Households' Response to Groundwater Quality Degradation Results from a Household Survey in Quebec

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Réaction de ménages du Québec face à la dégradation de la qualité des eaux souterraines

Résumé – Cette recherche étudie la réaction de ménages québécois face à la dégradation de la qualité des eaux souterraines. Plus spécifiquement, elle tente d'identifier les déterminants qui i) motivent les décisions des ménages en ce qui a trait aux activités de protection encourus pour se protéger contre les problèmes occasionnés par cette dégradation et ii) expliquent les différences entre les coûts engagés par les ménages ayant entrepris des activités de protection. Parmi les ménages déclarant souffrir de problèmes de qualité de l'eau, ceux jugeant subir des nuisances qui renvoient à la couleur, à l'odeur et au goût désagréable, sont moins enclins à prendre des mesures de protection et dépensent, en moyenne, moins pour ces mesures que ceux estimant souffrir de problèmes de contamination de l'eau. Les facteurs qui déterminent le comportement de protection des ménages sont la localisation géographique, la proximité des activités agricoles, l'orientation environnementale du chef de ménage et la présence d'enfants de moins de 18 ans au sein du ménage. L'ampleur des coûts de protection est influencée par la localisation géographique, la source d'approvisionnement en eau potable, le revenu, le niveau d'éducation et l'âge du chef de famille, aussi bien que le nombre d'enfants de moins de 18 ans que compte le ménage.

Mots-clés :
eaux souterraines, actions de protection, dépenses de protection, contamination, nuisances

Households' Response to Groundwater Quality Degradation. Results from a Household Survey in Quebec

Summary *– The research reported in this paper looks into Quebec households' response to groundwater quality degradation in terms of both the averting activities they undertake and the intensity of the costs they incur as a result. Of all the households suffering from water quality degradation problems, those facing water-related nuisances (odor, staining problems, and bad taste) are less inclined to take averting actions, and on average, they spend less to solve these problems than those suffering from water pollution by bacteria and minerals. Those on municipal water supply systems also tend to spend less on avoidance actions. Factors that determine households' averting behavior are their geographic location, their closeness to farming activities, the environmental orientation of the head of the household and the presence of children under 18 years of age. The intensity of averting costs is influenced by the geographic location, the source of drinking water, the income, the educational attainment and the age of the head of the household as well as the number of children under 18 years of age.*

Key-words :
groundwater, averting actions, averting costs, contamination, nuisances

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BECAUSE groundwater quality degradation has such negative impacts as human health hazards, increased fear and anxiety, avoidance cost and property value loss, ecological damage and loss of recreational value, loss or reduction of non-use values (Bouwer, 1990; Abdalla, 1990; Antle and Pingali, 1994; Amigues *et al.,* 1995), changes in groundwater quality have become a major issue in both rural and urban communities. In turn, this has led both policy-makers and individual households to take actions that improve the quality of drinking water and protect themselves from contamination (Collins and Steinback, 1993; Abdalla, 1990). These actions are generally referred to as averting actions, and the related costs as averting costs or defensive expenses (Smith and Desvousges, 1986). Among other things, they include purchase of bottled water, boiling water, hauling water, purchase of water treatment systems, changes in food and beverage purchase, as well as participation in public information meetings. The review of the literature shows that the benefits of such actions may depend on local conditions, a household's characteristics, the type of water supply system, and the level of awareness of the community (Abdalla, 1994; Raucher, 1986; Swartz and Strand, 1981; Laughland *et al.,* 1996). Furthermore, households with younger children, especially children under three years of age, were found to incur higher averting costs (Abdalla *et al.,* 1992). Swartz and Strand (1981) found a positive relation between the household level averting cost and its awareness level.

