Use of a health information telephone line, Info-Santé CLSC, for the surveillance of waterborne gastroenteritis

Marie-Line Gilbert, Patrick Levallois and Manuel J. Rodriguez

ABSTRACT

The increasing frequency of waterborne outbreaks demonstrates that classic indicators used for the surveillance of the microbiological quality of drinking water have several gaps and that routine public health surveillance seems insufficient to allow for the rapid detection of these outbreaks. The main objective of this study was to evaluate the possibility of using a regional health information telephone line, 'Info-Santé CLSC' (Info-Health Local Community Health Centre), for the surveillance of waterborne gastroenteritis. This study measured the incidence rate of calls for acute gastrointestinal illness (AGI) placed to the Info-Santé CLSC line, investigated the relationship between the frequency of calls for AGI placed to the Info-Santé CLSC line and the turbidity of the treated water in the Quebec City drinking water plant and evaluated the relevance and the conditions of use of the Info-Santé CLSC system for the surveillance of waterborne enteric illness. A relationship between the turbidity and the calls for AGI placed to Info-Santé CLSC line was observed. Significant time lags (11, 15 and 17 days prior to the outcome) were identified in the final model derived from a Poisson model using generalized additive models (GAM) as a time series analysis. Some recommendations to improve the system were formulated even though the system already seems to be useful for the surveillance of waterborne enteric diseases.

Key words | drinking water, health information telephone line, surveillance, time series analysis, turbidity, waterborne gastroenteritis

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INTRODUCTION

The pathogenic microorganisms found in drinking water are mainly linked with health problems affecting the gastrointestinal system, and contaminated water is a major carrier of the transmission of these different ailments. The evaluation of the quality of drinking water is currently based on the search for microbiological indicators rather than on the detection of pathogenic microorganisms. The indicators used in drinking water microbiology are mostly bacterial indicators. As the time between the collection of a water sample and the analysis of the microbial load is relatively long (this time can vary from 24 to 72 hours according to the technology applied) (Gouvernement du Québec 2001), contaminated water will already have been consumed by the population. Moreover,

some microorganisms, such as enteric parasite protozoa and viruses, are more resistant to traditional disinfection and are not well correlated with the presence of these indicators (AWWA 1999; Egorov *et al.* 2003).

One physical indicator of the water quality filtration performance is turbidity. According to certain authors, it seems to be correlated with the presence of waterborne microorganisms resistant to disinfection throughout the filtration system, but this conclusion is not accepted unanimously (Egorov *et al.* 2003). Moreover, while taking into consideration a time lag for the incubation period of the microorganisms, several studies showed that daily variations of the treated water turbidity could be positively

associated with the daily count of endemic gastrointestinal cases (Morris *et al.* 1996; Schwartz *et al.* 1997, 2000; Aramini *et al.* 2000b; Egorov *et al.* 2003).

An epidemiological surveillance system of waterborne enteric diseases would permit a rapid investigation of outbreaks and adoption of preventive measures. The actual notification systems in place in the Province of Quebec cannot be used for the detection of waterborne epidemics since problems of under-declaration, of non-diagnosis and of non-immediate availability of information are observed. Moreover, only some waterborne diseases are indexed. A pilot study for the identification of a possible surveillance system took place in 1999. The Info-Santé CLSC telephone system as well as the sales of antidiarrhoeal drugs were identified as possible surveillance systems for gastroenteritis in Quebec (Levallois *et al.* 1999).

Considering the threat that waterborne diseases represent for our society, this research project is designed to evaluate the feasibility of using a health information telephone line, Info-Santé CLSC, for the surveillance of waterborne gastroenteritis in Quebec. This objective will be reached by measuring the incidence of calls for acute gastrointestinal illness (AGI) placed to the Info-Santé CLSC telephone line according to characteristics based on person, time and place; by studying the relationship between the frequency of calls for AGI placed to the Info-Santé CLSC line and the turbidity of the treated water of the Quebec City drinking water plant; and by evaluating the relevance and the conditions for the use of the Info-Santé CLSC system for the surveillance of waterborne enteric diseases.

