delivered of which 60 kits contained a bacteriological water sample bottle. Participation rates for nitrate water samples and bacteriological water samples were 40.8% and 43.3% respectively. In the extended phase of the study, 365 well water kits were delivered to well owners. Participation rates improved during the extended study and were 47.4% for nitrate water samples and 47.1% for bacteriological water samples.

During the pilot phase of the study, 25% of the nitrate water samples were adverse and 15% of the bacteriological water samples were adverse. A nitrate sample was considered to be adverse if the result exceeded the *Ontario Drinking Water Quality Standard* for nitrate of 10 mg/L (SDWA 2002). A bacteriological sample was considered to be adverse if the water sample had one or more *E. coli* present per 100 ml sample or more than 5 total coliform colony forming units per 100 ml sample (OMHLTC 2003). During the extended phase, 17.3% of the nitrate water samples were adverse and 3.5% of the bacteriological water samples were adverse (Table 1).

The telephone survey response rate for the participant sample was 70.8%, while the response rate for the non-participant sample was 29.6% (Table 2). The difference in response rates between the two groups surveyed illustrates the difficulty encountered in making contact with certain portions of the population. Differences in demographics between these two groups of residents (including the ease with which they can be contacted either by telephone or visit follow-up) likely contributed to the lower response rate observed in the earlier phases of the study.

Specifically, residents were asked “on a scale of 1 to 5, with 1 being not interested and 5 being very interested, how

Table 1 | Pilot phase and extended phase response rate and water quality results

Pilot phase		
Participation		Response rate
Well water kits delivered	184 *	
Nitrate water samples collected	75	40.8%
Bacteriological water samples collected	26	43.3%
Water quality findings		% of adverse samples
Adverse nitrate results	19	25.3%
Adverse bacteriological results	4	15.4%
Extended phase		
Participation		Response rate
Well water kits delivered (both nitrate and bacteriological sample bottles included in kit)	365	
Nitrate water samples collected	173	47.4%
Bacteriological water samples collected	172	47.1%
Water quality findings		% of Adverse samples
Adverse nitrate results	30	17.3%
Adverse bacteriological results	6	3.5%

*Bacteriological water sample bottles were only delivered in 60 of the well water kits delivered during the pilot phase.

interested are you in finding out the nitrate (or bacteria) levels of your well”. According to the results from the telephone survey, 79% (29/34) of non-participants and 78% (56/63) of participants surveyed responded that they were very interested or interested in finding out the nitrate levels of their well water (4 or 5 on the scale). In addition, 85% (30/34) of non-participants and 94% (61/63) of participants responded that they were interested or very interested in finding out the bacteria levels of their well water (4 or 5 on the scale) (Table 3). The participant and non-participant groups did not differ significantly in their concern for the bacteriological or chemical quality of their well water ($P < 0.05$).

Both the participant and non-participant groups reported that they found the instructions that accompanied the water sampling kit not difficult to understand (no significant difference detected, $P < 0.05$) (Table 3). However, 17% (5/34) of non-participants reported that they did not read the sampling instructions and 17% (5/34) did not remember receiving sample instructions.

Table 2 | Follow-up telephone survey response rate

Sample group	Survey participation		Response rate
	Contacted	Responded	
Participant group	89	63	70.8%
Non-participant group	115	34	29.6%

The greatest disparity between participants and non-participants was observed in the self-reported difficulty encountered with having the well water sample ready for pick-up the following day. According to the survey results, 56% (19/34) of the non-participants reported that it was very difficult or difficult (4 or 5 on the scale) to have the sample ready for pick-up the next day. Conversely, 6% (4/62) of the participant group reported that it was very difficult or difficult (4 or 5 on the scale) to have the sample ready for pick-up the next day (Table 3), illustrating a statistically significant difference in responses between the two groups ($p < 0.01$).

A limited amount of demographic data were collected during the survey (household income and education level), and no significant difference could be detected between the two groups ($p < 0.05$). In future, it would be interesting to collect additional demographic data related to the presence of children, pregnant women or immuno-compromised individuals, all considered to be more sensitive to water quality.

Removing the barriers of cost and inconvenience approximately doubled the private well water background sampling rate in Waterloo region in 2005 of slightly less than 25%.