These studies are informative in two ways. First, they show that both households and water suppliers are willing to incur higher costs to protect the quality of groundwater. Second, the results indicate that the extent of these costs may be site-specific and therefore, policy-makers need to take such differences into account when initiating policies that intend to protect or improve groundwater quality. However, because most of these studies define contamination in terms of groundwater quality degradation due to bacteria or chemicals, they have left out a good deal of other averting actions that households may undertake to protect themselves. In fact, there is evidence that a great number of households will take actions to protect themselves against such water-related nuisances as odor, staining problems and bad taste (Collins and Steinback, 1993). Such an omission may have led to an underestimation of household level averting costs. In addition, to our knowledge, empirical studies dealing with households' averting behavior have primarily concerned themselves with water quality degradation in a single community. Thus, they have not been able to specifically test for differences in averting behaviors and costs that may arise from differences in geographic location. A third problem that these empirical studies have not addressed adequately is the influence of the source of drinking water, *i.e.* municipal water sup-

ply systems *vs* private systems. The research reported in this paper fills that void. First, we extend the definition of water pollution to include not only pollution due to bacteria, minerals and chemicals, but also any water related nuisances such as odor problems, staining problems and bad taste. Thus, averting costs consist of any expenditure undertaken to remedy these problems. Second, our sample is random and includes 2,333 households from four different communities located throughout the province of Quebec (Canada). To our knowledge, this not only makes it the most extensive study on household level averting behavior in Canada, but it also allows us to test for differences in averting behavior due to differences in geographic location and to lend a stronger support to results from similar studies that are not based on a random sample of households. Third, our sample is based on households who get their drinking water from either a public water supply system or from a private system such as private wells. Thus, the effect of the type of water supply system on households' averting behavior may be determined.

The main objective of the research reported in this paper is threefold : 1) to determine the factors that cause households to take averting actions when facing degradation of the quality of their domestic water supply ; 2) to estimate the household level averting cost and determine factors that may explain its intensity ; and 3) to provide public decision-makers with tools that may help them design better policies to fight against groundwater contamination.

In the following section, we present the data used in the study. We then present descriptive results that show the extent of water quality degradation suffered by the surveyed households as well as the intensity of the costs they incur as a result. This is followed by a summary of the results from two models that establish the relationships between respectively, the household's decision to take averting actions and the household's level of averting expenditures and a series of factors related to the type of water supply system, geographic location and household characteristics. We conclude with a summary of our results and their public policy implications.

DATA

To document households' averting behaviors in response to groundwater quality degradation, a questionnaire was administered from September 26 to October 10, 1995, to residents of four communities of the province of Quebec : Portneuf, Ile d'Orleans, Lanaudière and Nicolet-Yamaska. Portneuf is about 32 km North-West of Quebec City. Ile d'Orleans is located 3.5 km from Quebec City. Lanaudière and Nicolet-Yamaska are located 32 km and 121 km from Montreal, respectively. The choice of these municipalities was dictated by a number of consid-

erations. First, in addition to being located on sandy soil, they account for almost all the potato production of the province. Because potato production is chemical intensive and sandy soil allows for the easy infiltration of contaminated surface water, residents of these communities are more likely than others to experience groundwater quality degradation. In fact, a private well survey in these regions found a nitrate concentration above the 10mg/l per adult benchmark for drinking water. Although that level of concentration does not carry any real health threat for adults, expert opinions suggest that it could cause methemoglobinemia for young children, *i.e.* an excessive amount of methaemoglobin in red blood corpuscles causing asphyxial reactions. Second, following that finding, an intensive information campaign about the health hazards of that situation was undertaken by local health centers and pro-environmental groups. Third, in all these communities co-exist the two main types of water supply systems municipal water supply systems and private wells. Thus, these residents offer a unique opportunity to document household level response to water quality degradation in relation to both geographic location and type of water supply system.