Drinking water supply (Quebec City)

The choice of Quebec City as the case under study is based on the fact that its water utility is supplied by a source water system whose catchment area, the Saint-Charles River, is vulnerable to contamination by pathogenic microorganisms. The Quebec City drinking water treatment plant serves a population of approximately 240,000 people. It pumps its water at approximately 40 cm under the surface of the water not far from the banks of the Saint-Charles River. The water treatment plant implements conventional full treatment (pre-chlorination, coagulation, decantation, filtration, ozonation and post-chlorination) and several parameters

of raw and treated water quality are monitored periodically (e.g. fecal coliforms, total coliforms, etc.). From 2000 to 2002, the seasonal average raw water parameters ranged from 62 to 340 cells $100 \, ml^{-1}$ for fecal coliforms, from 376 to 1,602 cells $100 \, ml^{-1}$ for total coliforms and from 1.71 to 3.16 NTU (nephelometric turbidity unit) for turbidity. The conventional equipment consists of HACH 1720 D Low Range turbidimeters and it offers a detection limit lower than 0.1 NTU with an accuracy of ± 2% between 0 and 40 NTU. The data quality control is ensured by verification with manual laboratory analysis. Calibration is performed every three months with formazine. The capacity of the treatment plant is about 240 million litres of water per day. The surface area of the distribution network is approximately 1,025 km. Four reservoirs distributed throughout the territory have a total storage capacity of 179.4 million litres of water (personal communication from M. André Normand of Quebec City water treatment plant).

Info-Santé CLSC

Info-Santé CLSC is a bilingual telephone response service to the public that is easily and quickly accessible, and whose mission is to provide information concerning health problems such as gastrointestinal symptoms. This system is accessible 24 hours per day and 7 days per week all year round. The interviewers are nurses who question callers about their health and their reasons for calling. In light of this information, interviewers advise the patient on the actions to take to improve their state of health without making a specific medical diagnosis. A code is established according to the reason for each call. Users can remain anonymous or can identify themselves to the interviewer. For example, in 1998, Info-Santé CLSC received more than 2.4 million calls for the whole Province of Quebec, with an average of 6,500 calls per day (Ministère de la Santé et des Services Sociaux du Québec 1999).

METHODS

The general methodology of this study (particularly the modelling approaches with generalized additive models (GAM) techniques) was adapted from previous works

conducted by Schwartz *et al.* (1997, 2000), Aramini *et al.* (2000*b*) and Santé Canada (2002). The period of the study extended from 27 January 2000 to 17 May 2002 for a duration of approximately 28 months. In order to reflect the climate of the Province of Québec, the seasons were categorized as follows: summer from 1 June to 31 August; autumn from 1 September to 30 November, winter from 1 December to 28 or 29 February; spring from 1 March to 31 May. Also, a questionnaire-based survey was conducted with the nurses and managers of the Info-Santé CLSC service in order to evaluate this system as a surveillance system for waterborne enteric diseases.

The population studied included people of all ages living in the territory served by the Quebec City treatment plant and by the Info-Santé CLSC telephone system of the Basse-Ville-Limoilou-Vanier CLSC. Despite the large territory covered by the Quebec City water treatment plant, only the data from this particular CLSC were available for the study.

Population data were taken from the Quebec Statistical Institute and registers from Canada Statistics. The CLSC territories involved in our study represent 81,417 people in 2000, 81,028 people in 2001 and 80,626 people in 2002 (MSSS by Census 1996 of Canada Statistics). Turbidity data were provided by the Quebec City drinking water treatment plant. The treated water turbidity was monitored continuously using turbidimeters located at the exit of the plant. To simplify the handling of these data (a reading every 40 seconds), they were transformed into daily mean, median and maximum values. However, only mean daily turbidity measures were used for the analysis. The environmental parameter total daily precipitation in mm was provided by Environment Canada. Data about the population's calls were provided by the call centre of the Info-Santé CLSC telephone system. These data were drawn from the Impromptu software, currently used by Info-Santé CLSC for management of calls.

A call for 'acute gastrointestinal illness' (AGI) was defined as any telephone call consultation with a nurse at the Info-Santé CLSC involving one of the following symptoms: vomiting, diarrhoea, nausea, abdominal cramps or any symptoms related to the gastrointestinal tract, excluding post surgery and pregnancy cases. Only calls for which the identification number of the CLSC territory, the date of the call and the code of the diagnosis were known were retained.