Furthermore, the change in methodology between the pilot and extended phases of the study (e.g., well water kit provided in residential mailbox versus hanging well water kit on door knob) lead to an increase in study participation rate (42.0% to 47.3%). These findings support the notion

that both cost and inconvenience are necessary barriers to address in private well water sampling initiatives. It should be noted that during the follow-up telephone survey, it was found that 21% (7/34) of the non-participants noted that they were not home during the study period. This observation also supports the notion that the two groups of residents differ demographically and that by improving the accessibility of the water sampling kit (perhaps by extending the drop-off/collection phase or initiating this type of collection effort at different times of the year), sampling rates could be enhanced.

A similar private water study in a neighbouring Ontario health unit (Wellington-Dufferin-Guelph) observed a participation rate of 88% (38/43) (unreported data). However, the methodology was more resource intensive, including an initial letter from the local Medical Officer of Health followed by at least one personal visit from a local Public Health Inspector. If no response was received during the visit, another communication was mailed to the resident. (Personal Communication, John Yan, Certified Public Health Inspector, July 28, 2006) As such, the methodology was more labour intensive and involved significantly more staff time than the methodology used in the current study.

The incidence of adverse nitrate samples was greater in the pilot study than the extended study because the pilot study was conducted only in areas known to have elevated nitrate groundwater concentrations. The incidence of adverse bacteriological samples also varied between the pilot study (15%) conducted in November and the extended study (3.5%) conducted in February and March. This difference is telling of the seasonal variation which exists in private well drinking water quality. The sporadic

Table 3 | Perceptions of private well water sampling in a defined sample population

Survey questions	Survey responses	
	Participant group ($n = 63$)	Non-Participant group ($n = 34$)
Interest in nitrate levels of private water supply	78% were interested or very interested	79% were interested or very interested
Interest in bacteria levels of private water supply	94% were interested or very interested	85% were interested or very interested
Interpretation of water sample kit instructions	94% considered the instructions in the kit not difficult to understand	82% ($n = 28$ because 5 did not respond) considered the instructions in the kit not difficult to understand
Sample collection for next-day pick-up by local public health inspector	6% reported that it would be difficult or very difficult to have the sample ready for pick-up the next day	56% reported that it would be difficult or very difficult to have sample ready for pick-up the next day

incidence of adverse results demonstrates the importance of routine private well water sampling to protect health.

By removing two significant barriers (cost and convenience) to private well testing, we originally hypothesized that the participation rate would be quite high in the study, however this was not observed. Although the well water sampling rate almost doubled from the background rate in the sample regions, the relatively low participation rate (47% for bacteria and 45% for nitrate tests) for this study prompted the follow-up telephone survey.

Results of the telephone survey demonstrate that lack of time was the main barrier to participation in this study and hence private well water sampling. The barriers of inconvenience and cost noted in a previous study were partially removed in this study (Jones *et al.* 2006), although increasing the sampling period might have contributed to additional participation, particularly the 21% of non-participants who noted that they were not home during the study period and therefore unable to participate.

As concern for the bacteriological or chemical safety of the water supply did not differ significantly between study participants and non-participants it can be inferred that perceptions about water quality were not a barrier for sampling within the study population. In future studies, follow-up on the water quality interest questions would be an excellent way to further elucidate public perceptions related to private well water quality. Rather, it would be interesting to understand the factors which contribute to the observation that this study population is interested in their well water quality, to help inform public health initiatives to improve testing frequency.

Finally, it is hypothesized that lack of time is not only a reason for low participation in this study but also an important barrier for private well water sampling year-round.

CONCLUSIONS

The results of this study provide evidence that private drinking water quality can be sporadic. In addition, it was demonstrated that inconvenience and lack of time are key barriers to routine private well water sampling. The findings of this study can be considered by other health authorities when trying to improve sampling rates in their respective areas:

- Sample bottle pick-up and drop-off is a significant barrier to improving private well water testing for bacteria and chemicals;
- Dedicated resources (personnel and funds) to improve well water testing frequency does result in an increase in testing; and
- Interest in water quality is present thus public education messages should be directed at private well owners to highlight the importance of regular, routine testing.

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