The list of the surveyed households was obtained from the telephone directory (*i.e.* the white pages) of the respective municipalities. The questionnaire was administered by telephone to a random sample of 2,333 households. Of these, 790 were from Portneuf, 802 were from Lanaudière, 352 were from Ile d'Orleans, and 389 were from the Nicolet-Yamaska region. The respondents were asked to state the source of their drinking water and to tell whether or not they were experiencing any problem with their drinking water, namely, contamination by chemicals or bacteria, staining problems, odor problems and bad taste. The questionnaire also asked, among other things, the interviewees' purchase of bottled water, purchase of substitute foods or beverages, purchase of home water treatment devices, in response to the knowledge of the degradation of the quality of the drinking water in their communities. They were asked to state any monetary cost they incurred as a result of taking any averting actions. Information was collected about the household's income, the level of education, the environmental orientation and the age of the head of the family as well as the number of youngsters living at home.

To insure that the information collected was representative of the total population of the four communities, distributions about the surveyed households' source of drinking water, the type of water quality degradation problem experienced, the type of averting actions undertaken, the income of the head of the household were determined and compared to those of the respective body of residents. The lack of any discernible difference between the two sets of distributions suggests that the use of our sample will not result in any sample bias.

Respectively, 67.7 %, 66.3 % and 68.3 % of the respondents from Portneuf, Lanaudière, and Nicolet-Yamaska get their drinking water

from a municipal water supply system. In contrast, 98.6% of the respondents from the Ile d'Orleans region use private wells as their primary source of drinking water. This result may stem from the fact that Ile d'Orleans consists of 7 small municipalities. Thus, the per household cost of installing and maintaining a municipal water system may be far higher than that of private wells (Table A1).

EXTENT OF WATER POLLUTION AND WATER RELATED NUISANCES AND HOUSEHOLD AVERTING BEHAVIORS

Of the 2,333 respondents, 1,075 or 46% reported suffering from water pollution and water related nuisances. These problems are overwhelmingly attributed to deficiencies in sewage treatment systems and agriculture. More than three quarters of Portneuf and Ile d'Orleans residents believe that sewage degrades water quality in their communities. That percentage is even higher in Nicolet-Yamaska (Table A2). Of all agricultural activities, hog-raising and potato farming are the most cited contributing factors to groundwater quality degradation. Industrial activities rank lowest, even though they are believed to cause water quality degradation by more than half of the respondents in three of the communities, namely Portneuf, Lanaudière and Nicolet-Yamaska. Paper mills and chemical plants are industrial activities believed to cause the most damage to water quality. The low ranking of industrial activities may stem from the fact that all four communities are mainly rural and their activities are primarily agricultural based.

Descriptive analysis of the data also showed that, of the 1,075 respondents that reported experiencing problems with their drinking water, 64% or 683 of them took an averting action. Of these, 91 experience water pollution by bacteria and chemicals, and 592 suffer water-related nuisances such as staining and odor problems, and bad taste. Averting actions undertaken by households include boiling water (72%), purchase of bottled water (91%), purchase or rental of home water treatment devices (58%), purchase of substitute foods and beverages (78%). Thus, the purchase of bottled water is the most undertaken averting action. The purchase of substitute foods and beverages, and boiling water are also important averting activities.

On an annual basis, the respondents suffering from bacteria and chemical contamination spent an estimated $CAN 226 per household, as compared to $CAN 156 for those experiencing nuisances. These figures are similar to findings by Abdalla (1990) in Central Pennsylvania (*i.e.* $US 252/ year/ household), by Collins and Steinback, (1993) in West Virginia (*i.e.* $US 320 and $US 357 for bacteria and mineral contamination, respectively), and by Stenger-Letheux, (1997) in Alsace in

France (*i.e.* 700 francs, about $CAN 175)[(1)]. They are lower than the $US 2,120 estimated by Abdalla *et al.* (1992) in Perkasie (Southeastern Pennsylvania) and the $US 1,090 estimated by Collins and Steinback, (1993) in West Virginia for organic contamination. On average, residents of Portneuf spent $CAN 182/ household, as compared to $CAN 181 in Lanaudière, $CAN 223 in Nicolet-Yamaska and $CAN 267 in Ile d'Orleans (Table 1). Differences among these household level defensive costs suggest that geographic location may have an influence on households' willingness to pay to protect themselves against water quality degradation. Furthermore, since almost all the households in Ile d'Orleans get their drinking water from private wells, the higher defensive cost in that community supports the contention that households on a private water supply system have a higher willingness to pay than those on a municipal supply system (Abdalla, 1994). In fact, the latter group may rely on the water supplier to take care of problems arising from water quality degradation and therefore may not be willing to spend as much as the former.