Analyses were done using the software programs SAS (SAS Institute Inc. 8.2) and S-Plus (Insightful S-Plus 6.1 Academic). Descriptive analyses were carried out to identify the general trends and the relationships between water quality data and the health outcomes. The incidence rate of AGI was defined as follows:

Incidence rate of calls for AGI

$$= \frac{\text{Number of calls for AGI}}{\text{Population at risk} \times \text{interval of time}} \tag{1}$$

The population at risk was identified as the population living in the territory of the Basse-Ville-Limoilou-Vanier CLSC for the period of the study. The incidence rate of AGI was calculated annually and seasonally because of the potentially seasonal character of gastroenteritis. The data concerning the age and sex of each patient could not be used as they were not available for most of the calls.

Generalized additive models (GAM) were used to investigate the temporal relationships between the water quality and the number of calls for AGI and to improve the fit of non-parametric terms. A Poisson GAM model was fitted to the data. LOESS (moving regression smoother) was applied to fit a seasonal parameter in an attempt to control for seasonal trends in gastroenteritis. The outcome was the natural logarithm of the daily count of the number of calls for AGI.

The independent variables considered in the model were the following: the precipitation values from 0 to 40 days prior to the day of health outcomes (environmental parameter), the temporal confounders (day of the week and holidays), an autoregressive term of the number of calls made the day before to adjust for the correlation arising from daily observations made of health outcome event, and LOESS of seasonal parameter and of mean daily turbidity. The dependent variable was the natural logarithm of the number of calls per day. The following holidays were considered: Christmas, New Year, Easter, Victoria Day, Canada Day, St-Jean-Baptiste Day, Labour Day and Thanksgiving Day.

The selection of variables without turbidity was made on the basis of the smaller Akaike Information Criterion

(AIC) which is a measure of fit (Akaike 1981). The choice of significant lags for turbidity was made comparing the difference of deviances with $\alpha = 0.005$.

Temporal exposure response surface (TERS) plots were generated to describe the relationship between the turbidity and the relative rates of calls for acute gastrointestinal illness over a range of time lags. Relative rates were calculated by dividing the predicted number of calls related to a level of turbidity for a particular lag, by the predicted number of calls associated with the mean turbidity of the study, after adjusting for other parameters of the model. Relative rate represents the rate of calls related to a level of turbidity and a particular time lag.

RESULTS

Descriptive statistics

Characteristics of the finished water quality parameters are presented in Table 1. Mean daily turbidity was preferred to median daily turbidity given that several authors (Morris *et al.* 1996; Schwartz *et al.* 1997, 2000) use it as a water quality parameter and the correlation between the two measures was very strong ($R_{Pearson} = 0.95$). The average of the mean daily turbidity was 0.267 NTU during the study period and the maximum value was 0.75 NTU.

The total incidence rate of calls per year for the duration of the study was 19.123 calls per 1,000 person-years. Table 2 presents the incidence rates of calls per year. Incidence

rates increased over the years; however it must be noted that the number of users of Info-Santé also increased.

Time series analysis

A model of the outcome was derived from the time series using a Poisson analysis. A basic model was defined in which the following variables were tested: season, day of the week (categorical), holidays (binary), logarithm of the number of calls the day before and precipitation. The variable *season* was considered as a categorical variable and a smoothed date seasonal parameter. The final model selected with the categorical variable for season is as follows:

$$\log(\text{no. calls}) \sim \text{season} + \text{day of the week}$$
$$+ \log(\text{no. calls day before}) \tag{2}$$

This model had an AIC equal to 1,074.13 and a deviance of 1,052.13 with a statistical significance of 0.05. The model selected for the smoothed date seasonal parameter is the following:

$$\log(\text{no. calls}) \sim \text{lo}(\text{date, span} = 0.26128)$$
$$+ \text{day of the week} \tag{3}$$
$$+ \log(\text{no. calls day before})$$

This model had an AIC of 1,010.16 and a deviance of 980.05 with a statistical significance of 0.05. The model with

Table 1 | Summary statistics for the finished water quality: 27 January 2000 to 17 May 2002

Finished water quality data	Mean daily turbidity (NTU)	Median daily turbidity (NTU)	Maximum daily turbidity (NTU)
Minimum	0.110	0.110	0.130
1st quartile	0.210	0.210	0.450
Mean	0.267	0.260	1.289
Median	0.260	0.250	1.140
3rd quartile	0.310	0.300	1.820
Maximum	0.750	0.680	3.320
Standard deviation	0.084	0.077	0.889

Table 2 │ Incidence rate of calls for AGI by year

Years	Number of calls	Interval of time	Population	IR per 1,000 person-years
2000	1,197	340 days	81,417	16.04
2001	1,566	365 days	81,028	19.33
2002	792	137 days	80,626	26.20

the smoothed date seasonal parameter was preferred since the AIC and the deviance were weaker, which means the fit is better with the second model.

Following this, the choice of the mean turbidity values to be included in the model was carried out. Because of their inter-dependence, the 40 lagged terms of turbidity (corresponding to 40 days prior to the outcome) were included one by one. Only significant terms, defined as those for which the difference on deviance with the basic model was at least 7.88 ($\alpha = 0.005$) were retained. Indeed, a difference on deviance of nested models follows a chi-square distribution with one degree of freedom in this case. The most significant turbidity lag was entered in the model and we checked whether the other terms were still significant. The final general model obtained is the following:

$$\log(\text{no. calls}) \sim \text{loess}(\text{Date}, \text{span} = 0.26128)$$
$$+ \text{day of the week}$$
$$+ \log(\text{no. calls day before}) \qquad (4)$$
$$+ \text{loess}(\text{meantb}_{1-40}, \text{span} = 0.95)$$

Significant variables included in the final model were the LOESS (moving regression smoother) of the date (seasonal parameter), the day of the week, the log of the number of calls made the day before and the LOESS of the mean turbidity from 1 to 40 days prior to the outcome. The correlation between the observed and the predicted values was 70.0% ($r^2 = 0.4901$).

The daily mean turbidity was preferred to the daily maximum turbidity when considering the population's exposure. As the readings were made at 40-second intervals, the possibility of observing a higher reading, non-representative of the full day's trend, was great. Therefore, a high reading would not be representative of the daily turbidity

and the population's exposure since it could result from a cause that is not associated with the water treatment plant or the treated water quality such as: the detachment of a part of the pipe biofilm or the presence of suspended solids following flow or pressure changes within the distribution system. From a public health point of view, it seemed adequate to use the daily mean turbidity. Moreover, the comparison of the models obtained with each measurement (daily mean turbidity and daily maximum turbidity) showed that daily mean turbidity produced the best fit to the data. Finally, the use of this measurement allowed a better comparison with the previous studies.

Relative rate analysis

Figure 1 represents the surface response interpolated from the values of the relative rates (RR). It is interesting to note that, in general, the rate for calls (established by the RR) increases with an increase in mean daily turbidity. Peaks for lags of 11, 15 and 17 days were also observed. A relative rate of 1.76 represents an 76% increase of the predicted number of calls for the 0.75 NTU level when the lag 17 is taken into account in the model, compared with the predicted number of calls for the mean turbidity level (when no lagged turbidity is included in the model), after adjusting for other parameters of the model. The RR values of the peaks for lags of 11, 15 and 17 days are, respectively, 1.33, 1.53 and 1.76.

DISCUSSION

Treated water turbidity has been used as an indicator of water quality in several other studies (Morris *et al*. 1996; Schwartz *et al*. 1997, 2000; Aramini *et al*. 2000*a*; Santé
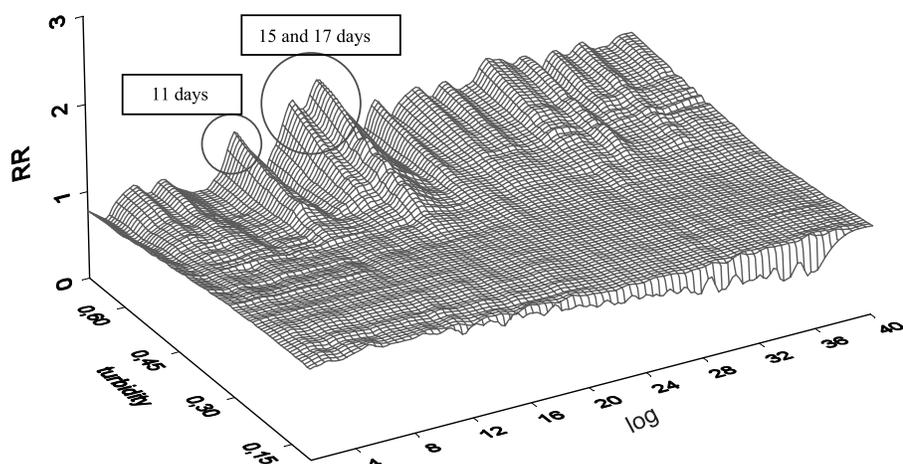
Figure 1 | Relative rates.