Table 1. **Household level averting behavior and cost in response to groundwater pollution and drinking water related nuisances**

	Communities				
	Portneuf	Lanaudière	Nicolet-Yamaska	Ile d'Orleans	Total
Total number of households	790	802	339	352	2,333
Number of households who reported suffering from water pollution and/or water related nuisances	322	339	209	205	1,075
Number of households who incurred averting costs	170	237	173	117	697
Per household annual average averting cost (in $CAN)	182	181	223	267	

Source: Baseline survey data

Of those households who reported suffering water quality degradation problems, 392 did not take any defensive action. Of these, 251 get their drinking water from municipal water-supply systems whereas the remaining 141 get their water from private wells. They all belong to the group experiencing only water-related nuisances. Possible reasons for the absence of any averting action may be that: i) these nuisances are not serious or are not even perceived as nuisances, ii) even though they cause some inconveniences, they are not perceived as life threatening or they have not reached the point where it would be worthwhile incurring expenses to eliminate them. This contention is partly supported by our

[(1)] More precisely, Stenger-Letheux (1997) estimated the willingness to pay, per year and per household, for preservation of the groundwater quality in Alsace.

previous finding that, on average, bacteria and chemical contamination cause households to spend more on defensive actions than nuisances. For the 251 households connected on municipal water-supply systems, a further reason may be that although they are aware of the inconveniences caused by water-related nuisances, they rely upon their public water supplier to take such actions and to bear all the related avoidance expenses. As suggested by Smith and Desvousges (1986), this attitude may stem from or may be reinforced by the fact that households most often tend to have confidence in their water supplier's ability to take care of the quality degradation problem. Furthermore, these households may assume that public works related to maintaining municipal water supply systems should be paid for by taxes and that households should not incur any additional private costs.

Also, worth noting is that 14 households undertook defensive expenses even though they did not report suffering any problem with their drinking water[(2)]. These households' behavior may stem from the uncertainty surrounding the effects of water quality degradation and from the information campaigns led by local health centers and pro-environmental groups. Indeed, as contended by Swartz and Strand, (1981), in the face of imperfect information, households incur "necessary avoidance costs" defined as costs "occurring when there is uncertainty surrounding the contamination effects and when all the information is released, even though it is not complete". It also lends further support to findings by Abdalla *et al.* (1992) and Smith and Desvousges (1986) that households' awareness of the contamination affects their averting behavior.

MODEL AND RESULTS

To investigate empirically the issues at hand, two distinct models were used. The first deals with households reporting suffering water degradation problems and looks into the factors that cause these households to take prospective actions. The second model deals with households who are willing to spend money on averting actions and looks into factors that determine these households' levels of averting expenditures.

For a household facing water quality degradation problems, the two possible decisions are "take an averting action "if the damage is deemed serious and "no action", otherwise. Thus, the appropriate empirical model is a logit. The dependent variable is *AACTI0N* and is equal to 1 if the household took at least one averting action in response to water

(2) The 14 households are found by substracting the 683 households who reported taking an averting action from the 697 who incurred an averting cost (Table 1, raw 3).

quality degradation in its community, and 0, otherwise[3]. Three sets of independent variables were expected to help households make that decision: 1) the households' geographic location, 2) the type of water supply system (*i.e.* municipal water supply system *vs* private water supply systems), and 3) the households' characteristics. The description of the specific independent variables used in the analysis are presented in Table 2. The empirical model is as follows:

$$AACTION = a_o + a_1 PNF + a_2 LAN + a_3 ILO + a_4 MWSS + a_5 GENDER + a_6 EDUC + a_7 ENVIRO + a_8 EXPO + a_9 CHILDREN$$

Where a_i (i = 0 ……9) are coefficients to be determined and *AACTION* is as defined above. All over variables are as defined in table 2.