Canada 2002). The detection limit of the equipment used by the treatment plant (0.1 NTU) and the large size of the database (40-second readings per 24-hour period) give cause to validate the precision of the data. Moreover, it is well known that it is common for people with health problems such as gastroenteritis to call Info-Santé CLSC before consulting a physician. Consequently, we think that the Info-Santé CLSC database could be used to identify the less-serious cases of the disease; it could be used for the detection of epidemic peaks and thus to determine from the water treatment data whether there is a relationship between this data and the quality of the distributed drinking water.

With regard to the retrospective nature of this study, the Info-Santé CLSC system could not generate data exclusively on acute gastroenteritis. Indeed, the diagnosis considered all ailments concerning the gastrointestinal system. In addition to gastroenteritis, data on constipation and gastrointestinal disorders related to a subjacent disease do not constitute a source of possible epidemics. The Info-Santé CLSC system database has a limited size (3,555 calls) because only one CLSC could be included in the study. On the other hand, this allowed for the consideration of a more homogeneous population. Because of the ecological nature of this study, there was no information about water consumption, individual susceptibility, sex and age.

The annual mean incidence rate of calls for AGI placed to the Info-Santé CLSC telephone line (19.123 calls per 1,000 person-years) is not easily comparable with the incidence rates obtained by other authors. This result

must be considered with care since it is necessary to look at the factor of awareness of the service, that is to say the knowledge of its existence among the population. In 1998, a study had revealed knowledge of the service among 75% of the population (Ministère de la Santé et des Services Sociaux du Québec 1999). Moreover, data on the use of the Info-Santé CLSC telephone service or other similar service data are rather limited in the literature. These results cannot be interpreted in terms of episodes per person-years since a call cannot be considered an episode in every case. In addition, even if two calls can be associated with the same episode, it would not be acceptable to eliminate calls with the argument that a second call for the same episode was made, because it could be a call for another member of the family who is also sick. The transmission of gastrointestinal diseases through person-to-person contact is widely known. The incidence of gastrointestinal diseases is difficult to establish since only a portion of the affected people develops symptoms, and only a proportion of the latter will require medical care (Payment 2001; World Health Organization 2001). Mean annual incidence rates varying from 180 to 3,800 episodes per 1,000 person-years, dependent on the definition and the method of observation used, have been mentioned by various authors (Dingle *et al.* 1953; Hodges *et al.* 1956; Fox *et al.* 1966; Monto *et al.* 1983; Payment *et al.* 1991; Hoogenboom-Verdegaal *et al.* 1994; de Wit *et al.* 2001). According to the literature, survey methodology has presented incidence rates varying from 180 to 900 episodes per 1,000 person-years (Dingle *et al.* 1953; Hodges *et al.*

1956; Payment *et al.* 1991; Hoogenboom-Verdegaal *et al.* 1994; de Wit *et al.* 2001), telephone survey methodology showed an incidence rate of 1,200 episodes per 1,000 person-years (Monto & Koopman 1980; Monto *et al.* 1983) and the visit methodology presented an incidence rate of 3,800 episodes per 1,000 person-years (Fox *et al.* 1966). These rates are higher than the rates observed in the current research. The reasons could be that the system is not known to everybody and that not all people call Info-Santé CLSC when they are sick.

In the final model, significant time lags were identified: 11, 15 and 17 days. Only lags that were significant over two or three consecutive days were considered. These lags are similar to those found in former studies (Schwartz *et al.* 1997, 2000; Morris *et al.* 1998; Aramini *et al.* 2000*b*; Santé Canada 2002). Lags are consistent with incubation periods of common waterborne protozoa (*Cryptosporidium*, *Giardia*) (AWWA 1999). Moreover, the relationships (relative rates) between the water turbidity and calls for AGI have a similar width to the relationships observed by Aramini *et al.* in a study conducted in Vancouver. It should be noted that the Vancouver water plant did not use filtration.