Table 2. Description of the independent variables

Geographic Location
PNF = 1 if household resides in Portneuf and 0, otherwise.
LAN = 1 if household resides in Lanaudière and 0, otherwise.
ILO = 1 if household resides in Ile d'Orleans and 0, otherwise.
Water Supply System
MWSS = 1 if source of household's drinking water is a municipal water supply system and 0, otherwise.
Households' characteristics
GENDER = 1 if household's head is male and 0, if female.
EDUC = number of years of schooling of the head of the household.
ENVIROO = 1 if the head of the household reported having little or no concern about environmental degradation problems and 0, otherwise.
EXPO = 1 if the household is in farming or lives next to a farm and 0, otherwise.
CHILDREN = 1 if at least one child under the age of 18 lives in the household and 0, otherwise.
AGE = age of the head of the household.
INCOME = income of the head of the household.

Households' geographic location is taken to refer to the community of residence. It is illustrated in Table 2 by *PNF* for Portneuf, *LAN* for Lanaudière and *ILO* for Ile d'Orleans. Nicolet-Yamaska is taken as the basis. It is expected that because of differences in geographic location among communities, households who reside in separate communities will react differently to the degradation of the quality of their drinking water. This variable captures the effect of such things as: 1) the proximity to a large urban center, such is the case for Ile d'Orleans, 2) the prox-

[3] The averting actions considered in this study are: 1) purchase of bottled wate, 2) boiling water, 3) hauling water, 4) purchase of water treatment systems, 5) changes in food and beverage purchase, and 6) participation in public information meetings.

imity to a farming area or to an industrial site, 3) site-specific soil texture, and 4) variations in the micro-climates. In fact, such differences may impact not only on households' preferences for a specific water-quality, but also on the intrinsic quality of the water. Likewise, households who get their drinking water from a municipal water supply system *(MWSS)* are expected to have different reactions to water quality degradation problems from those on private wells. More specifically, we expect those households who get their water from a *MWSS* to rely more on the supplier to take care of the problem. Thus, they are less likely than others to take any averting action.

Certain characteristics of households may help them to decide whether or not to take any averting action in the face of the degradation of the quality of the drinking water. Because, in general, women tend to be more concerned about health hazards caused by undrinkable water, households led by females are more likely to take defensive actions than those led by males. The effect of education on a household's averting behavior is ambiguous. In fact, households led by a better-educated individual are more likely to take averting actions because that person is able to collect and understand technical information regarding the consequences of using contaminated water. However, because he/she has a better understanding of these facts, she/he is more likely to avoid taking unnecessary action. A household led by an environmentally oriented person is more likely to take steps to protect itself against any adverse effects of polluted water. This holds true for any household involved in farming or residing next to a farm as well as for one that has children under the age of 18 living at home.

Results of the logit regression are presented in Table 3.

Table 3. **Estimated logit model for factors affecting households' response to groundwater quality degradation**

Variables	Estimates	T-Ratios
Intercept	.48	2.44***
Portneuf *(PNF)*	1.22	8.36***
Lanaudiere *(LAN)*	.66	4.62***
Ile d'Orleans *(ILO)*	.53	2.91***
Municipal water supply system *(MWSS)*	-.05	-.45
Gender of the head of the household *(GENDER)*	-.10	-1.02
Education of the head of the household *(EDUC)*	-.14	-1.40
Environmental orientation of the head of the household *(ENVIRO0)*	-.36	-2.95***
Exposure *(EXPO)*	.26	1.86**
Children under 18 years of age living in the household *(CHILDREN)*	.15	3.75***

*** indicates statistical significance at 1 % level.
** indicates statistical significance at 5 % level.
Percent of correct predictions = 63 %.
Number of observations = 1,075, McFadden's R^2 =.19