The effect varies in time according to the parasitic load present in the water and the immunological state of the individuals. It should also be considered that the time lag could in part be linked with person-to-person transmission. Indeed, Morris *et al.* (1998), in their study of the Milwaukee cryptosporidiosis outbreak, mentioned a 13- to 16-day lag attributed to secondary infections (Morris *et al.* 1998). The presence of multiple significant lags is consistent with observations in previous studies and suggests a multiple aetiological pattern.

According to the results obtained herein, the Info-Santé CLSC telephone system seems useful to carry out the surveillance of waterborne enteric diseases. Indeed, the World Health Organization (WHO) considers surveillance as a meticulous and continuous examination of all aspects of the appearance and extent of a disease, which are relevant for its effective control (World Health Organization 2000). Moreover, the aims of the surveillance of infectious diseases are to immediately identify health problems, to observe their evolution and to guide decisions on their control (Health Canada: Division of Enteric 2001; Hunter 2003). The Info-Santé CLSC telephone service

seems to correspond to this definition, in particular because of its high accessibility and its widespread visibility (75%). In addition, Info-Santé CLSC is already associated with other components of the health system of Quebec such as the regional public health department. In addition, this study makes it possible to identify a certain number of recommendations that could improve the system. For example, a precise definition targeting only the calls for gastroenteritis was recommended. Other examples are the collection of information about the postal code with all characters and about the age and the sex of each patient. The application of a statistical method to end up with a statistically valid increased number of calls and thus to declare an outbreak and, finally the development of tools that would integrate the turbidity data with the calls data are other examples of improvements that would increase the effectiveness of the service as a surveillance tool.

CONCLUSIONS

This research initially aimed to evaluate the feasibility of using the Info-Santé CLSC telephone system for the surveillance of waterborne gastroenteritis. It was based on linking data on the calls to the Info-Santé CLSC telephone service and the quality of water in Quebec City. An approach based on a time series analysis according to the Poisson model was applied.

The results obtained showed an annual mean incidence rate of 19.123 calls per 1,000 person-years. They allowed the identification of a significant statistical relationship between the turbidity of the Quebec City drinking water and the calls due to AGI to the Info-Santé CLSC system. The Info-Santé CLSC telephone system has the potential to become a surveillance system for waterborne enteric diseases. However, further epidemiological research has to be conducted in the future to evaluate the new case definition and to define an outbreak detection baseline.

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REFERENCES

Akaike, H. 1981 Likelihood of a model and information criteria. *J. Econometrics* **16**(1), 3–14.

Aramini, J., McLean, M., Wilson, J., Holt, J., Copes, R., Allen, B. & Sears, W. 2000a La qualité de l'eau potable et l'utilisation des services de santé pour des maladies gastro-intestinales dans la région du Grand Vancouver. *Can. Commun. Dis. Rep.* **26**(20), 170–173.

Aramini, J., Wilson, J., Allen, B., Holt, J., Sears, W., McLean, M. & Copes, R. 2000b *Drinking Water Quality and Health Care Utilization for Gastrointestinal Illness in Greater Vancouver*. University of Guelph, Vancouver/Richmond Health Board, University of British Columbia, Santé Canada.

AWWA 1999 *Manual of Water Supply Practices - M48: Waterborne Pathogens*, 1st edition. American Water Works Association, Denver, Colorado.

de Wit, M. A., Koopmans, M. P., Kortbeek, L. M., Wannet, W. J., Vinje, J., van Leusden, F., Bartelds, A. I. & van Duynhoven, Y. T. 2001 Sensor, a population-based cohort study on gastroenteritis in the Netherlands: incidence and etiology. *Am. J. Epidemiol.* **154**(7), 666–674.

Dingle, J. H., Badger, G. F., Feller, A. E., Hodges, R. G., Jordan, W. S. & Rammelkamp, C. 1953 A study of illness in a group of Cleveland families: I Plan of study and certain general observations. *Am. J. Hyg.* **58**, 81–91.

Egorov, A. I., Naumova, E. N., Tereschenko, A. A., Kislitsin, V. A. & Ford, T. E. 2003 Daily variations in effluent water turbidity and diarrhoeal illness in a Russian city. *Int. J. Environ. Health Res.* **13**(1), 81–94.