They indicate that, as expected, a household's geographic location is an important factor in its decision to take averting actions as suggested by the significant coefficients of *PNF*, *LAN*, and *ILO*. All the coefficients associated with this variable are not only positive, but also significant, implying that households residing in Portneuf, Lanaudière and Ile d'Orleans are more likely to take averting actions than those in Nicolet-Yamaska. Furthermore, of all the four communities, Portneuf is where residents are more inclined to take protective actions against water quality degradation, as suggested by the larger positive coefficient associated with the *PNF* variable. Households in Lanaudière come in a distant second, followed by those in Ile d'Orleans. These results, along with our descriptive findings, show that even though Nicolet-Yamaska residents, on average, spend more ($CAN 223) to protect themselves against water quality degradation than those in both Portneuf and Lanaudière, they are slower in taking any averting action. Morever, they spend less than Ile d'Orleans residents ($CAN 223 vs $CAN 267) and are also less likely to take protective actions. Results in table 3 also suggest that a household's decision to take defensive actions is independent of the source of the drinking water. In fact, the coefficient associated with the *MWSS* variable is not significant. Likewise, a household led by a female is no more likely than its counterparts to take any avoidance action, as implied by the negative, but not significant coefficient of the variable *GENDER*. These results contrast with our prior expectations, but are supported by other studies (Abdalla, 1992). The same holds true for a household led by a better-educated individual. Results in Table 3 also suggest that a household is more likely to take averting actions if it is a farming household, lives next to a farm or has children under 18 years of age.

The second model deals with factors that determine a household's averting expenditure level. The sample used to investigate the intensity of averting costs includes the 683 households who took averting actions, in addition to: 1) the 14 households who engaged averting expenses without suffering any water quality degradation problem, and 2) the 251 households on the municipal supply system that reported suffering water quality problems, but chose not to take any averting action. By including that last group in our sample for estimation, we assume that the overriding reason of their attitude is their willingness to not support any averting cost in addition to what they incur indirectly through municipal taxes. In that case, the water supplier averts on their behalf. In fact, it may be convincingly argued that these households incur indirectly part of the averting cost through their real-estate taxes. Therefore, not including them in the estimation may lead to a sample bias. Worth noting is that the sample used in the model excludes all the households on municipal water supply systems that did not report suffering any water quality problem. This choice may be explained by the fact that even though all the households on municipal water supply systems indirectly incur averting expenditures, those who are not aware of such

problems would not have spent any money on protective actions, whether they were getting their water from private wells or from a municipal system.

Due to the lack of information on the amount of real-estate taxes in the selected communities, we set the values of averting cost for the 251 households on municipal water supply systems to zero. Thus, the household level averting cost may vary from zero (no action) to a substantial monetary amount, like for water treatment devices. Given that a large number of observations have a zero value, the sample is censored. Therefore, the proper model for assessing the intensity of averting cost is a Tobit model (Maddala, 1986, p. 149; Judge *et al.,* 1988, p. 795). Thus, the empirical model is the following:

$$C_i = a_0 + a_1 PNF + a_2 LAN + a_3 IL0 + a_4 MWSS + a_5 EDUC + a_6 EXP0 + a_7 INC0ME + a_8 AGE + a_9 CHILDREN \qquad \text{if } C_i > 0$$

$C_i = 0$ otherwise.

Where a_i (with i= 0-9) are parameters to be estimated and C_i the dependent variable is the household's monthly averting cost. To estimate that figure, households were asked to report their monthly expenditures on boiling water, purchase of bottled water, rental of home water treatment devices, purchase of substitute foods and beverages. For the purchase of durable goods such as home water treatment devices, two things were done to obtain the monthly corresponding averting cost. First, it was estimated that, on average, such a device was effective in treating water contamination problems for 5 years. Then, the reported purchasing price was divided by 60 to obtain the desired figure. The household's monthly averting expenditure was then calculated as the sum of all the monthly expenses undertaken for averting activities.

Novel in the above model are the income *(INC0ME)* and the age *(AGE)* of the head of the household. It is expected that the higher the income the head of a household earns, the more that household is able to undertake averting expenses. *AGE* is a binary variable which value is 1 if the head of the household is more than 55 years old and 0, otherwise. Older household heads, because of failing health, may be more inclined to spend more on averting activities. All other independent variables are as defined in Table 2.

A two-stage estimation procedure of the Tobit model was used. This procedure was first used by Heckman (1976) and explained in Maddala (1986, pp. 158-159) and Judge *et al.* (1985, pp. 779-785). First, a dummy variable I_i is defined. Its value is 1 for those households with a non-zero averting cost, and 0, otherwise. Then, using a probit model, consistent estimates of the ratio of the parameters to the standard deviation as well as estimate values of both the density function and the distribution function are obtained. Second, using these results and all the

observations, we get consistent estimates of the a_i parameters by applying the OLS regression method to the original model (Maddala, 1986; Judge *et al.,* 1985).

The results of the two-stage tobit regression are summarized in Table 4.

Table 4. **Two-stage tobit estimates of factors affecting household level averting cost**

Variables	Estimates	T-Ratios
Intercept	1.23	6.83***
Portneuf *(PNF)*	-.75	- 8.52***
Lanaudière *(LAN)*	-.52	-6.10***
Ile d'Orleans *(ILO)*	.39	8.56***
Municipal water supply system *(MWSS)*	-.13	-1.91**
Education of the head of the household *(EDUC)*	-.16	-2.36***
Exposure *(EXPO)*	-.08	-1.00
Income of the head of the household *(INCOME)*	.17	2.62***
Age of the head of the household *(AGE)*	-.17	-1.77**
Children under 18 years of age living in the household *(CHILDREN)*	.07	2.41***

*** indicates statistical significance at the 1 % level.
** indicates statistical significance at the 5 % level
Percent of correct predictions = 77 %
Number of observations = 948, McFadden's R^2 = .22

As suggested by these results, a household's geographic location plays an important role in determining the level of its averting expenditures: households residing in Portneuf and Lanaudière spend less on averting activities than those in Nicolet-Yamaska, whereas those in Ile d'Orleans spend more. This lends some support to our descriptive finding that the average averting cost in Ile d'Orleans is higher than that in Nicolet-Yamaska, whereas that in both Lanaudière and Portneuf is lower (Table 1). A household is likely to undertake higher defensive expenses if: 1) it has children under 18 years of age living at home, or 2) the head of the household earns a higher income as indicated by the positive and significant coefficients associated with *CHILDREN* and *INCOME* variables, respectively (Table 4). In contrast, households that have a better educated head of family, or one who is over 55 years old, tend to spend less on averting. This conclusion holds true for households who get their water from a municipal water-supply system. The negative relation between averting cost and education may indicate that, because better educated heads of households are able to collect and understand technical information about water contamination and the different treatment devices, they are able to undertake more effective averting activities and ultimately end up paying less for such activities. The negative effect of age on averting cost contrasts with our prior expectations, but is supported by findings of similar studies (Smith and Desvousges, 1986).

This may imply that older heads of households tend to be more accustomed to groundwater quality degradation and see them as temporary problems that need not be a cause of concern. This may be the case if these problems are recurring, or in the case of nuisances, if the households have been experiencing them for a long period of time.

SUMMARY OF THE RESULTS AND THEIR PUBLIC POLICY IMPLICATIONS

Because of its many adverse impacts (*e.g.* human health hazards, increased fear and anxiety, avoidance cost and property value loss, ecological damage and loss of recreational value, loss or reduction of non-use values), groundwater contamination is a cause of concern for both private citizens and policy-makers. In this research, a random sample of 2,333 households from four Quebec communities, namely, Portneuf, Lanaudière, Ile d'Orleans, and Nicolet-Yamaska, was used to investigate households' response to groundwater contamination. This research differs from prior studies in many ways. By including households from different communities, it is possible to test for any difference in averting behavior arising from differences in geographic location. Second, the sample contains households who get their drinking water from different sources: public water supply systems and private wells. Thus the effect of the source of water supply can be determined. Also, results from our research complete and extend results from these previous studies.