Fox, J. P., Elveback, L. R., Wassermann, F. E., Ketler, A., Brandt, C. D. & Kogon, A. 1966 The virus watch program. *Am. J. Epidemiol.* **83**, 389–412.

Gouvernement du Québec 2001 Règlement sur la qualité de l'eau potable, L.R.Q., c. Q-2, r.18.1.1. Éditeur officiel du Québec.

Health Canada: Division of Enteric, Food and Waterborne Diseases 2001 *Introductory Background Literature Review, National Studies on Acute Gastrointestinal Illness (NSAGI)*. Health Canada, Guelph, Canada.

Hodges, R. G., McCorkle, L. P., Badger, G. F., Curtiss, C., Dingle, J. H. & Jordan, W. S. 1956 A study of illness in a group of Cleveland families: XI The occurrence of gastrointestinal symptoms. *Am. J. Hyg.* **64**, 349–356.

Hoogenboom-Verdegaal, A. M., de Jong, J. C., During, M., Hoogenveen, R. & Hoekstra, J. A. 1994 Community-based study of the incidence of gastrointestinal diseases in The Netherlands. *Epidemiol. Infect.* **112**(3), 481–487.

Hunter, P. R. 2003 Principles and Components of Surveillance Systems. In *Drinking Water and Infectious Disease: Establishing the Links* (eds. Waite, M., Hunter, P. R. & Ronchi, E.), CRC Press LLC, London. pp. 3–11.

Levallois, P., Gosselin, P., Carignan, G., Gingras, S., Barthe, C. & Payment, P. 1999 *Évaluation du risque de maladies d'origine hydrique chez les populations utilisant de l'eau potable de réseaux publics, dont la source origine du Saint-Laurent ou de ses tributaries*. Direction de la santé publique de Québec, Québec, Canada.

Ministère de la Santé et des Services Sociaux du Québec 1999 *Évaluation provinciale des services Info-Santé CLSC: Rapport final 1994–1999*. Ministère de la Santé et des Services sociaux, Québec, Canada.

Monto, A. S. & Koopman, J. S. 1980 The Tesumseh Study: XI The occurrence of acute enteric agents in the community 1976–1981. *Am. J. Epidemiol.* **112**, 323–333.

Monto, A. S., Koopman, J. S., Longini, I. M. & Isaacson, R. E. 1983 The Tecumseh Study: XII Enteric agents in the community 1976–1981. *J. Infect. Dis.* **148**, 284–291.

Morris, R. D., Naumova, E. N., Levin, R. & Munasunghe, R. L. 1996 Temporal variation in drinking water turbidity and diagnosed gastroenteritis in Milwaukee. *Am. J. Public Health* **86**(2), 237–239.

Morris, R. D., Naumova, E. N. & Griffiths, J. K. 1998 Did Milwaukee experience waterborne cryptosporidiosis before the large documented outbreak in 1993? *Epidemiology* **9**(3), 264–270.

Payment, P. 2001 Transmission of gastrointestinal diseases: hygiene as the final barrier. *Am. J. Public Health* **29**, 218–221.

Payment, P., Franco, E., Richardson, L. & Siemiatycki, J. 1991 Gastrointestinal health effects associated with the consumption of drinking water produced by point-of-use domestic reverse-osmosis filtration units. *Appl. Environ. Microbiol.* **57**, 945–948.

Santé Canada 2002 *Étude de la relation qui existe entre l'eau potable et la gastro-entérite à Edmonton: 1993–1998*. Division des entéropathies et des maladies d'origine hydrique et alimentaire, Guelph, Canada.

Schwartz, J., Levin, R. & Hodge, K. 1997 Drinking water turbidity and pediatric hospital use for gastrointestinal illness in Philadelphia. *Epidemiology* **8**, 615–620.

Schwartz, J., Levin, R. & Goldstein, R. 2000 Drinking water turbidity and gastrointestinal illness in the elderly of Philadelphia. *J. Epidemiol. Community Health* **54**, 45–51.

World Health Organization 2000 *WHO Report on Global Surveillance of Epidemic-prone Infectious Diseases. WHO/CDS/CSR/ISR/2000.1*. WHO, Geneva.

World Health Organization 2001 *Water Quality: Guidelines, Standards and Health: Assessment of Risk and Risk Management for Water-Related Infectious Disease*. WHO, Geneva.