Of all the households suffering water quality degradation problems, those facing water-related nuisances (odor, staining problems, and bad taste) are less inclined to take averting actions and, on average, spend less to solve these problems than those suffering from water pollution by bacteria and minerals. Thus, the type of degradation problem is an important factor in explaining both household level averting behavior and costs. Also evident from the results is that households getting their water from a municipal water supply system are no less likely than their counterparts to take any averting action. In addition, a household's geographic location influences its decision to take averting actions. Households' characteristics that are important in explaining its averting decision are the environmental orientation of the head of the family, the number of children under the age of 18, and the closeness to farming activities. The intensity of averting expenditures is better explained by geographic location, the source of drinking water, income, education and age of the head of the household, and the number of children under 18 years of age.

A first policy implication of these results is that policies that intend to cause households to take averting actions should not discriminate

among them on the basis of the source of their water supply. In fact, household level averting behavior is found to be independent from that factor. Similarly, such policies should be made irrespective of the distribution of the heads of the household across gender and their level of education in any given community. In contrast, more information on the consequences of groundwater pollution should be made readily available to less environmentally oriented heads of household, and to households living away from farming areas. These households tend to not take averting actions. In addition, given that the number of children under the age of 18 is an overriding positive factor in households' decision to both take defensive actions and to spend on these actions, information should be made available to parents of young children from and disseminated through such channels as the *"Centre local de santé communautaire"* (CLSC), *i.e.* Local Community Health Centers, pediatricians, kindergartens and high schools. Policy-makers in communities with a municipal water supply system, through diversified incentives including financial and material benefits, should encourage water suppliers to invest more in averting activities. As suggested by our results, this will result in additional economic savings for many households. In fact, assuming that averting costs are a lower bound for households' willingness to pay for reduction in water contamination (Courant and Porter, 1981 ; Bartik, 1988 ; Laughland *et al.,* 1996), such a public policy will result in at least $CAN 226 annual savings for households suffering water contamination by bacteria and minerals, and $CAN 156 annual savings for those suffering water-related nuisances. In communities with private wells, such incentives may be in the form of a lump-sum reduction in municipal real-estate taxes or a reduction in such taxes of the amount a given household reported having spent on improving its water quality. If these are done, poor households, less educated and elder persons will be provided with a better protection against groundwater contamination. Indeed, these households are found to spend less on averting activities and thus may be running undue risks. Finally, for better averting results, policy-makers should avoid duplicating policies from one community to another. In fact, our results show that both averting behavior and costs are site-specific. This implies that successful policies in one community may result in failure in others if no attention is given to community specificities.

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APPENDIX

Households' sources of drinking water and sources of groundwater contamination

Table A1. **Frequency Counts (in %) by region of the respondents getting their drinking water from private wells, a municipal water supply system or an alternate source**

	Private wells	Municipal water supply system	Alternate sources*	Total
Portneuf	23.52	67.74	8.74	100
Lanaudière	29.29	66.33	4.38	100
Ile d'Orleans	98.57	.29	1.14	100
Nicolet-Yamaska	27.02	68.31	4.68	100

Source: Baseline survey data

* Alternate sources of drinking water include, among other things, purchase of bottled water, purchase of soft drinks, tea, juices, hauling in water.

Table A 2. **Frequency counts (in %) of the respondents who believe that industry, sewage, and agriculture are major sources of groundwater pollution and drinking water related nuisances in their community ***

	Portneuf	Lanaudière	Ile d'Orleans	Nicolet-Yamaska
Industry	50.6	57.89	19.6	56.18
Deficiencies in sewage treatment systems	76.96	72.16	78.00	88.63
Agriculture	65.85	78.86	80.40	85.23

Source: Baseline survey data

* Figures in the columns of Table A2 do not add up to 100 % because they are estimated taking into account the first, second and third most likely sources of groundwater pollution reported by the respondents.